# Arctic Wall Performance

## A super-insulated vapor-permeable wall design in Interior Alaska

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Alaskans spend more than twice the national average on energy and more per capita than any other state. In Alaska homes, 80% of total energy use goes toward space heating. Thus improving the energy efficiency of building practices and products has a major impact on those who live here. Energy efficient construction not only reduces energy costs but also improves the comfort and durability of the home.

The Cold Climate Housing Research Center (CCHRC) and Fairbanks builder Thorsten Chlupp (Reina, LLC) recently tested a building envelope design that provides a new energy efficient construction option in Alaska.

The Fairbanks test house has a double-wall, airtight system with cellulose insulation and vapor diffusion-open capabilities. The system, dubbed the Arctic Wall, builds on the concepts of the Residential Exterior Membrane Outside Insulation Technique (REMOTE) Wall.

The key components are:

- the majority of the insulation is outside the structural framing and air barrier
- the building envelope is extremely airtight
- the wall is open to water vapor diffusion and provides substantial moisture buffering capabilities

Traditional cold climate construction practices use a vapor barrier on the warm side of the wall, whereas the Arctic Wall system is intentionally left open to allow vapor to move freely to either the interior or exterior of the house. This study investigates the wall performance in this capacity. Sensors placed in the wall monitored the temperature, relative humidity, and moisture accumulation within the walls. Data from these sensors are used to assess the potential for moisture buildup and subsequent mold growth.

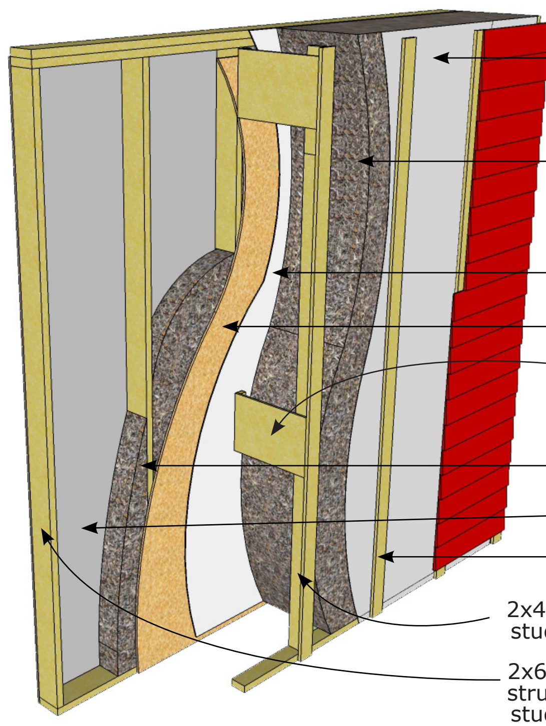



Figure 1. Arctic Wall detail

This study addresses the following questions:

- Are the temperature, relative humidity, and moisture content conditions favorable for mold growth?
- What is the direction of moisture transport through the walls?

### Wall System Description

The Arctic Wall system uses dense-pack cellulose and eliminates the traditional vapor barrier. A diagram of the wall system is shown in Figure 1.

The system is comprised of a 2x6 interior structural wall filled with blown-in dense-pack cellulose. Gypsum drywall is fastened directly to interior side of the structural wall. Half-inch grade "C-D" exterior grade plywood sheathing board (CDX plywood) that has been taped and sealed is fastened to the exterior side

**Vapor Barriers, Vapor Retarders & Air Barriers**

Conventional cold climate construction includes a vapor barrier in the wall. Vapor barriers are intended to stop or slow the migration of water vapor into the wall, depending on their rating.

Water permeance is measured in perms. Class I vapor retarders (commonly referred to as vapor barriers, such as 6 mil polyethylene plastic sheeting) are 0.1 perm or less. Class II vapor retarders are greater than 0.1 perm but less than 1.0 perm.

When air moves through the wall section, vapor moves with it. Although Class I vapor retarders are often installed to prevent wall assemblies from accumulating moisture from the indoors that is trying to get out, they are rarely perfectly sealed around every electrical and plumbing penetration.

In cold climates, vapor barriers have also served as the primary *air barrier* in conventional construction. But leaks in the vapor retarders provide ample opportunity for excess moisture to get into a wall during the heating season. Plus, placing a vapor barrier behind the drywall effectively prevents the wall from drying inward and can therefore create moist conditions inside the wall favorable to mold growth.

of the structural wall. The tape used on the sheathing is an airtight, vapor-permeable material. A layer of Tyvek® HomeWrap®, a vapor-permeable air barrier, is secured to the exterior side of the taped sheathing. The combined taped sheathing and vapor-permeable air barrier is referred to as the air barrier system.

