Long-Term Interstitial Moisture Performance of a Tight Energy-Efficient Residence

Mike Nuess, Washington State Energy Office

Introduction

The long-term thermal, structural, air quality, and cosmetic performance of a building depend in part upon the moisture conditions occurring in the components of its thermal shell.

Moisture studies in the Pacific Northwest have identified a potential for moisture problems, but the variations of moisture levels in critical areas of wood framed buildings have not been continuously measured across all the seasons of the year. Hence, it has not been possible to determine whether or not, how frequently, or for how long these areas are both warm enough and wet enough for wood-destructive fungal growth to occur.

Research Approach

This project sought to demonstrate the effectiveness of moisture controlling systems in a tight, energy-efficient residence by frequently measuring the variation of moisture levels across all seasons for a one year period. Moisture levels continued to be measured, but less frequently, during the following three years.

Building Description

The building envelope was deemed very tight based on blower door test results of 1.2 air changes per hour at an induced indoor to outdoor pressure difference of 50 Pascals (ductwork included). Though currently atypical, this level of tightness is practically achievable. This air change rate was measured both upon completion of construction and one year after completion of construction. The measured annual space heating energy consumption was 2.5 kWh/ft^2/yr (97 MJ/(m^2 • yr). The mechanical ventilation system was designed to operate continuously in a manner that depressurized the occupied portion of the building 2 to 13 Pascals lower than outdoors, and pressurized the crawlspace exhaust plenum 3 to 7 Pascals higher than the occupied zone. The primary purpose of this design was to utilize the normal operation of the continuous mechanical ventilation system to establish the differential pressure necessary to limit soil gas entry into the occupied portion of the building. Figure 1 shows a generic description of the mechanically induced and maintained pressure conditions.

The building shell is wood framed. The wall framing consists of two wood framed walls spaced 5.5 inches apart, resulting in a overall wall thickness of approximately one foot. The entire interstitial wall space is filled with fiberglass batt insulation. The interior sheetrock is the designed air barrier. A vapor impermeable interior primer paint provides the vapor barrier. The roof is of typical truss construction.

Methodology

Humidity sensors were calibrated and placed inside of structural wood in six critical locations. Placement occurred during construction. Wires were connected to the sensors and routed to a common site in the mechanical room for convenient reading with a hand-held meter.

Locations with the greatest moisture potential were selected: generally downwind from the prevailing wind direction, shaded areas on the north side, and (for walls) high in the building. In the attic and crawlspace zones, one sensor was placed on the warm side of the insulation and another was placed on the cold side. Two sensors were placed on the cold side of the insulation in two separate locations on the north wall upstairs. Intermittent readings were recorded and corrected for temperature, utilizing a correction slide rule provided by the sensor manufacturer. The temperature at each specific sensor location was calculated utilizing equation(1).

$$T_x = T_i - \frac{R_x}{R_t}(T_i - T_o),$$

where T_x = Temperature at sensor location.
T_i = Inside temperature.
R_x = Sum of resistances from inside to sensor location.
R_t = Total assembly resistance.
T_o = Outside temperature.

