

RESEARCH REPORT



Depressurization Spillage Testing of Ten Residential Gas-Fired Combustion Appliances



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Depressurization Spillage Testing of Ten Residential Gas-Fired Combustion Appliances

Final Report

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Abstract

In 2005, CMHC partnered with NRCan on a project to evaluate the performance of a small sample of residential combustion appliances using a new depressurization spillage test procedure. The tests were done at a Canadian commercial testing laboratory. The new combustion spillage test was found to be relatively easy to perform. Seven gas-fired appliances were tested at 50 Pa depressurization. Three had no detectable spillage. Three had low, but measurable spillage. However, one had 13 % spillage.

In 2007 CMHC funded testing of ten more new direct vent or power vent “spillage-resistant” gas appliances at the same laboratory. The results were similar to those from the 2005 project. At 50 Pa, five had essentially no spillage. Three had low, but measurable spillage. Two had more than 2 % spillage, including one with over 10 % spillage.

These results indicate that, while gas appliance manufacturers can produce products that are spillage resistant, there are some outliers. Certain products that appear to be spillage resistant by design do not perform as well as expected. The spillage test enables manufacturers to identify those products and to develop corrective measures to improve their performance. This will enable manufacturers to develop and market more spillage-resistant combustion appliances.

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RESEARCH HIGHLIGHT

June 2008

Technical Series 08-103

Laboratory Depressurization Test for Residential Gas Appliances—Part 2

INTRODUCTION

CMHC partnered with Natural Resources Canada (NRCan) to develop a depressurization spillage test protocol. The research projects described in this *Research Highlight*¹ evaluated the performance of a sample of residential combustion appliances using the new test.

Spillage from combustion appliances is a complex problem. The frequency and severity of combustion spillage is affected by the installation of the equipment and the use of other air-exhausting equipment in the home, which can overpower the appliance venting system.

Existing Canadian codes and standards have attempted to deal with combustion spillage by such strategies as requiring makeup air supplies for installations that may not have sufficient air leakage to support the proper operation of the combustion appliances.

Manufacturers have also developed appliances that are more spillage resistant. Generally, they have either been designed so that their combustion and venting components should not be exposed to the pressure regime inside the house, or they have been equipped with strong power venting systems that should be able to operate even under depressurized conditions.

The first type of product are often referred to as direct-vent or isolated combustion appliances. They are usually vented using sidewall-mounted terminals rather than through a chimney.

Power-vented water heater tanks are one of the more familiar examples of the second type of appliance designed for improved resistance to combustion spillage.

Despite the widespread availability of appliances that have been designed to have greater resistance to depressurization spillage, no standard protocol exists that allows manufacturers to directly test and rate their products for combustion spillage resistance. This means that manufacturers have no accepted way to notify consumers, builders or other stakeholders of the rated spillage resistance of their appliances, or to indicate which of their products perform better under reduced pressure conditions that might cause spillage in other products.

The new depressurization spillage test has been developed as a key instrument towards addressing this gap. The two research projects focused on the performance of contemporary appliances. They did not investigate the depressurization spillage resistance of older designs of combustion appliances that may still be installed in Canadian houses.

RESEARCH PROGRAM

The first research program was conducted between January, 2005 and May, 2005. The second was conducted in the fall of 2007. Testing was done at Bodycote, a Canadian commercial testing laboratory.

In the 2005 project, seven combustion appliances (two water heaters, three furnaces and two fireplaces) were chosen to cover a cross-section of the types of gas-fired equipment that are now being installed in Canadian homes.

The appliances and their venting systems were purchased from regular HVAC distributors, not directly from manufacturers. They were shipped directly to the testing laboratory by the distributors. Each was installed and tested, following the manufacturer's certified installation instructions, using the maximum equivalent length and type of venting materials specified by the manufacturer.

¹ This updates the Technical Series *Research Highlight* 05-111, "Laboratory Depressurization Test for Residential Gas Appliances," published by CMHC in September, 2005.

Research Highlight

Laboratory Depressurization Test for Residential Gas Appliances—Part 2

In the 2007 project, another 10 combustion appliances were tested, including a condensing storage-tank water heater, two tankless water heaters, a wall-hung boiler, two fireplaces and four furnaces.

The spillage test incorporates a “pass” threshold of two per cent spillage. This figure was chosen to give some flexibility in the choice of test instrumentation and it provides a small margin for errors associated with cumulative uncertainties in the testing procedure and the required measurements.

This is the same tolerance that is used in static leakage tests for combustion-vent sections of sealed-combustion appliances that operate with positive vent pressures. Such appliances already require vent-leakage tests according to existing appliance certification standards (for example, CSA 4.3, CSA 4.9, CSA B140.0). However, it must be understood that static leakage tests are performed at different pressures and they are performed with the appliances and their vent systems at ambient temperature, not operating.

Acceptance of the two per cent “pass” tolerance for the spillage test should not be construed as a judgment that two per cent combustion spillage would be acceptable performance for combustion appliances. Indeed, two per cent spillage from certain types of combustion appliances may not be acceptable for all installations.

THE SPILLAGE TEST

The following briefly describes the depressurization spillage test. In figure 1, the box with a flame represents the combustion appliance installed inside the depressurized test room. The horizontal ducts (with white arrows) attached to the appliance represent the combustion air inlet and the combustion vent.

The appliance is shown drawing its combustion air from outside the test room and exhausting its combustion products outside the test room. Some appliances draw their combustion air from inside the test room. The vertical lines represent the thermal load and output from the appliance that may either be released inside the test room or ejected outside the room (ejection is simpler for products that heat water, such as water heaters and boilers).

