Bodycote MATERIALS TESTING CANADA INC.
2395 SPEAKMAN DRIVE, MISSISSAUGA, ONTARIO L5K 1B3, CANADA · TEL: (905) 822-4111 · FAX: (905) 823-1446

Laboratory Evaluation to Assess a Proposed Test Method to Determine Transient Combustion Spillage

A Confidential Report to:	Natural Resources Canada 580 Booth Street 13th Floor, Rm. 13D Ottawa, Ontario K1A 0E4
Attention:	Mr. James Glouchkow
Telephone: Fax:	613-943-9235 613-996-9909
Report No.:	04-06-M278b Rev. 1 33 Pages, 2 Appendices
Date:	August 29, 2005

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF TEST DATA SHEETS (APPENDIX B)

1.0 INTRODUCTION

Interest has been expressed in the development of a test procedure to determine the level of spillage of combustion products during start-up; operation and shutdown of a gas fired appliance when operating in a depressurized environment.

Bodycote Materials Testing Canada Inc. (BMTC) was contracted by Natural Resources Canada (NRCan) to conduct laboratory testing to assess a proposed test procedure to address this issue. NRCan's work was supported by Canada Mortgage and Housing Corporation (CMHC).

This report is focused on a new *'transient spillage test'* that can be used to evaluate the performance of a wide range of residential combustion equipment. It can be used:

- for evaluating combustion equipment that transfers heat directly to air such as furnaces and those that transfer heat directly to water such as boilers and water heaters
- to capture potential start-up and shut-down issues
- to evaluate air heating appliances without requiring any precision laboratory cooling equipment

In order to evaluate the proposed transient spillage test procedure, BMTC was supplied with 7 gas-fired residential appliances and their approved venting systems. Upon receipt, each appliance was assigned a unique BMTC Sample Number. Descriptions of each appliance, together with their assigned Sample Numbers are detailed in Table 1.

Table 1 – Appliance Descriptions and Assigned BMTC Sample Numbers

Appliance Type	Description	Maximum Rated Input		BMTC Sample Number
		Btu/h	kW	
Water Heater	Power Vent	36,000	10.5	04-06-M0278-1
Furnace	Mid-Efficiency	75,000	22	04-06-M0278-2
Water Heater	Power Vent	34,000	10	04-06-M0278-4
Furnace	High Efficiency	80,000	23.4	04-06-M0278-5
Furnace	High Efficiency	80,000	23.4	04-06-M0278-6
Fireplace	Direct Vent Insert	24,000	7	04-06-M0278-7
Fireplace	Direct Vent Zero Clearance	21,000	6.2	04-06-M0278-8

Prior to carrying out any depressurization spillage testing, testing was performed to determine the integrity of the respective appliance venting and combustion system with regard to leakage rates.

All appliances were tested using the transient spillage procedure. As a point of comparison, BMTC Sample Numbers 04-06-M0278-1 and 04-06-M0278-2 were also tested using an earlier 'steady state' version of the test protocol that has previously been applied to products that first heated water.

2.0 TEST METHODOLOGY

2.1 Depressurization Spillage - General Test Procedure

The appliance shall be set-up in a test room that is equipped with an exhaust fan with sufficient capacity to allow for depressurization of the room to 0.2” w.c. (50 Pa.) with the appliance operating at the manufacturers’ maximum rated input.

The exhaust vent terminal and, if applicable, the combustion air inlet shall be installed through the wall of the test room to discharge the combustion products into the adjacent space and bring combustion air from the adjacent space. The test shall be performed with the maximum certified equivalent lengths of venting and shall be installed in accordance with the manufacturers’ instructions.

The adjacent space shall be adequately ventilated to ensure that the combustion products do not contaminate the space. A supplemental gas-capture and exhaust apparatus may be used to remove the combustion products from the space adjacent to the test room, provided that the CO_2 content, vent temperature and flow of the combustion products in the appliance combustion venting system is not affected by the operation of the apparatus.

A sampling port shall be installed to monitor the CO_2 level inside the test room and shall be located at the entrance of the depressurization exhaust duct. The pressure inside the test room shall be monitored at a location determined by the test laboratory but within 3-ft. (1 m) of the appliance under test. The pressure shall be maintained within ±0.01” w.c. (±2 Pa.) for the duration of the depressurization test by adjusting the flow through the test room exhaust fan. The airflow through the exhaust fan shall be measured and recorded throughout the test.

2.2 Transient Spillage Test Procedure

The appliance under test and the test room shall be set-up as outlined in Section 2.1. Using the test room exhaust fan the test room shall be depressurized to 0.2” w.c. (50 Pa.) and shall be maintained at this level for the duration of the test. The test room, adjacent space and combustion vent temperature shall be at equilibrium ambient conditions prior to the commencement of the test.

A gas meter reading shall be recorded immediately prior to initiating burner operation.

The CO_2 level in the test room and the test room exhaust fan flow shall be recorded on a time-step basis of 30 seconds.

Burner operation shall be terminated after 5 minutes of operation and a gas meter reading shall be recorded. Measurements shall continue for an additional 2 minutes after burner shutdown.

The CO_2 level in the adjacent space shall be recorded immediately following the test.

If the calculated cumulative spillage exceeds 2% with the test room depressurized to 0.2” w.c. (50 Pa.) additional tests shall be conducted to determine the depressurization pressure threshold level. The test shall be repeated with the test room depressurized to 0.08" w.c. (20 Pa.) If the calculated cumulative spillage is still in excess of 2%, the test shall be repeated with the test room depressurized to 0.02" w.c. (5 Pa.).

2.2.1 Transient Spillage Calculations

Transient spillage is calculated and reported over the entire 7-minute test period. For each time interval, calculate the CO_2 leakage into the room from the measured exhaust flow during the interval multiplied by the increase in CO_2 from the background level. If the appliance draws combustion air (including air used for pre-purge and post-purge) from the depressurized test room, the volume of combustion air shall be determined by either direct measurement or by combustion analysis. The combustion air drawn from the test room is added to the measured exhaust flow for each time interval.

Sum the intervals over the 7 minutes to calculate the cumulative CO_2 that has been removed by the exhaust fan.

Add the amount of CO_2 that remains in the test room calculated from the volume of the test room and the change in CO_2 between the start and end of the test.

Calculate the spillage as total CO_2 leakage divided by the CO_2 produced by the burner during the test time.

The appliance passes the test if the CO_2 spillage calculated over the entire test period is under 2% of the CO_2 generated by the appliance during the cycle (5 minutes of burner operation). The final 2 minutes of monitoring are conducted to observe the effects of shutdown spillage.

2.2.2 Steady State Depressurization Spillage Test Procedure

The appliance under test and the test room shall be set-up as outlined in Section 2.1. A load shall be imposed on the appliance to cause the burner to operate. The load shall be adjusted as necessary to maintain steady firing of the burner system at the maximum rated input for the duration of the test. Using the test room exhaust fan the test room shall be depressurized to 0.2" w.c. (50 Pa.). This level of depressurization shall be maintained for the duration of the test.

The CO_2 levels in the test room and the adjacent space shall be monitored during the test. The test shall be continued until steady state is obtained. Steady state shall be acceptable when the firing rate, net vent gas temperature, vent CO_2, test room CO_2, adjacent area CO_2 and test room exhaust fan flow do not vary by more than ±2% for three sets of readings taken over a fifteen minute period.

If the calculated spillage exceeds 2% with the test room depressurized to 0.2" w.c. (50 Pa.), the test shall be repeated with the test room depressurized successively by 0.12" w.c. (30 Pa.), 0.08" w.c. (20 Pa.), 0.04" w.c. (10 Pa.) and 0.02" w.c. (5 Pa.) until the calculated spillage is under 2%.

2.2.3 Steady State Depressurization Spillage Calculations

The CO_2 volume leakage from the appliance into the test room shall be calculated in CFM as follows:

*Leakage = ($CO_{2\ (test\ room)}$ – $CO_{2\ (adjacent\ space)}$) * Exhaust Fan Flow (including combustion air from room if applicable)* Scaling Factor*
[The scaling factor is required to convert the concentration units of CO_2 to a decimal fraction and thereby calculate the leakage in SCFM]

The CO_2 generated by the combustion process, in SCFM shall be determined as follows:

CO_2 generated by the appliance burner = Input rate (Btu/h)/1000 * 0.0167 SCFM/1000 Btu/h

Spillage = Leakage / CO_2 generated by the appliance burner

2.3 Static Leakage Test Procedure

The static leakage test procedure that was used in this project to evaluate leakage of appliance vents and components is based on vent leakage tests that are included in existing test codes for gas-fired appliances. Vent leakage tests are normally intended for use only with direct vent appliances.

For this project the static leakage test was performed at a pressure of 0.1” w.c. (25 Pa.) as follows:

The component of interest shall be sealed at the point at which they would normally be connected to the vent and air intake terminals. The sealing means shall incorporate fittings suitable for introducing air to the specimen and shall include provisions to determine the air static pressure.

The internal static pressure in each section shall be determined using a pressure measurement instrument with measurement accuracy of at least 0.01” w.c. (2.5 Pa.).

A suitable supply of clean air shall be introduced into the specimen through a calibrated metering device. The air supply into the specimen shall be adjusted to produce an internal air pressure of 0.1” w.c. (25 Pa.), and the air flow rate required to produce this pressure shall be recorded as the section leakage (in cubic feet per hour).

2.3.1 Static Leakage Calculations

The airflow required to maintain the pressure of the test specimen at 0.1”w.c. (25 Pa.) shall be reported. The maximum allowable static leakage for each test specimen, corresponding with 2% leakage at the rated appliance input shall also be reported. The static leakage corresponding with 2% leakage shall be determined as follows:

$$L_C = 0.02 * 15 * I$$

Where:

L_C is the leakage rate in ft^3/h corresponding with 2% leakage.

The factor 15 is based on the formation of approximately 15 ft^3 combustion products (including 50% excess air) per 1000 Btu/h input.

I is the appliance burner input rate (in thousands of Btu/h)

3.0 TRANSIENT DEPRESSURIZATION SPILLAGE TEST SET-UP

All depressurization spillage tests were conducted using a supplemental gas-capture hood and exhaust system to remove the combustion products from the space adjacent to the test room.

The same procedure was used for setting up the steady state testing.

3.1 Sample Number 04-06-M0278-1 – Power Vented Water Heater

The power vented water heater was installed in the test room and set-up in accordance with the manufacturers' instructions. The appliance had a rated input of 36,000 Btu/h (10.5 kW) and incorporated an intermittent pilot and electronic ignition system. Venting requirements, as specified by the manufacturer comprised 2" ABS pipe and fittings. The maximum specified exhaust vent length of 60 equivalent feet was installed. The vent was terminated outside of the test room using a 90° terminal elbow supplied with the unit. The water heater utilized air from inside the test room for combustion and for the dilution of the exhaust products prior to entering the venting system. Photographs of the set-up are shown in Figures 1 and 2.

