The REMOTE Wall System

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INTRODUCTION

Modified PERSIST Residential Construction

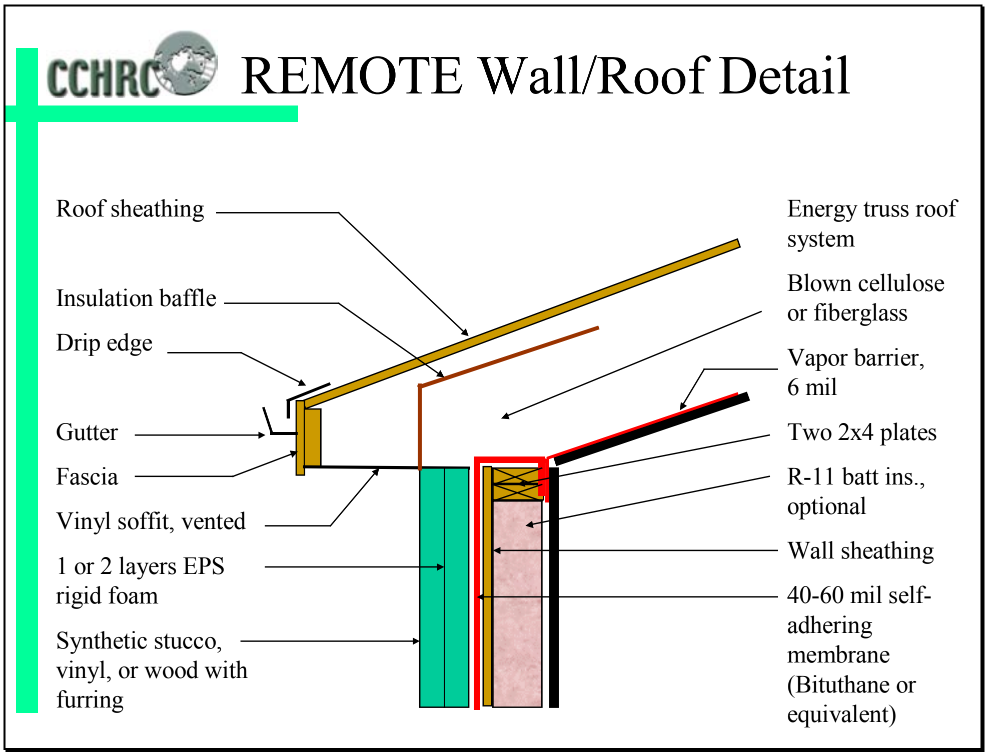
PERSIST stands for the "Pressure Equalized Rain Screen Insulated Structure Technique". A simplified explanation of this technique is that it is based on a peel-and-stick membrane located on the exterior of the sheathing of a framed structure acting as the air/vapor retarder in a cold climate. Canadian studies have indicated that the costs of replacing structurally degraded framing members are 290% more than initial construction, so preventing this loss is important. The PERSIST type design is an attempt to eliminate moisture intrusion or condensation from degrading the structural components of a building. There appears to be good reasoning and science behind this approach and it is worthy of study to determine the efficacy of the concept. There are material/labor cost savings and increases that need to be analyzed during the construction process as well. There is a strong interest in building and monitoring a modified PERSIST building envelope in both the dry and wet climates of Alaska.

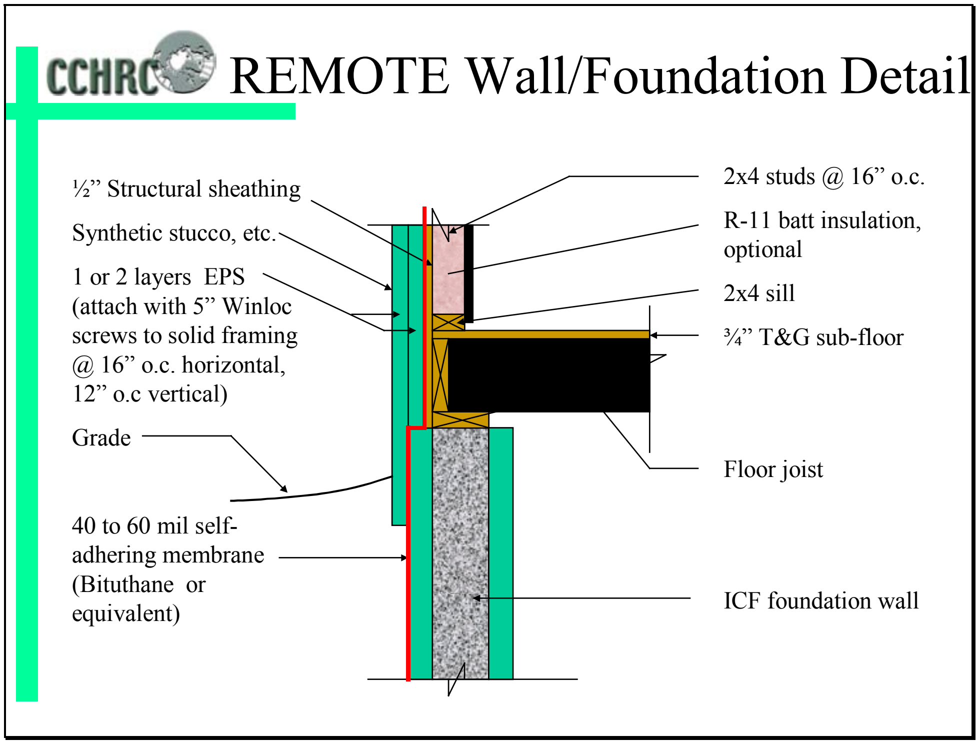
Fairbanks study of the REMOTE wall system