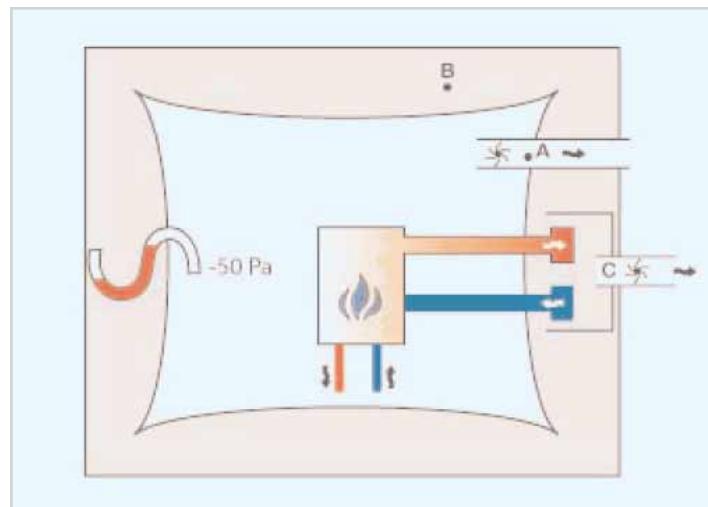


Figure 1 Simplified concept of the depressurization spillage test

The test room is depressurized (by 50 Pa in the illustration) with respect to its surroundings using a variable fan installed in duct “A” that discharges outside the building. A supplemental exhaust system, “C,” captures and removes the combustion products to avoid contaminating the area “B” around the test room.

The appliance is operated to obtain five minutes of burner operation. The amount of CO₂ that was released or “spilled” into the test room is determined over five minutes and an additional two minutes (to include any spillage of combustion gases from the venting system after the burner shuts down). The amount of CO₂ (carbon dioxide) that was spilled into the test room is divided by the amount of CO₂ that was produced by the burner during the test to calculate the percentage of combustion spillage.

For each unit, the test was initially performed with the test room depressurized by 50 Pa compared with the pressure outside the room. If the combustion spillage exceeded two per cent, the test was repeated with the room depressurized by 20 Pa. Finally, if the measured spillage exceeded two per cent at 20 Pa, a test was performed with the room depressurized by five Pa.

RESEARCH FINDINGS

The spillage test was relatively easy to perform. Of the 17 gas-fired appliances tested at 50 Pa depressurization, eight had no detectable spillage; six had minor, but measurable spillage; and three had spillage greater than the two per cent threshold. Table 1 summarizes the test results.

Based on these test results, it is evident that many existing products are capable of performing well when depressurized. At the same time, other products that appear similar do not perform as well. The new test can reliably identify those products that perform well.

Because of the two per cent spillage tolerance, this test may have difficulty in conclusively differentiating between a close “pass” and a marginal “fail.” If such a spillage result were obtained, further investigations and repeat tests would likely be warranted before reaching a conclusion.

In the first project, the closest result to the spillage threshold was 1.55

per cent for one product. While higher than ideal, that test result was more than 20 per cent below the proposed limit. The result was considered to be a “pass.”

Similarly, in the second project, one appliance had 2.6 per cent spillage at 50 Pa depressurization, just above the threshold. This was considered a “failure.” The manufacturers of both products, however, should be looking at their designs in light of the test results, and implementing improvements so that their appliances can match the performance of competing devices.

IMPLICATIONS FOR THE INDUSTRY AND OTHER STAKEHOLDERS

The facility and instrumentation requirements for the depressurization spillage test are low enough that manufacturers should have little or no difficulty in setting up the test in their own facilities and using their test facilities as a product development tool. This will enable them to verify the performance and improve the

Table I Laboratory test results for “spillage-resistant” gas-fired appliances

Appliance	Year of research	Direct vent (D) or power-vented (P)	% spillage		
			@ 50 Pa	@ 20 Pa	@ 5 Pa
Power-vented water tank A	2005	P	1.1		
Power-vented water tank B	2005	P	1.6		
Power-vented water tank C	2007	P	0.5		
Tankless water heater A	2007	D	0.2		
Tankless water heater B	2007	P	0.1		
Wall-hung boiler A	2007	D	0.2		
Non-condensing furnace A	2005	P	0.2		
Condensing furnace* A	2005	P	0.0		
Condensing furnace B	2005	P	0.1		
Condensing furnace C	2007	P	0.6		
Condensing furnace D	2007	P	-0.5		
Condensing furnace E	2007	P	0.0		
Condensing furnace F	2007	P	2.6	1.4	
Fireplace A	2005	D	13	3.5	0
Fireplace B	2005	D	0.7		
Fireplace C	2007	D	10.3	2.0	0
Fireplace D	2007	D	1.0		

*The condensing furnaces could be set up either as a direct-vent (two pipe) or power-vented (one pipe) appliance. They were tested as power-vented.

Research Highlight

Laboratory Depressurization Test for Residential Gas Appliances—Part 2

spillage resistance of their products.

The spillage test is a new tool that allows manufacturers to include depressurization-spillage-resistance ratings in their literature alongside their other product performance data. It is anticipated that the spillage test will be immediately useful to manufacturers who want to emphasize the performance of their products in depressurized environments, such as in houses with large exhaust appliances.

The test results for 17 gas appliances show that these “spillage-resistant” devices generally operated safely at up to 50 Pa of depressurization, which is what Canadian codes and standards have been implying in recent years. A small number of appliances have excessive spillage. Integration of the spillage test into gas appliance standards would catch those appliances with poor design and detailing, and keep them out of houses with potentially high levels of depressurization.

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Essais en laboratoire d'appareils à gaz résidentiels soumis à une dépressurisation – deuxième partie

INTRODUCTION

La Société canadienne d'hypothèques et de logement (SCHL), en partenariat avec Ressources naturelles Canada (RNCan), a élaboré un protocole d'essai de refoulement des gaz sous l'effet de la dépressurisation (dépressurisation-refoulement). Les travaux de recherche décrits dans le présent Point en recherche¹ avaient pour objectif d'évaluer la performance d'un échantillon d'appareils à combustion résidentiels à l'aide du nouvel essai.

Le refoulement produit par les appareils à combustion est un problème épique. La fréquence et la sévérité des refoulements de gaz de combustion sont fonction de la mise en place de l'équipement et de l'utilisation d'équipements d'extraction présents dans la maison qui peuvent surclasser le système d'évent de l'appareil. Les codes et normes en vigueur à l'heure actuelle au Canada ont tenté de régler le problème de refoulement au moyen de stratégies comme le fait d'exiger une alimentation en air comburant dans les maisons qui ne présentent peut-être pas suffisamment de fuites d'air pour alimenter convenablement en air comburant les appareils à combustion.