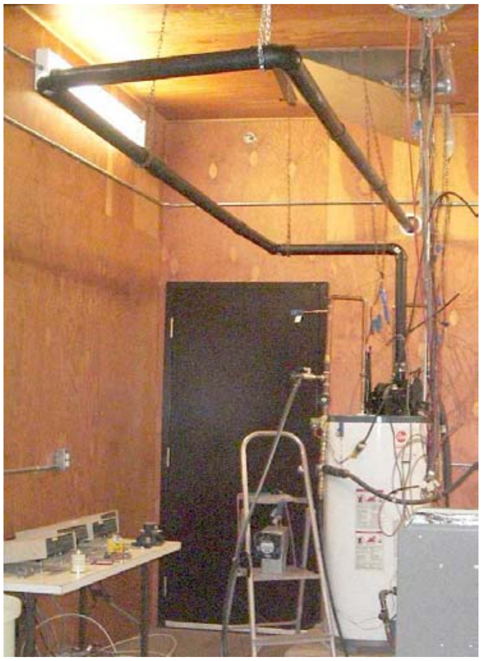


Figure 1 – Water Heater Vent Configuration
Sample No. 04-06-M0278-1

Figure 2 – Exhaust Vent Termination
Sample No. 04-06-M0278-1

3.2 Sample Number 04-06-M0278-2 – Mid-Efficiency Furnace

This induced draft mid-efficiency furnace is certified as a Category I appliance, and is approved as a fan- assisted negative pressure vent appliance. The furnace had a rated input of 75,000 Btu/h (22 kW) and incorporated an intermittent pilot and electronic ignition system.

In order to accommodate the sidewall venting requirement for installation in the BMTC test room, an accessory kit, specified by the manufacturer was purchased. The kit, comprised a sidewall power venter, a barometric damper and associated controls. It was installed and the supplemental control system was integrated with the furnace controls in accordance with the instructions.

The venting system comprised 4" double-wall 'Type B' vent and the maximum equivalent length of 35 feet, as specified in the installation instructions was installed. The furnace utilized air from inside the test room for combustion. Photographs of the set-up are shown in Figures 3 to 5.

Figure 3 – Mid-Efficiency Furnace
'Type B' Vent Configuration
Sample No. 04-06-M0278-2

Figure 4 – Barometric Damper Location
Sample No. 04-06-M0278-2

Figure 5 – Power Venter Exhaust Terminal
Sample No. 04-06-M0278-2

3.3 Sample Number 04-06-M0278-4 – Power Vented Water Heater

The power vented water heater was installed in the test room and set-up in accordance with the manufacturers' instructions. The appliance had a rated input of 34,000 Btu/h (10 kW) and incorporated an intermittent pilot and electronic ignition system. Venting requirements, as specified by the manufacturer comprised 2" ABS pipe and fittings. The maximum specified exhaust vent length of 50 equivalent feet was installed. The vent was terminated outside of the test room using a 90° terminal elbow supplied with the unit. The water heater utilized air from inside the test room for combustion and for the dilution of the exhaust products prior to entering the venting system. Photographs of the set-up are shown in Figures 6 and 7.

Figure 6 – Water Heater Vent Configuration
Sample No. 04-06-M0278-4

Figure 7 – Exhaust Terminal
Sample No. 04-06-M0278-4

3.4 Sample Number 04-06-M0278-5 – High Efficiency Furnace

The high efficiency condensing furnace was installed in the test room and set-up in accordance with the manufacturers' instructions. The furnace had a rated input of 80,000 Btu/h (23.4 kW) and incorporated an intermittent pilot and electronic ignition system. The manufacturers' installation requirements specify that the furnace can be installed as a direct vent or non-direct vent system.

When installed as a direct vent system, combustion air is supplied from outside the building envelope and exhaust products are discharged to outdoors. A non-direct venting system would utilize indoor air for combustion while venting the combustion products outdoors.

For the requirements of this testing, a non-direct venting system was installed. 60 equivalent feet of 2" ABS pipe, the maximum length specified by the manufacturer was installed from the exhaust of the furnace, terminating outside of the test room. Air from inside the test room was used for combustion. Photographs of the set-up are shown in Figures 8 and 9.

Figure 8 – High Efficiency Furnace Vent Configuration
Sample No. 04-06-M278-5

Figure 9 – Exhaust Vent Termination
Sample No. 04-06-M278-5

3.5 Sample Number 04-06-M0278-6 – High Efficiency Furnace

The high efficiency condensing furnace was installed in the test room and set-up in accordance with the manufacturers' instructions. The furnace had a rated input of 80,000 Btu/h (23.4 kW) and incorporated an intermittent pilot and electronic ignition system. The manufacturers' installation requirements specify that the furnace can be installed as a direct vent or non-direct vent system.

When installed as a direct vent system, combustion air is supplied from outside the building envelope and exhaust products are discharged to outdoors. A non-direct venting system would utilize indoor air for combustion while venting the combustion products outdoors.

For the requirements of this testing, a non-direct venting system was installed. In compliance with the manufacturers' specifications, the maximum vent length of 30 feet of 2" ABS pipe plus 5, 90° elbows was installed from the exhaust of the furnace, terminating outside of the test room. To comply with the manufacturers' requirements for a non-direct vent system, a 9" length of ABS pipe and a 90° elbow were installed on the combustion air intake of the furnace. Two perforated disks, supplied with the furnace were positioned in this elbow as per the installation requirements. Air from inside the test room was used for combustion. Photographs of the set-up are shown in Figures 10 and 11.

Figure 10 - High Efficiency Furnace Vent Configuration
Sample No. 04-06-M278-6

Figure 11 - High Efficiency Furnace Vent Configuration
Showing Combustion Air Intake
Sample No. 04-06-M278-6

3.6 Sample Number 04-06-M0278-7 – Direct Vent Fireplace Insert

This fireplace is designed for installation as a retrofit for an existing solid fuel fireplace cavity. The unit supplied had a maximum rated input of 24,000 Btu/h (7 kW) and incorporated a standing pilot, having an input of approximately 1,500 Btu/h and a manually operated piezo ignition system. The appliance was equipped with an integral variable speed blower for air distribution. The blower was activated using a temperature sensing device within the fireplace enclosure.

Being a direct vent system, combustion air is supplied from outside the building envelope and exhaust products are discharged to outdoors.

The fireplace was installed in the test room and set-up in accordance with the manufacturers' instructions. Two 3" diameter double-ply flexible aluminum pipes, one for combustion air and one for exhaust products were connected to the fireplace using high temperature silicone sealant. The flexible pipes were routed through the side wall of the test room and extended vertically, terminating at the vent terminal supplied by the manufacturer. While the extended length of the flexible pipes was specified as 35 feet each, limitations of the test area restricted this length to approximately 20 feet each. Photographs of the vent set-up are shown in Figures 12 and 13.

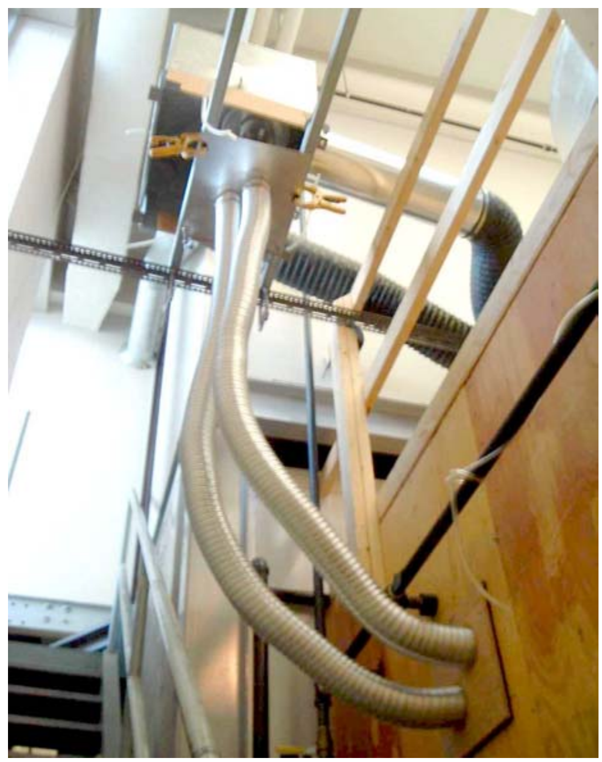


Figure 13 – Fireplace Insert Vent Configuration
Outside Test Room
Sample No. 04-06-M0278-7

Figure 12 – Fireplace Insert Vent Termination
Sample No. 04-06-M0278-7

3.7 Sample Number 04-06-M0278-8 – Direct Vent Zero Clearance Fireplace

This type of fireplace is designed for installation where there is no existing fireplace, typically during new home construction and requires no clearance to combustible materials. The supplied fireplace had a rated input of 21,000 Btu/h (6.2 kW) and incorporated a standing pilot, having an input of approximately 1,100 Btu/h and a manually operated piezo ignition system.

Being a direct vent system, combustion air is supplied from outside the building envelope and exhaust products are discharged to outdoors.

The fireplace was installed in the test room and set-up in accordance with the manufacturers' instructions. The venting for this unit utilized a concentric double-ply flexible aluminum pipe system. A 4"diameter inner pipe was used to vent the exhaust products, while a 7" diameter outer pipe provided the combustion air. Spring type spacers installed on the 4" diameter pipe acted to maintain an annular separation between the two pipes.

The concentric vent system was connected to the fireplace using high temperature silicone sealant in accordance with the manufacturers' instructions. The vent system was extended vertically for approximately 4 feet and horizontally for 8 feet, terminating at the side-wall vent terminal supplied by the manufacturer. Photographs of the set-up are shown in Figures 14 to 16.

Figure 14 –Zero Clearance Fireplace In Operation
Sample No. 04-06-M0278-8

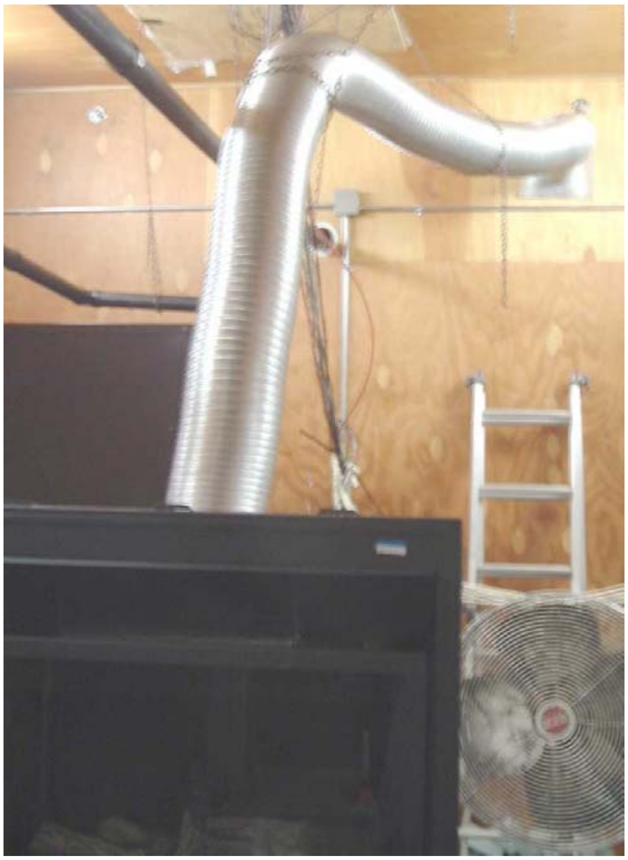


Figure 15 – Zero Clearance Fireplace Vent Configuration
Sample No. 04-06-M0278-8

Figure 16 – Zero Clearance Fireplace Vent Termination
Sample No. 04-06-M0278-8

4.0 LEAKAGE TESTING

The leakage test methodology outlined in Section 2.4 was developed as a requirement for the éKOCOMFORT™ AIMS evaluation program to determine the integrity of the venting and combustion modules of these integrated units. The procedure was developed primarily for direct vent appliances that utilize outdoor air for combustion and vent the combustion products outdoors.

