

2497

Technical Report Summary



Ventilation and Air Quality in R-2000 Homes



Introduction

The R-2000 Super Energy Efficient Home Program is a cooperative industry/government initiative sponsored by Energy, Mines and Resources Canada (EMR) and delivered by the Canadian Home Builders' Association (CHBA). Established in 1980, the program supports building industry development, product development, and the training of builders to construct and market houses to the R-2000 energy performance target and technical requirements. These requirements encourage builders to treat the whole house as a system, incorporating the most appropriate combination of features.

R-2000 homes feature high levels of insulation and control of air leakage by means of improved air barrier techniques. The homes are equipped with advanced heating systems, mechanical ventilation and air distribution systems, and they are designed to make use of passive solar energy. Depending on the characteristics of the house and the climate zone in which it is located, a reduction of up to 70% in the amount of energy used for space heating can be achieved when compared with general building practice. A computerized energy analysis program is used to predict energy consumption for each house before construction, and inspections and tests are carried out during and after construction to provide assurance that the houses have been constructed in accordance with the R-2000 technical requirements.

The R-2000 Home Program places great emphasis on superior indoor air quality. Builder training courses and technical manuals discuss household contaminants; how they originate and how they can be controlled. Every R-2000 Home is equipped with a mechanical ventilation system to ensure an adequate supply of fresh air.

A mechanical ventilation capacity of 0.5 air changes per hour (ach) was adopted as the standard for R-2000 homes — with a subsequent additional requirement for a minimum continuous ventilation rate of 5 litres per second (L/s) per room for normal occupancy, based on ASHRAE Standard 62-81, Ventilation for Acceptable Indoor Air Quality. Therefore the ventilation requirements recognize the need to provide both continuous ventilation for normal conditions and additional ventilation on an intermittent basis to control excessive humidity and odours when the need arises. The system must also be balanced — neither creating nor contributing to an overall positive or negative pressure difference in the building envelope relative to the exterior.



The R-2000 Home Monitoring Program

In 1983, with the assistance of the Buildings Energy Conservation Sector Committee (BECSC), EMR embarked on a monitoring program designed to measure the performance of R-2000 homes. The initial phase concentrated on quality assurance for occupants through indoor air quality monitoring and ventilation system testing in the first R-2000 demonstration homes. A sample of conventionally built homes recently constructed by contractors participating in the R-2000 Home Program was also included for comparison. The objective was to assess whether the mechanical ventilation systems installed in the R-2000 homes were capable of supplying ventilation air in accordance with program requirements, and whether the supply and exhaust air flows of the heat recovery ventilators were balanced in accordance with these requirements. Air change rates were also monitored to allow ventilation rates in R-2000 homes to be compared with those in conventional homes relying on natural air leakage. The levels of three common indoor contaminants — formaldehyde, radon and nitrogen dioxide — were also measured. The results of this general phase of the monitoring program will provide a basis for more detailed monitoring activities in future years.

Monitoring Procedures

The field monitoring was carried out by specially trained technicians from EMR offices in each province and territory, using simple, inexpensive equipment. A comprehensive monitoring manual was prepared, and laboratory and field support was provided by the Ontario Research Foundation, regional engineering firms and several laboratories in Canada and the U.S.A.

Detailed background information on each R-2000 Home was provided by the builder. This included a set of construction plans, a description of the building envelope characteristics and mechanical systems, airtightness test results, and information on costs and homeowner response. Supplementary information on construction details, occupancy and the operation of mechanical systems was obtained during subsequent site visits by the regional technicians.

The Ventilation System

While all the R-2000 homes in this study had a heat recovery ventilator (HRV) for continuous mechanical ventilation, only one control home was equipped with a mechanical ventilation system. Only the results of monitoring in the R-2000 homes were therefore considered.

The mean maximum air flow for all homes was found to be 69.3 L/s. This is equivalent to 0.5 ach, which meets the overall ventilation system capacity required by the R-2000 Home Program. Air flow rates were similar, regardless of house size, location, or type of distribution system. Therefore, while the average capacity of the ventilation systems installed in all R-2000 homes was 0.5 ach, in smaller homes (with an interior volume of less than 500 m³) the capacity was equivalent to 0.61 ach, whereas in larger homes it was equivalent to 0.41 ach. This reflects the fact that HRVs with sufficient capacity to meet the program requirements for continuous and intermittent ventilation in some large homes were not widely available during the initial demonstration phase of the program. However, most ventilation systems were capable of providing continuous ventilation in accordance with the requirements of ASHRAE Standard 62-81, which averaged 49.2 L/s or 0.35 ach. The capacity was found, on average, to be 45% greater than that necessary to meet the ASHRAE requirements.

Monitoring showed that only 28% of HRVs in R-2000 homes had supply and exhaust air flows balanced at low speed within 10% as specified in the requirements for ventilation equipment. This has now been corrected. It was apparent that most installers did not carry out field balancing; in fact, less than 15% of installations contained balancing dampers. This reflected a lack of trained and experienced installers with access to air flow balancing equipment. Steps have been taken to ensure that HRV units now installed are balanced and meet minimum air flow requirements. These steps include revisions to the installation guidelines, and the provision of national training courses for installers through the Heating, Refrigerating and Air Conditioning Institute of Canada (HRAI). Monitoring of R-2000 homes will continue for the purpose of verifying that the ventilation requirements are being met.