An exterior balloon-framed 2x4 wall wrapped with a vapor-permeable membrane (Tyvek® HomeWrap®) contains 12 inches of blown dense-pack cellulose against the air barrier system. A 1x4 furring strip sandwiches the outer membrane to the outer framing; the exterior siding is attached to the furring strips, providing a ¾-inch air gap. The air gap created by the furring strips provides ventilation behind the siding and a drainage plane along the outer membrane.

## Measured Data Analysis & Summary

Temperature, humidity, and moisture content sensors were installed throughout various walls in the house to monitor the hygrothermal (combined heat and moisture transport) conditions within the walls. Sensors were placed on the coldest walls (north side of the house), warmest walls (south side of the house), and areas of high humidity (upstairs bathroom). The data for each location were evaluated for potential condensation events, year-round temperatures, humidity levels, and wood moisture content within the wall cavity.

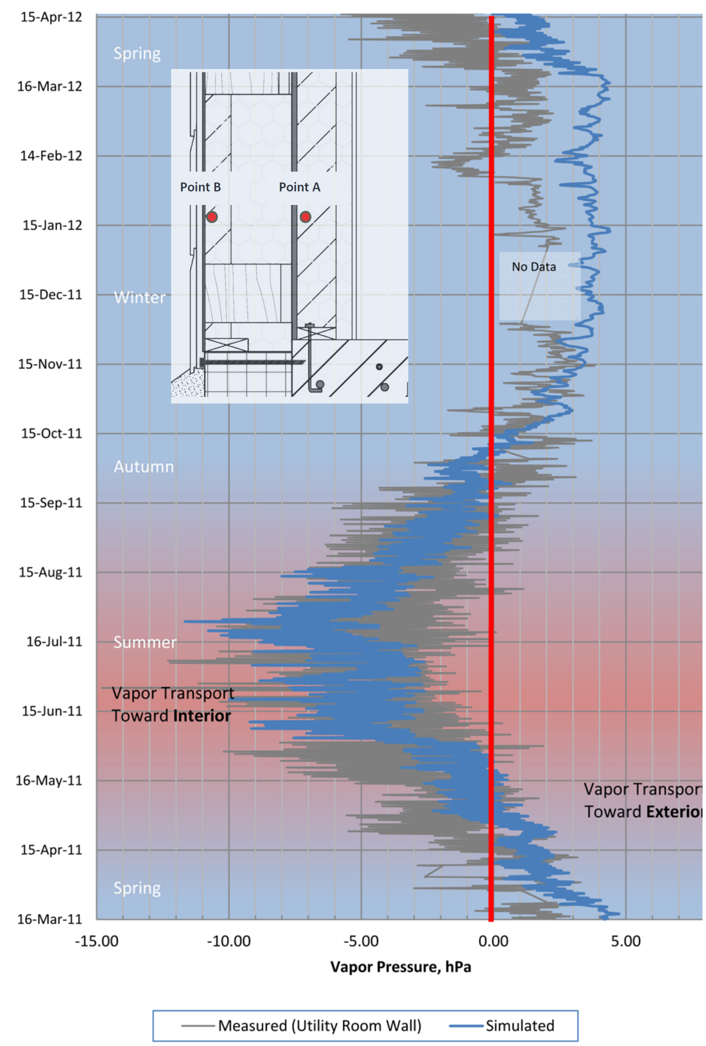



Figure 2. Vapor movement in the wall. Seasonal vapor pressure difference between the interior side of the air barrier (Point A) and the inner edge of the outer membrane (Point B). The vapor transport is toward the interior during warmer months and toward the exterior during the colder months.

## Summary of Findings

Data was collected over 13 months and the home's performance was modeled over nine years. Both sets of data were used to evaluate the hygrothermal performance of the wall.

The computer model revealed that the humidity and moisture content in the wall (cellulose and plywood) do not reach the levels and duration required for mold growth. In contrast, conventional cold climate construction is easily within the danger zone for mold growth, especially when moisture penetrates the stud cavity through gaps in the vapor barrier.

The temperatures measured in the walls were not sufficient to support mold growth. During the study, the interior side of the air barrier system does not come close to dew point (the point at which vapor condenses to water), indicating the structural framing is well protected from moisture.

Figure 3 shows that measured relative humidity in the walls is also not high enough to support mold growth. Additionally, modeling shows that water does not build up over a 9-year period but rather dries out every year. As shown in Figure 2, the direction of moisture transport varies seasonally, which is the purpose of the vapor diffusion-open wall design. The vapor pressure curve of a conventional wall does not exhibit such a widely fluctuating seasonal characteristic and, without the ability to dry out, may hold moisture within the walls.

**Vapor Diffusion and Airtightness**

The highly airtight Arctic Wall minimizes air movement and heat loss through the walls. The home was measured as much tighter (0.45 air changes per hour at 50 Pascals of pressure) than the maximum air-tightness of 3 ACH 50 set by the 2012 International Energy Code.

