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The Canadian Residential Duct and Chimney Survey

The research described in this Highlight took place many years ago, but it has never been released in a summary form. This Highlight has been written for distribution now because the findings of the research project remain valid and can still contribute to the understanding of residential duct and chimney performance.

INTRODUCTION

The installed flow and thermal performance of ducts and chimneys in housing is not well known. Field surveys by Canada Mortgage and Housing Corporation (CMHC) have revealed that many fans, furnaces and fireplaces are not working as intended, leading to problems such as insufficient air flow and backdrafting of combustion gases. This project was initiated to achieve a better understanding of the nature and extent of such problems by examining the current operation of ventilation systems, ducts and chimneys in Canadian houses.

RESEARCH PROGRAM

Testing was conducted using the Duct Test Rig (DTR), a device for measuring air flows and heat losses in ducts and chimneys. The DTR, which was designed and developed as part of an earlier project, has a powerful fan and an adjustable orifice mounted in a portable flow chamber. By means of multiple attachments, the flow chamber can be easily fitted to different types of ventilation supply and exhaust openings. By adjusting the speed of the DTR fan, the flow and induced pressure through the ventilation device can be recorded.

Houses in the five major populated regions of the country were tested. Within each region, two communities were selected (Vancouver and Kelowna; Winnipeg and Calgary; Toronto and London; Montréal and Québec City; and Halifax and Fredericton). One community was heavily populated, while the second community was chosen to represent the greatest difference from the first in terms of climate, style of house and fuel type. Twenty houses were tested in each of the ten communities. In addition, five houses were tested in Ottawa. A public advertising campaign was used to find houses for possible inclusion in the study. An attempt was then made to match the houses selected for testing to a statistical profile of housing types (year of construction, number of storeys, fuel type, etc.) in the area to ensure the test houses were representative of the housing stock.

To accomplish the survey in a timely manner, a different research team was used in each part of the country. To ensure consistency of methodology, the field crews were trained and supervised by a Field Research Manager and a Field Manual that presents the Test Protocol in a step-by-step fashion was developed for the crews to follow.

RESULT

Exhaust fans

Exhaust fans tested in the survey included four basic types: bath, kitchen, clothes dryer and central vacuum (but only if exhausted outside and not into a basement). The object in measuring exhaust fans in the field was to provide a clear indication of how performance is influenced by fan age, accumulations of dust, grease, bugs, etc., and installation practices. All the data collected during the survey was condensed and organized into database files. A statistical summary of the average air flow of exhaust fans is presented in Table 1.

Table 1 Average airflows of exhaust fans

	Airflow under standard conditions (L/s)	Airflow with 10 pa pressure (L/s)	Average flow loss/gain due to leakage
Bathroom fans	17.2	14.4	5.78 L/s loss
Kitchen fans	58.5	51.5	12.6 L/s loss
Dryers	37.6	38.3	N/A
Vacuums	23.9	N/A	17.6% loss / 18.2% gain

The vast majority of bathroom fans were ceiling mounted units with diameters of 75 to 100 mm. Tremendous variations existed in the duct lengths. Although the industry assumes axial fans are much less powerful than centrifugal fans, the database showed no statistical difference between the fan types. Houses in Montreal appeared to have lower flows for bathroom fans, possibly due to the predominantly older housing stock in these communities. Flows from bathroom fans varied greatly with changes in hood pressures. A number of problems were identified with bathroom fans, including blocked ducts, non-functioning fans, improper venting, and two cases where bathroom fans exhausting through attics terminated short of the roof and were generating huge mould patches. The low flows, poor response to static pressure, high leakage rates and generally poor condition of bathroom fans suggests that huge numbers of bathroom fans across Canada should be replaced or serviced.

A large standard deviation and the extremes in airflow recorded emphasize the variety of kitchen fans present in existing homes. Kitchen fans were sometimes blocked at the inlet by grease from cooking; often as much as 75% of the free area was blocked. Exhaust flows for kitchen fans were greatly influenced by the condition of the backdraft damper.

Dryers were tested "as found", without any attempt to clean filters or adjust temperature settings. Average air flow for dryers was more consistent than other types of exhaust devices, but the installed flows were significantly less than the 75 L/s typically specified by manufacturers. While many dryers were extremely old and decrepit, they still seemed to exhaust and perform well. No check was done to see the impact of filling the dryer with clothes on the amount of exhaust flow.