In 2002, CCHRC undertook a simple study of the performance of two residential dwellings built with different wall systems. One was a standard wall system with an interior vapor/air barrier and the other was a modified PERSIST wall that has been named "REMOTE" which stands for Residential Exterior Membrane Outside Insulation Technique. This was a short-term data collection period as the buildings were monitored from the first of December 2002 through March of the same year. The results of this short term data collection period can really only be used to predict possible long term performance and should not be construed to imply a thorough evaluation of wall system performance of the building over a substantial period of time.

PERSIST uses an approach in which the roof and walls are sealed with a membrane on the exterior of the sheathing and all the insulation is exterior to that membrane. A second roof is then constructed to provide and overhang and protective roofing material. This study hoped to show that by eliminating the extra expense of a second roof, and instead using a traditional cold roof found in most northern construction, that the principals behind PERSIST would be able to be transferred to residential construction in a cost effective manner.

Another modification in this study was the inclusion of insulation in the wall cavity on the warm side of the air/vapor barrier. Also, the REMOTE design used in the Fairbanks study does not have a true rain screen and may be more accurately described as a concealed barrier wall enclosure. The REMOTE Fairbanks wall system that was studied has an acrylic stucco finish applied directly to the insulation located on the outside of the membrane. Detailed cross-sections of this wall system are shown in the figures below.



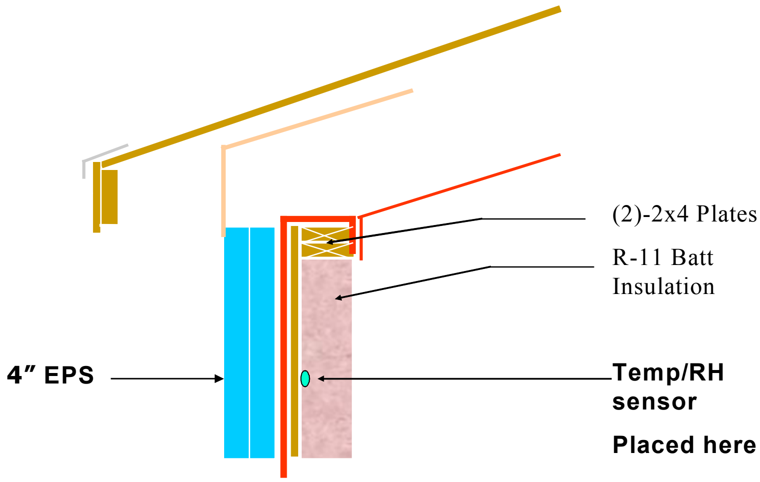


DEW POINT MONITORING IN THE WALL

The REMOTE wall system we monitored in Fairbanks had 4” of high-density expanded polystyrene foam (R value of 5 per inch according to manufacturer) on the cold side of the air barrier, and R-11 fiberglass batts on the warm side. There was some concern over the possibility of condensation if the wall system became saturated from moisture for an extended period and unable to dry during non-condensing periods.

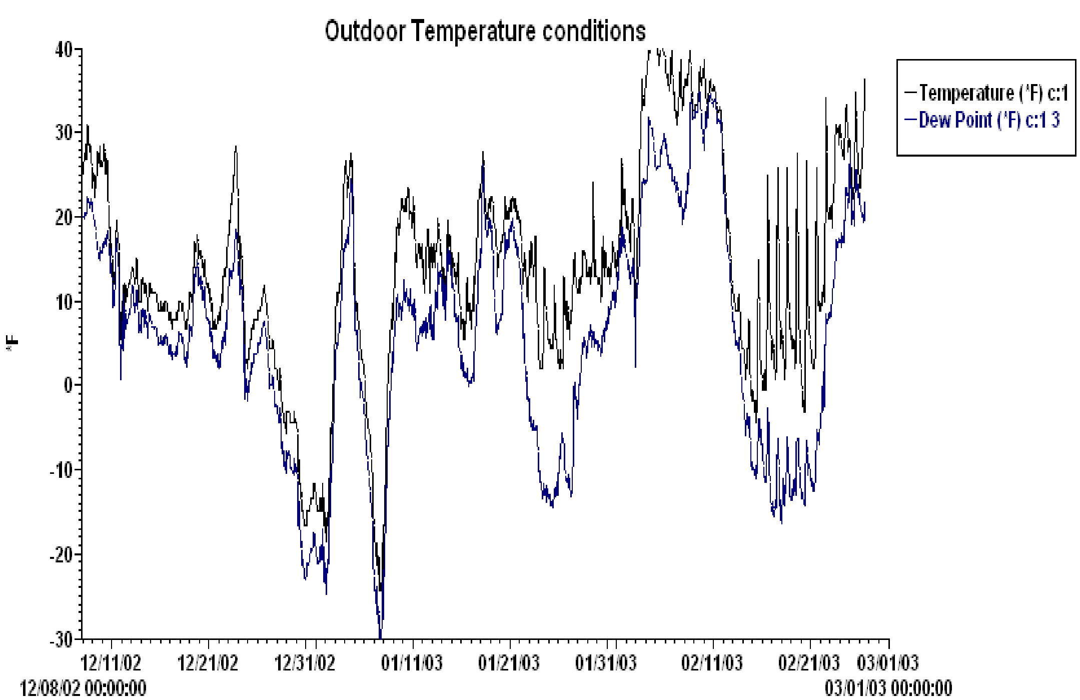
To monitor for this concern, we placed an external probe from a HOBO LCD datalogger to measure temperature and RH inside the wall cavity on the cold side of the R-11 fiberglass batt insulation next to the sheathing, which is on the warm side of the air/moisture barrier membrane.