Les fabricants ont également mis au point des appareils qui sont moins sujets aux refoulements. En règle générale, ils ont soit été conçus de manière à ce que les composants de combustion et d'évent ne soient pas exposés aux régimes de pression qui sévissent dans la maison, ou ils sont dotés de systèmes d'évent puissants qui devraient être capables de fonctionner même dans des conditions de dépressurisation.

La première catégorie de produit consiste en des modèles à ventouse à double effet. Ils sont habituellement munis d'un évén mural au lieu d'une cheminée.

Les chauffe-eau à tirage induit constituent l'un des exemples courants de la deuxième catégorie d'appareils conçus pour mieux résister au refoulement des gaz de combustion.

Malgré la plus grande disponibilité d'appareils conçus pour résister aux refoulements sous l'effet d'une dépressurisation, aucun protocole ne permet aux fabricants de mettre à l'essai et de coter leurs produits pour connaître leur résistance aux refoulements. Ainsi, les fabricants ne disposent pas d'une méthode normalisée pour communiquer aux consommateurs, aux constructeurs ou aux autres intervenants une cote de résistance aux refoulements de leurs appareils. Il en est de même s'ils souhaitent indiquer lesquels de leurs produits affichent une meilleure performance dans des conditions de pression réduite qui pourraient provoquer des refoulements de gaz de combustion dans d'autres produits.

Le nouvel essai de dépressurisation-refoulement a été mis au point afin de combler cette lacune. Les deux études dont il est ici question ont mis l'accent sur la performance des appareils contemporains. On ne s'est pas arrêté à étudier la résistance à la dépressurisation-refoulement d'appareils à combustion plus anciens que l'on retrouve encore aujourd'hui dans les maisons au Canada.

PROGRAMME DE RECHERCHE

Le premier programme de recherche a été mené de janvier 2005 à mai 2005. Le second a eu lieu au cours de l'automne 2007. Les essais ont été réalisés dans les locaux de Bodycote, un laboratoire d'essais commercial canadien.

Lors du programme de 2005, sept appareils à combustion (deux chauffe-eau, trois générateurs de chaleur et deux foyers à gaz) ont été choisis de manière à représenter une large gamme de types d'équipements à gaz que l'on met en place à l'heure actuelle dans les maisons au Canada.

¹ Le présent document fait suite au feuillet documentaire numéro 05-111 de la série technique de la collection « Le point en recherche », intitulé Essais en laboratoire d'appareils à gaz résidentiels soumis à une dépressurisation, publié par la SCHL en septembre 2005.

Les appareils et leur système d'évent ont été achetés dans le commerce auprès de marchands en gros d'équipement de CVC, sans passer par les fabricants. Les appareils ont été livrés directement au laboratoire d'essais par les grossistes. Tous les produits ont été installés et mis à l'essai conformément aux instructions du fabricant, moyennant le type et la longueur équivalente maximale de l'évent spécifiés par le fabricant.

Pour l'étude de 2007, dix appareils à combustion de plus ont été mis à l'essai, soit un chauffe-eau au gaz à accumulation et à condensation, deux chauffe-eau instantanés, une chaudière murale, deux foyers et quatre générateurs de chaleur.

L'essai de refoulement incorpore une limite supérieure de refoulement de 2 %, qui constitue en quelque sorte la note de passage. Cette limite a été choisie pour assurer une certaine souplesse dans le choix de l'instrumentation d'essai et elle autorise une faible marge d'erreur associée aux incertitudes cumulatives de la procédure d'essai et des exigences de mesurage.

Il s'agit de la même tolérance employée dans les essais statiques d'étanchéité des événements des gaz de combustion desservant des appareils à combustion étanches qui fonctionnent sous pression positive. Pour de tels appareils, on exige déjà des essais d'étanchéité d'événements selon les normes existantes de certification d'appareils (par exemple : CSA 4.3, CSA 4.9 et CSA B140.0). Il faut toutefois savoir que les essais d'étanchéité statiques sont menés à des pressions différentes et qu'ils sont réalisés sur les appareils et le système d'évent à température ambiante et lorsque l'appareil est à l'arrêt.

Le fait de fixer le critère de réussite à un seuil de 2 % de fuites de gaz de combustion ne devrait pas être interprété comme un niveau de performance acceptable pour les appareils à combustion. En effet, un refoulement de 2 % des émanations d'un appareil à combustion peut ne pas être acceptable dans toutes les situations.

ESSAI DE DÉPRESSURISATION-REFOULEMENT

L'essai de dépressurisation-refoulement est décrit sommairement ci-dessous.

Dans la figure 1, l'encadré avec la flamme représente l'appareil à combustion installé dans la chambre d'essai de dépressurisation. Les conduits horizontaux (pourvus de flèches blanches) qui sont fixés à l'appareil représentent le conduit d'air comburant et l'autre, l'évent des gaz de combustion. Le dessin montre que l'appareil tire l'air comburant de l'extérieur de la chambre d'essai et évacue les gaz de combustion au même endroit. Certains appareils tirent l'air

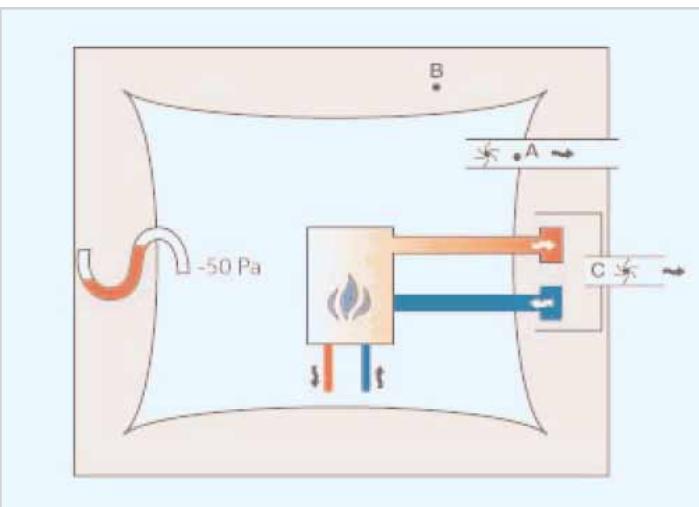


Figure 1 Schéma simplifié de l'essai de dépressurisation-refoulement

comburant de l'air à l'intérieur de la chambre d'essai. Les lignes verticales représentent la charge thermique, et la puissance de sortie, de l'appareil qui peut être libérée dans la chambre d'essai ou évacuée à l'extérieur de la chambre (l'évacuation s'avère plus simple pour les appareils qui chauffent l'eau comme les chauffe-eau et les chaudières).