The configuration of the appliances supplied for the present evaluation and the types of venting specified was such that not all of the test procedures were applicable.

4.1 Sample Numbers 04-06-M278-1 and 04-06-M278-4 – Power Vented Water Heaters

The two water heaters supplied were both power vented units that utilized indoor air for combustion and Schedule 40 ABS pipe to vent the combustion products to outdoors. Indoor air was also used by both appliances to reduce the temperature of the combustion products to acceptable levels prior to entering the ABS exhaust vent. Discussions between BMTC and NRCan concluded that vent leakage testing on these two venting systems was not required, as the integrity of the ABS vent pipe material was deemed to be such that no leakage would occur.

4.2 Sample Number 04-06-M278-2 – Mid Efficiency Furnace

The induced draft mid-efficiency furnace supplied utilized indoor air for combustion and was installed using 'Type B' vent to exhaust the combustion products.

As discussed earlier, a retrofit kit including a power venter and barometric damper was installed to accommodate side wall venting. The power venter, barometric damper and the Tee fitting that was used for installation of the damper were removed from the system prior to conducting the leakage test on the exhaust vent.

The opening used to accommodate the barometric damper was sealed and both ends of the vent were sealed. Fittings were incorporated to allow for the introduction of air and for the measurement of static pressure. A metering device was installed to measure the air flow rate. Clean air was introduced into the system and the flow rate was adjusted to provide a static pressure of 0.1" w.c. (25 Pa.). The air flow rate required to maintain this static pressure was recorded. A photograph of the test set-up is shown in Figure 17.

Figure 17 – Static Leakage Test Set-up
'Type B' Vent System
Sample No. 04-06-M0278-2

4.3 Sample Numbers 04-06-M278-5 and 04-06-M278-6 – High Efficiency Furnaces

As with the power vented water heaters, a similar situation was evident with the two high efficiency furnaces submitted for evaluation. Both units were tested as “one-pipe” non-direct vent units and therefore utilized indoor air for combustion. ABS pipe was used on both furnaces for the venting of combustion products. Again, it was concluded that performing leakage testing on these vents would be of no benefit.

As both furnaces had the option of being installed as direct vent systems, it was considered prudent to perform leakage testing on the heating module (combustion chamber and heat exchanger) assemblies of these units.

Leakage testing on both high efficiency furnaces was performed by sealing the combustion air inlet and exhaust products outlet connections at the furnace. Fittings were incorporated to allow for the introduction of air and for the measurement of static pressure. A metering device was installed to measure the air flow rate. Clean air was introduced into the system and the flow rate was adjusted to provide a static pressure of 0.1” w.c. (25 Pa.). The air flow rate required to maintain this static pressure was recorded. Photographs of the test set-up for each furnace are shown in Figures 18 and 19.

Figure 18 – Heating Module Leakage Test Set-up
Sample No. 04-06-M278-5

Figure 19 – Heating Module Leakage Test Set-up
Sample No. 04-06-M278-6

4.4 Sample Numbers 04-06-M278-7 and 04-06-M278-8 – Direct Vent Fireplaces

Both of the fireplaces supplied were direct vent appliances, utilizing outdoor air for combustion and exhausting the combustion products to outdoors. The venting systems for both units comprised seamless double ply flexible aluminum pipe. As with the ABS vent system used on the power vented water heaters and high efficiency furnaces, it was concluded that performing leakage testing on these vents would be of no benefit. As such, leakage testing was limited to the heating module (combustion chamber and heat exchanger) assemblies.

The combustion air inlet and exhaust products outlet connections were sealed at the fireplace. . Fittings were incorporated to allow for the introduction of air and for the measurement of static pressure. A metering device was installed to measure the air flow rate. Clean air was introduced into the system and the flow rate was adjusted to provide a static pressure of 0.1” w.c. (25 Pa.). The air flow rate required to maintain this static pressure was recorded. Photographs of the test set-up are shown in Figures 20 to 22.

Figure 20 – Air Intake and Exhaust Connections
(Shown with connections sealed)
Sample No. 04-06-M278-7

Figure 21 – Heating Module Leakage Test Set-up
Sample No. 04-06-M278-8

Figure 22 – Concentric Vent Connection
(Shown with exhaust duct sealed)
Sample No. 04-06-M278-8

5.0 TEST RESULTS

The results of the testing performed are detailed below. A summary of the test results is presented in Table 4.

Details of equipment and instrumentation used throughout the testing are shown in Appendix A.

5.1 Transient Spillage Test Results

The data recorded during the transient spillage testing is presented in Appendix B.

5.1.1 Sample Number 04-06-M0278-1 – Power Vented Water Heater

Base test room CO_2 = 430 ppm
Base adjacent space CO_2 = 422 ppm

Room Static Pressure = -0.2" w.c. (-50 Pa)
Room Exhaust Fan Flow = 261 scfm (123 l/s)
Appliance Exhaust Flow = 21 scfm (10 l/s)

Room CO_2 at start of test = 433 ppm
Room CO_2 at end of test = 443 ppm
Volume of test room = 1578 ft^3

Transient spillage = *(CO_2 in test room at end of test + Cumulative CO_2 removed) / CO_2 generated*

Where:

CO_2 remaining in test room at end of 7 minute test
= *((Room CO_2 at end of test - Room CO_2 at start of test) * Scaling Factor) * Volume of Test Room*
(Where the Scaling Factor converts CO_2 concentrations in ppm to a decimal fraction)
= ((443 – 433) * 0.000001) * 1578
= 0.016 ft^3

CO_2 removed from test room per time interval
= *($CO_{2\ (test\ room)} - CO_{2\ (adjacent\ space)}$) * (Exhaust Fan Flow + Appliance Exhaust Flow) * (Scaling Factor)*

Cumulative CO_2 removed from test room
= *Cumulative Sum of CO_2 removed from test room per time interval*
= 0.0175 ft^3

CO_2 generated by appliance during 5 minute burner operation
= *(Input Rate [Btu/h]/1000) * (0.0167 [SCFM]/1000 [Btu/h]) * Time [minutes]*
= ((36,000 * 0.0167) / 1000) * 5
= 3 ft^3

Transient spillage = (0.016 + 0.0175) / 3 = 0.0112

Transient Spillage at 0.2" w.c. (50 Pa) depressurization = 1.1%

5.1.2 Sample Number 04-06-M0278-2 – Mid-Efficiency Furnace Test #1

Base test room CO_2 = 440 ppm
Base adjacent space CO_2 = 440 ppm

Room Static Pressure = -0.2" w.c. (-50 Pa)
Room Exhaust Fan Flow = 267 scfm (126 l/s)
Appliance Exhaust Flow = 18 scfm (9 l/s)

Room CO_2 at start of test = 441 ppm
Room CO_2 at end of test = 452 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = 0.018 ft^3
Cumulative CO_2 removed from test room = 0.0046 ft^3
CO_2 generated by appliance during 5 minute burner operation = 6.26 ft^3

Transient spillage **=** **(**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient spillage at 0.2" w.c. (50 Pa) depressurization = 0.4%

5.1.2.1 Sample Number 04-06-M0278-2 – Mid-Efficiency Furnace Test #2

Test performed with increased flow at supplemental gas-capture hood in order to minimize contamination of adjacent area.

Base test room CO_2 = 442 ppm
Base adjacent space CO_2 = 423 ppm

Room Static Pressure = -0.2" w.c. (-50 Pa)
Room Exhaust Fan Flow = 282 scfm (133 l/s)
Appliance Exhaust Flow = 18 scfm (9 l/s)

Room CO_2 at start of test = 442 ppm
Room CO_2 at end of test = 448 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = 0.01 ft^3
Cumulative CO_2 removed from test room = 0.0003 ft^3
CO_2 generated by appliance during 5 minute burner operation = 6.3 ft^3

Transient spillage **=** **(**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient spillage at 0.2" w.c. (50 Pa) depressurization = 0.2%

5.1.3 Sample Number 04-06-M0278-4 – Power Vented Water Heater Test #1

Base test room CO_2 = 414 ppm
Base adjacent space CO_2 = 426 ppm

Room Static Pressure = -0.2" w.c. (-50 Pa)
Room Exhaust Fan Flow = 248 scfm (117 l/s)
Appliance Exhaust Flow = 31 scfm (14 l/s)

Room CO_2 at start of test = 413 ppm
Room CO_2 at end of test = 433 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = 0.032 ft^3
Cumulative CO_2 removed from test room = 0.0107 ft^3
CO_2 generated by appliance during 5 minute burner operation = 2.75 ft^3

Transient spillage **= (**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient Spillage at 0.2" w.c. (50 Pa) depressurization = 1.6%

5.1.3.1 Sample Number 04-06-M0278-4 – Power Vented Water Heater Test #2

Test performed with water heater exhaust venting directly into the test room. This test was conducted to validate the test procedure and to establish the calculated spillage. Ideally, the resultant spillage should equal 100% under this test condition.

Base test room CO_2 = 454 ppm
Base adjacent space CO_2 = 441 ppm

Room Static Pressure = -0.2" w.c. (-50 Pa)
Room Exhaust Fan Flow = 269 scfm (127 l/s)
Appliance Exhaust Flow = 31 scfm (14 l/s)

Room CO_2 at start of test = 440 ppm
Room CO_2 at end of test = 1235 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = 1.255 ft^3
Cumulative CO_2 removed from test room = 1.087 ft^3
CO_2 generated by appliance during 5 minute burner operation = 2.74 ft^3

Transient spillage **= (**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient spillage at 0.2" w.c. (50 Pa) depressurization = 85%

5.1.4 Sample Number 04-06-M0278-5 – High-Efficiency Furnace

Base test room CO_2 = 446 ppm
Base adjacent space CO_2 = 439 ppm

Room Static Pressure = -0.2” w.c. (-50 Pa)
Room Exhaust Fan Flow = 279 scfm (132 l/s)
Appliance Exhaust Flow = 20 scfm (9.5 l/s)

Room CO_2 at start of test = 447 ppm
Room CO_2 at end of test = 453 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = 0.009 ft^3
Cumulative CO_2 removed from test room = -0.0062 ft^3
CO_2 generated by appliance during 5 minute burner operation = 6.05 ft^3

Transient spillage **= (**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient spillage at 0.2” w.c. (50 Pa) depressurization = 0.05%

5.1.5 Sample Number 04-06-M0278-6 – High-Efficiency Furnace

Base test room CO_2 = 423 ppm
Base adjacent space CO_2 = 436 ppm

Room Static Pressure = -0.2” w.c. (-50 Pa)
Room Exhaust Fan Flow = 295 scfm (139 l/s)
Appliance Exhaust Flow = 24 scfm (11 l/s)

Room CO_2 at start of test = 426 ppm
Room CO_2 at end of test = 426 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = -0.001 ft^3
Cumulative CO_2 removed from test room = 0.0092 ft^3
CO_2 generated by appliance during 5 minute burner operation = 6.21 ft^3

Transient spillage **= (**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient Spillage at 0.2” w.c. (50 Pa) depressurization = 0.14%

5.1.6 Sample Number 04-06-M0278-7 – Direct Vent Fireplace Insert – Test #1

Base test room CO_2 = 443 ppm
Base adjacent space CO_2 = 409 ppm

Room Static Pressure = -0.2" w.c. (-50 Pa)
Room Exhaust Fan Flow = 274 scfm (129 l/s)
Appliance Exhaust Flow = 9 scfm (4 l/s)

Room CO_2 at start of test = 443 ppm
Room CO_2 at end of test = 548 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = 0.166 ft^3
Cumulative CO_2 removed from test room = 0.1128 ft^3
CO_2 generated by appliance during 5 minute burner operation = 2.1 ft^3

Transient spillage **=** **(**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient spillage at 0.2" w.c. (50 Pa) depressurization = 13.3%

5.1.6.1 Sample Number 04-06-M0278-7 – Direct Vent Fireplace Insert – Test #2

Repeat of Test #1. Additional circulating fan installed in test room to improve mixing and ensure uniform environment.