Location of Wall Sensor During Study

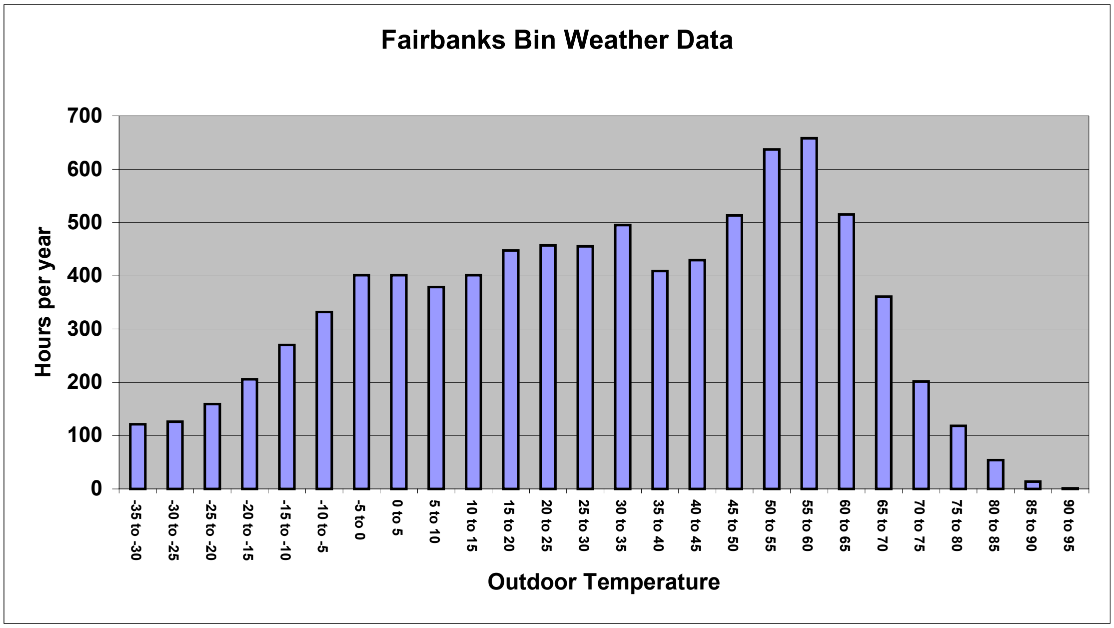


Exterior weather conditions during monitoring

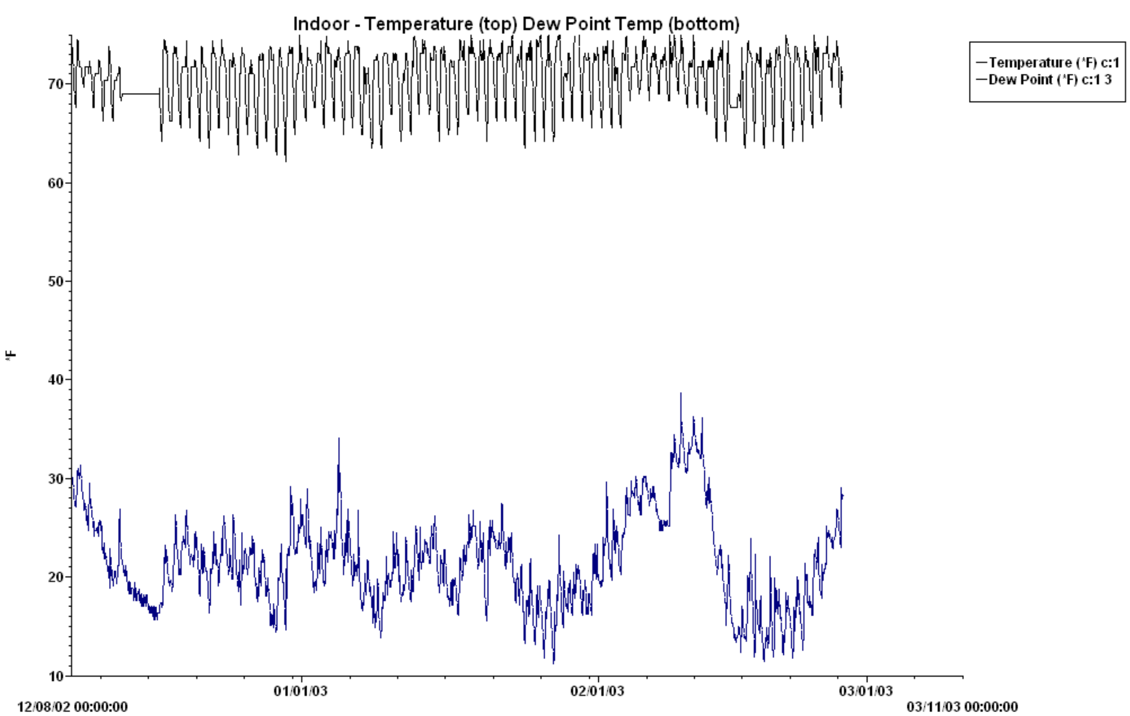
Top Line is Temperature; Bottom line is Dew Point Temperature