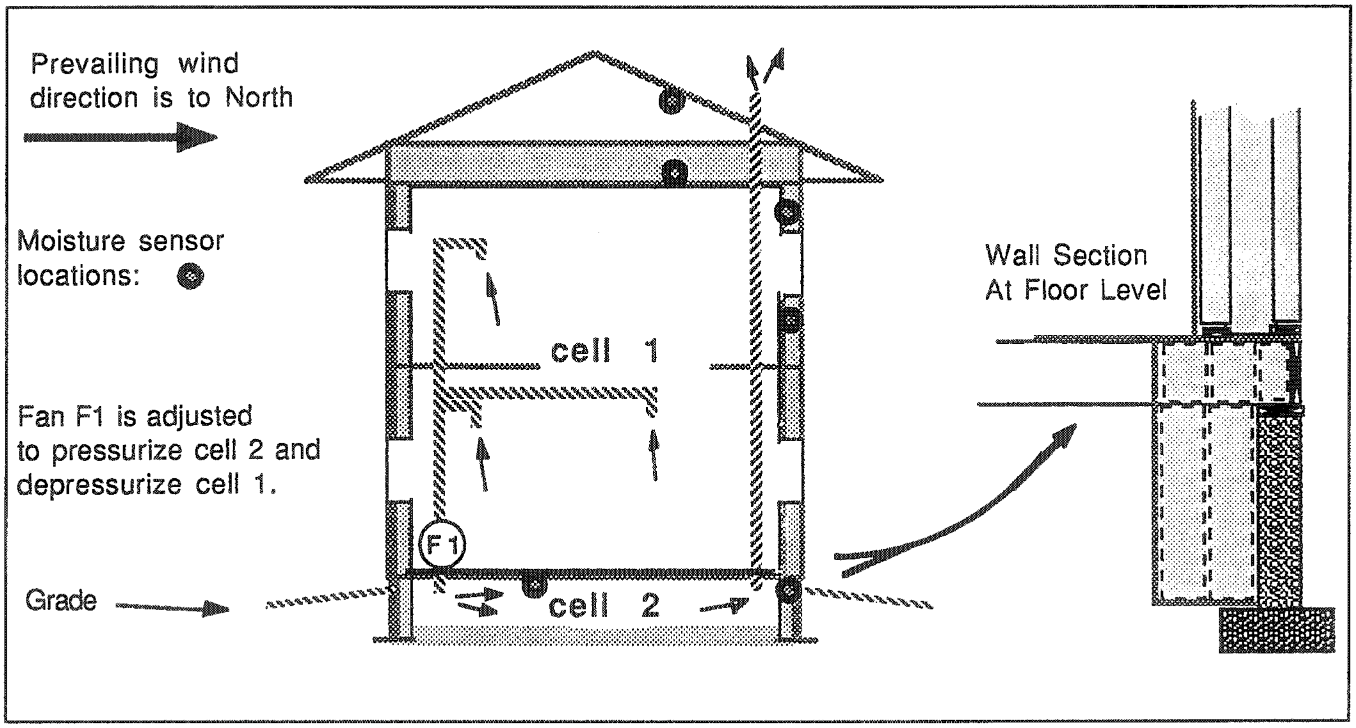

Figure 1. Exhaust Air Side of Continuous Ventilation System

Complete sets of recorded data included moisture sensor readings at each of six locations, indoor temperature, and outdoor temperature. Fifty-three sets of complete readings were recorded. Forty-one sets were recorded in the first 13 months. Recordings occurred approximately weekly during the first heating season (Figure 2).

Results

Construction of the building shell took place in the late fall of 1988. High moisture levels occurred during this period, particularly in the crawlspace zone. The building was commissioned and occupied in January of 1989. Interstitial moisture levels at the sensor locations remained at initial levels through March. By June, moisture levels in five of the six locations had dropped to what would remain baseline levels over the next three years. By the end of August, moisture levels in the sixth location had also dropped to what would remain a baseline level over the next few years. Moisture levels did not appear to increase above the baseline during the next three heating seasons.

Conclusion

The results indicate that a potential for moisture problems has not occurred, even in the pressurized area. Moisture levels in the sixth location (rim joist area) were consistently higher than in other areas due to the continuous pressurization of this zone, but remained well within acceptable limits. Extensive care was taken to insure installation of an effective and durable air/vapor barrier (Nuess 1991) in this zone, and this level of care was likely quite necessary. The effectiveness of this air/vapor barrier system could be better evaluated by creating deliberate openings near the sensor location and measuring the changes in wood moisture content.

Reference

Nuess, R. M., and R. J. Prill. 1991. "Controlling Radon While Increasing Comfort, Energy Efficiency, and Indoor Air Quality in New Residential Construction." *Proceedings from the 84th Annual Meeting of the Air & Waste Management Association,* Paper #91-63.4, Air & Waste Management Association, Pittsburgh, PA.

