#3380

Canadian Research into the Installed Performance of Kitchen Exhaust Fans

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ABSTRACT

The 1985 National Building Code of Canada specifies that new houses must have an installed exhaust capacity of at least 0.5 air changes per hour. However, field testing has shown that the performance of installed exhaust equipment is highly variable, and that household usage of exhaust fans is unpredictable. How are builders to meet the code specification and maintain acceptable airflow and sound levels?

A government research project was designed to give builders a clear guide to the selection and installation of household exhaust fans. This paper will be restricted to the results for kitchen range hoods. The contractor investigated existing literature and equipment to establish household usage patterns, the performance of fans and exhaust system components, and the potential for new products and systems. Field inspections on 20 houses across Canada showed how the fans were installed and by whom. Field testing revealed the deviation of these fans from rated flow levels. Simultaneous laboratory testing helped to explain why the systems failed to meet rated capacity.

The end product is a builder's guide to exhaust fans. The most succinct recommendations are to avoid using the cheapest products and to install to the manufacturer's specifications.

INTRODUCTION

Canada Mortgage and Housing Corporation (CMHC), the federal agency responsible for housing policy, completed an investigation of household exhaust equipment in 1988. It was designed to provide the background for a publication suitable for builders on the proper specification and installation of residential exhaust systems. Mechanical ventilation in Canadian houses is increasingly necessary since tighter building envelopes are restricting the availability of natural air flow. The 1985 National Building Code (NBC) specifies that houses must have a built-in mechanical capability of one-half air change per hour, though few of the provincial codes have so far adopted the NBC. The Canadian Standards Association (CSA) standard, Residential Ventilation Requirements, CSA F326 (CSA 1988), also lists minimum required ventilation rates, and should be accepted as a national standard. These codes and standards require an accurate estimation of exhaust fan flow rates at the ventilation system design stage.

What makes such accurate design improbable are the current fan specification and installation practices. While a CSA standard on exhaust fans, CSA C260, had existed since 1976 (CSA 1976), it had never been called up in any building code. Surveys had shown that exhaust fan usage was sporadic due to perceived inefficiency and noise. The field-tested performance of exhaust fans in CMHC combustion spillage research tended to verify these perceptions. When researchers attempted to predict house depressurization through airtightness tests and exhaust fan capacity, the real margin of venting safety lay in the inability of most fan systems to move significant amounts of air.

If fans are to be effective, builders must be able to install them in an effective manner. The CMHC decided to investigate the reasons for poor performance in installed fans and to create a booklet for builders on the results of this study (HRAI 1988). Although both bathroom and kitchen fans were investigated, this paper generally uses only the kitchen fan results.

PROCEDURES

Literature Search

The primary objectives of the literature search were to establish what research currently existed on exhaust fan usage, flow measurement, and sound measurement, and what equipment was suitable for residential spot ventilation. This search was to include European and Eastern technology. The contractor was also instructed to look into the future so that equipment on the edge of production would be considered.

The literature search started by contacting individuals with a known background in exhaust fan design, research, or distribution. They were asked to list the relevant recent studies or projects of which they were aware, including those currently in progress. This approach led to international contacts, which were also useful in specifying the types of exhaust equipment used in other parts of the world. Both national and international trade associations