La chambre d'essai est dépressurisée (de 50 Pa selon l'illustration) par rapport aux espaces environnants au moyen d'un ventilateur à vitesse variable installé dans le conduit « A » qui évacue l'air à l'extérieur du bâtiment. Un conduit d'extraction supplémentaire « C » recueille et élimine les produits de combustion afin d'éviter de contaminer les espaces « B » au pourtour de la chambre d'essai.

L'appareil est mis en marche de manière à ce que le brûleur fonctionne pendant cinq minutes. La quantité de CO₂ refoulée ou qui se « déverse » dans la chambre d'essai est déterminée pendant cinq minutes et une période additionnelle de deux minutes (afin de capter les gaz de combustion qui s'échappent du système d'évent après l'arrêt du brûleur). On divise la quantité de CO₂ (dioxyde de carbone) déversée dans la chambre d'essai par la quantité de CO₂ produite par le brûleur durant l'essai pour calculer le pourcentage de refoulement de gaz de combustion.

Pour chaque appareil, l'essai a d'abord été mené à une dépressurisation de la chambre d'essai de 50 Pa par rapport à la pression à l'extérieur de la chambre. Si le refoulement de gaz excédait 2 %, l'essai était répété avec la chambre dépressurisée de 20 Pa. Enfin, si le pourcentage de refoulement excédait 2 % à 20 Pa, un essai était réalisé à une dépressurisation de la chambre de 5 Pa.

Tableau I Résultats des essais en laboratoire sur des appareils à gaz « résistant aux refoulements »

Appareil	Année d'étude	Ventouse (V) ou tirage induit (Ti)	% de refoulement		
			À 50 Pa	À 20 Pa	À 5 Pa
Chauffe-eau à tirage induit A	2005	Ti	1,1		
Chauffe-eau à tirage induit B	2005	Ti	1,6		
Chauffe-eau à tirage induit C	2007	Ti	0,5		
Chauffe-eau instantané A	2007	V	0,2		
Chauffe-eau instantané B	2007	Ti	0,1		
Chaudière murale A	2007	V	0,2		
Appareil sans condensation A	2005	Ti	0,2		
Appareil à condensation* A	2005	Ti	0,0		
Appareil à condensation B	2005	Ti	0,1		
Appareil à condensation C	2007	Ti	0,6		
Appareil à condensation D	2007	Ti	-0,5		
Appareil à condensation E	2007	Ti	0,0		
Appareil à condensation F	2007	Ti	2,6	1,4	
Foyer A	2005	V	13	3,5	0
Foyer B	2005	V	0,7		
Foyer C	2007	V	10,3	2,0	0
Foyer D	2007	V	1,0		

* Les appareils à condensation pouvaient être installés soit en configuration ventouse à double effet ou en configuration à tirage induit. Ils ont été mis à l'essai en configuration tirage induit.

CONSTATATIONS

L'essai de refoulement est relativement facile à réaliser. Des 17 appareils à gaz mis à l'essai à 50 Pa de dépressurisation, huit ne présentaient aucun refoulement décelable, six affichaient un léger refoulement, bien que mesurable, et trois appareils présentaient un refoulement de gaz supérieur au seuil de 2 %. Les résultats sont présentés sommairement dans le tableau 1.

Selon les résultats obtenus, il est évident que de nombreux produits courants sont en mesure d'afficher une performance satisfaisante même en situation de dépressurisation, alors que d'autres produits, qui semblent similaires, ne présentent pas une aussi bonne performance. Le nouvel essai peut donc faire ressortir les produits performants.

En raison du seuil de tolérance de refoulement de 2 % prévu par l'essai, on aura peut-être de la difficulté à distinguer une performance réussie serrée d'un échec marginal. Si un tel résultat était obtenu, de plus amples recherches et des essais répétés seraient probablement requis avant d'arriver à une conclusion.

Lors des essais menés au cours du premier programme de recherche, le résultat le plus près de la limite a été de 1,55 %, dans le cas d'un seul appareil. Bien que plus élevé que la valeur idéale, ce résultat est plus de 20 % inférieur à la limite proposée. Ce résultat a donc été considéré comme ayant « réussi ».

De même, lors du second programme, un appareil a présenté un refoulement de 2,6 % à 50 Pa de dépressurisation, tout juste au-dessus du seuil. Ce résultat a été considéré comme un échec. Les fabricants des deux produits devaient toutefois revoir leur conception à la lumière des résultats de ces essais et procéder à des améliorations permettant à leurs appareils d'obtenir la même performance que les produits concurrents.

CONSÉQUENCES POUR LE SECTEUR ET AUTRES INTERVENANTS

Les exigences en matière d'installation et d'instrumentation visant l'essai dépressurisation-refoulement sont suffisamment modestes de manière à ce que les fabricants éprouvent peu de difficultés, voire aucune, à monter l'essai dans leur propre installation et à utiliser leur installation d'essai comme outil de développement de produits. Les fabricants pourront ainsi vérifier la performance de leurs produits et en améliorer la résistance aux refoulements.

L'essai de dépressurisation-refoulement est un nouvel outil qui permet aux fabricants d'inclure dans leurs documents techniques une cote de résistance au refoulement à la suite d'une dépressurisation en plus des autres données de performance de leurs produits. On s'attend à ce que l'essai de refoulement soit immédiatement utile aux fabricants qui veulent souligner la performance de leurs produits en milieu dépressurisé, comme c'est le cas dans une maison dotée d'appareils d'extraction de grande capacité.