Base test room CO_2 = 450 ppm
Base adjacent space CO_2 = 411 ppm

Room Static Pressure = -0.2" w.c. (-50 Pa)
Room Exhaust Fan Flow = 266 scfm (125 l/s)
Appliance Exhaust Flow = 9 scfm (4 l/s)

Room CO_2 at start of test = 456 ppm
Room CO_2 at end of test = 531 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = 0.118 ft^3
Cumulative CO_2 removed from test room = 0.1467 ft^3
CO_2 generated by appliance during 5 minute burner operation = 2.07 ft^3

Transient spillage **=** **(**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient spillage at 0.2" w.c. (50 Pa) depressurization = 12.8%

5.1.6.2 Sample Number 04-06-M0278-7 – Direct Vent Fireplace Insert – Test #3

Test room depressurization at 0.08" w.c. (20 Pa.)

Base test room CO_2 = 455 ppm
Base adjacent space CO_2 = 421 ppm

Room Static Pressure = -0.08" w.c. (-20 Pa)
Room Exhaust Fan Flow = 139 scfm (66 l/s)
Appliance Exhaust Flow = 9 scfm (4 l/s)

Room CO_2 at start of test = 455 ppm
Room CO_2 at end of test = 482 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = 0.044 ft^3
Cumulative CO_2 removed from test room = 0.0299 ft^3
CO_2 generated by appliance during 5 minute burner operation = 2.09 ft^3

Transient spillage **= (**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient Spillage at 0.08" w.c. (20 Pa) depressurization = 3.5%

5.1.6.3 Sample Number 04-06-M0278-7 – Direct Vent Fireplace Insert – Test #4

Test room depressurization at 0.02" w.c. (5 Pa.)

Base test room CO_2 = 441 ppm
Base adjacent space CO_2 = 412 ppm

Room Static Pressure = -0.02" w.c. (-5 Pa)
Room Exhaust Fan Flow = 55 scfm (26 l/s)
Appliance Exhaust Flow = 9 scfm (4 l/s)

Room CO_2 at start of test = 441 ppm
Room CO_2 at end of test = 442 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = 0.001 ft^3
Cumulative CO_2 removed from test room = -0.0007 ft^3
CO_2 generated by appliance during 5 minute burner operation = 2.08 ft^3

Transient spillage **= (**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient spillage at 0.02" w.c. (5 Pa) depressurization = 0.01%

5.1.7 Sample Number 04-06-M0278-8 – Direct Vent Zero Clearance Fireplace

Base test room CO_2 = 414 ppm
Base adjacent space CO_2 = 409 ppm

Room Static Pressure = -0.2” w.c. (-50 Pa)
Room Exhaust Fan Flow = 282 scfm (133 l/s)
Appliance Exhaust Flow = 15 scfm (7 l/s)

Room CO_2 at start of test = 415 ppm
Room CO_2 at end of test = 412 ppm
Volume of test room = 1578 ft^3

CO_2 remaining in test room at end of 7 minute test = 0.005 ft^3
Cumulative CO_2 removed from test room = 0.0086 ft^3
CO_2 generated by appliance during 5 minute burner operation = 1.95 ft^3

Transient spillage **=** **(**CO_2 remaining in test room at end of test + Cumulative CO_2 removed) / CO_2 generated

Transient spillage at 0.2” w.c. (50 Pa) depressurization = 0.7%

5.2 Steady State Depressurization Spillage Test Results

5.2.1 Sample Number 04-06-M0278-1 – Power Vented Water Heater

Table 2 – Steady State Depressurization Spillage Test Data – Sample No. 04-06-M0278-1

Time	T_{vent}		CO_2 (vent) (%)	CO_2 (test room) (ppm)	CO_2 (adjacent space) (ppm)
	(°F)	(°C)			
15:10	123.0	50.6	3.2	504	489
15:15	122.9	50.5	3.2	507	487
15:20	122.9	50.5	3.2	503	484
15:25	122.9	50.5	3.2	500	486

The maximum variance of $T_{exhaust}$, $CO_{2\ (exhaust)}$, $CO_{2\ (test\ room)}$ and $CO_{2\ (adjacent\ space)}$ did not exceed 2% during the test period.

Base test room CO_2 = 508 ppm
Base adjacent space CO_2 = 488 ppm

Average fuel input rate = 37,299 Btu/h
Room Static Pressure = -0.2" w.c. (-50 Pa)
Room Exhaust Fan Flow = 276 scfm (130 l/s)
Appliance Exhaust Flow = 21 scfm (10 l/s)

Spillage = Leakage / CO_2 generated by the unit.

Where:

*Leakage = ($CO_{2\ (test\ room)}$ – $CO_{2\ (adjacent\ space)}$) * (Exhaust Fan Flow + Appliance Exhaust Flow) * (Scaling Factor)*

(Where the Scaling Factor converts CO_2 concentrations in ppm to a decimal fraction)

CO_2 generated by the unit = (Input Rate [Btu/h]/1000) x (0.0167 [SCFM]/1000 [Btu/h])

The spillage from the appliance was calculated to be -0.1%.

5.2.2 Sample Number 04-06-M0278-2 – Mid-Efficiency Furnace

Table 3 – Steady State Depressurization Spillage Test Data – Sample No. 04-06-M278-2

Time	$T_{exhaust}$		CO_2 (exhaust) (%)	CO_2 (test room) (ppm)	CO_2 (adjacent space) (ppm)
	(°F)	(°C)			
15:40	379.2	192.9	7.9	466	428
15:45	379.4	193.0	7.9	466	427
15:50	379.4	193.0	7.9	464	430
15:55	379.6	193.1	7.9	464	430

The maximum variance of $T_{exhaust}$, $CO_{2\ (exhaust)}$, $CO_{2\ (test\ room)}$ and $CO_{2\ (adjacent\ space)}$ did not exceed 2% during the test period.

Base test room CO_2 = 429 ppm
Base adjacent space CO_2 = 422 ppm

Average fuel input rate = 75,070 Btu/h
Room Static Pressure = -0.2” w.c. (-50 Pa)
Room Exhaust Fan Flow = 262 scfm (124 l/s)
Appliance Exhaust Flow = 18 scfm (9 l/s)

Spillage = Leakage / CO_2 generated by the unit.

Where:

*Leakage = ($CO_{2\ (test\ room)}$ – $CO_{2\ (adjacent\ space)}$) * (Exhaust Fan Flow + Appliance Exhaust Flow) * (Scaling Factor)*

(Where the Scaling Factor converts CO_2 concentrations in ppm to a decimal fraction)

CO_2 generated by the unit = (Input Rate [Btu/h]/1000) x (0.0167 [SCFM]/1000 [Btu/h])

The spillage from the appliance was calculated to be 0.6%.

5.3 Static Leakage Test Results

5.3.1 Sample Numbers 04-06-M0278-1 and 04-06-M0278-4 – Power Vented Water Heaters

No leakage testing was performed on these appliances as the integrity of the ABS vent pipe material was deemed to be such that no leakage would occur.

5.3.2 Sample Number 04-06-M0278-2 – Mid-Efficiency Furnace

Leakage testing was performed on the combustion exhaust vent.

The leakage rate recorded during the test was 186 cfh (87.8 l/min)

Leakage rate expressed as a percentage of the input rating (including 50% excess air)
= 186 / (15 * 75)
= 16.5%

Corresponding leakage rate at 2% (L_C) = 0.02 * 15 * 75
= 22.5 cfh (10.6 l/min)

As this furnace is certified as a Category I appliance, the vent system operates under negative pressure. As such, subjecting this type of vent to a static leakage test is not applicable.

5.3.3 Sample Number 04-06-M0278-5 – High-Efficiency Furnace

Leakage testing was performed on the furnace heating module (combustion chamber/heat exchanger).

The leakage rate recorded during the test was 10.8 cfh (5.1 l/min)

Leakage rate expressed as a percentage of the input rating (including 50% excess air)

= 10.8 / (15 * 80)
= 0.9%

Corresponding leakage rate at 2% (L_C) = 0.02 * 15 * 80
= 24 cfh (11.3 l/min)

5.3.4 Sample Number 04-06-M0278-6 – High-Efficiency Furnace

Leakage testing was performed on the furnace heating module (combustion chamber/heat exchanger).

The leakage rate recorded during the test was 9.5 cfh (4.5 l/min)

Leakage rate expressed as a percentage of the input rating (including 50% excess air)
= 9.5 / (15 * 80)
= 0.8%

Corresponding leakage rate at 2% (L_C) = 0.02 * 15 * 80
= 24 cfh (11.3 l/min)

5.3.5 Sample Number 04-06-M0278-7 – Direct Vent Fireplace Insert

Leakage testing was performed on the fireplace heating module (combustion chamber/heat exchanger).

The leakage rate recorded during the test was 6 cfh (2.9 l/min)

Leakage rate expressed as a percentage of the input rating (including 50% excess air)
= 6 / (15 * 24)
= 1.7%

Corresponding leakage rate at 2% (L_C) = 0.02 * 15 * 24
= 7.2 cfh (3.4 l/min)

5.3.6 Sample Number 04-06-M0278-8 – Direct Vent Zero Clearance Fireplace

Leakage testing was performed on the fireplace heating module (combustion chamber/heat exchanger).