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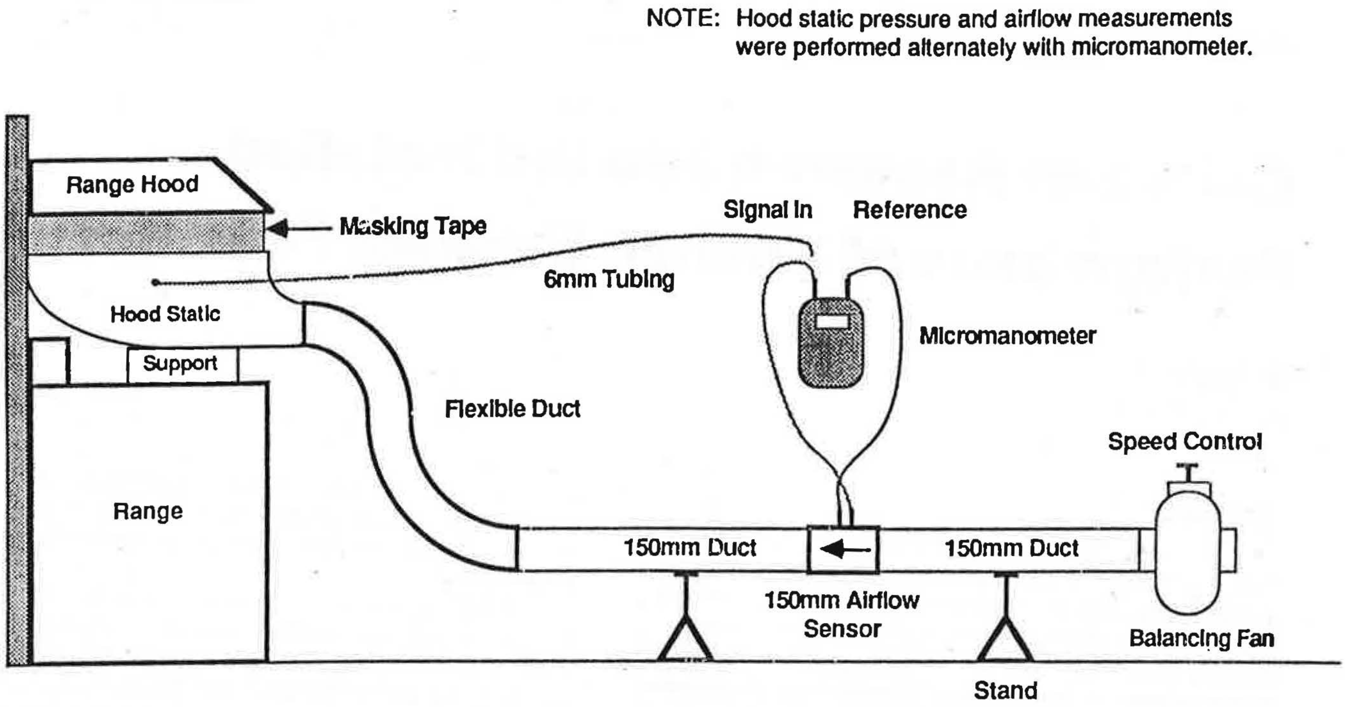

Figure 1 *Device to field-test the installed airflow of kitchen range hoods*

were canvassed, as were representatives of various manufacturers and suppliers. The contractors also used standard on-line data-base searches through the National Technical Information Service, the Engineering Index, and other data bases.

Field Testing

Field surveys were designed to establish the types of exhaust equipment currently being installed in Canadian houses, the installation procedures for the systems, and the regional differences in these practices. Regional subcontractors were instructed to go into new housing developments built by different construction contractors. They were to photograph and document installation and equipment details while the houses were still in the rough-in stage. These surveys were conducted on 20 houses in four geographic locations. The contractor knew that such an inspection had just been completed for Toronto, Canada's largest city, and that these data could form part of the project.

Field testing consisted of airflow and sound pressure level measurements on newly installed exhaust fans within the same general vicinity as those inspected. Due to equipment and timing limitations, it was not possible to check these characteristics on exactly the same fan systems as were inspected in the survey stage. The field testers chose houses in the same developments for both the survey and field testing phases, under the assumption that the quality of the installations would not vary widely when the same tradespeople were involved.

During the testing, airflows were measured with a device created by the contractor, as illustrated in Figure 1. The apparatus negated the effects of the additional flow restrictions imposed by the device by using an integral fan to create zero pressure at the hood/fan interface. Fixed pitot grids were connected to electronic manometers. Sound level testing was performed with a sound level meter. Both sets of tests were well outlined to the regional field testers in protocols supplied by the prime contractor.

Laboratory Testing

This part of the project was intended to establish the system characteristic data that did not emerge in the literature and equipment search and also to demonstrate, in a controlled setting, the degradation of airflow when an exhaust system deviates from proper design. The missing component data were found to be in the area of duct caps or termination devices, and five units were tested. As a check on the measurement technique, a pressure vs. flow curve was also developed for a length of straight ducting. The degraded ducting system for range hood fans compared the flow through the manufacturer's recommended taped 85 /255 mm (3.25/10 in) ductwork to the flow in an untaped 100 mm (4 in) duct of the same configuration. These systems represented the extremes of the range hood installations observed in the field survey.