Les résultats obtenus pour 17 appareils à gaz révèlent que ces appareils « résistant aux refoulements » ont généralement pu fonctionner d'une manière sécuritaire à une dépressurisation de 50 Pa, ce que suggèrent les codes et les normes ces dernières années au Canada. Un petit nombre d'appareils entraînent un refoulement excessif. L'intégration de l'essai de dépressurisation-refoulement dans les normes régissant les appareils à gaz devrait permettre d'intercepter les produits mal conçus et fabriqués afin de les empêcher d'entrer dans les maisons susceptibles de présenter des niveaux élevés de dépressurisation.

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Gestionnaire de projet à la SCHL : Don Fugler

Consultants pour le projet de recherche : Peter Edwards

Recherche sur le logement à la SCHL

Aux termes de la partie IX de la *Loi nationale sur l'habitation*, le gouvernement du Canada verse des fonds à la SCHL afin de lui permettre de faire de la recherche sur les aspects socio-économiques et techniques du logement et des domaines connexes, et d'en publier et d'en diffuser les résultats.

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Attachment 1: Depressurization spillage test procedure and calculations

Attachment 2: Sample calculation and reporting template

Summary

A simple test has been developed to accurately measure the amount of combustion spillage from residential combustion appliances and their venting systems operating under selected levels of depressurization. The test uses carbon dioxide (CO₂) produced in the fuel combustion process as a tracer gas. The test method was specifically designed so that it would not require the use of precision space conditioning facilities. The detailed test procedure and the results obtained from testing some gas-fired residential appliances have been described in earlier reports.^{1 2}

In this project ten (10) natural-gas fired appliances were obtained and tested to determine their spillage resistance. The units that were tested during this project were either direct vent or power vent appliances. Those types of appliances are generally considered by the gas industry and regulators to be “spillage resistant”.

The sample set comprised:

- One high efficiency “condensing” power-vented storage-tank water heater
- Two tank-less “instantaneous” water heaters (one direct-vent, one power-vent)
- One high efficiency direct-vent wall-hung “boiler”
- Two direct-vent gas fireplaces
- Four high efficiency “condensing” furnaces

Seven of the appliances were purchased by CMHC from regular HVAC distributors and they were directly shipped to the testing laboratory by the distributors. Three were provided by Reliance Home Comfort. Each was installed, following the manufacturers’ certified installation instructions. For appliances that used PVC or ABS pipe for their combustion vents, the test installations included sufficient combustion vent piping inside the test room to approximate, but not exceed, the maximum allowable equivalent vent lengths specified by the manufacturers. Each of the four condensing furnaces is approved for installation as either a direct-vent (two-pipe) or as a non direct-vent (single-pipe) system. The furnaces were installed and tested as non direct-vent units, drawing their combustion air from inside the depressurized test room.

For each unit, tests were initially performed with the room depressurized by 50 Pa (0.2 inches H₂O) compared with the pressure outside the room. If the combustion spillage exceeded 2 %, the test was repeated with the room depressurized by 20 Pa (0.08 inches H₂O). Finally, if the measured spillage exceeded 2 % at 20 Pa, a test was performed with the room depressurized by 5 Pa (0.02 inches H₂O).

¹ *Laboratory Evaluation to Assess a proposed Test Method to Determine Transient Combustion Spillage, Bodycote Materials Testing Report 04-06-M278b for NRCan, July 2005*

² *Development and Evaluation of a new Depressurization Spillage Test for Residential Gas-Fired Combustion Appliances, Peter Edwards Co. for NRCan and CMHC, July 2005*

During each test, the amount of CO₂ that was released into the test room from the appliance and its venting system was determined from the measurements. This was compared with the amount of CO₂ produced by combustion of the fuel consumed during the test. The ratio of the two provides a direct measure of the combustion spillage of the appliance and its venting system.

The 50 Pa depressurization tests results were as follows:

- Five appliances had essentially undetectable levels of combustion spillage
- Three appliances had low, but measurable combustion spillage (between 0.5 % and 1 %)
- One appliance had 2.6 % spillage
- One product had significant combustion spillage (approximately 10 %)

Based on a performance benchmark for a combustion appliance to have less than 2 % combustion spillage at its rated depressurization level, eight of the ten appliances passed at 50 Pa. Another passed at 20 Pa. The tenth product did not pass at 50 Pa (10 % spillage) and was borderline at 20 Pa (2 % spillage). It easily passed at 5 Pa, at which pressure there was no detectable combustion spillage.

The results are summarized in Table 1. Detailed test results are published in a separate laboratory test report.³

³ *Laboratory Testing to Determine Depressurization Combustion Spillage, Bodycote Testing Group Report 07-06-M0255 for CMHC, November 2007*

Overview of the spillage test

The spillage test was developed as a simple tool to allow manufacturers and others to verify the spillage resistance of combustion appliances. It was expected that development and demonstration of a simple test would encourage manufacturers to provide depressurization resistance ratings alongside their other product performance data, and potentially lead to certification of spillage resistance.

A brief synopsis of the combustion depressurization spillage test is shown below.

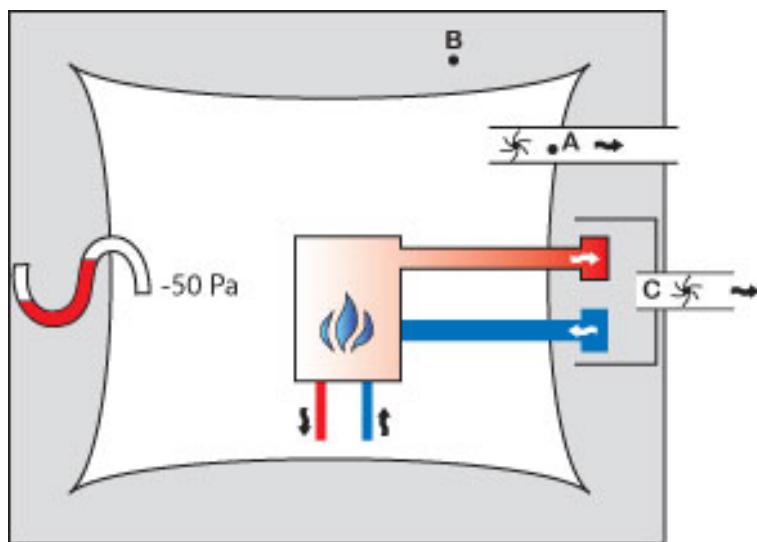


Figure 1: Simplified Concept of Depressurization Spillage Test

In Figure 1, the box with a flame represents a combustion appliance that is installed inside a depressurized test room. The horizontal ducts (with white arrows) attached to the appliance represent the combustion air inlet and the combustion vent. The vertical lines represent the thermal load and output from the appliance that may either be released inside the test room or rejected outside the room (rejection is simpler for products that heat water such as water heaters and boilers). The appliance is shown drawing combustion air from outside the test room and venting its combustion products outside the test room. Other appliances may draw their combustion air from inside the test room.