The leakage rate recorded during the test was 4.7 cfh (2.2 l/min)

Leakage rate expressed as a percentage of the input rating (including 50% excess air)
= 4.7 / (15 * 21)
= 1.5%

Corresponding leakage rate at 2% (L_C) = 0.02 * 15 * 21
= 6.3 cfh (3 l/min)

Table 4 – Summary of Test Results

	Power Vented Water Heater 04-06-M278-1	Mid-Efficiency Furnace 04-06-M278-2	Power Vented Water Heater 04-06-M278-4	High Efficiency Furnace 04-06-M278-5	High Efficiency Furnace 04-06-M278-6	Direct Vent Fireplace Insert 04-06-M278-7	Direct Vent Zero Clearance Fireplace 04-06-M278-8
Maximum Rated Input (MBtu/h) (kW)	36 (10.5)	75 (22)	34 (10)	80 (23.4)	80 (23.4)	24 (7)	21 (6.2)
Maximum Equivalent Exhaust Vent Length (ft) (m)	60 (18)	35 (11)	50 (15)	60 (18)	55 (17)	35 (11)	12 (4)[1]
Maximum Equivalent Combustion Air Vent Length (ft) (m)	-	-	-	60 (18)[2]	55 (17)[2]	35 (11)	12 (4)[1]
Burner Pre-Purge Time (seconds)	15	15	15	60	45	0	0
Burner Post-Purge Time (seconds)	30	15	30	30	15	0	0
Transient Spillage at 0.2" w.c. (50 Pa) Depressurization (%)	1.1	0.4 / 0.2[3]	1.6	0.05	0.14	13.3 / 12.8[4]	0.7
Transient Spillage at 0.08" w.c. (20 Pa) Depressurization (%)	-	-	-	-	-	3.5	-
Transient Spillage at 0.02" w.c. (5 Pa) Depressurization (%)	-	-	-	-	-	0.01	-
Steady State Spillage at 0.2" w.c. (50 Pa) Depressurization (%)	-0.1	0.6	-	-	-	-	-
Static Leakage (cfh) (l/min)	-	186 (87.8)[5]	-	10.8 (5.1)[6]	9.5 (4.5)[6]	6.0 (2.9)[6]	4.7 (2.2)[6]
Static Leakage (%)[7]	-	16.5	-	0.9	0.8	1.7	1.5

1. Tested with 4 ft. (1.2 m) vertical, 8 ft. (2.4 m) horizontal venting installed.
2. Appliances tested as single pipe installations – combustion air vent not installed.
3. Reduction in calculated spillage from 0.4% to 0.2% after flow increased at supplemental gas-capture hood to minimize contamination of adjacent area.
4. Reduction in calculated spillage from 13.3% to 12.8% after installation of additional circulation fan in test room to improve mixing and ensure uniform environment.
5. Leakage testing conducted on exhaust vent only.
6. Leakage testing conducted on combustion chamber/heat exchanger only.
7. Leakage rate expressed as a percentage of the appliance input rating (including 50% excess air).

6.0 TESTING COMMENTS

Results of the transient combustion spillage tests performed show that 6 of the 7 appliances had a calculated spillage of less than 2% with the test room depressurized to 0.2” w.c. (50 Pa.) prior to the commencement of the testing.

The direct vent fireplace insert, had a spillage of 13.3% with the test room depressurized to 0.2” w.c. (50 Pa.). This test was repeated with an additional air circulation fan installed in the test room to provide additional mixing of the room environment. The repeated test resulted in a calculated spillage of 12.8%. This 4% reduction in spillage may be attributed to better mixing of the test room environment or, the level of repeatability of the test method. Additional tests were conducted on this appliance with the test room depressurized to 0.08” w.c. (20 Pa.) and 0.02” w.c. (5 Pa.), resulting in calculated spillage of 3.5% and 0.01% respectively.

During some of the transient spillage tests conducted, oscillations were apparent in the readings recorded from the analyser being used to monitor CO_2 concentrations in the adjacent area. The magnitudes of the oscillations were in the order of ±15ppm. Transient spillage for these tests was calculated using both the recorded values and an averaged value over the test period. In both cases the calculated spillage were in agreement. The spillage values reported are based on the average of the values recorded.

The –0.1% result reported for one of the steady state spillage tests may be attributed to a number of factors:

- The analysers used to monitor CO_2 concentrations in the test room and adjacent space have an accuracy of ±1% and ±2% of full scale respectively.
- Infiltration of ambient air from outside of the test room into the test room environment.
- Contamination of the adjacent space environment due to appliance exhaust products external influences beyond the control of the test personnel.
- Proper mixing of the environment inside the room.

These factors may also account for the value of 85% reported for the test in which the appliance was exhausted directly into the test room.

In order to minimize the above effects, the following steps were taken:

- Analysers were calibrated prior to commencement and at the completion of each test.
- All evident openings in the test room envelope were sealed.
- Flow in the supplemental exhaust products capture hood was increased to adequately vent the appliance exhaust products in order to minimize contamination of the adjacent space.
- Air circulation fans were operated in the test room to ensure proper mixing of the environment.

The static leakage test that was performed on the exhaust vent of the mid-efficiency furnace resulted in a reported leakage rate of 16.5% (expressed as a percentage of burner input rate (including 50% excess air)). As this furnace is certified as a Category I appliance, the vent system operates under negative pressure. As such, subjecting this type of vent to a static leakage test is not applicable.

The static leakage test that was performed on the heating module of the direct vent fireplace insert resulted in a reported leakage rate of 1.7% (expressed as a percentage of burner input rate (including 50% excess air)). Based on an acceptable leakage rate of less than 2%, this appliance would satisfy the requirement. However, the transient spillage tests performed at 0.2" w.c. (50 Pa.) and 0.08" w.c. (20 Pa.) depressurization resulted in spillage of 12.8% and 3.5% respectively. Based on an acceptable spillage of less than 2%, this appliance would not satisfy the requirement.

The static leakage test is performed with the appliance not in operation. Conversely, the transient spillage test is performed with the appliance operating. It can be surmised that, with the appliance operating, expansion of sheet metal parts subjected to temperature differences could result in the separation of adjoining surfaces thereby allowing leakage of combustion products. If the leakage were such that combustion products enter the test room, the transient spillage test procedure would detect the elevated concentrations of CO_2 and identify any leakage as spillage.

Reported by:

Chris Runcieman, C.E.T.
Senior Technologist, Ext. 484
Building Performance Centre

Reported by:

Don Giannini, B.Tech, C.E.T.
Senior Technologist, Ext. 491
Building Performance Centre

Reviewed by:

David Bailey, P.Eng.
Operations Manager, Ext. 307
Engineering & Transportation

REGISTRATION

ISO 9002-1994 registered by QMI, Registration #001109

APPENDIX A

(1 Page)

Table 5 - Details of Equipment and Instrumentation Used

Device	Make	Model	MII Number	Full Scale Range(s)	Accuracy
CO_2 Analyser	Beckman	865	B00335	2500/1000/500 ppm	±1% full scale
CO_2 Analyser	Nova	PN300D	A09088	2000 ppm	±2% full scale
Laminar Flow Element	Meriam	50MC2-4	B00609	400 scfm (189 l/s)	±0.5%
Laminar Flow Element	Meriam	50MW20-1	A011554	7.5 scfm (3.5 l/s)	±0.5%
Pressure Transducer	Love	HM 28	B04244	10” w.c. (2.5 kPa)	±0.2% full
Pressure Transducer	Dwyer	477-1-FM	B04246	20” w.c. (5 kPa)	±0.5% full
Pressure Transducer	Baratron	2200A	A11647	1000 torr (133 kPa)	±0.5% full
Thermocouple	T Type	-	B02988	-	±2°F (±1.1°C)
Thermocouple	T Type	-	B02989	-	±2°F (±1.1°C)

APPENDIX B

(12 Pages)

Transient Spillage Test at 50 Pa. Depressurization

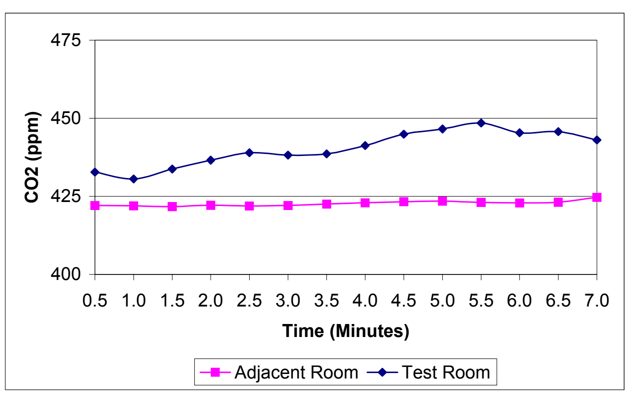
Sample No.: 04-06-M278-1
Client: NRCan
Test Date: 4/20/2004

CO_2 leakage per time base interval = ($CO_{2\ (test\ room)}$ - $CO_{2\ (adjacent\ room)}$)·(Exhaust Fan Flow + Appliance Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\ (test\ room\ end)}$ - $CO_{2\ (test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

											Post Purge	Inducer Blower Off		
Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\ (test\ room,\ base)\ (ppm)}$:	430	430	430	430	430	430	430	430	430	430	430	430	430	430
$CO_{2\ (adjacent\ room,\ base)\ (ppm)}$:	422	422	422	422	422	422	422	422	422	422	422	422	422	422
$CO_{2\ (test\ room)\ (ppm)}$:	433	431	434	437	439	438	439	441	445	447	448	445	446	443
$CO_{2\ (adjacent\ room)\ (ppm)}$:	422	422	422	422	422	422	423	423	423	423	423	423	423	425
Exhaust Fan Flow (ACFM):	272.9	272.9	272.9	272.9	272.9	272.9	272.9	272.9	272.9	272.9	272.9	272.9	272.9	272.9
Exhaust Fan Flow (SCFM):	261.3	261.3	261.3	261.3	261.3	261.3	261.3	261.3	261.3	261.3	261.3	261.3	261.3	261.3
Vent CO_2 concentration (%)[1]:	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2]:	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	20.9	0.0	0.0	0.0
Scaling Factor:	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
∴ $CO_{2\ (depresurization)}$ Leakage (ft^3) =	0.0003	0.0000	0.0005	0.0008	0.0012	0.0011	0.0011	0.0014	0.0018	0.0020	0.0024	0.0018	0.0018	0.0013

[1] Vent CO_2 concentration measured at vent terminal (appliance operating at steady state conditions)
[2] Total combustion products exhausted from test room (including excess air & dilution air)

Test Room CO_2 at end of 7 minute test =	443	ppm
Test Room CO_2 at start of test =	433	ppm
Volume of test room =	1578	ft^3
CO_2 remaining in test room at end of test =	0.016	ft^3
Total CO_2 removed from test room over 7 minute test period =	0.0175	ft^3
Total CO_2 leakage =	0.0337	ft^3
CO_2 Generated by appliance during 5 minute burner ON time =	3.006	ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	1.121%	



Transient Spillage Test at 50 Pa. Depressurization

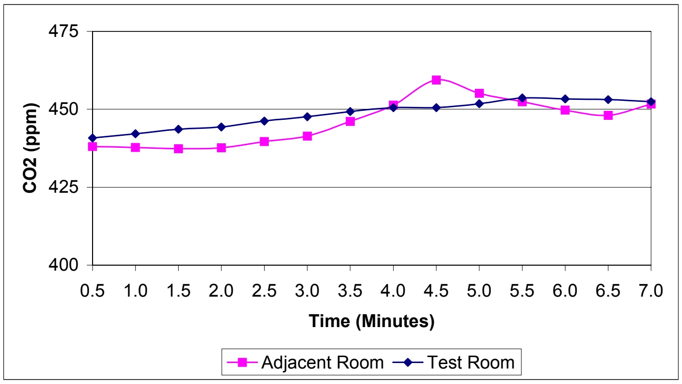
Sample No.: 04-06-M278-2
Client: NRCan
Test Date: 4/21/2004

CO_2 leakage per time base interval = ($CO_{2\,(test\ room)}$ - $CO_{2\,(adjacent\ room)}$)·(Exhaust Fan Flow + Applaince Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\,(test\ room\ end)}$ - $CO_{2\,(test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