The contractor used a nozzle chamber to Air Movement and Control Association, Inc. (AMCA) standards for this testing (see Figure 2). Pressures were measured using micromanometers, and fan speed was monitored with a strobe tachometer.

RESULTS

Literature and Equipment Search

Part of this phase of the project was to establish the status of research into residential exhaust fan characteristics and usage and then to use this information to structure the ensuing work necessary to fill in the gaps. The most significant findings can be summarized briefly.

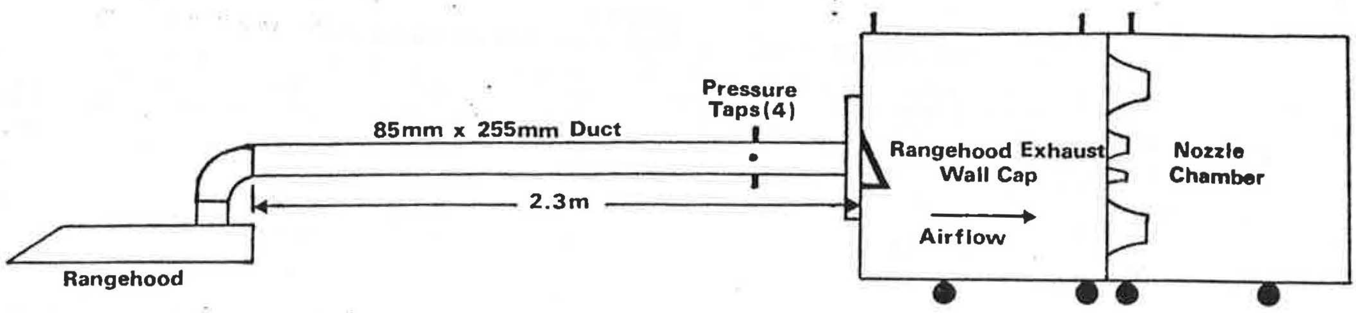

Figure 2 *Laboratory setup to test range hood system characteristics*

Current Canadian exhaust fan installation equipment and practices were documented for the Toronto area by Bach (1987). Studies on usage include those done for Ontario Hydro (Ontario Hydro 1972), the Ontario Ministry of Energy (Kani and Brooke 1984), and the CMHC (Yuill 1987). These reports describe a typical pattern of separate kitchen and bathroom exhaust fans, often indifferently installed and infrequently used. Noise and perceived ineffectiveness were the reasons cited for non-use in the surveys. A survey of American equipment (GEOMET 1986) suggested that there are similarities in equipment and usage patterns in the U.S. European equipment tended toward mechanical or passive central exhaust systems, with passive make-up air supplies. Occupant acceptance of cold drafts through these inlets varied, and the authors concluded that, in the even colder Canadian climate, householder resistance to passive intakes would be even more pronounced.

Equipment testing standards in Canada were set by the Canadian Standards Association (CSA), with CSA C260. This standard has never been referenced by code bodies and is currently being revised. American ventilating products can be voluntarily certified by the Home Ventilating Institute (HVI), and many of these products are sent to the Canadian market virtually unchanged.

The HVI tests do provide some information on the flow of exhaust products. A recent Ontario Hydro project (ORF 1987) compared the manufacturer's flow rating (which, in Canada, may differ from the HVI ratings) to laboratory tests, and found that low-priced products were consistently rated higher than their actual performance. (See Table 1.) The kitchen fans were more apt to be within 10% of their flow rating than the bathroom exhaust products. Medium-priced fans achieved their rated flow with more consistency than inexpensive fans in both the bathroom and kitchen models.

Data on the characteristics of termination devices (wall or roof caps) were obtained from the old CSA 260 standard and informally from manufacturers. The existing curves for these devices were found to be outdated and, in some cases, erroneous. Investigation of exhaust equipment from other than residential sources (e.g., computer fans, automotive equipment) showed that these fans did not offer a substantial performance improvement when compared to the better existing residential products.