In the example, the test room is depressurized by 50 Pa with respect to its surroundings using a fan installed in duct "A". A supplemental exhaust system "C" captures and removes the combustion products from the vicinity of the vent to avoid contaminating the area "B" adjacent to the test room.

To perform the depressurization spillage test:

- The combustion appliance is installed in the test room.
- A fan is used to draw air from the test room so that the appliance can be tested against the selected level of depressurization.
- The appliance is operated
- Measurements of the following parameters are taken
 - room pressure,
 - fuel consumption
 - airflow drawn from the room by the depressurization fan
 - the CO₂ concentration (A) in the air being removed from the room
 - the CO₂ concentration (B) in the surrounding area
 - the CO₂ concentration in the combustion vent (used in conjunction with the measured fuel consumption to calculate the combustion and dilution air flow for non direct-vent appliances)
- The combustion spillage is determined by calculating the amount of CO₂ released into the test room during the test divided by the amount of CO₂ produced by combustion of the fuel consumed during the test

Prior to this project, the test had been validated and demonstrated in a 2005 project that investigated the depressurization spillage of seven gas-fired appliances.

Descriptions of tested appliances

The gas-fired appliances tested during this project were:

- One high efficiency “condensing” power-vented storage-tank water heater
- Two tank-less “instantaneous” water heaters (one direct-vent, one power-vent)
- One direct-vent wall-hung “boiler”
- Two “direct-vent” gas fireplaces
- Four high efficiency “condensing” furnaces

Seven products were purchased by CMHC from regular HVAC distributors and they were directly shipped to the testing laboratory by the distributors. Three were provided by Reliance Home Comfort.

Each appliance was installed, following the manufacturers’ certified installation instructions. Three required proprietary vent kits that were obtained from the distributors. The others were installed using venting materials and vent configurations specified by their manufacturers. For each of the appliances that used PVC or ABS pipe for their combustion vents, the test installation included sufficient combustion vent piping inside the test room to approximate, but not exceed, the maximum allowable equivalent vent length specified in the manufacturer’s literature.

The condensing furnaces were approved for installation as either direct-vent or as non direct-vent systems. They were installed and tested as non direct-vent units, drawing their combustion air from inside the depressurized test room.

Test results

The 50 Pa depressurization tests results were as follows:

- Five appliances had essentially undetectable levels of combustion spillage
- Three appliances had low, but measurable combustion spillage (between 0.5 % and 1 %)
- One appliance had 2.6 % spillage
- One product had significant combustion spillage (approximately 10 %)

Based on a performance benchmark for a combustion appliance to have less than 2 % combustion spillage at its rated depressurization level, eight of the ten appliances “passed” at 50 Pa. One passed at 20 Pa. The tenth product did not pass at 50 Pa (10 % spillage) and was borderline at 20 Pa (2 % spillage). It easily passed at 5 Pa, at which pressure there was no detectable combustion spillage.

The test results are shown in Table 1

Table 1: Summary of 2007 depressurization spillage results

Type of Appliance	Direct Vent Zero Clearance Fireplace		Power Vented Water Heater Tank	Wall-Hung Boiler	Tank-less Water Heater		Condensing Furnace ¹			
Identification	A	B	C	D	E	F	G	H	I	J
Direct Vent	Y	Y	N	Y	Y	N	N	N	N	N
Rated Input kW ² (Btu/h*1000)	5.3 (18)	5.3 (18)	22.3 (76)	22.3 (76)	52.8 (180)	58.3 (199)	20.5 (70)	20.5 (70)	23.4 (80)	17.6 (60)
Depressurization Spillage (%)										
50 Pa	10.3	1.0	0.5	0.2	0.2	0.1	0.6	-0.5	0.0	2.6
20 Pa	2.0	-	-	-	-	-	-	-	-	1.4
5 Pa	0.0	-	-	-	-	-	-	-	-	-

¹ Condensing furnaces were tested using their approved single-pipe venting configurations

² Rated inputs are for operation on high fire for products with variable inputs or multi-stage burners

The results from the 2005 tests are shown in Table 2 for comparison.

Table 2: Summary of 2005 depressurization spillage results

Type of Appliance	Power-Vented Water Heater Tank	Furnace	Condensing Furnace	Fireplace Insert	Zero Clearance Fireplace
Identification	A	B	C	D	E
Direct Vent	N	N	N	N	Y
Maximum Rated Input kW (Btu/h*1000)	10.5 (36)	10 (34)	22 (75)	23.4 (80)	23.4 (80)
Depressurization Spillage (%)					
50 Pa	1.1	1.55	0.2	0.04	0.14
20 Pa	-	-	-	-	3.5
5 Pa	-	-	-	-	0.0

Discussion

The 2% spillage threshold

The test incorporates a “pass” threshold of 2% spillage. This figure is used for this test to provide for flexibility in the choice of test instrumentation and to allow for a small margin of error from simplifications in the testing procedure and calculations. It should be noted that acceptance of a 2% “pass” tolerance in the new depressurization spillage test should not be construed as a general finding that 2% combustion spillage constitutes acceptable performance for all combustion appliances. Indeed, 2% spillage from certain types of combustion appliances may not be acceptable for all installations.

