RESEARCH HIGHLIGHTS

Technical Series 00-106

FIELD TESTS OF VENTILATION SYSTEMS INSTALLED TO MEET THE 1993 OBC AND 1995 NBC

Introduction

The 1995 National Building Code of Canada (NBC), Section 9.32, introduced requirements for the design and installation of residential ventilation systems in new houses. These requirements are more complex than the clauses in previous Building Codes and were predicted to be more problematic for builders and installers to meet. After several provinces had adopted 1995 NBC for their provincial Building Code, CMHC commissioned a study titled Field Tests of Ventilation Systems Installed to Meet 1995 NBC in order to:

- Identify the types of systems being installed to meet the 1995 NBC;
- Determine if the systems being installed comply with the NBC requirements, and if not, to identify and quantify the shortcomings;
- Determine if systems meeting the word of the Code also comply with the intent of the Code; and
- Estimate ventilation system costs.

The project was extended to include an evaluation of houses with ventilation systems designed to meet the residential ventilation requirements in the 1993 Ontario Building Code (OBC), as the OBC had some interesting and significant differences from the NBC.

Research Program

The project was composed of the following tasks:

- Identify information needed to evaluate ventilation systems relative to project objectives.
- Develop and refine the field test the methodology on several houses, then do preliminary data analysis.
- Select and field test houses between January and April, 1999. In all, thirty-eight NBC houses were tested: thirteen in Manitoba, four in Saskatchewan, twelve in Alberta, seven from the Atlantic provinces, and two in the Yukon.
- Test Ontario houses. Eleven OBC houses were tested in July, 1999.

An effort was made to ensure that the study include a diversity of system types, house sizes and installers. R-2000 houses were not included in the survey sample. Except for the Atlantic region, most test houses were unoccupied. Builders or installers who arranged houses were provided with written reports describing ventilation system deficiencies found during the inspections and tests. Tests in each house included:

- Identifying system deficiencies or Code violations based on visual examinations;
- Conducting airtightness tests following CAN/CGSB-149.10 “Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method”;
- Measuring airflow performance of forced-air heating systems by pitot traverse, and exhaust appliances and make-up air systems using flow collars or flow measuring stations;
- Measuring supply airflows into bedrooms using a flow hood;
- Measuring house pressures with exhaust appliances running individually and in combination;
- Recording furnace and fan nameplate data;
- Recording DHW system nameplate data;

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- Recording nameplate data of decorative and wood heating appliances;
- Sketching ventilation system ductwork layouts, including duct sizes;
- Plotting temperature profiles downstream of ventilation air intakes in forced-air heating system return ducts;
- Estimating mixed air temperatures based on relative airflows, both at winter design temperatures and at minimum outdoor air temperatures;
- Collecting data for HOT2000 simulations or design condition heat loss calculations on selected houses, and;
- Completing Option Checklists (from the CMHC manuals *Complying with the Ventilation Requirements in the 1995 National Building Code and Complying with the Ventilation Requirements in the 1993 Ontario Building Code*, as appropriate) for each house. Reference to "CMHC/NBC Option 1", for instance, refers to the first recommended option in the CMHC text on the National Building Code.

Photos were taken of the front elevation and notable features or conditions in each house. Supply and exhaust fan sound levels were not measured. Some builders and ventilation system installers were surveyed regarding the types of ventilation systems they install, how they select system types, system costs, and problems encountered in meeting the Code or system performance. Codes officials and inspectors were not interviewed in this study.

The information gathered for test houses was processed and analyzed to determine if the ventilation systems installed in the houses complied with the prescriptive requirements in the respective Building Codes. The tests went beyond examining compliance with NBC clause 9.32; they included evaluation of compliance with depressurization limits in fuel codes, furnace manufacturers' requirements, and the intent of the NBC and OBC, not just the word of the Code.

Results

The testing contractors did not find any houses that complied with all requirements. Grouping the results regionally, they found:

- Atlantic Canada houses typically contained a heat recovery ventilator (HRV), and the systems met house ventilation capacities. Ducting, airflows, and grills often varied from code requirements; kitchen exhausts were notably deficient. Airflows to bedrooms were inadequate in many places.
  Most houses did not experience excessive depressurization. The costs of the ventilation systems ranged from $500 for a simple system to roughly $2000 for an HRV installed in a 3 bedroom bungalow. Generally, the lack of compliance led to less than optimal ventilation levels, but there were no dangerous situations observed.

- Ontario houses, built to 1993 OBC (amended 1997) do not permit spillage susceptible appliances when there is unbalanced ventilation. Most houses tested had exhaust-only ventilation with spillage resistent furnaces and DHW. Some had HRVs. Costs were estimated at $100 - $500 for an OBC Option 1 system and $2000 - $3500 for the OBC Option 2 system (both cost estimates for the ventilation systems only; changes to heating systems would be additional). Airtightness testing of the Ontario houses showed them to be the leakiest houses of the study. Even then, many could be depressurized to greater than 5 Pa. However, with spillage-resistent appliances, the levels of depressurization were not excessive. The lack of compliance with Ontario houses was generally due to duct sizing, producing insufficient exhaust airflows. The OBC stipulates that the air circulation controls are separate from the principal exhaust controls. Compliance with this requirement was easy, but there is no assurance that the fresh air introduced by ventilation systems will reach the target rooms.