Flows for vacuums were very consistent. Most vacuums were tested without a hose attached. However, in two cases a hose was attached and it was found that attaching a hose had a significant impact, decreasing flows by 25 to 40%, respectively. Vacuum dust collection drums were often at least half full during tests, but no testing was done to determine the impact of a full drum on system flow. Air was lost or gained depending where the leaks occurred—in the ducting or at the vacuum unit. Noise of the vacuums was often a complaint. Installers might consider using a larger duct for exhausting vacuum cleaners to cut down on velocity noises.

Chimneys

Chimneys, including site-built masonry (metal lined, tile lined or unlined), prefabricated B-vents and insulated metal chimneys were tested by disconnecting the appliance from the vent and connecting the DTR in place of the appliance. By adjusting the speed of the DTR fan, the flows through the chimney system were recorded for different positive hood pressures. These flows were used to calculate the "free area" of the vent, using the following equation:

$$\text{Free Area (cm}^2\text{)} = \text{Flow (L/s at 10 Pa)} \times 4$$

This equation is roughly equivalent to the CGSB Standard 149.10 M86, for calculating Equivalent Leakage Area (ELA) values. The calculated free area was then compared against the total physical area of the vent opening and a percentage reduction in area (due to chimney restrictions) could then be calculated.

To measure the air flow lost through leakage in the vent connector, the vent connector was disconnected from the vertical chimney and plugged. Air flow was then measured at a hood pressure of 50 Pa. A similar process was used to measure leakage in a vertical chimney; the chimney top was bagged, while the DTR measured air flow at the base.

To measure the thermal characteristics of a chimney, the DTR was fitted with a hood containing a 1 kW duct heater. The heater was operated for a 5-minute period while continuously recording flows and temperature at the vent connection, vent to chimney junction, and chimney exit. Voltage and amperage draw of the DTR fan and heater were used to calculate the heat input. The flow in the chimney was allowed to increase normally, while maintaining a constant heat input. The thermal test data was used to calculate the "characteristic length" of each chimney; this is a property of a chimney related to its thermal losses at steady-state conditions.

A statistical summary of test results for chimneys is presented in Table 2.

Table 2 Calculated results for chimneys

	Reduction in free area (%)	"Characteristic length" (m)	Airflow loss due to leakage at 50 Pa (L/s)
Furnaces	10.2	7.8 (tile-lined masonry)	7.3
Wood stoves (A-vent)	N/A	25.0	6.5
Fireplaces	22.6	20.2	N/A

Flows through chimneys varied depending on the type and area of the flue and the presence of a cap. More detailed statistics are required to expose the impact of these variables. Wood stoves were noted to be much more restricted by creosote than fireplace or furnace chimneys and some very long flue connectors were noticed on wood stoves. It was difficult to plug chimneys on wood stoves for a leakage test so these results are not available. When inspecting fireplaces prior to testing, field crews almost always discovered fireplace dampers left open. Tile liners were also observed to be installed in a haphazard fashion, with many gaps, which weaken the structure and collect creosote.

Heating systems

Simple statistical summaries of the test results for heating systems are presented in Table 3.

Table 3 Calculated results for heating systems and ducts

Heating systems	Average total air flow delivered to registers	258.4 L/s
	Firing rates of furnaces	27.8 kW
	Total heat delivered to registers	10.9 kW
	Percentage heat delivered to registers	39.2%
Heating Ducts	Characteristic length of duct	22.3 m (73.2 ft.)
Passive Ducts	Airflow at 50 Pa	12.9 L/s

The low duct efficiency (only 39.2% of heat is delivered to the registers) is attributable to duct leakage, radiation losses and restrictive ducts and registers (register grilles were typically found to be very restrictive, reducing the boot area by 50-65%). No single problem predominated. The longer the run, the greater the losses in air flow and heat. A number of houses were tested that had two or more furnace systems, which permitted more centralized duct layouts; these houses showed very good duct efficiency.

Most heating ducts had 125 mm diameters, although a few had diameters of 75 and 100 mm. The boots of heating ducts appear to account for the majority of leakage since they are not taped at the joints. In some cases, a single house would have more than 10 different varieties of boots and registers.

Only five per cent of the housing stock, at the time of testing, appeared to have passive fresh air ducts. Far more frequently, fresh air ducts are connected to return air plenums and operate as an "active" air supply system whenever the furnace blower operates. Such ducts were termed "passive" and included in the passive duct sample.

IMPLICATIONS FOR THE HOUSING INDUSTRY

The results of this project have been used in a number of applications. The surveyed flow rates of fans, dryers and central vacuums have been used for calculations of total house exhaust capacity, and to predict house depressurization levels. The high leakage area of heating ducts has been cited frequently, usually to account for poor performance and level of control in Canadian forced air heating systems.

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Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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