Minimizing uncertainties

In order to minimize the uncertainties during the tests, the following procedures were implemented during the project:

- CO₂ analysers were calibrated before and after each test using calibration gas.
- All evident openings in the envelope of the test room were sealed.
- Flow in the supplemental exhaust products capture system was increased to improve the capture efficiency and minimize contamination of the space adjacent to the test room. Care was taken to ensure that the supplemental capture system did not affect the CO₂ level in the combustion vent section of the appliance.
- Air circulation fans were operated in the test room to promote proper mixing of the environment inside the room.

Conclusions and Recommendations

This project confirms that a relatively simple depressurization spillage test can be used to differentiate between products that spill and those that do not.

Many existing spillage resistant appliances perform well. Some do not. This test can be used to differentiate the good and the bad, and improve the performance of the bad units.

Performance requirements for combustion spillage susceptibility should be included in building codes, appliance installation codes and product certification standards. This will lead to the selection of more appropriate combustion appliances that better match the design-depressurization characteristics of the types of buildings in which they will be used.

Depressurization Spillage Test Procedure

1 Installation & Preconditioning of Combustion Appliance

1.1 Test Setup

The appliance shall be installed in the test room using the manufacturer's installation instructions, and using the venting materials, connectors and vent terminations specified by the manufacturer. Gas supply and potable water connections, if applicable, may use flexible piping or hoses.

1.2 Preconditioning

Before performing a combustion spillage test, a new appliance shall be operated at its maximum firing rate for a period of at least two (2) hours to allow for the removal of manufacturing residues within the appliance and its venting system that may affect the test measurements.

1.3 Depressurization

The test room shall be equipped with an exhaust fan and be sufficiently sealed to allow the test room to be evacuated to produce the depressurization level required for the test while the appliance is operating.

Note: In most cases, depressurization of the test room by up to 50 Pa (0.2 in water column) will be sufficient for the test.

1.4 Combustion & Vent Terminals

The combustion air inlet and vent terminals shall be installed at the wall or ceiling of the test room to discharge the vent products from the test room and to bring combustion air into the test room (if applicable). The test shall be performed with the maximum certified equivalent lengths of combustion vent and combustion air intake (if applicable) installed and connected inside the test room in accordance with the manufacturer's instructions. The combustion and vent terminals may connect with an outdoor space or may connect with the adjacent space surrounding the test room.

The adjacent space around the test room shall be adequately ventilated to ensure that the combustion products do not cause contamination of the space. A supplemental gas-capture and exhaust apparatus may be used to remove combustion products from the space adjacent to the test room, provided that the CO₂ content, vent temperature and flows of the combustion products in the appliance venting system are not affected by the operation of the apparatus.

1.5 Sampling Ports

A sampling port shall be installed to monitor the CO₂ level within the test room and in the exhaust duct from the test room.

A sampling port shall be installed to monitor the pressure inside the test room. This pressure shall be monitored in a location between 0.5 m and 1 m of the appliance burner.

2 Test Tolerances

Pressure

The test room fan shall be operated and adjusted to produce the required static pressure in the test room (below the pressure in the surrounding area). The specified depressurization level shall be maintained within ± 2 Pa for the duration of the depressurization test by adjusting the flow through the test-room exhaust fan. The airflow through the test-room exhaust fan shall be measured during the test.

Temperature

Before a spillage test is performed the depressurization fan shall be operated until the test room temperature and the combustion vent temperature are within $\pm 3^{\circ}\text{C}$ of the ambient temperature in the surrounding space.

Note: This ensures that the spillage test will have a reproducible “cold-start” venting condition.

3 Test Procedures

3.1 The pressure inside the test room shall be adjusted to the level at which the appliance is to be tested within the tolerance outlined in Section 2

3.2 The appliance shall be operated at its maximum firing rate or at another firing rate if specified.

3.3 Measurements of the test room depressurization, CO₂ level, the test room depressurization flow, and the CO₂ level in the space adjacent to the test room shall be recorded prior to the start of the test and at least every 30 seconds during the test.

Adjustments to the depressurization flow shall be made as required to maintain the required room pressure. Measurements shall continue for an additional 2 minutes after burner shutdown.

3.4 The readings from the gas meter or other device used to measure the fuel consumed by the appliance shall be recorded immediately before starting the burner, when the burner is shut off, and at the conclusion of the test.

3.5 If the appliance draws combustion air from inside the test room, the CO₂ content and temperature in the combustion venting system at the vent termination shall be monitored during the test to establish the excess-air⁴ level in the combustion vent.

3.6 The burner shall be shut off after five minutes of burner operation. This may be achieved by adjusting a control thermostat, terminating a water draw etc. as appropriate. For appliances without remote thermostat controls the fuel supply to the appliance may be shut off to terminate burner operation provided that the appliance does not use any standing gas pilot.

3.7 The electricity supply (if applicable) to the appliance shall be shut off seven minutes following the time that burner ignition occurred.

⁴ At the discretion of the testing agency, excess air may be determined using calculations from the Combustion and Fuels chapter of the current edition of ASHRAE Fundamentals. Combustion charts or combustion software are also acceptable methods to determine the excess air. North American Combustion Handbook,; Vol. 1 published by North American Mfg. Co., is one acceptable source for combustion charts

4 Calculations

Combustion spillage shall be calculated and reported over the seven minute test period as outlined in attachment 2.