- In western and northern Canada, the majority of ventilation systems were CMHC/NBC Option 1 systems (outdoor intake coupled to a forced-air furnace return duct). These systems were estimated to cost $250 to $600, depending on the house and equipment selected. Installed costs for CMHC/NBC Option 3 (HRV) systems were estimated at $1,500 to $3,000. In all cases, the HRV installed was a builder model (i.e., a basic, modestly priced model). In Alberta, six out of eight contractors said they had installed make-up air systems to offset large volume exhaust devices. Typically, these were a fan with electric preheat, motorized dampers, sensors and interlock relays. Make-up air systems in two study houses took the form of an additional outdoor air duct connected to the furnace return; one had electric preheat. In Manitoba, the depressurization issue had only been addressed by one builder, who installed direct-vent combustion appliances to avoid the possibility of flue gas spillage. One installer estimated the cost to install a make-up air system at $700 including fan, heater, ductwork and controls.

- The western houses had all the same problems as the other two regions above - ducting, grilles, lack of certified fans, etc - plus two consistent trends of excessive house depressurization and furnace heat exchanger chilling through the fresh air intake. The levels of house depressurization found in the Prairie houses could exceed 50 Pascals in some cases. These high levels of depressurization cause chimney backdrafting and spillage.

Thirty-one of the thirty-eight NBC study houses were predicted to be depressurized by at least 5 Pa by operating the dryer, rangehood and principal exhaust system; all but one were predicted to be depressurized by at least 5 Pa by operating all installed exhaust devices. The exception had a balanced ventilation system, and no supplemental exhausts. A clothes dryer with a modest flow rate was the only installed device with a net exhaust airflow. The research clearly showed that compliance with 9.32.3.8, "Protection Against Depressurization" in the 1995 NBC does not, in any way, ensure compliance with the B149 Gas Appliance Installation Codes requirements which limit depressurization of spillage-susceptible gas appliances to 5 Pa. The B149 requirement was not being enforced in the test houses.

Discussion

Codes relating to solid-fuel and oil-fired combustion appliances do not identify specific depressurization limits. Given that combustion products from oil and solid-fuel combustion appliances can be at least as hazardous to human health as combustion products from gas-fired combustion appliances, Code-specified depressurization limits for all spillage-susceptible combustion appliances should be developed.

Most of the contractors surveyed said they spent time doing "formal" designs, including duct layouts on floor plans and calculations regarding fan selection. Some indicated that layout was done on site. Based on site observations, it can be said that the "formal" design process rarely followed the duct sizing tables in 9.32 or duct design methods referenced in Part 6 of the 1995 NBC.

Most installers surveyed do not formally commission ventilation systems. Based on the number of deficiencies related to principal exhaust fan controls and switches, it may be concluded that many installers do not check the operation of the systems they install after the electrician has completed wiring.

A theoretical calculation was done to estimate the "worst case" impact of outdoor air on return air entering a furnace heat exchanger at winter design condition temperatures for houses with CMHC/NBC Option 1 systems. The temperature was calculated for the amount of air being returned from the house (based on pitot traverse measurements) mixed with the amount of air measured in the outdoor air intake. A temperature of 18°C was used for return air from the house; two outdoor air temperatures were used, the 2½ % January design temperature (only 2½ % of January temperatures are lower than this value) and an extreme outdoor temperature. The same calculations were repeated using the target outdoor air supply airflow for the house. Based on these calculations and observations based on field test data, it is expected that average furnace return air temperatures in many houses with CMHC/NBC Option 1 ventilation systems may occasionally fall below 15.5°C, and, on rare occasions, may fall to mean air temperatures below 12°C. Variation from this mean, across the duct, may result in local return air temperatures below 10°C during cold weather in some CMHC/NBC Option 1 or Option 2 installations, especially if house temperatures are setback a significant amount.

Implications for the Housing Industry

This research has raised, or confirmed, that there are problems in the design, installation, commissioning, and approval of ventilation systems in new Canadian homes. The research also showed heating and ventilating (HVAC) systems had similar problems in all regions and that HVAC system approvals were inadequate in several jurisdictions. There are several issues evolving from this work:

1. In the short term, modifications to existing design, practice, and installation can alleviate most of the

problem identified, especially those involving combustion safety. To prove this, the research team tested three houses in Manitoba diligently planned, executed, and inspected, and using spillage resistent heating appliances. Deviations from Code were minimal and inconsequential. Some of the Atlantic and Ontario houses tested were also quite satisfactory: code deviations were few and not safety related.

2. The Task Group on Review of Mechanical Ventilation Requirements for Houses, convened by the Canadian Commission on Building and Fire Codes, is currently examining alternative wording for the ventilation clause, Section 9.32, of the National Building Code. Changes will be made to make it easier to follow, more feasible, and safer, with regards to combustion safety. Recommendations will be field tested prior to inclusion in the Code.

3. It is clear from the research that inspection authorities, be they municipal building officials or gas inspectors, have not been effective at enforcing code requirements. This suggests that either codes will need to be made easier to follow, or that inspection of new houses requires a stronger commitment to adequate staffing and staff training.

4. Builders should require ventilation and heating contractors to commission installed equipment, including depressurization testing where required.

Housing Research at CMHC

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