Taped plywood sheathing and house wrap serves as the primary air barrier system. While this system is very airtight, it allows water to move through vapor diffusion. Vapor barriers, or Class I vapor retarders, are deliberately excluded from this wall design. The vapor permeability provides greater drying potential for the wall throughout the year.

The cellulose insulation in this wall system is capable of storing moisture, or moisture buffering, over the winter without succumbing to moisture damage or mold.

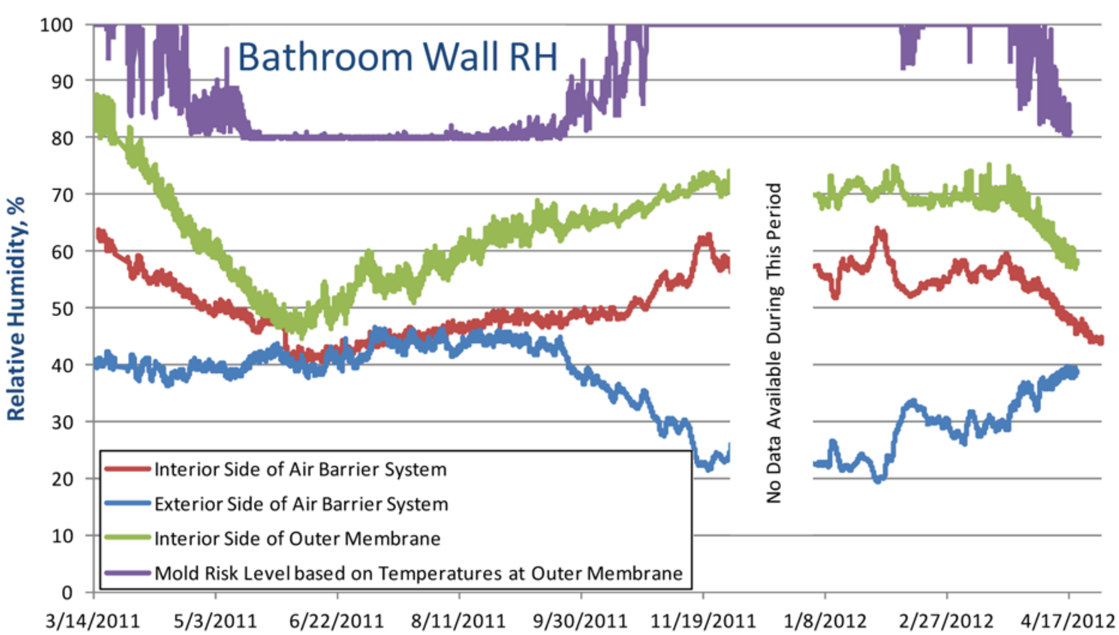



Figure 3. Relative humidity in the wall. The master bathroom wall was monitored for relative humidity (RH) since it was the most likely area to experience high humidity (e.g. showers). RH levels at the sheathing ranged from 23%–65%. The interior side of the outer membrane never exceeded the RH mold risk level limits shown by the purple line. These measurements show that mold risk in these locations is not a concern.

A vapor-diffusion open wall without the key components listed above would fare poorly in a subarctic climate or even much warmer climates. However, with enough exterior insulation, a well-sealed air barrier in the right place, and the ability to buffer moisture in the wall, the system performs as designed.

The reasons this wall design provided ample moisture control in a cold climate without using a Class I vapor retarder include:

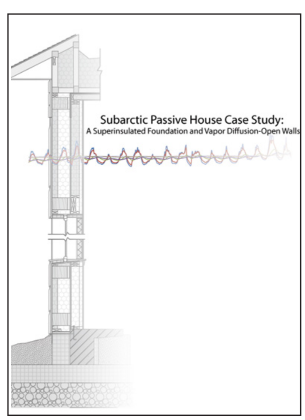
- The airtight design manages the moisture movement into the wall.
- The vapor-open design allows for the absorption and release of moisture across large surface areas (i.e. the whole wall surface instead of leaks in a vapor barrier)
- The cellulose provides the ability to buffer moisture for the annual cycle of moisture loading in this climate.

Future research possibilities could study the performance of this wall design with varying wall thicknesses and amounts of cellulose. Additionally, modeling this wall design for other regions in Alaska, such as Southwest, Anchorage, and Southcentral, may provide insight on its performance in climates with more rain and wind-driven precipitation.

View of the latest version of the wall cavity laying on its side. Bottom is inner structural wall with an air barrier; top is the outer wall.

Case study home in Fairbanks

This super-insulated Fairbanks home was built using the vapor-diffusion open Arctic Wall. Thirteen months of measured data from within the walls revealed that conditions remained below the levels required for mold growth and the wall effectively managed moisture fluctuations year round. This building envelope design provides a new energy efficient construction option in Alaska.

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