Example Calculation of Spillage

Test Conditions

Test Room Static Pressure	-50 Pa
Room Exhaust Fan Flow	123 L/s (261 scfm)
Combustion Air Flow from Room	10 L/s (21 scfm)
(Note: Sample water heater draws combustion air from the test room)	
Fuel Input Rate during Test	10.6 kW 36000 Btu/h
Room CO ₂ at start of test	433 PPM
Room CO ₂ at end of test	443 PPM
Volume of test room	44.7 M ³ (1578 ft ³)

Spillage = (*CO₂ accumulated in the test room between start and end of test + CO₂ removed by room depressurization fan and appliance combustion air*) / *CO₂ produced by combustion*

Calculations

CO₂ accumulated in the test room during test

((Room CO₂ at end of test - Room CO₂ at start of test) * Scaling Factor) * Volume of Test Room

(The Scaling Factor converts CO₂ concentrations in ppm to a decimal fraction)

$$((443 - 433) * 0.000001) * 44.7 = 0.000447 \text{ M}^3$$

$$((443 - 433) * 0.000001) * 1578 = 0.01578 \text{ ft}^3$$

CO₂ removed from test room during each time interval

$(CO_2_{(test\ room)} - CO_2_{(adjacent\ space)}) * (Exhaust\ Fan\ Flow + Combustion\ air\ Flow) * Scaling\ Factor * Duration\ of\ time\ interval$

Cumulative CO₂ removed from test room

Cumulative Sum of CO₂ removed from test room per time interval
= 0.0175 ft³ or 0.000496 M³

CO₂ generated by appliance during 5 minute burner operation

$$= (Input\ Rate\ [Btu/h]/1000) * (0.0167\ [SCFM]/1000\ [Btu/h]) * Time\ [minutes]$$

$$= ((36,000 * 0.0167) / 1000) * 5$$

$$= 3.0\ ft^3\ or\ 0.0850\ M^3$$

$$\text{Spillage} = (0.000447 + 0.000496) \text{ M}^3 / 0.0850 \text{ M}^3 = 0.0111$$

$$\text{Spillage} = (0.01578 + 0.0175) \text{ ft}^3 / 3 \text{ ft}^3 = 0.0111$$

$$\text{Spillage} = 1.1\%$$

An example of the excel reporting template with the results of a spillage test of a furnace is shown on the next page

Attachment 2: Sample Calculation and Test Data

Spillage Test at 50 Pa. Depressurization: Example calculation

Sample No.:
 Manufacturer:
 Appliance Type: Furnace
 Model Number:
 Serial Number:
 Client: CMHC
 Test Date: 14/11/2007

Test Notes: Test performed with furnace circulating blower operating continuously.
 Appliance installed as a non-direct (1-pipe) vent system with 62 equivalent feet of vent using 2" ABS pipe

$$CO_2 \text{ leakage per time base interval} = (CO_2 \text{ (test room)} - CO_2 \text{ (adjacent room)}) \cdot (\text{Exhaust Fan Flow} + \text{Appliance Exhaust Products Flow}) \cdot (\text{Scaling Factor})$$

$$CO_2 \text{ remaining in test room at end of test} = (CO_2 \text{ (test room end)} - CO_2 \text{ (test room start)}) \cdot (\text{Scaling Factor}) \cdot (\text{Test Room Volume})$$

$$CO_2 \text{ generated by appliance} = (\text{Input Rate (Btu/h)}/1000) \cdot (0.0167 \text{ SCFM}/1000 \text{ Btu/h})$$

$$\text{Spillage} = \text{Total } CO_2 \text{ Leakage} / CO_2 \text{ generated by appliance}$$

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) ¹ :	423	423	423	423	423	423	423	423	423	423	423	423	423	423
CO ₂ (adjacent room, base) ¹ :	426	426	426	426	426	426	426	426	426	426	426	426	426	426
CO ₂ (test room) ppm ² :	422	425	435	438	442	448	456	460	463	468	472	471	467	464
CO ₂ (adjacent room) ppm ² :	425	428	426	430	432	423	422	417	418	419	440	438	432	427
Exhaust Fan Flow (ACFM):	286.5	286.5	286.5	286.5	286.5	286.5	286.5	286.5	286.5	286.5	286.5	286.5	286.5	286.5
Exhaust Fan Flow (SCFM):	261.6	261.6	261.6	261.6	261.6	261.6	261.6	261.6	261.6	261.6	261.6	261.6	261.6	261.6
Appliance CO ₂ concentration (%) ¹ :	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	0.0	0.0	0.0	0.0
Combustion Air Flow (SCFM) ² :	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	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	1.00E-06
CO ₂ (depressurization) Leakage (ft ³) =	0.0001	0.0001	0.0016	0.0015	0.0017	0.0040	0.0050	0.0063	0.0067	0.0073	0.0049	0.0047	0.0049	0.0052

¹ CO₂ concentration measured at appliance (during spillage test)

² Includes combustion air and excess air

$$\text{Average depressurization during 7 minute test} = -50.9 \text{ Pa}$$

$$\text{Test Room CO}_2 \text{ at end of 7 minute test} = 464 \text{ ppm}$$

$$\text{Test Room CO}_2 \text{ at start of test} = 422 \text{ ppm}$$

$$\text{Volume of test room} = 1578 \text{ ft}^3$$

$$CO_2 \text{ remaining in test room at end of test} = 0.065 \text{ ft}^3$$

$$\text{Total CO}_2 \text{ removed from test room over 7 minute test period} = 0.0539 \text{ ft}^3$$

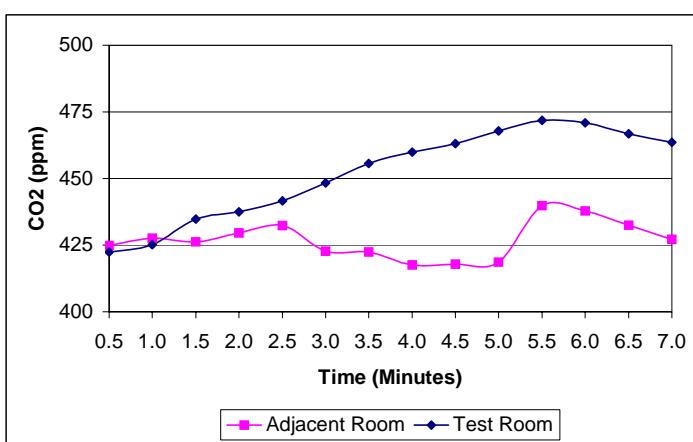
$$\text{Total CO}_2 \text{ leakage} = 0.1189 \text{ ft}^3$$

$$\text{Gas Meter End} = 8633.32 \text{ ft}^3$$

$$\text{Gas Meter Start} = 8628.68 \text{ ft}^3$$

$$CO_2 \text{ Generated by appliance during 5 minute burner ON time} = 4.64 \text{ ft}^3$$

$$\text{Spillage (Total CO}_2 \text{ leakage/ Appliance CO}_2) = 2.56\%$$



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