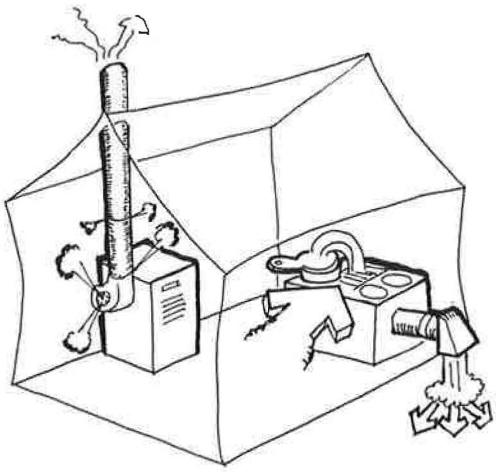
#4238

House Depressurization Limits for Mid-Efficiency Gas-Fired Furnaces

Sebastian Moffatt Peter Moffatt



It has been widely assumed that mid-efficiency or induced-draft gas furnaces can tolerate moderate levels of house depressurization, without suffering from the pressure-induced spillage problems that have plagued conventional natural draft furnaces. On this basis, housing authorities have increasingly promoted mid-efficiency furnaces as the most practical solution to avoiding chimney backdrafting and spillage problems, especially in tighter-built, mechanically-ventilated housing.

As new codes and standards for ventilation and indoor air quality encourage mechanical ventilation systems in housing, many of which are likely to be exhaust only, the transition to mid-efficiency furnaces is likely to accelerate. These are often the most convenient and cost effective way for builders to avoid onerous requirements for large make-up air supply systems with expensive controls and tempering devices.

However, frequent or continuous house depressurization is becoming a common characteristic of Canadian housing stock that is placing exceptional demands on chimney performance.

Mid-efficiency furnaces were originally designed for energy efficiency only. Relying on these appliances to prevent combustion gas spillage has been expedient, but no research has been done to establish their performance in depressurized houses. Instead, assumptions have been made pressure limits based primarily on experience with natural draft furnaces.

House depressurization limits

The maximum safe level of house depressurization for a particular appliance and chimney design is referred to as the House Depressurization Limit (HDL). When a house exceeds the HDL, the potential exists for prolonged start-up spillage or continuous spillage or backdrafting whenever the furnace operates.

For a house with a natural-draft gas furnace, the HDL is approximately 5 Pascals (although this could vary by 1 or 2 Pascals, depending on the chimney height and whether it is insulated or located on the outside wall). When such a house is depressurized by more than 5 Pascals, the chimney may backdraft under stand-by conditions. Upon firing, the furnace is unable to reverse the backdraft and establish proper venting. Instead, all the combustion gases spill indoors through the dilution air opening of the furnace for as long as the furnace operates.

Because mid-efficiency gas furnaces incorporate an induced-draft fan, it has been assumed that the appliance is always capable of establishing proper venting on start-up. The HDL for mid-efficiency furnaces is typically assumed to be close to the minimum draft that is likely to exist in a hot chimney - somewhere between 20 and 30 Pascals. However, most mid-efficiency gas furnaces are not intended to pressurize the flue, they are vented into a natural draft chimney. Only those units designed for side wall venting are designed or certified to pressurize the flue.

Problems can happen at relatively low depressurization levels. In one experimental R-2000 house it was discovered that indoor/outdoor pressure differentials of 9 Pascals were enough to cause continuous combustion gas spillage from a side-wall vented, induced-draft furnace. Reasons for combustion gas spillage in the house were complex and included manufacturing defects, poor installation practices, and an apparent design flaw in the induced-draft fan assembly.

What was tested

Because there has been no research done on house depressurization limits for houses with induced draft furnaces, Sheltair Scientific was commissioned to do some field tests.

