RADON CONTROL - TOWARDS A SYSTEMS APPROACH

Mike Nuess and Richard Prill
Washington Energy Extension Service, Washington State Energy Office

INTRODUCTION

The normal operation of a commercially available continuous mechanical ventilation system incorporated into a tight house, and designed to control pressure-differences, may provide sufficient day-to-day control of pressure-differences (induced by weather and mechanical systems) to prevent entry of radon and other soil-air pollutants. This may be reasonably accomplished by developing a "two-cell, barrier-enhanced pressure-difference control system."

BUILDING DESCRIPTION

In 1988, a tight and energy efficient two-story residential building was constructed in Spokane, WA. The building was calculated to need 2.5 kWh/(ft^2•yr) for space heating. The building is of double-wall construction. R 45 wall insulation extends from the R 60 ceiling to the concrete footing. R 25 fiberglass batt insulation is laid directly upon the ground (over a gravel capillary break). The vapor retarder is established on the interior surface of the drywall with a rated paint. The post construction tested air leakage rate was 1.4 air changes per hour (ach) at an induced indoor/outdoor pressure-difference of 50 Pa. One year later it tested the same.

The building can be divided into two distinct "cells", that are atmospherically decoupled from both each other and the outdoor air. The tightness and isolation of these two cells enables pressure-difference control with the mechanical ventilation system. Cell 1 contains all occupied space. Cell 2 is atmospherically decoupled, but thermally coupled to cell 1. The first floor subfloor is the air barrier between cells.

A commercially available integrated residential HVAC system (HPV) provides continuous ventilation, partial space heating, space cooling, and water heating. Two 60 ft. long by 4 in. diameter, tightly sealed earth tubes (4 ft. below grade) provide outdoor air which is mixed with recirculating air before it passes over the supply-side coil and is distributed to living areas.

On the exhaust air side, stale indoor air is removed from kitchen and bathrooms by fan F1 and ducted to cell 2. From this point the air remains isolated from cell 1. The air travels across cell 2, then exits via a sealed duct which leads to the HPV. Continuous operation of fan F2 is necessary to maintain a lower pressure inside the HPV than in the mechanical room, so that no leakage back to the indoor air occurs. After passing through the HPV the air is exhausted outside above the roof.

Depending on fan operation, cell 2 can be either pressurized or depressurized relative to cell 1 and/or the soil air. This project incorporated four fans in the ventilation system in order to enable comparison between these two approaches, as well as several others.

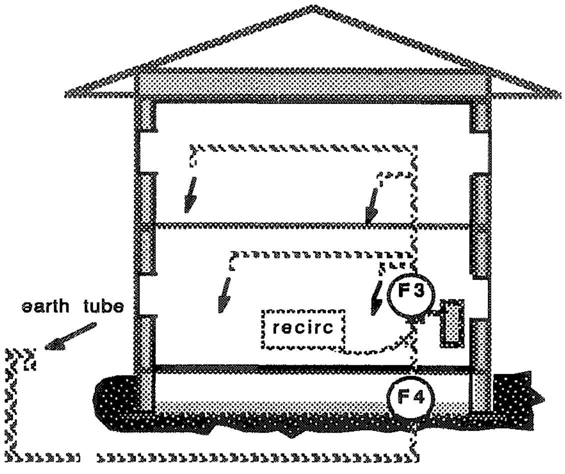

Figure 1. Fresh Air Supply

The primary mode of operation for the first year was to adjust fan F1 to maintain a slightly lower pressure at the ceiling of cell 1 than that outdoors (while pressurizing cell 2). This typically resulted in a 2-13 Pa lower pressure at the ceiling of cell 1 relative to outdoors during space heating. The neutral pressure plane was maintained above the ceiling of cell 1, there was no exfiltration, and all air exchange was induced by the HVAC system. The resultant pressure-difference between cell 1 and cell 2 was generally 3 to 7 Pa during space heating.

PERFORMANCE DYNAMICS

Few data are available at this time and results should be considered preliminary.

Ventilation. Intermittent measurements by the authors indicate that the mechanically induced air exchange rate for the first year has been roughly .6 ACH, or enough outdoor air supply for 11 persons at 7 L/s (15 cfm) per person. The pressure-difference control under these conditions appears to have been very robust. Though pressure-differences were not continuously monitored, they were frequently checked during cold and windy periods. No reversals of the desired pressure-difference directions were observed.

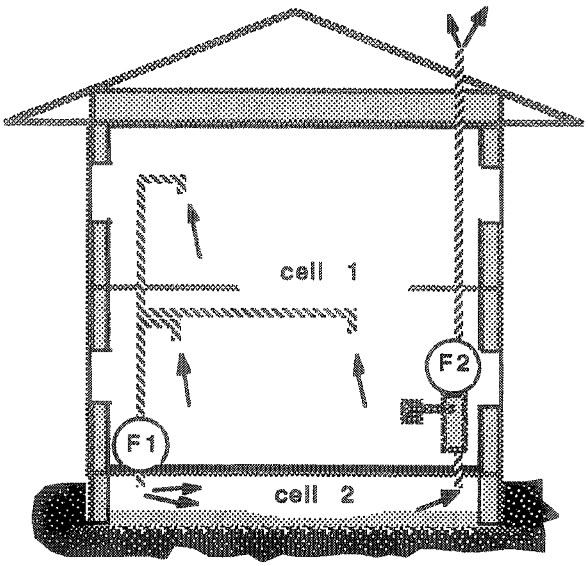

Figure 2. Exhaust Air

Energy. The building was occupied in January of 1989, and extensive energy performance monitoring was begun by the Bonneville Power Administration and the Washington State Energy Office. Once these data are analyzed a more complete energy performance picture will become available. Electrical main and submeter readings were recorded by the authors between March 4, 1989 and March 3, 1990. Electric resistance heating used 1.4 kWh/ft^2. The HPV used 3.5 kWh/ft^2 for continuous ventilation, space heating and cooling, water heating, and pressure-difference control.