Air Change Rates

Regardless of a specified ventilation system capacity of at least 0.5 ach and a continuous ventilation rate based on ASHRAE 62-81, the actual air change rate in a home is influenced by a number of factors, including natural air infiltration, occupant activities, and the operation of other air-exhaust equipment. Measurement by means of a 30-day monitoring technique known as capillary adsorption tube sampling (CATS), which detects an inert tracer gas, showed an average rate of 0.37 ach in R-2000 homes. This was slightly higher (10%) than in the control homes. The rates in both R-2000 and control homes with a forced-air heating system were generally 20-30% higher than in homes with electric baseboard heating, indicating that good air circulation within the building envelope is a factor in overall ventilation effectiveness. Current program requirements now specify the inclusion of a ventilation distribution system, regardless of the type of heating system installed.

Formaldehyde

Formaldehyde is a gas which is present in indoor air as a result of "offgassing" or "outgassing" from household products (draperies, glue, paint) and building materials (particleboard, plywood), or as a product of some types of combustion, including tobacco smoking.

Dupont Pro-Tek monitoring badges were installed for a period of seven days in the living and sleeping areas of R-2000 homes and a group of conventional homes during the late winter and early spring of 1984. Levels were found to be similar in all homes, and were generally well below the Health and Welfare Canada interim guideline for indoor air, which is 0.1 parts per million (ppm). In homes with an electric baseboard heating system, average levels were 14-23% higher than in homes with a forced-air heating system. Hence, R-2000 homes in the Maritimes and Quebec, where electric baseboard heating predominates, had average levels which were slightly higher but still below the interim guideline.

Repeat testing with the AQRI PF-1 monitor in the spring of 1985 again showed formaldehyde levels to be below the interim guideline. The average level in a group of control homes was 16% higher than in a group of R-2000 homes. Homes with electric baseboard heating again had higher levels than those with forced-air heating.

Radon

Radon is a colourless, odourless gas which is normally present in air in very low concentrations. It is formed during the natural decay of radioactive elements which are present in soil, rocks and groundwater throughout Canada, though the amount varies widely from region to region. The gas in turn decays into radon daughters, and both can be found in indoor air.

Radon enters indoor air from the soil by way of foundation cracks in the building, or through the water supply. It can also be released from building materials such as stone and concrete.

The RAD Surveymeter, an inexpensive active monitoring device, was used to measure levels of radon daughters over a seven-day period in 1985. The results showed a geometric mean of 0.006 working-levels (WL) in R-2000 homes and 0.007 WL in control homes. As expected, the levels varied according to region, being higher in the Maritimes and lower in Quebec than in other regions. However, levels were generally well below guidelines being considered by the Subcommittee on Radiation Surveillance of the Federal/Provincial Advisory Committee on Environmental and Occupational Health.

Nitrogen Dioxide

Nitrogen dioxide is a colourless, odourless gas which reaches indoor air mainly as a product of combustion, either from fuel-burning appliances or tobacco smoke.

Nitrogen dioxide levels were measured over a seven-day period in 40 R-2000 and 7 control homes, using a passive monitoring device containing a treated screen which absorbs the gas. Levels were found to be very low, ranging from 0.004 to 0.008 ppm. Levels in R-2000 homes occupied by smokers were found to be slightly elevated. However, the presence of woodburning appliances had no effect. This is attributed to the R-2000 requirement for woodburning appliances to have well-sealed doors and an outside supply of combustion air. All levels were well below the acceptable limit of 0.05 ppm in ambient air established by Environment Canada. A subcommittee of the Federal/Provincial Advisory Committee on Environmental and Occupational Health has been established to determine an acceptable level for the indoor environment.

Conclusions

These first monitoring results indicate that air quality and ventilation rates in R-2000 homes compare favourably with those of conventionally built houses. Furthermore, contaminant levels in the majority of homes were well within current guidelines. It is clear from this study that homes with a continuous air barrier which are equipped with a mechanical ventilation system provide air quality comparable with, or better than, conventionally built homes.

These results are for the first 300 pilot and demonstration homes, which were built in accordance with the initial R-2000 technical requirements, to which a number of refinements have since been made. As the R-2000 Home Program evolves, considerable effort is being directed to refining the

requirements governing ventilation and indoor air quality, revising training courses, improving certification and inspection procedures, and updating national standards to address issues raised during the monitoring program. This will result in improved air quality for R-2000 homes. A national advisory committee has been established for ongoing consideration of changes to the technical requirements. This will ensure that the R-2000 Home continues to represent a high-quality product which conforms with or exceeds accepted good building practice. The R-2000 Home Program will continue to support field monitoring, laboratory testing, standards writing and industry development, and R-2000 homes will continue to be at the forefront of housing quality in Canada.