Five mid-efficiency furnaces were tested to establish their susceptibility to pressure-induced spillage. Each furnace was of different manufacture, and was tested as found in randomly selected Vancouver houses. Four of the five furnaces were spilling combustion gases under normal operating conditions - without house depressurization. This was primarily due to the poor design of the induced-draft fan housing.

An effort was made to locate at least one example of every make of mid-efficiency furnace currently sold in Canada. In several cases (eg. Clair and York), the distributors had not yet sold any mid-efficiency furnaces in British Columbia, so not all units were included in the study.

Each mid-efficiency furnace was treated as part of a system as installed, including the house, chimney, and the appliance. There was no attempt to isolate and separately test each component of these systems.

The testing was done at the end of the heating season when weather conditions were mild and calm (i.e. worse case conditions for the venting of combustion appliances). All tests were carried out when winds were below 10 km/hr and indoor/outdoor temperature differences less than 16°C but more than 4°C.

Seven questions were asked before establishing depressurization limits.

1. Do combustion gases spill indoors under normal operating conditions? Potential gas spillage sources can be joints and elbows in the vent connections; at the flue collar; in the furnace around the fan housing; and the draft hood of a domestic hot water heater (if commonly vented).
2. Does the spillage quantity increase with increases in house depressurization?

3. What is the shut down response time for the furnace when major spillage occurs at the vent safety shut-off switch?

4. Is there a house depressurization level at which the appliance/chimney system fails to establish an updraft?

5. If a domestic hot water heater shares the same flue as the furnace, what is the pressure at which the system fails to establish an up-draft?

6. With the flue pipe completely blocked, how long does it take the appliance to shut down?

7. Does house depressurization affect the combustion efficiency of an induced draft appliance?

Manufacturers indicated that mid-efficiency furnaces were designed to operate under atmospheric pressures and have never been tested at the factory or at the Canadian Gas Association (CGA) for the purpose of establishing house depressurization limits. Although manufacturers recognize that a significant market has been created for mid-efficiency furnaces because the appliances are assumed to provide safer venting in airtight housing, they are not prepared to guarantee safe performance at any amount of house depressurization.

Induced draft furnaces fall into two categories, depending on how they can be vented. One category is approved for horizontal venting through a side wall of a house, the second is approved only for venting into a vertical natural draft chimney and can share a flue with a naturally aspirated gas-fired domestic hot water heater.

Furnaces approved for horizontal venting have a pressure proving switch that shuts the furnace off if the induced draft fan does not operate or if the chimney is plugged for any reason. Under normal operation the furnace is expected to pressurize the flue when there is a wind blowing against the wall termination, or when starting up against a cold flue. Manufacturers' installation literature requires that the flue be sealed with high temperature silicone or flue tape to prevent spillage of combustion gases.

The current design of most mid-efficiency furnaces does not appear to be appropriate for use in airtight housing where frequent or continuous house depressurization is a possibility.

Furnaces approved for connection to a natural draft chimney must carefully control the flow of combustion gases so that the flue is not over-pressurized. The control is achieved by means of an opening and a pressure relief box at the induced draft fan outlet. A pressure proving switch measures the pressure differential across the opening, and if no significant pressure differential exists, (as may happen if the fan is not operating or because a plugged chimney is preventing flow through the orifice) the appliance shuts down. These units are also equipped with a thermally activated vent safety shut-off switch (or "spillage switch") that is designed to shut down the appliance within 5 minutes if there is continuous spillage out of the spillage port due to blockage in the flue.

CGA certification does not specifically address operation in a depressurized house. The primary concerns are with the production of carbon monoxide and with combustion gas spillage caused by the pressurization of the flue connector. Apparently no inspection is specified for spillage caused by faulty design.

To test the spillage switch in accordance with the CGA standard, enough restriction is placed downstream of the induced draft fan to create 12.5 Pascals of static pressure. Under this condition the furnace must shut down within 5 minutes. An assumption is made that a domestic water heater can safely vent into a shared flue connector if the furnace does not positively pressurize the vent by more than 12.5 Pascals.