Typical Fairbanks outdoor temperature ranges



Interior conditions during monitoring



The outdoor temperature low was a mere –27F that may be considered moderate by Fairbanks standards. We had dry interior Relative Humidity (RH), an average of 15.68% RH was found with a low of 10.2% and a high of 27%. These dry conditions, which would not be those experienced with a high density population of a similar structure or with occupants that produced greater moisture (use of a humidifier, more showers/cooking etc.) were very conducive to this wall system operating with such a difference between wall temperature and dew point temperature. Without mechanical ventilation, this wall system, like any tight wall system, could be very susceptible to moisture problems in our climate.

Condensation potential

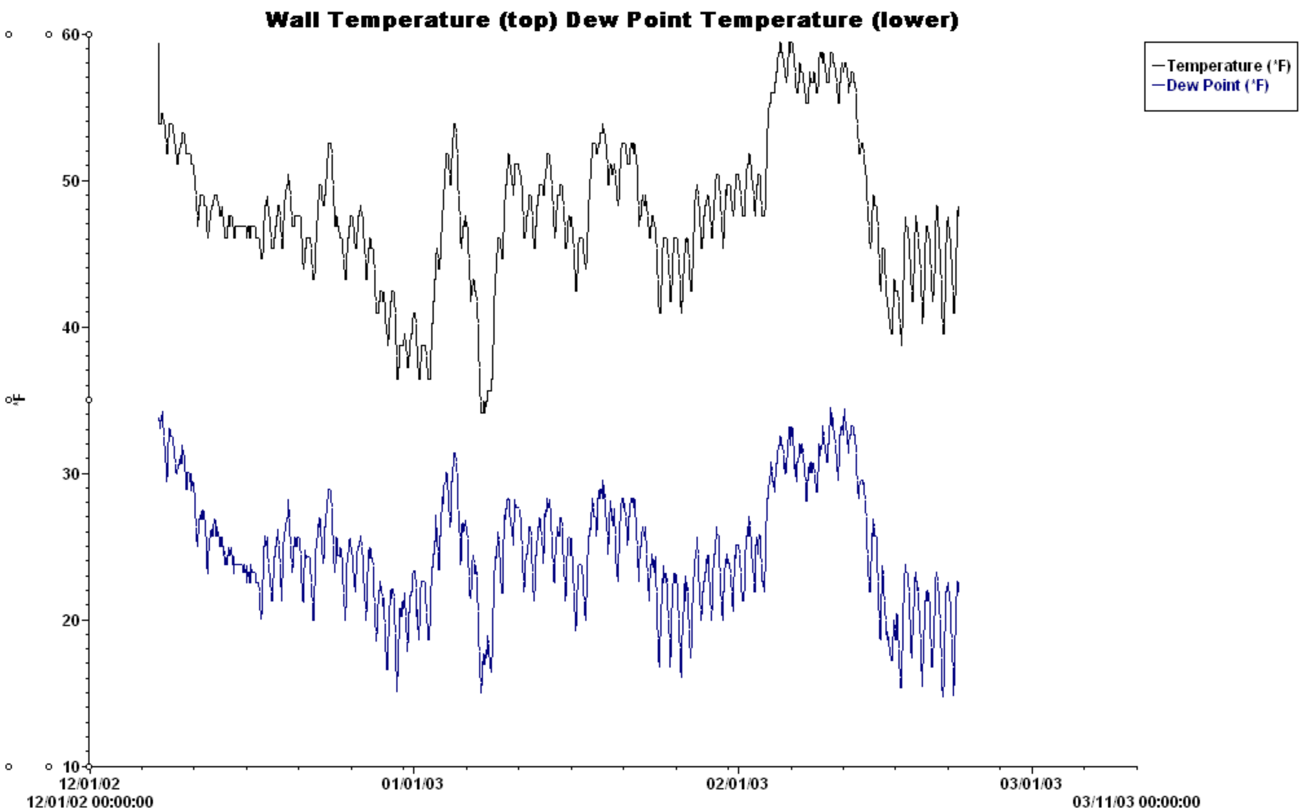
If we look at a Psychometric chart for a 70-degree room at 15.68% relative humidity (RH), dew point would take place at 22.5 degrees F, with an absolute humidity (AW) of 1.271 grains per cubic foot. For a 70-degree room with 35% RH, dew point would take place at 37 degrees and have an AW of 2.49 grains per cubic foot. The same room with 50% RH would have a dew point of 50.5 degrees, and an AW of 4.048.
An RH of 35% is not that difficult to achieve in a standard residential dwelling in Fairbanks during the winter. Looking at the wall conditions in the following chart, we see that reaching dew point temperature for a 35% RH room is not impossible. The question that remains, is would the wall temperature continue to remain at a low enough temperature and RH to avoid a prolonged condensation condition that could lead to a moisture event?