A couple of areas of fan system research seemed to exceed the mandate of the project. The capture efficiency work by Annis (1978) was reviewed. Current capture research by Kelso and Kuehn will be useful once the conclusions are reached, and equipment design may be modified to reflect the findings. This research was not considered far enough advanced for easy translation into a builder's equipment and installation guide. Likewise, European experiments into ventilation efficiency promise to affect residential exhaust products but presently lack the practical nature necessary for the intended audience.

Installation Survey

Including the results from the Toronto area survey (Bach 1987), a total of 27 houses were inspected at the rough-in stage. Since all were built by different construction contractors, this survey gives a fair view of the variety of kitchen range fan installations across the country. (See Table 2 for a summary of the survey results.)

One of the more surprising results was the multiplicity of trades that had a hand in the installations. Ducting was roughed in by the sheet metal or general contractor, though in some cases the electrician handled that job as

TABLE 1
Results on Laboratory Testing of Kitchen Range Fans

Product Identification Letter	Claimed Performance (L/s)	Claimed Performance (cfm)	Measured Performance (L/s)	Measured Performance (cfm)	Measured/ Claimed
HA	83	176	71	150	.85
HB	94	200	101	215	1.08
HC	85	180	83	175	.97
HD	85	180	59	125	.69
HE	85	180	66	140	.78
HF	85	180	85	180	1.00
HG	76	160	66	140	.88
HH	94	200	97	205	1.03
HI	76	160	66	140	.88

TABLE 2
Summary of Field Survey Findings for Kitchen Range Hoods

CITY	DUCT SIZE mm	NUMBER OF ELBOWS	EQUIVALENT LENGTH m (1)	GALVANIZED DUCTS USED (2)	FLEX DUCTS USED (3)	DUCT INSULATION	FAN INSTALLER	DUCT INSTALLER	DUCT JOINTS TAPED
Vancouver	100-150	0 to 3	0.3 to 16	Yes	No	NA	elect or sht mtl	elect or sht mtl	NR
Calgary (4)	100	3	1 to 8	Yes	No	NR	elect	sht mtl cont	NA
Toronto	100	1 to 3	2 to 12	Yes	No	Yes	elect	sht mtl cont	yes in cupboard
Quebec	85 × 255	0 to 4	0.2 to 25	Yes	No	Yes	elect	general cont	yes except in cupboard
Halifax	85 × 255	0 to 2	0.3 to 2	Yes	No	NR	elect	elect	Yes

NOTES:
NA — Information not available
NR — Not reported
(1) — Equivalent lengths shown do not include the termination devices.
(2) — Sheet Metal Contractors usually installed galvanized ducts.
(3) — Electrical Contractors usually installed vinyl flex duct, although aluminum flex was also used.
(4) — Very few examples; most observed installations had recirculation hoods.

well. The fan itself was hung and wired by the electrician, with the possibility that the hood would be mounted later by another tradesperson. The outside termination, supplied by the general contractor or sheet metal contractor, was installed by the siding contractor or general construction laborer. Sheet metal contractors were most likely to put in ducting that corresponded to the manufacturer's recommendations.

In Table 2, one can see that the range hood ducting could be anywhere from the specified 85/255 mm (3.25/10 in) to a nominal 100 mm (4 in) round duct. There were no observations of vinyl flex duct in this survey, but metal flex was seen in Halifax and Vancouver. The termination devices varied from rectangular 85/255 spring-operated wall cap to the ubiquitous 100 mm (4 in) dryer vent cap. The table also lists the equivalent ducting lengths, which ranged from virtually zero to a prodigious 25 m (82 ft). Insulation of the ducting, as it passed through unheated spaces, was equally inconsistent. The Halifax survey contractor said insulation "is entirely incidental" in his area and that testing of the completed exhaust systems for compliance to design flows was extremely unlikely.