											Post Purge			Power Venter Off
Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\,(test\ room,\ base)\ (ppm)}$:	440	440	440	440	440	440	440	440	440	440	440	440	440	440
$CO_{2\,(adjacent\ room,\ base)\ (ppm)}$:	440	440	440	440	440	440	440	440	440	440	440	440	440	440
$CO_{2\,(test\ room)\ (ppm)}$:	441	442	444	444	446	448	449	451	451	452	454	453	453	452
$CO_{2\,(adjacent\ room)\ (ppm)}$:	438	438	437	438	440	441	446	451	459	455	452	450	448	452
Exhaust Fan Flow (ACFM):	277.4	277.4	277.4	277.4	277.4	277.4	277.4	277.4	277.4	277.4	277.4	277.4	277.4	277.4
Exhaust Fan Flow (SCFM):	267.4	267.4	267.4	267.4	267.4	267.4	267.4	267.4	267.4	267.4	267.4	267.4	267.4	267.4
Appliance CO_2 concentration (%)[1] :	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2] :	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1	16.7	0.0	0.0	0.0
Scaling Factor:	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
∴ CO_2 (depresurization) Leakage (ft^3) =	0.0004	0.0006	0.0008	0.0009	0.0009	0.0008	0.0004	-0.0001	-0.0012	-0.0004	0.0002	0.0005	0.0007	0.0001

[1] CO_2 concentration measured at appliance (appliance operating at steady state conditions)
[2] Total combustion products exhausted from test room (including excess air)

Test Room CO_2 at end of 7 minute test =	452	ppm
Test Room CO_2 at start of test =	441	ppm
Volume of test room =	1578	ft3
CO_2 remaining in test room at end of test =	0.018	ft3
Total CO_2 removed from test room over 7 minute test period =	0.0046	ft3
Total CO_2 leakage =	0.0229	ft3
CO_2 Generated by appliance during 5 minute burner ON time =	6.2625	ft3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	0.4%	



Transient Spillage Test at 50 Pa. Depressurization

Sample No.:	04-06-M278-2
Client:	NRCan
Test Date:	4/25/2004

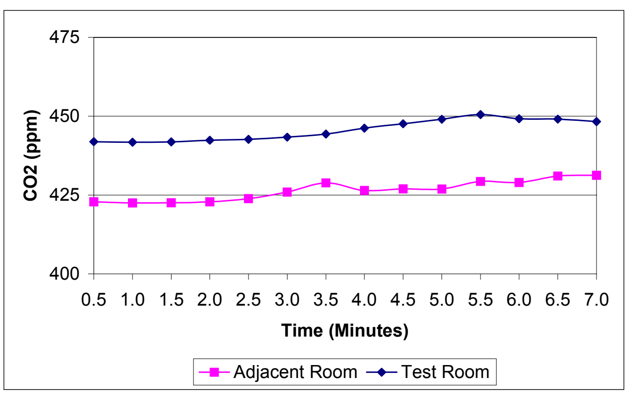
Increased Flow at exhaust products capture hood in adjacent area

CO_2 leakage per time base interval = ($CO_{2\,(test\ room)}$ - $CO_{2\,(adjacent\ room)}$)·(Exhaust Fan Flow + Appliance Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\,(test\ room\ end)}$ - $CO_{2\,(test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

											Post Purge			Power Vent Off
Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\,(test\ room,\ base)}$ (ppm):	442	442	442	442	442	442	442	442	442	442	442	442	442	442
$CO_{2\,(adjacent\ room,\ base)}$ (ppm):	423	423	423	423	423	423	423	423	423	423	423	423	423	423
$CO_{2\,(test\ room)}$ (ppm):	442	442	442	442	443	443	444	446	448	449	451	449	449	448
$CO_{2\,(adjacent\ room)}$ (ppm):	423	423	423	423	424	426	429	426	427	427	429	429	431	431
Exhaust Fan Flow (ACFM):	291.3	291.3	291.3	291.3	291.3	291.3	291.3	291.3	291.3	291.3	291.3	291.3	291.3	291.3
Exhaust Fan Flow (SCFM):	281.9	281.9	281.9	281.9	281.9	281.9	281.9	281.9	281.9	281.9	281.9	281.9	281.9	281.9
Appliance CO_2 concentration (%)[1] :	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2] :	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1	18.1	16.7	0.0	0.0	0.0
Scaling Factor:	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	0.000001
∴ CO_2 (depresurization) Leakage (ft^3) =	0.0000	0.0000	0.0000	0.0001	0.0000	-0.0002	-0.0005	0.0001	0.0002	0.0005	0.0003	0.0002	-0.0001	-0.0003

[1] CO_2 concentration measured at appliance (appliance operating at steady state conditions)
[2] Total combustion products exhausted from test room (including excess air)

Test Room CO_2 at end of 7 minute test =	448	ppm
Test Room CO_2 at start of test =	442	ppm
Volume of test room =	1578	ft^3
CO_2 remaining in test room at end of test =	0.010	ft^3
Total CO_2 removed from test room over 7 minute test period =	0.0003	ft^3
Total CO_2 leakage =	0.0104	ft^3
CO_2 Generated by appliance during 5 minute burner ON time =	6.26	ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	0.2%	



Transient Spillage Test at 50 Pa. Depressurization

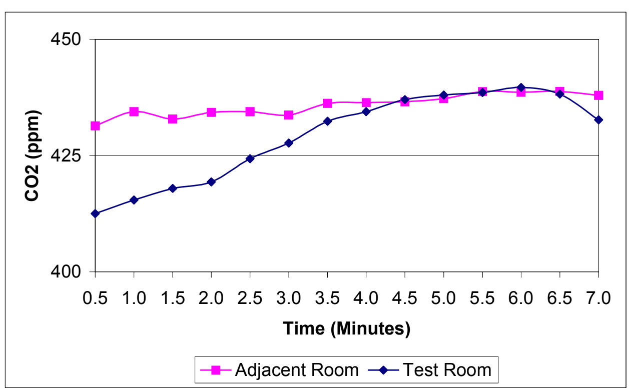
Sample No.: 04-06-M278-4
Client: NRCan
Test Date: 5/3/2004

CO_2 leakage per time base interval = ($CO_{2\ (test\ room)}$ - $CO_{2\ (adjacent\ room)}$)·(Exhaust Fan Flow + Applaince Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\ (test\ room\ end)}$ - $CO_{2\ (test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

											Post Purge			
Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\ (test\ room,\ base)\ (ppm)}$:	414	414	414	414	414	414	414	414	414	414	414	414	414	414
$CO_{2\ (adjacent\ room,\ base)\ (ppm)}$:	426	426	426	426	426	426	426	426	426	426	426	426	426	426
$CO_{2\ (test\ room)\ (ppm)}$:	413	415	418	419	424	428	432	434	437	438	439	440	438	433
$CO_{2\ (adjacent\ room)\ (ppm)}$:	431	434	433	434	434	434	436	436	437	437	439	439	439	438
Exhaust Fan Flow (ACFM):	259.0	259.0	259.0	259.0	259.0	259.0	259.0	259.0	259.0	259.0	259.0	259.0	259.0	259.0
Exhaust Fan Flow (SCFM):	247.6	247.6	247.6	247.6	247.6	247.6	247.6	247.6	247.6	247.6	247.6	247.6	247.6	247.6
Vent CO_2 concentration (%)[1] :	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2] :	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	29.9	0.0	0.0	0.0
Scaling Factor:	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
∴ CO_2 (depresurization) Leakage (ft^3) =	-0.0009	-0.0009	-0.0003	-0.0003	0.0003	0.0009	0.0012	0.0015	0.0018	0.0018	0.0017	0.0017	0.0015	0.0009

[1] Vent CO_2 concentration measured at vent terminal (appliance operating at steady state conditions)
[2] Total combustion products exhausted from test room (including excess air & dilution air)

Test Room CO_2 at end of 7 minute test =	433	ppm
Test Room CO_2 at start of test =	413	ppm
Volume of test room =	1578	ft^3
CO_2 remaining in test room at end of test =	0.032	ft^3
Total CO_2 removed from test room over 7 minute test period =	0.0107	ft^3
Total CO_2 leakage =	0.0426	ft^3
CO_2 Generated by appliance during 5 minute burner ON time =	2.745	ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	1.6%	



<u>Transient Spillage Test at 50 Pa. Depressurization</u>

Sample No.: 04-06-M278-4
Client: NRCan
Test Date: 5/3/2004

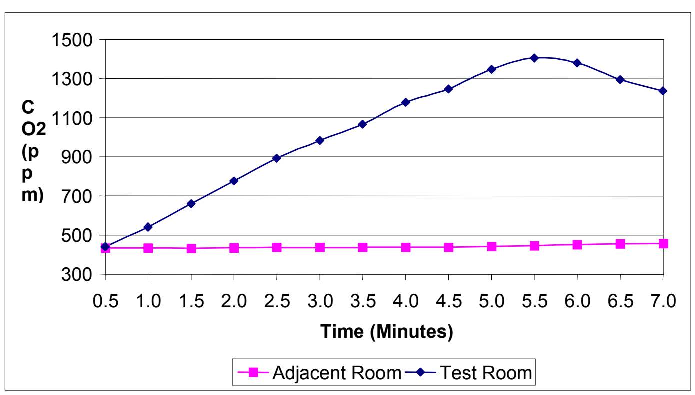
Appliance Exhausting into Test Room

CO_2 leakage per time base interval = ($CO_{2\,(test\ room)}$ - $CO_{2\,(adjacent\ room)}$)·(Exhaust Fan Flow + Applaince Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\,(test\ room\ end)}$ - $CO_{2\,(test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

										Post Purge			
Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\,(test\ room,\ base)\ (ppm)}$:	454	454	454	454	454	454	454	454	454	454	454	454	454	454
$CO_{2\,(adjacent\ room,\ base)\ (ppm)}$:	441	441	441	441	441	441	441	441	441	441	441	441	441	441
$CO_{2\,(test\ room)\ (ppm)}$:	440	542	660	776	892	982	1067	1178	1247	1348	1406	1380	1295	1235
$CO_{2\,(adjacent\ room)\ (ppm)}$:	434	434	432	435	436	436	437	439	439	441	445	452	456	458
Exhaust Fan Flow (ACFM):	282.0	282.0	282.0	282.0	282.0	282.0	282.0	282.0	282.0	282.0	282.0	282.0	282.0	282.0
Exhaust Fan Flow (SCFM):	268.6	268.6	268.6	268.6	268.6	268.6	268.6	268.6	268.6	268.6	268.6	268.6	268.6	268.6
Vent CO_2 concentration (%)[1] :	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2]	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	29.9	0.0	0.0	0.0
Scaling Factor:	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
∴ CO_2 (depresurization) Leakage (ft3) =	-0.0010	0.0127	0.0289	0.0440	0.0595	0.0715	0.0829	0.0975	0.1067	0.1200	0.1273	0.1229	0.1109	0.1026

[1] Vent CO_2 concentration measured at vent terminal (appliance operating at steady state conditions)
[2] Total combustion products exhausted (including excess air & dilution air) - not used in calculation as appliance was venting into test room.