Given the information above, we can look at the potential for condensation in the REMOTE wall cavity in Fairbanks. To determine if there is a potential for significant moisture accumulation, one would also have to model the ability of the wood material (studs and sheathing) to adsorb and release moisture and reduce the RH based on the permeability of the drywall and paint. Clearly, as we saw from the wall conditions during monitoring, the RH and temperature drop within the wall cavity, which greatly reduce the potential wetting hours.

Exterior Temp	Sheathing Temp.	Indoor RH at Dew Point	Hours/Yr
-50	23	16	39
-40	27	19	70
-30	31	23	245
-20	35	27	365
-10	38	32	605
0	42	37	800
10	46	43	780
20	50	50	995
30	54	57	950
40	58	66	835
50	62	76	1150
60	66	87	1175
70	70		751

Wall Conditions during monitoring

During the study period we did not see the interior wall temperature and dew point



temperature come any closer than 20 degrees F. Apparently in these conditions (internal, external and within the wall cavity) the wall system worked fine and maintained an acceptable distance between temperature and dew point.

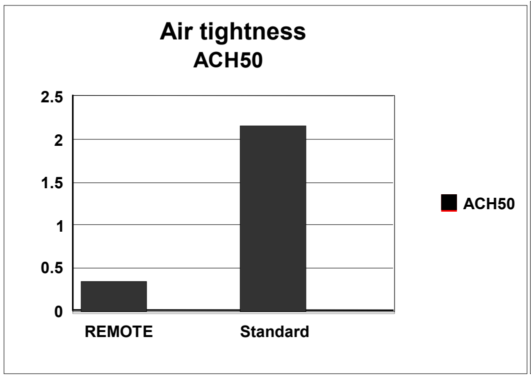
Effective R-Value of Fiberglass Batt

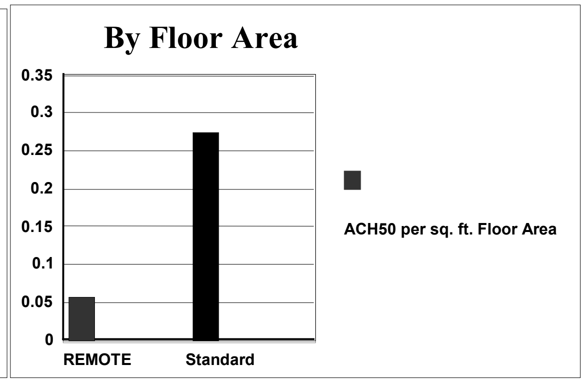
We employed a ratio analysis of temperature and R-Value by looking at inside, mid-wall, and exterior temperatures. The ratios of the mid-wall temperature to inside temperature, and mid-wall to outside temperature were used to estimate the effective R-Value of the fiberglass insulation in the interior wall cavities. It was assumed the effective R-Value of the continuous exterior foam insulation was R-5 per inch as tested by the manufacturer.

The difference in temperatures measured between the indoor, outdoor and wall dataloggers show that the R-11 Fiberglass batt provided 40% of the effective R-Value of the wall total wall R-Value on the average. If we believe that the R-Value of the foam is in fact 20, then the effective R-value of the R-11 Batt is closer to an R-13 based on the wall temperature ratio of 40%. Obviously this impacts the ratio of 2/3 of the R-value on the cold side of the vapor barrier rule of thumb that we attempt to follow in this area of heating degree-days in order to avoid condensation on the warm side of the vapor/air barrier. Yet, wall temperature and dew point temperature did not come any closer than 20 degrees during the monitoring period.

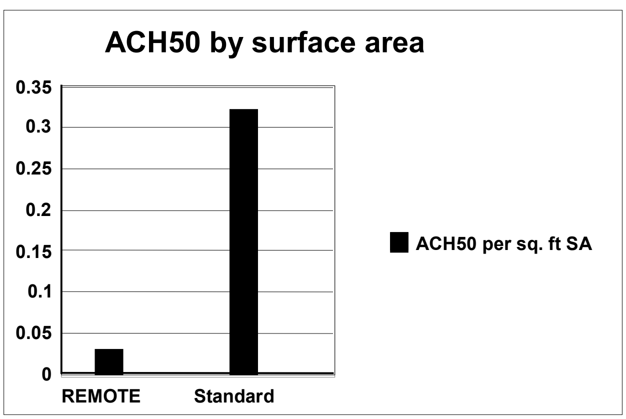
AIR TIGHTNESS

Air tightness was the most significant difference in comparisons between the standard house and the REMOTE house. The tables show the difference in air tightness between the Standard and REMOTE home #1.





