Thermal Performance of Fiberglass Wall Batts versus Blown Insulation

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ABSTRACT

Calibrated hot box testing was performed on a variety of conventional wall insulations. The resulting surface-to-surface R-values were used to compare blown insulations to fiberglass wall batts. Testing was performed in accordance with ASTM C976 in an 8 ft. X 10 ft. (2.44 m by 3.05 m) calibrated hot box. Insulations were tested in a wood stud frame finished with gypsum board on the metering chamber side and wood fiber sheathing on the climatic side. Blown fiberglass, dry cellulose, and wet-sprayed cellulose samples were tested with electrical and plumbing fixtures installed in the wall cavities. Fiberglass wall batts were tested with and without various installation abnormalities in addition to the electrical and plumbing fixtures. Results show little difference in thermal performance between walls insulated with fiberglass batts and walls insulated with blown materials. Heat flowmeter tests were also performed to characterize all construction materials.

INTRODUCTION

Fiberglass batt insulation and blown insulation are often used to perform the same function to provide a high-efficiency thermal barrier in building systems. When the two insulation types are evaluated as individual entities in a heat flowmeter or other accepted test apparatus, their performance can be compared directly. An R-13 blown insulation product and an R-13 fiberglass batt perform equally when evaluated in the laboratory. When these insulations are applied in actual building systems they interact both physically and thermally with the wall cavity and all building components that exist in the wall cavity, such as plumbing and electrical fixtures.

If the two insulation products were installed identically, the heat transfer mechanisms in the wall systems and thus the overall thermal performance of the walls would be independent of the type of insulation. Due to the radically different methods used to install the two types of insulation, it cannot be assumed that their thermal performances are equally affected by all existing heat transfer mechanisms. This is most evident when the cavities contain electrical fixtures and plumbing runs, which pose problems for the installation of both types of insulation. Arguments have been made for both insulation types as to which will provide the best thermal performances when standard installation practices are used.

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TESTING PROCEDURE

Test Method

The testing was performed in a calibrated hot box (CHB) in accordance with ASTM Standard Test Method C976, "Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box". The basic theory behind the CHB testing is that the sample provides the only thermal barrier between two chambers that are held at different but constant temperatures. For this testing, the warmer of the two chambers is referred to as the metering chamber and the cooler chamber is referred to as the climatic chamber. The whole CHB is placed in an environment that is held at the same temperature as the metering chamber. Thus, heat flow from the metering chamber is limited to a path through the sample to the climatic chamber.

During the testing, the temperature of the two sample faces is monitored along with the total power input to the metering chamber. After these values reach a state of equilibrium the temperatures and the total power are used to calculate the whole wall R-value. Corrections for flanking losses are made using the temperature difference across the walls of the CHB and a correlation based on a finite element program developed for the specific construction of the sample frame used and this CHB.

The frame opening of the CHB was 10 ft. (3.05 m) wide and 8 ft. (2.44m) high. All test samples were mounted in a sample frame 1 ft. (.305m) deep. The temperature of the metering chamber for all tests was 100°F (37.8°C). The temperature of the climatic chamber for all tests was 50°F (10.0°C).

<u>Sample Construction</u>: All samples were tested in one of two 1 ft. (.305m) deep sample frames. A wood stud wall construction was installed in each frame. This stud wall consisted of 2 by 4 studs on nominal 16 in. (.406 m) centers with a double 2 by 4 base plate and a 2 by 4 top plate. A sketch of the stud frame is shown in Figure 1.

All tests performed using the test frame designated as Frame One were covered on the climatic chamber side by a 1/2 in. (12.7 mm) layer of commercially available wood fiber sheathing. The metering chamber side of the wall was covered by a layer of 1/2 in. (12.7 mm) commercially available gypsum board. The covering materials on both sides were applied as two full 4 ft. by 8 ft. (1.22m by 2.44 m) sheets and one 2 ft. by 8 ft. (.61 m by 2.44 m) sheet. All materials were attached to the stud frame with 1.5 in. (38.1 mm) dry wall screws on 12 in. (.305 m) centers. All wall covering joints were sealed with duct tape to prevent air leakage.

All tests performed using the test frame designated as Frame Two were covered identically to Frame One except for the addition of a layer of 1/4 in. (6.4mm) clear acrylic sheet, which was placed between the wood fiber sheathing and the studs on the climatic chamber side of the sample. The acrylic sheet was installed to enable the wall cavities to be viewed from the back side during the application of the blown insulation.

The first two tests were performed using R-13 unfaced fiberglass batts in each of the two test frames as described above. After these two tests, both frames were modified for all remaining tests. The modifications consisted of the addition of electrical wiring and plumbing pipes. A three-conductor wire was run across the width of the frame and connected to a standard two-plug outlet box which was located in the center cavity. The face of the outlet box was sealed to prevent air leakage. The wire was run through 1 in. (25.4 mm) holes drilled through every stud, 2 ft. (.61 m) above the base plate. Two 1/2 in. (12.7 mm) copper pipes were installed in the center cavity. The pipes ran from the base plate up to a horizontal mounting stud nailed to the vertical studs 30 in. (.762 m) above the base plate.

The copper pipes included a 90^{o} elbow and a short pipe section which extended out of the wall through the gypsum board. The pipe sections and the penetrations through the gypsum board were sealed to prevent air leakage. A sketch of the electrical and plumbing additions is shown in Figure 2.