Test Room CO_2 at end of 7 minute test = 1235 ppm
Test Room CO_2 at start of test = 440 ppm
Volume of test room = 1578 ft^3
CO_2 remaining in test room at end of test = 1.255 ft^3
Total CO_2 removed from test room over 7 minute test period = 1.0866 ft^3
Total CO_2 leakage = 2.3412 ft^3
CO_2 Generated by appliance during 5 minute burner ON time = 2.74 ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) = 85.4%



Transient Spillage Test at 50 Pa. Depressurization

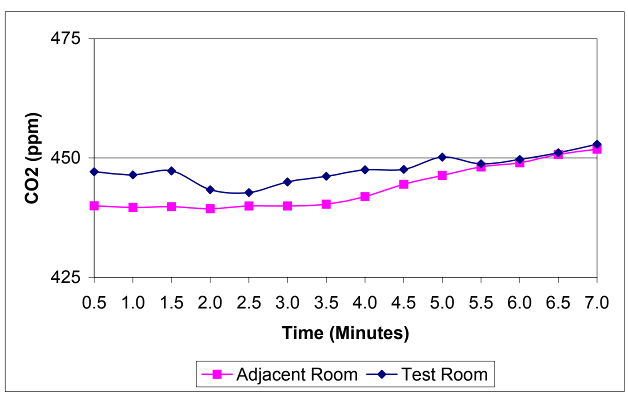
Sample No.: 04-06-M278-5
Client: NRCan
Test Date: 5/5/2004

CO_2 leakage per time base interval = ($CO_{2\ (test\ room)}$ - $CO_{2\ (adjacent\ room)}$)·(Exhaust Fan Flow + Applaince Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\ (test\ room\ end)}$ - $CO_{2\ (test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

											Post Purge			
Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\ (test\ room,\ base)\ (ppm)}$:	446	446	446	446	446	446	446	446	446	446	446	446	446	446
$CO_{2\ (adjacent\ room,\ base)\ (ppm)}$:	439	439	439	439	439	439	439	439	439	439	439	439	439	439
$CO_{2\ (test\ room)\ (ppm)}$:	447	446	447	443	443	445	446	448	448	450	449	450	451	453
$CO_{2\ (adjacent\ room)\ (ppm)}$:	440	440	440	439	440	440	440	442	444	446	448	449	451	452
Exhaust Fan Flow (ACFM):	286.4	286.4	286.4	286.4	286.4	286.4	286.4	286.4	286.4	286.4	286.4	286.4	286.4	286.4
Exhaust Fan Flow (SCFM):	279.4	279.4	279.4	279.4	279.4	279.4	279.4	279.4	279.4	279.4	279.4	279.4	279.4	279.4
Appliance CO_2 concentration (%)[1] :	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2] :	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	19.0	0.0	0.0	0.0
Scaling Factor:	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
∴ CO_2 (depresurization) Leakage (ft^3) =	0.0000	0.0000	0.0001	-0.0005	-0.0006	-0.0003	-0.0002	-0.0002	-0.0006	-0.0005	-0.0010	-0.0009	-0.0009	-0.0008

[1] CO_2 concentration measured at appliance (during transient spillage test)
[2] Total combustion products exhausted (including excess air)

Test Room CO_2 at end of 7 minute test =	453	ppm
Test Room CO_2 at start of test =	447	ppm
Volume of test room =	1578	ft^3
CO_2 remaining in test room at end of test =	0.009	ft^3
Total CO_2 removed from test room over 7 minute test period =	-0.0064	ft^3
Total CO_2 leakage =	0.0027	ft^3
CO_2 Generated by appliance during 5 minute burner ON time =	6.045	ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	0.04%	



Transient Spillage Test at 50 Pa. Depressurization

Sample No.: 04-06-M278-6
Client: NRCan
Test Date: 12/5/2004

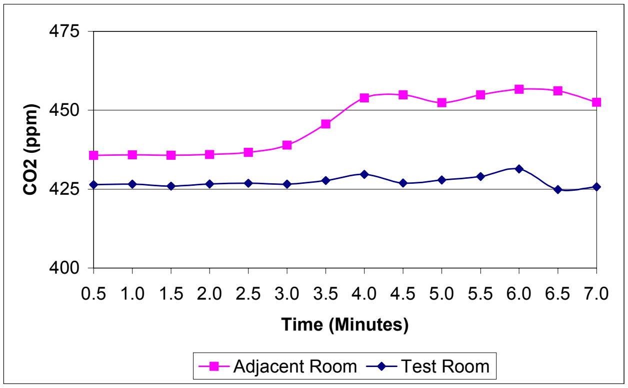
Test with 9" section of 2" ABS pipe on air intake. Pipe terminates with 90° elbow incorporating perforated disks (supplied)

CO_2 leakage per time base interval = ($CO_{2\,(test\ room)}$ - $CO_{2\,(adjacent\ room)}$)·(Exhaust Fan Flow + Applaince Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\,(test\ room\ end)}$ - $CO_{2\,(test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

											Post Purge			
Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\,(test\ room,\ base)\ (ppm)}$:	423	423	423	423	423	423	423	423	423	423	423	423	423	423
$CO_{2\,(adjacent\ room,\ base)\ (ppm)}$:	436	436	436	436	436	436	436	436	436	436	436	436	436	436
$CO_{2\,(test\ room)\ (ppm)}$:	426	427	426	427	427	427	428	430	427	428	429	431	425	426
$CO_{2\,(adjacent\ room)\ (ppm)}$:	436	436	436	436	437	439	446	454	455	452	455	457	456	453
Exhaust Fan Flow (ACFM):	305.5	305.5	305.5	305.5	305.5	305.5	305.5	305.5	305.5	305.5	305.5	305.5	305.5	305.5
Exhaust Fan Flow (SCFM):	295.4	295.4	295.4	295.4	295.4	295.4	295.4	295.4	295.4	295.4	295.4	295.4	295.4	295.4
Appliance CO_2 concentration (%)[1] :	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2] :	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	24.4	22.9	0.0	0.0	0.0
Scaling Factor:	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
∴ CO_2 (depresurization) Leakage (ft^3) =	0.0006	0.0006	0.0005	0.0006	0.0006	0.0006	0.0008	0.0011	0.0007	0.0008	0.0010	0.0013	0.0003	0.0004

[1] CO_2 concentration measured at appliance (during transient spillage test)
[2] Total combustion products exhausted (including excess air)

Test Room CO_2 at end of 7 minute test =	426	ppm
Test Room CO_2 at start of test =	426	ppm
Volume of test room =	1578	ft^3
CO_2 remaining in test room at end of test =	-0.001	ft^3
Total CO_2 removed from test room over 7 minute test period =	0.0098	ft^3
Total CO_2 leakage =	0.0088	ft^3
CO_2 Generated by appliance during 5 minute burner ON time =	6.21	ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	0.14%	



Transient Spillage Test at 50 Pa. Depressurization

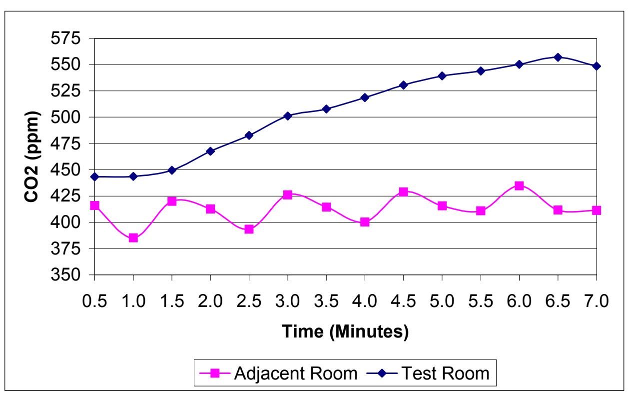
Sample No.: 04-06-M278-7
Client: NRCan
Test Date: 7/6/2004

Note: Using Nova analyser to monitor test room, Beckman to monitor adjacent space
Standing pilot. Burner operated at max input. Fireplace blower set to max speed (on/off controlled by thermodisk)
CO_2 leakage per time base interval = ($CO_{2\ (test\ room)}$ - $CO_{2\ (adjacent\ room)}$)·(Exhaust Fan Flow + Applaince Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\ (test\ room\ end)}$ - $CO_{2\ (test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\ (test\ room,\ base)\ (ppm)}$:	443	443	443	443	443	443	443	443	443	443	443	443	443	443
$CO_{2\ (adjacent\ room,\ base)\ (ppm)}$:	409	409	409	409	409	409	409	409	409	409	409	409	409	409
$CO_{2\ (test\ room)\ (ppm)}$:	443	444	450	468	483	501	508	519	530	539	544	550	557	548
$CO_{2\ (adjacent\ room)\ (ppm)}$:	416	385	420	413	394	426	414	400	429	416	411	435	412	411
Exhaust Fan Flow (ACFM):	278.3	278.3	278.3	278.3	278.3	278.3	278.3	278.3	278.3	278.3	278.3	278.3	278.3	278.3
Exhaust Fan Flow (SCFM):	273.7	273.7	273.7	273.7	273.7	273.7	273.7	273.7	273.7	273.7	273.7	273.7	273.7	273.7
Appliance CO_2 concentration (%)[1] :	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2] :	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	0.0	0.0	0.0	0.0
Scaling Factor:	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
∴ CO_2 (depresurization) Leakage (ft3) =	-0.0005	-0.0005	0.0003	0.0028	0.0049	0.0074	0.0083	0.0098	0.0114	0.0126	0.0132	0.0141	0.0150	0.0139

[1] CO_2 concentration measured at appliance (during transient spillage test)
[2] Total combustion products exhausted (including excess air) - not used in calculation as appliance is a direct vent unit.
Note: Oscillations of $CO_{2\ (adjacent\ room)}$ readings due to analyser operation. Average value of 413 ppm used for calculations.

Test Room CO_2 at end of 7 minute test =	548	ppm
Test Room CO_2 at start of test =	443	ppm
Volume of test room =	1578	ft^3
CO_2 remaining in test room at end of test =	0.166	ft^3
Total CO_2 removed from test room over 7 minute test period =	0.1128	ft^3
Total CO_2 leakage =	0.2789	ft^3
CO_2 Generated by appliance during 5 minute burner ON time =	2.1	ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	13.3%	



Transient Spillage Test at 50 Pa. Depressurization

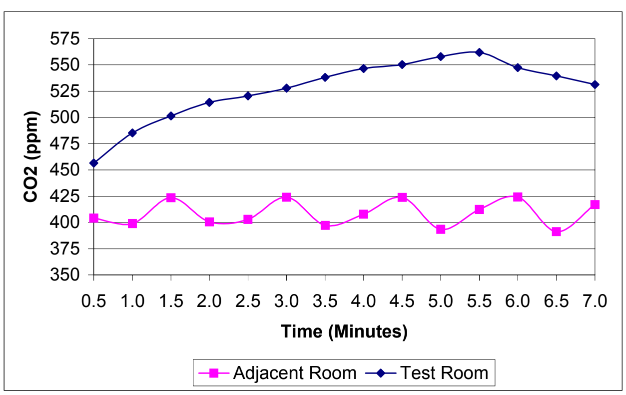
Sample No.: 04-06-M278-7
Client: NRCan
Test Date: 8/6/2004

Note: Using Nova analyser to monitor test room, Beckman to monitor adjacent space
Standing pilot. Burner operated at max input. Fireplace blower set to max speed (on/off controlled by thermodisk)
Additional circulating fan installed in test room to improve mixing and ensure uniform environment
CO_2 leakage per time base interval = ($CO_{2\,(test\,room)}$ - $CO_{2\,(adjacent\,room)}$)·(Exhaust Fan Flow + Applaince Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\,(test\,room\,end)}$ - $CO_{2\,(test\,room\,start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\,(test\,room,\,base)\,(ppm)}$:	450	450	450	450	450	450	450	450	450	450	450	450	450	450
$CO_{2\,(adjacent\,room,\,base)\,(ppm)}$:	411	411	411	411	411	411	411	411	411	411	411	411	411	411
$CO_{2\,(test\,room)\,(ppm)}$:	456	485	501	514	520	528	538	547	550	558	562	547	540	531
$CO_{2\,(adjacent\,room)\,(ppm)}$:	404	399	424	401	403	424	397	408	424	393	412	424	391	417
Exhaust Fan Flow (ACFM):	272.0	272.0	272.0	272.0	272.0	272.0	272.0	272.0	272.0	272.0	272.0	272.0	272.0	272.0
Exhaust Fan Flow (SCFM):	266.2	266.2	266.2	266.2	266.2	266.2	266.2	266.2	266.2	266.2	266.2	266.2	266.2	266.2
Appliance CO_2 concentration (%)[1] :	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2] :	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	0.0	0.0	0.0	0.0
Scaling Factor:	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
∴ CO_2 (depresurization) Leakage (ft^3) =	0.0011	0.0049	0.0071	0.0088	0.0096	0.0106	0.0120	0.0131	0.0136	0.0146	0.0151	0.0132	0.0121	0.0110

[1] CO_2 concentration measured at appliance (during transient spillage test)
[2] Total combustion products exhausted (including excess air) - not used in calculation as appliance is a direct vent unit.
Note: Oscillations of $CO_{2\,(adjacent\,room)}$ readings due to analyser operation. Average value of 409 ppm used for calculations.