The First chart shows the difference in overall Air Tightness when measured by ACH50 (Air Changes Per Hour at 50 pascal pressure differential)
The second chart shows the ACH50 per square foot of heated floor area
The chart below shows the ACH50 by square foot of exposed surface area

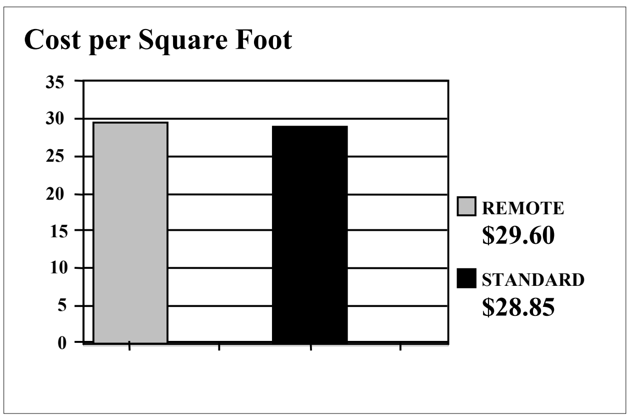


COST COMPARISONS

The cost comparison used two types of construction of similar sized houses by the same contractor in the same housing development. The homes were built one year apart. During that year labor costs increased 30%, therefore actual labor costs for the REMOTE were reduced to make them comparable.

The REMOTE wall is described and shown in detail above, the siding was an acrylic stucco system, which is more expensive than vinyl siding. The REMOTE house had a main floor square footage of 1248, lower level square footage of 616 square feet with a garage square footage of 672 square feet, making a total of 2,536 square feet of heated floor space. The volume of the REMOTE house is 21,970 cubic feet

The standard wall construction had an interior polyethylene sheeting vapor retarder, R-21 fiberglass batts in a 2"x6" wall with 1" of exterior foil faced polyisocyanurate foam and vinyl siding. The Standard house had a main floor square footage of 1194, lower level square footage of 549 square feet with a garage square footage of 658 square feet. Making a total of 2,401 square feet of heated floor space. The Volume of the Standard house is 18,300 cubic feet



Compared costs come to $0.85 per square foot difference between the two buildings. Compared costs only included similar components; items such as windows, floor covering, cabinets, fixtures, etc were excluded from the comparison.

Another approach to cost comparison has been to look at the wall components and compare

Cost Comparison - Juneau

Cost Comparison of Conventional Construction for the walls of a 32' x 56' single story house			
Conventional Construction		REMOTE Construction	
Component	Cost	Component	Cost
2x6 stud* (175 @ $4.59)	803	2x4 stud* (175 @ $3.19)	558
R-21 batt insulation	893	3"EPS foam sheathing	662
6 mil polyethylene	64	Bituthane	1152
Tyvek	184	none	0
None	0	PT furring	162
TOTAL - conventional	1944	TOTAL - REMOTE	2534
*vert. lumber est. at 1/ft		Incremental Cost	590

the two material costs. These tables compare conventional construction to a REMOTE and do not include the same components as the REMOTE and Standard houses compared above.

Cost Comparison- Fairbanks

Cost Comparison of Conventional Construction for the walls of a 32' x 56' single story house			
Conventional Construction		REMOTE Construction	
Component	Cost	Component	Cost
2x6 stud* (175 @$4.55)	796	2x4 stud* (175 @$2.93)	513
R-21 batt insulation (effective R-18)	964	4.5'' EPS foam sheathing (effective R-18)	993
6 mil polyethylene	58	Bituthane	861
2x6 plates	295	2x4 plates	197
Tyvek	186	Furring	132
TOTAL - conventional	2299	TOTAL - REMOTE	2696
*Vert. lumber est. at 1/ft		Incremental Cost	397

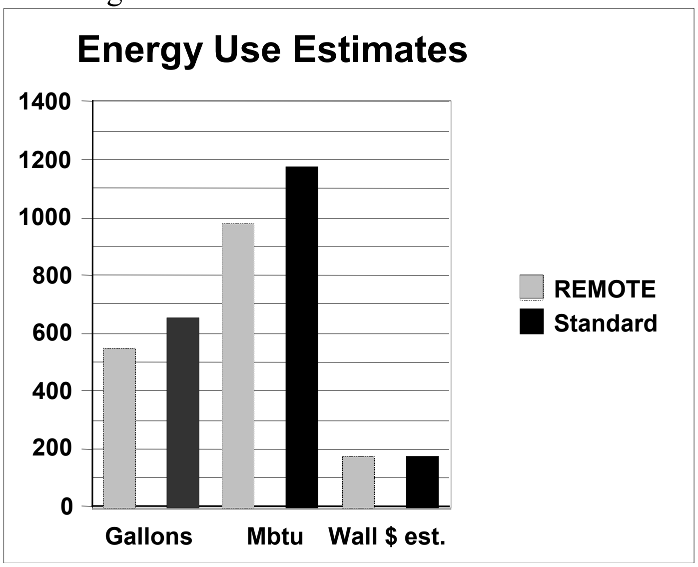
Other Cost Comparison Issues

Cost Comparison of Conventional Construction vs. REMOTE			
Conventional Extras		REMOTE Extras	
Component	Cost	Component	Cost
Rim joist sealing	+	Insulation installation	+
Window sealing	+	Furring for siding	+
Vapor barrier sealing	+	Window/door flashing	+
Temporary heat	+	Ventilation	+
Callbacks/durability	+		

FUEL USE - Estimates and Actual Performance

Estimates

The chart below shows the heating fuel (not hot water) use estimates from AKWARM energy modeling software:



The Remote fuel estimate was for 549 gallons of fuel for heating and 140 gallons for domestic hot water.
The Standard home estimate was for 651 gallons of fuel for heating and 220 gallons for domestic hot water. Actual fuel use for the Standard home is not available.