Field Test Results

Results of the flow and sound testing are contained in Table 3. There are nine range hood fan models represented in this survey, ranging in rated flow from 65 to 140 L/s (140 to 300 cfm). Only 3 of 17 tested fans exceeded

TABLE 3
Summary of Airflow and Sound Testing

HOUSE NO.*	FAN MODEL	RATED AIRFLOW L/s @ 250 Pa	MEASURED AIRFLOW L/s	RATED AIRFLOW %	RATED SOUND LEVEL SONES	MEASURED SOUND LEVEL dBA	SOUND LEVEL FAN OFF dBA
1B	1	85	12	14	7.0	71	23
2B	1	85	50	59	7.0	66	54
9B	2	85	78	92	5.5	71	24
11A	3	75	52	69	6.5	62	42
12A	4 (Recirc)	75	23	31	NL	62	42
13A	5	75	37	49	HL	65	43
14A	3	75	34	45	6.5	66	35
15Q	3	75	17	23	6.5	64	24
16Q	3	75	16	21	6.5	68	20
17Q	6	140	30	21	NR	65	20
18Q	6	140	32	23	NR	65	34
19Q	7	NA	17	NA	NR	63	31
20Q	8	65	24	37	5.0	64	27
21Q	1	85	23	27	7.0	65	22
22N	9	75	24	32	NL	71	36
23N	6	140	27	19	4.5	69	34
24N	3	75	27	36	6.5	66	33
AVERAGE VALUES		89	31	37	6.3	66	32

NOTES:
NA — Information not available
NL — Product information not listed
NR — Information not recorded
*B = Vancouver, B.C.; A = Calgary, Alberta; Q = Quebec, P.Q.; N = Halifax, Nova Scotia

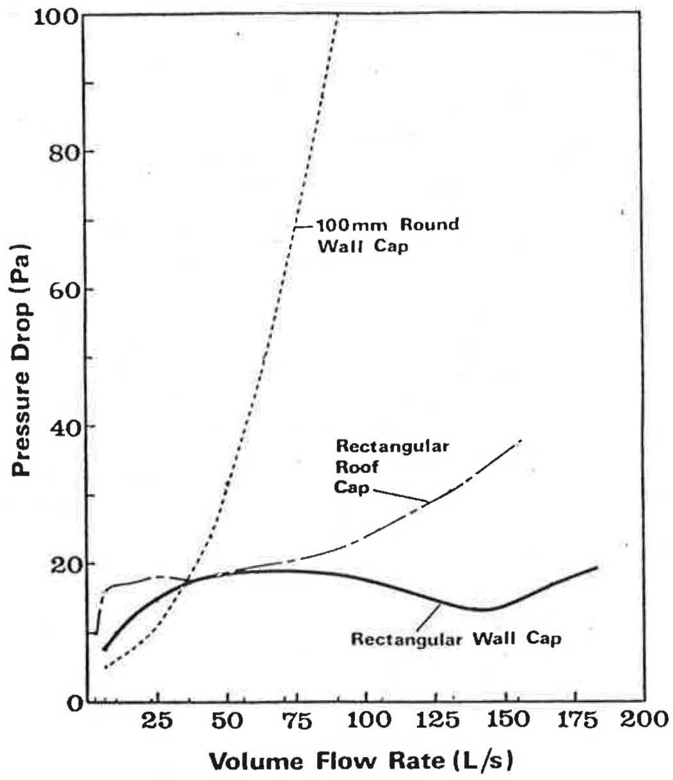

Figure 3 *Pressure vs. flow characteristics of wall and roof caps for range hood systems*

50% of rated flow. The lowest measured fan moved only 12 L/s (25 cfm).

Sound pressure levels, measured in the kitchen at 1.5 m (5 ft) from the floor and 0.3 m (1 ft) from the front of the stove, ranged from 62 to 71 dBA, or almost an order of magnitude. According to ASHRAE, the difference between sound pressure levels of 60 and 70 dB is equivalent to conversational speech at 1 m (3 ft) and a freight train at 30 m (100 ft), respectively (ASHRAE 1985).

Laboratory Testing

The laboratory testing covered the characteristics of wall and roof caps, and the flow changes when the system was degraded from a good to unadvisable installation. The flow vs. pressure curves for wall and roof caps observed in the field surveys are shown in Figure 3. Note the curious lack of pressure dependency on flow for the spring-loaded wall cap. The rectangular duct roof cap (Figure 3) also shows a very flat curve, contrary to the typical pressure vs. flow curve seen in the 100 mm (4 in) dryer-vent-type cap. Table 4 shows that a standard range hood venting through a 100 mm (4 in) dryer vent cap sacrifices about 40% of its flow when compared with the manufacturer's recommended rectangular ducting system. In this test, the effects of joint taping were not significant although losses of up to 25% were observed in the bathroom fan taping experiments. More research is needed to quantify the effects of taping.