Test Room CO_2 at end of 7 minute test =	531	ppm
Test Room CO_2 at start of test =	456	ppm
Volume of test room =	1578	ft^3
CO_2 remaining in test room at end of test =	0.118	ft^3
Total CO_2 removed from test room over 7 minute test period =	0.1467	ft^3
Total CO_2 leakage =	0.2647	ft^3
CO_2 Generated by appliance during 5 minute burner ON time =	2.07	ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	12.8%	



Transient Spillage Test at 20 Pa. Depressurization

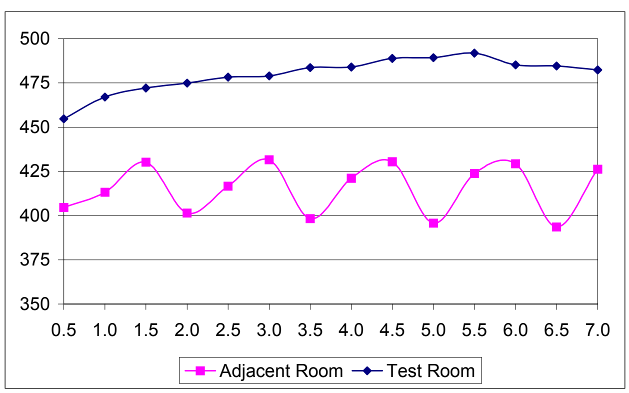
Sample No.: 04-06-M278-7
Client: NRCan
Test Date: 8/6/2004

Note: Using Nova analyser to monitor test room, Beckman to monitor adjacent space
Standing pilot. Burner operated at max input. Fireplace blower set to max speed (on/off controlled by thermodisk)
Additional circulating fan installed in test room to improve mixing and ensure uniform environment
CO_2 leakage per time base interval = ($CO_{2\,(test\ room)}$ - $CO_{2\,(adjacent\ room)}$)·(Exhaust Fan Flow + Applaince Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\,(test\ room\ end)}$ - $CO_{2\,(test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\,(test\ room,\ base)\ (ppm)}$:	455	455	455	455	455	455	455	455	455	455	455	455	455	455
$CO_{2\,(adjacent\ room,\ base)\ (ppm)}$:	421	421	421	421	421	421	421	421	421	421	421	421	421	421
$CO_{2\,(test\ room)\ (ppm)}$:	455	467	472	475	478	479	484	484	489	489	492	485	485	482
$CO_{2\,(adjacent\ room)\ (ppm)}$:	405	413	430	401	417	432	398	421	430	396	424	429	394	426
Exhaust Fan Flow (ACFM):	142.4	142.4	142.4	142.4	142.4	142.4	142.4	142.4	142.4	142.4	142.4	142.4	142.4	142.4
Exhaust Fan Flow (SCFM):	139.0	139.0	139.0	139.0	139.0	139.0	139.0	139.0	139.0	139.0	139.0	139.0	139.0	139.0
Appliance CO_2 concentration (%)[1] :	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2] :	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	0.0	0.0	0.0	0.0
Scaling Factor:	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
∴ CO_2 (depresurization) Leakage (ft^3) =	0.0004	0.0013	0.0016	0.0018	0.0020	0.0021	0.0024	0.0024	0.0028	0.0028	0.0030	0.0025	0.0025	0.0023

[1] CO_2 concentration measured at appliance (during transient spillage test)
[2] Total combustion products exhausted (including excess air) - not used in calculation as appliance is a direct vent unit.
Note: Oscillations of $CO_{2\,(adjacent\ room)}$ readings due to analyser operation. Average value of 415 ppm used for calculations.

Test Room CO_2 at end of 7 minute test =	482	ppm
Test Room CO_2 at start of test =	455	ppm
Volume of test room =	1578	ft^3
CO_2 remaining in test room at end of test =	0.044	ft^3
Total CO_2 removed from test room over 7 minute test period =	0.0299	ft^3
Total CO_2 leakage =	0.0736	ft^3
CO_2 Generated by appliance during 5 minute burner ON time =	2.09	ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	3.5%	



<u>Transient Spillage Test at 5 Pa. Depressurization</u>

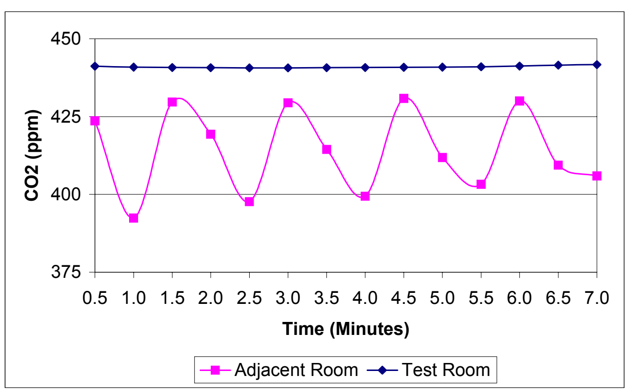
Sample No.: 04-06-M278-7
Client: NRCan
Test Date: 8/6/2004

Note: Using Nova analyser to monitor test room, Beckman to monitor adjacent space
Standing pilot. Burner operated at max input. Fireplace blower set to max speed (on/off controlled by thermodisk)
Additional circulating fan installed in test room to improve mixing and ensure uniform environment
CO_2 leakage per time base interval = ($CO_{2\ (test\ room)}$ - $CO_{2\ (adjacent\ room)}$)·(Exhaust Fan Flow + Applaince Exhaust Products Flow)·(Scaling Factor)
CO_2 remaining in test room at end of test = ($CO_{2\ (test\ room\ end)}$ - $CO_{2\ (test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)
CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)
Spillage = Total CO_2 Leakage / CO_2 generated by appliance

Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\ (test\ room,\ base)\ (ppm)}$:	441	441	441	441	441	441	441	441	441	441	441	441	441	441
$CO_{2\ (adjacent\ room,\ base)\ (ppm)}$:	412	412	412	412	412	412	412	412	412	412	412	412	412	412
$CO_{2\ (test\ room)\ (ppm)}$:	441	441	441	441	441	441	441	441	441	441	441	441	442	442
$CO_{2\ (adjacent\ room)\ (ppm)}$:	424	392	430	419	398	429	414	399	431	412	403	430	409	406
Exhaust Fan Flow (ACFM):	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9	55.9
Exhaust Fan Flow (SCFM):	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5
Appliance CO_2 concentration (%)[1] :	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2] :	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	0.0	0.0	0.0	0.0
Scaling Factor:	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
∴ CO_2 (depresurization) Leakage (ft^3) =	0.0000	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	0.0000	0.0000	0.0000

[1] CO_2 concentration measured at appliance (during transient spillage test)
[2] Total combustion products exhausted (including excess air) - not used in calculation as appliance is a direct vent unit.
Note: Oscillations of $CO_{2\ (adjacent\ room)}$ readings due to analyser operation. Average value of 414 ppm used for calculations.

Test Room CO_2 at end of 7 minute test =	442	ppm
Test Room CO_2 at start of test =	441	ppm
Volume of test room =	1578	ft^3
CO_2 remaining in test room at end of test =	0.001	ft^3
Total CO_2 removed from test room over 7 minute test period =	-0.0007	ft^3
Total CO_2 leakage =	0.0001	ft^3
CO_2 Generated by appliance during 5 minute burner ON time =	2.08	ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	0.01%	



Transient Spillage Test at 50 Pa. Depressurization

Sample No.: 04-06-M278-8
Client: NRCan
Test Date: 9/6/2004

Note: Using Beckman analyser to monitor test room, Nova to monitor adjacent space
Standing pilot. Burner operated at max input. No integral blower on this unit.
Additional circulating fan installed in test room to improve mixing and ensure uniform environment

CO_2 leakage per time base interval = ($CO_{2\,(test\ room)}$ - $CO_{2\,(adjacent\ room)}$)·(Exhaust Fan Flow + Applaince Exhaust Products Flow)·(Scaling Factor)

CO_2 remaining in test room at end of test = ($CO_{2\,(test\ room\ end)}$ - $CO_{2\,(test\ room\ start)}$)·(Scaling Factor)·(Test Room Volume)

CO_2 generated by appliance = (Input Rate (Btu/h)/1000)·(0.0167 SCFM/1000 Btu/h)

Spillage = Total CO_2 Leakage / CO_2 generated by appliance

Time (minutes):	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
$CO_{2\,(test\ room,\ base)\ (ppm)}$:	414	414	414	414	414	414	414	414	414	414	414	414	414	414
$CO_{2\,(adjacent\ room,\ base)\ (ppm)}$:	409	409	409	409	409	409	409	409	409	409	409	409	409	409
$CO_{2\,(test\ room)\ (ppm)}$:	412	413	413	414	415	415	416	416	416	416	417	416	416	415
$CO_{2\,(adjacent\ room)\ (ppm)}$:	406	404	405	409	405	406	410	407	403	406	404	405	404	407
Exhaust Fan Flow (ACFM):	291.4	291.4	291.4	291.4	291.4	291.4	291.4	291.4	291.4	291.4	291.4	291.4	291.4	291.4
Exhaust Fan Flow (SCFM):	281.7	281.7	281.7	281.7	281.7	281.7	281.7	281.7	281.7	281.7	281.7	281.7	281.7	281.7
Appliance CO_2 concentration (%)[1] :	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	0.0	0.0	0.0	0.0
Combustion Products Flow (SCFM)[2] :	15	15	15	15	15	15	15	15	15	15	0	0	0	0
Scaling Factor:	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06
∴ CO_2 (depresurization) Leakage (ft^3) =	0.0002	0.0006	0.0005	0.0001	0.0007	0.0007	0.0001	0.0005	0.0011	0.0008	0.0011	0.0009	0.0009	0.0005

[1] Vent CO_2 concentration measured at appliance (during transient spillage test)
[2] Total combustion products exhausted (including excess air) - not used in calculation as appliance is a direct vent unit.

Test Room CO_2 at end of 7 minute test =	415	ppm
Test Room CO_2 at start of test =	412	ppm
Volume of test room =	1578	ft^3
CO_2 remaining in test room at end of test =	0.0048	ft^3
Total CO_2 removed from test room over 7 minute test period =	0.0086	ft^3
Total CO_2 leakage =	0.0134	ft^3
CO_2 Generated by appliance during 5 minute burner ON time =	1.95	ft^3
Spillage (Total CO_2 leakage/ Appliance CO_2) =	0.7%