REMOTE actual fuel use

Fairbanks has an average of 14,274 Heating Degree Days (HDD), this of course varies from year to year but is the figure that the AKWARM software uses to model a building and estimate fuel use.

For REMOTE House #1, we saw fuel use of 517 gallons for 144 days (5,770 HDD) from January 3, 2003 through May 27, 2003. This would be **.**0896 gallons per HDD, or an annual actual use of 1,278 gallons for space and water heating. AKWARM estimated a total annual fuel use of 689 gallons for space and water heating, or .0482696 gallons per HDD

For REMOTE house #2 we took a period when was occupied by the owners and not under construction. From 1/20/03 through 03/03/03 the house used 240 gallons of fuel for domestic hot water and heat. The Heating Degree Days (HDD) for the period at the site was measured at 2015. In this analysis, we see that actual use was **.**1092 gallons of fuel per HDD, or an annual use of 1,702 gallons for space and water heating. AKWARM estimated an annual use of 1,194 gallons of fuel for space an water heating, or .0884 gallons per HDD.

By using the same gallons of fuel per HDD that the estimating software employed, we would have expected to see a much lower actual fuel use for both houses. The actual fuel use shows that both homes are using fuel at a rate much higher than the estimate.

The question becomes what could be responsible for the dramatic difference in actual fuel use as opposed to estimated fuel use in these two airtight well-insulated efficient structures. We do not have conclusive evidence in this area and hope that a continued study will help us come to specific conclusions and answers.

What possibilities have we considered so far? Some Scandinavian studies have shown a higher usage of fuel for heated slabs as opposed to unheated slabs for the first 3 years of use, but this would only account for an increased fuel use of perhaps 10 to 13%, which does not come close to the discrepancy.

With some minimal data collection we have some preliminary results that point to an oversized heating system as possibly responsible for the majority of this discrepancy.

Boiler Run time Fuel Use Estimate

An estimated fuel usage based on boiler runtime and outdoor temperatures was performed on the Dasher Home. Boiler runtime and outdoor temperature data was monitored for a short period of time in September 2003 and again in November 2003. The two monitoring periods provided both warm non-space heating days and several days at -20 degrees F.

The fuel use estimate during non-heating days shows a base fuel use of approximately 8000 btu's per hour. This base fuel use is the combination of domestic hot water usage water tank losses, and boiler standby losses. Using the national average of 64 gallons of hot water for a family of four and 110 deg F temperature rise, would require approximately 2800 btu/hr (boiler input) on a daily average. Assuming the 64 gallons of hot water usage is appropriate, the remaining 5200 btu/hr is the standby loss of the boiler and water heater. Boiler standby losses are both jacket and piping losses into the adjoining space, and chimney losses to the outdoors. Water heater losses are thru the insulated tank and piping. During space heating months the heat loss to the adjoining spaces is utilized, but is wasted during non-space heat periods. Chimney losses, including the heated air pulled thru the barometric dampers accounts for a substantial portion of the total standby losses. Quantifying those standby losses in Alaska for different types of boilers and sizes would be a useful study.

Similar monitoring of two low mass boilers shows less than 50% the summer standby losses as compared to the Dasher home. The differences during space heating periods are unknown.

Heating contractors are reluctant to reduce nozzle size in this climate, however that may be a worthwhile endeavor in addressing excessive fuel consumption. Better fuel filters are available that should decrease the concern over smaller nozzle size. In addition, the new cast iron sections in boilers such as the one found in the REMOTE homes are connected with neoprene gaskets reducing the old concern of leakage and thermal stress when they are allowed to go cold. Such an installation setup would be a worthwhile study and should reduce standby loss significantly, especially in non heating conditions