DISCUSSION

With regard to the sound level testing, it is difficult to compare these levels with the HVI sound ratings since there is no direct method to translate a sone rating into dBA, and manufacturers were reluctant to supply the information necessary for a calculated conversion. It is likely that the variance of the derived sound rating from the observed level would be swamped by the sampling inconsistencies created by the field instrumentation and protocol. For example, despite attempts to use a standardized and rational protocol in sampling, the field sound level results for the same bathroom fan model varied by almost 30 dBA during the tests. Installation differences and the reverberation characteristics of the rooms tested would also contribute to the wide variance of results.

The differences between the installations observed in the fan survey and the installations tested in the field are assumed to be small. While the format of the study did not allow for the observation and testing of identical units, the test results imply that the second lot of fans was installed in the same haphazard fashion as was observed in the first phase.

The unusual pressure vs. flow characteristic of the spring-assisted backdraft damper (Figure 3) has been explained as the result of the pressure requirement to open the dampers initially. As the flow rate increases, the dampers open to their maximum aperture, and the loss coefficient approaches a minimum value. At very high flow rates, beyond those required to create maximum openings, the loss coefficient increases with flow rate (HRAI 1988).

TABLE 4
Laboratory Testing of Range Hood System Degradation

WALL CAP	DUCT SIZE	COMMENTS	VOLUME FLOW RATE EXITING FROM CAP		PRESSURE RISE AT FAN (obtained from fan speed)		VOLUME FLOW RATE LEAVING FAN (obtained from fan speed)		ESTIMATED LEAKAGE	
			L/s	cfm	Pa	Inches H_2O	L/s	cfm	L/s	cfm
Installation in Accordance with Manufacturer's Instructions										
Manufacturer's Rangehood Exhaust Wall Cap	85 × 255 mm (3¼ × 10 inch)	Joints Taped	86	182	50	0.20	90	191	4	8
Typical Installation										
100 mm Dryer Vent Single Damper	100 mm	Joints Untaped	52	110	133	0.53	52	110	0	0
100 mm Dryer Vent Single Damper	100 mm (4 inch)	Joints Taped	52	110	137	0.55	50	106	2	4

Results of this survey, and of others like it, prompted the southern British Columbian code inspectors to insist upon fan installations that met manufacturers' recommendations (Gertsman 1988). Ironically, this has resulted in the very problem whose puzzling absence helped to spark this research: now that the exhaust equipment in that part of Canada is being properly installed, there are more reports of combustion spillage from naturally aspirated appliances due to excessive house depressurization caused by exhaust equipment.

CONCLUSIONS

This research was initiated to gather information for the preparation of a builder's guide to residential spot exhaust equipment. The most succinct conclusions are:

1. North American kitchen range hood fans will continue in their present configurations for several years. Current research into capture efficiencies may provoke some design changes, but no immediate major technological changes are anticipated in the near future based on the results of an international literature search.

2. Following a combination of ASHRAE-type design and adequate manufacturer's installation instructions will result in an exhaust system that expels the predicted amount of air. The data necessary for this design—characteristics of the fans, ducting, and termination devices—are now adequately established. Using uncertified fans, or installing fans with convoluted ducting, will jeopardize the designed airflow.

3. Canadian kitchen range hoods being installed in new tract housing, as typified by the field surveys, are likely to vent less than half their rated airflow. This is due to the lack of system design; the use of cheaply built equipment with poor airflow delivery characteristics; inappropriate duct material, duct sizing, or duct routing; or a combination of these factors.

4. While the greatest potential gains are to be made in the field by simple adherence to good practice, there are several areas of improvement in range hood exhaust systems that are not yet quantified or commercially available. These factors include research into the effects of duct taping, the possible implications of the capture efficiency work now in progress, and the integration of kitchen systems with central exhausts as they become more common.

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