Moisture. Humidity sensors (5) were calibrated and placed inside structural wood framing in six locations. An attempt was made to select locations with the greatest moisture potential; generally downwind from the prevailing wind direction, north shaded areas, and (for walls) high in the building. Thirty-seven intermittent readings were taken (approximately weekly during the heating season), corrected for temperature and recorded. Monitored moisture levels in all locations dropped by the end of the summer, and remained approximately constant through the following winter.

Radon Control. Five continuous radon monitors were placed in the same location for six days to establish a comparison baseline. Then they were placed in five different building locations for a thirteen day period between 11/11/89 and 11/23/89. Fan F1 was off during the first 112 hours of this period, so fan F2 depressurized both cell 1 and cell 2 relative to outside (cell 2 more negative than cell 1). After 112 hours, Fan F1 was activated and

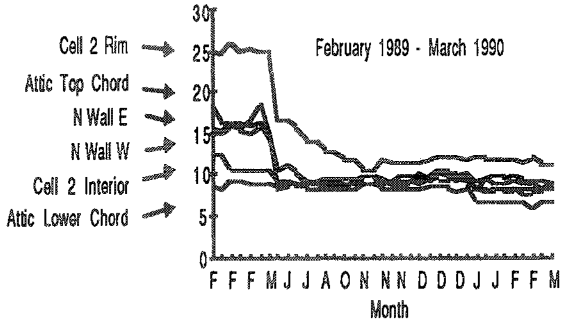

Figure 3. % Wood Moisture Content in Six Locations

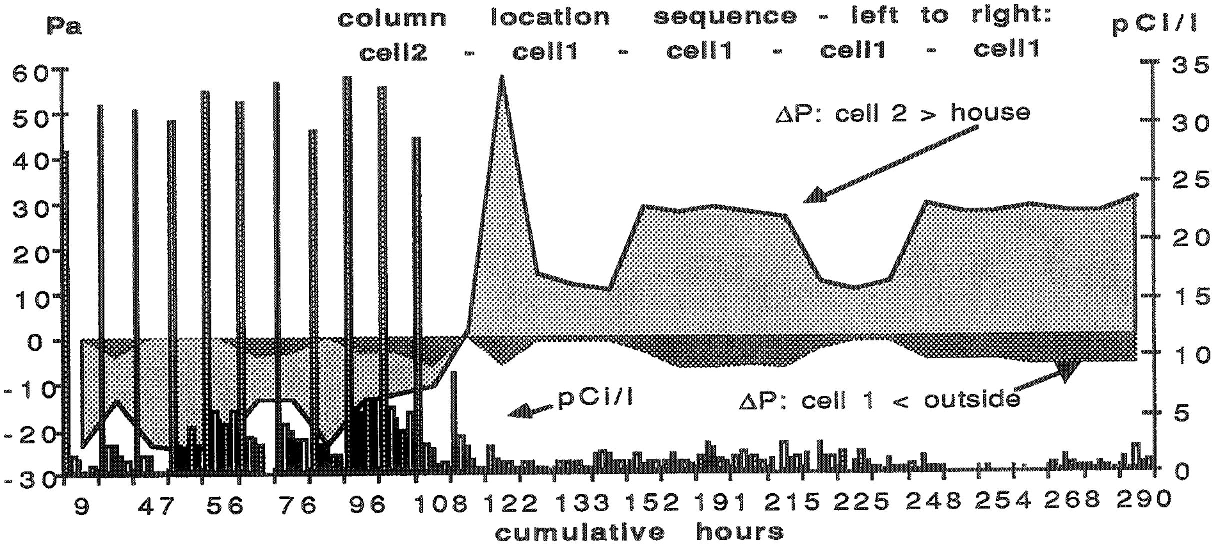

Figure 4. Radon Levels in Five Locations

adjusted to maintain a slightly lower pressure at the ceiling of cell 1 relative to outside during the space heating mode. This resulted in a 10 to 60 Pa greater pressure in cell 2 (depending on HPVAC-80 operating mode). Thirty-two intermittent readings were recorded. Radon levels in both cell 1 and cell 2 decreased when cell 2 was pressurized.

INDICATIONS

1. Pressure-difference control of soil-air entry via a designed continuous mechanical ventilation system incorporated into a tight house is readily achievable.
2. The radon source at this location is sufficient to allow the demonstration of radon control, and comparison of the impact of different pressure-difference scenarios on radon entry.
3. Airflows through the HPV can be reduced by dampers so that the flows necessary to maintain required pressure-differences can be reduced. The goal of maintaining soil gas entry control at .35 ACH may be achievable at this level of envelope tightness.
4. Careful attention to air-vapor barrier installation can enable control of moisture levels in the Spokane climate, even under conditions of constant and relatively large pressurization.

FUTURE DIRECTIONS

1. Obtain continuous radon and pressure-difference monitoring capability.
2. Maintain capability to continuously monitor temperatures, airflows, and moisture.
3. Evaluate the degree of pressure-difference necessary to control radon and determine the associated air exchange rates, climatic conditions, and energy costs.
4. Compare different pressure-difference scenarios and their impact on radon levels.