Fuel Use Estimate

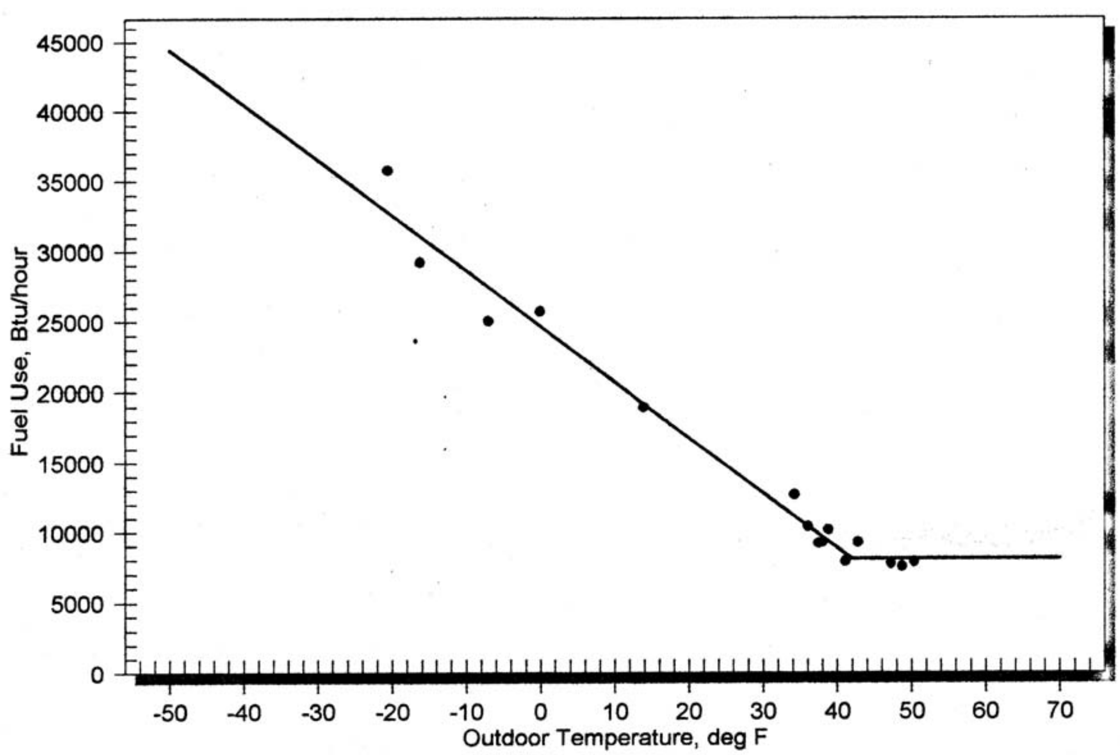
Run Description: Dasher Home

Results

Normalized Annual Fuel Use:	142.7 MMBtu/year in Fairbanks, AK
Design Fuel Use:	44,430 Btu/hour at a -50 deg F design temperature with a 0% safety margin

Model Parameters

R-squared:	0.979	Slope:	395 Btu/hr-degF
Balance Point:	41.9 deg F	Base Fuel Use:	8,089 Btu/hour
# of Points:	15		



The table below shows Fairbanks fuel use comparisons based on different AkWarm energy rating points with the actual REMOTE fuel use at the bottom, a future study would attempt to compare the most similar with actual use as well.

	Gal/sqft/yr	AKWARM Rating Points	Btu/sqft design	Total UA/sqft
	0.30	89.5	16.6	0.18
	0.40	90.1	22.6	0.25
	0.26	90.2	15.7	0.18
	0.38	88.8	20.7	0.29
	0.40	88.7	22.4	0.28
	0.33	91.2	18.4	0.20
	0.33	91.3	16.7	0.18
	0.35	88	19.0	0.23
	0.32	88.8	18.0	0.20
	0.43	92.4	22.8	0.26
	0.45	91.9	23.5	0.28
	0.44	88	22.4	0.23
	0.31	88	17.4	0.20
	0.37	89.4	20.3	0.27
	0.28	91.4	16.1	0.19
	0.34	89.4	19.3	0.23
REMOTE	0.23	94.2	12.8	0.11
actual	0.44	94.2	19.1	0.18

REMOTE vs. Exterior Insulated Finish System (EIFS)

We looked briefly at an EIFS home by the same builder for some comparisons. The EIFS was a wall system that employed (from inside out) interior polyethylene vapor barrier, 2x6 framing, R-19 fiberglass batts, sheathing, 4" of expanded polystyrene insulation, and an acrylic stucco. Areas probed with a Delmhorst moisture meter were areas that were unprotected from rainfall.

With minor exceptions we were looking at the same wall system. The REMOTE has a weather barrier between the foam and sheathing, the EIFS does not.
The EIFS wall was older, had more cracks in the surface and had recently been exposed to rainfall. The REMOTE wall was less than a year old, had no visible cracks in the surface areas and had recently been exposed to the same rainfall.

Not surprisingly, the conditions on the older system registered slightly higher moisture content readings, but both were well below the level in which we would have concerns. The EIFS probe was able to read the MC of the sheathing, while the REMOTE probe encountered the bithuthane peel and stick membrane.
The only area that we saw considerable moisture readings were in the foam insulation below grade, however when probed a few days after the rainfall, the numbers were back to those found above grade.

CONCLUSIONS

In this relatively short study, the REMOTE wall system performed quite well. Even with the addition of insulation in the interior stud cavity, the interior of the sheathing never approached the dew point, the temperature at which condensation might occur. The air tightness of the REMOTE house was about 0.4 ACH_{50} compared to about 2 ACH_{50} for the standard house. This means that very little energy is wasted heating infiltration air but, like any tight wall system, requires a good mechanical ventilation system. The air tightness also appeared to slightly increase the effectiveness of the fiberglass batt insulation in the stud cavity from a nominal R-11 to an effective R-13. Moisture probes of areas vulnerable to rainfall using a Delmhorst moisture meter indicated moisture levels well below any level of concern.

The cost of the REMOTE wall system is somewhat higher than the conventional system, but apples-to-apples comparisons are difficult to make. In this study, including labor, we compute the REMOTE wall to cost about $0.85 more per square foot of heated space (including the garage) than the conventional approach. Other estimates, that exclude labor, put the cost premium at about $0.30 per SF of heated space. For a 2,500 SF house, the REMOTE premium would be about $1,500 to $2,125 over the conventional wall system. CCHRC is continuing to research ways to reduce this cost; but this cost seems worth the benefits of a healthy, durable home.

There remain questions about the fuel-usage rates observed in this study. The REMOTE home appears to be using fuel at a rate almost twice what was predicted by the AkWarm analysis (which was very low). This rate is not overly excessive compared to other highly rated homes; but is higher than was expected for such a well-built home. Given the insulation values and the air tightness results, this is unlikely to be an envelope issue. The best explanation to-date is that the boiler is oversized and the standby and stack losses are using the extra fuel as compared to the predicted rate.