Vent Safety Shut-Off switches consist of simple bi-metallic discs usually with manual resets. The 5 minute delay is about the same duration as the normal operating time of a furnace and appears to be too long to be effective. The spillage switch design was a compromise between practicality and safety. The industry did not want appliances shutting down when occupants were away, (possibly causing major freeze damage to the house). The industry also wanted to prevent nuisance calls for distributors and installers. Hence the 5 minute delay.

What was found?

The current design of most mid-efficiency furnaces does not appear to be appropriate for use in airtight housing where frequent or continuous house depressurization is a possibility. Only one of the five furnaces models tested performed well in all situations. Sealed combustion furnaces may be more appropriate.

Manufacturers of mid-efficiency furnaces should be requested to

House	Furnace	Spillage with no depressurization	Spillage during depressurization	Time delay for vent safety shut-off switch	Ability to establish proper venting	Input of shared dhw
1	Amana Air Command	none	Spillage from chimney at 25 Pa & from safety port @ 30 Pa	2 minutes at 30 Pa	performs well up to 30 Pa	No DWH heater present
2	Carrier Bryant	Continuous small amounts around induced draft fan housing	Quantities around fan housing increased. Spills from safety port at 20 Pa	No effect up to 20 Pa (home could not be depressurized above 20 Pa)	Could not establish draft at 15 Pa	Spills via shared flue at 10 Pa
3	ICG Ultimate II	Continually at induced draft fan housing, fan outlet, and around pressure reading box	Slight increase with depressurization. Spillage from chimney joints at 33 Pa, and from safety port at 40 Pa	32 seconds at 50 Pa.	Required 55 seconds to establish draft at 22.5 Pa	Spills via shared flue at 15 Pa
4	Airco Turbo 8300	Continually at fan axle, flue collar and fan housing	Spills large quantities from axle hole with minor house depressurization.	No affect up to 50 Pa.	Performs well up to 50 Pa	No DHW heater present
5	Lennox Conservator 3	Continuously at collar above fan, at axle, bottom of fan housing and furnace connection with fan housing.	Quantity of spillage increases up to 15 Pa. and chimney spills in large quantities.	No switch present, and no shut-off even with major spillage occurring	Performs well up to 20 Pa	Spills via shared flue at 10 Pa

consider redesign of their appliance so that it is gas tight and suitable for use in houses susceptible to depressurization.

Canadian Gas Association should consider incorporation of a test for house or room depressurization limits as part of the standard testing of mid-efficiency furnaces.

Tests need to be conducted to quantify the amount of spillage taking place through the fan housing of the draft inducing fan assembly under normal operating conditions.

Installers of side-wall vented mid-efficiency furnaces should be required to do a commissioning test after installation to test the tightness of the venting system and the safety shut-off. The commissioning tests should entail the blocking of the flue at the wall outlet to confirm that the appliance will actually shut down.

The Vent Failure Sut-off Switch on mid-efficiency furnaces should be redesigned to serve a useful purpose. Where possible the exit port should be redesigned to minimize the quantities of spillage, and time delay should be shortened to a more reasonable time period (e.g. 3 minutes).

The study suggests that instead of more testing of specific models of furnaces, standards writing groups and housing regulatory groups adopt the following House Depressurization Limits (HDL's) for mid-efficiency appliances:

1) 5 Pa Where there is no evidence of flue sealing

or

if the furnace shares a flue with natural draft appliance

2) 10 Pa Where there is clear evidence of flue sealing

and

the flue is single, or shared with an appliance

3) 20 Pa Where the furnace is side vented

and

the furnace shuts down when the outlet is blocked

Although there are exceptions, induced draft furnaces should not be installed in houses designed to operate under continuous depressurization.

From "House Depressurization limits for Mid efficiency Gas-Fired Furnaces", a paper presented at Renewables: A clean Energy Solution, the 15th Annual Conference of the Solar Energy Society of Canada, (Penticton, June 1989).