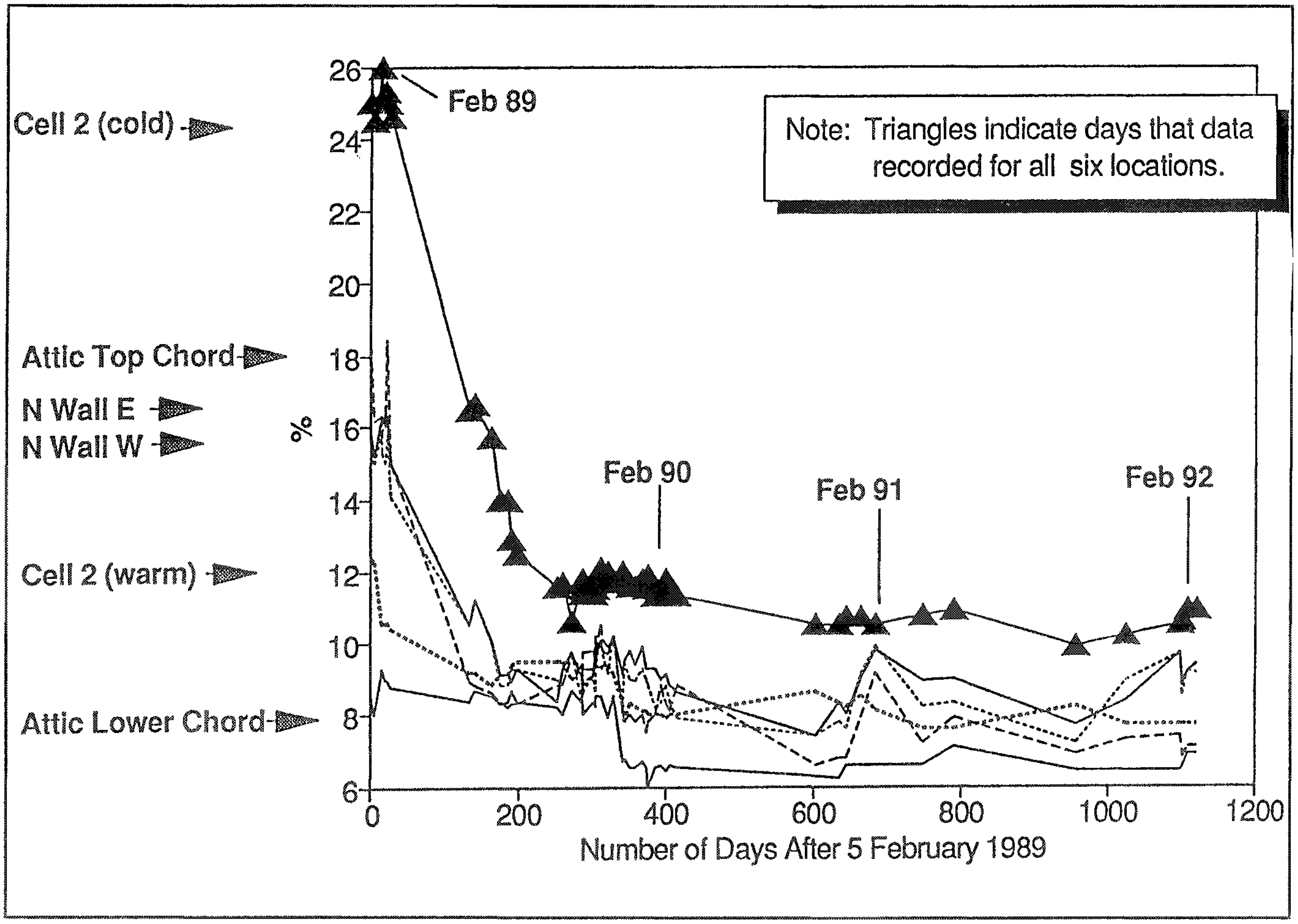

Figure 2. % Moisture Content in Structural Wood. Six critical building shell locations.