For all tests, 24 type T thermocouples, and 30 gauge wire, were attached to each side of the sample. The thermocouples were taped directly to the gypsum board and wood fiber sheathing. The thermocouple locations are marked on the sketch of the stud wall in Figure 1. A simple averaging of the individual thermocouple readings was performed to arrive at the average surface temperatures.

All blown insulations were installed in frame two, and at the lowest product density possible, which would still result in a visually satisfactory void-free end product. Each cavity was blown from two locations, one at the top of the cavity and one just below the horizontal run of electrical wire. During the blowing process the sheathing was removed to allow viewing of the cavities through the acrylic sheet on the back side of the sample. On several occasions the installer was requested to go back and improve the quality of the installation, after the cavity was blown acceptably, as viewed from the installer's side of the sample. It was not possible to quantify the quality of the installations, but photographs of all test constructions were taken to document the details of the material installation.

RESULTS

After all CHB testing was completed, all construction materials used in the samples were tested in heat flow meters to characterize their thermal performance. The measured thermal performances of the individual materials were used to subtract out the effect of the acrylic sheet. A complete list of heat flow meter results for all construction materials is given in Appendix A.

Ten samples of the R-13 wall batts were tested in a 36 by 36 in. (.91 by .91 m) heat flow meter. The tests were run at a 75^{o}F (23.9^{o} C) mean temperature in accordance with ASTM Standard Test Method C518, "Steady-state Thermal Transmission Properties by Means of the Heat Flow Meter". The average measured R-value for the batts tested at a thickness of 3.5 in. (8.9mm) was 12.43 hour$\cdot^{o}$F$\cdot$ft.^{2}/Btu (2.19 m$^{2}\cdot$K/W). The batts were tested at this thickness to correspond to the installed thickness tested in the CHB. The R-13 batts are manufactured to a nominal thickness of 3.625 in. (92 mm). The R-13 product should achieve an R-value of 12.8 hr. ^{o}F$\cdot$ft^{2}/Btu (2.25 m^{2}K/W) when compressed to 3.5 in. (88.9 mm).

The measured results from the CHB testing are whole wall R-values. These whole wall R-values are a measure of the surface-to-surface thermal performance of the complete wall construction. This includes the insulation, studs, gypsum board, and sheathing. In actual application the overall R-values of a wall would also include the effects of the air films on each sample face and any exterior finish over the wood fiber sheathing. The effect of air films and exterior finishes was not measured and is not included in the reported R-values.

For the samples that included the extra layer of acrylic sheet a calculated R-value is reported which is the measured R-value of the sample with the effect of the acrylic sheet subtracted out. All reported numbers have been corrected for flanking losses and indicate the actual thermal performance of the complete wall construction. The reported numbers have an accuracy of +/- 2% for intercomparison purposes. The accuracy of the absolute value of the numbers may be slightly higher.

The samples tested and the results are given below. The units on all reported R-values are hour·°F·ft²/Btu (m²·K/W).

Test
No.

1) R-13 batts fit tightly into all cavities without the electrical and plumbing additions. R-value = 11.4 (2.01).

2) R-13 batts after the electrical and plumbing additions; batts compressed behind additions. R-value = 11.4 (2.01).

3) R-13 batts after the electrical and plumbing additions; batts slit and fit around additions. R-value = 11.5 (2.03).

4) R-13 batts after the electrical and plumbing additions; batts placed with designed abnormalities. Abnormalities consisted of a continuous 1 in. (25.4 mm) gap around the electrical outlet and a 4 in. (101.6 mm) gap at the top of one cavity. Batts compressed behind electrical and plumbing additions. Void areas consisted of 1% of total cavity area and compressed areas consisted of 3.8% of total cavity area. R-value = 10.8 (1.90).

5) Blown fiberglass insulation after electrical and plumbing additions. Insulation blown to 1.9 lbs/ft³ (30.44 kg/m³). R-value = 11.5 (2.03).

6) Dry blown cellulose insulation after electrical and plumbing additions. Insulation blown to 4.1 lb/ft³ (65.68 kg/m³). R-value = 11.0 (1.94).

7) Wet-sprayed cellulose insulation after electrical and plumbing additions. Insulation density at time of testing was 3.8 lb/ft³ (60.88 kg/m³). R-value = 11.0 (1.94).

The wet-sprayed cellulose sample was left to dry without the gypsum board layer for three days. The gypsum board was then added and the sample was weighed until its weight loss indicated that it was finished drying. At this time, 35 days after the material was sprayed, the sample was tested.

DISCUSSION

The results given above are significantly lower than the measured thermal performance of the insulation materials alone. This discrepancy is due to the effect of the wood studs acting as heat flow paths around the insulated cavities. This can be demonstrated by using the heat flowmeter results from all construction materials and ASHRAE series-parallel path calculations to predict the effects due to heat transfer through the studs.

A sample calculation is given in Appendix B. Using the ASHRAE calculations, the R-value of the wall containing fiberglass batts without electrical and plumbing additions should be 12.19 hr.°F·ft²/Btu (2.14 m²·K/W). The measured R-value for sample number one, with the acrylic sheet, was 11.65 hr.°F·°ft²/Btu (2.05 m²·K/W), 4.4% lower than the calculated value. Calculations were made before the effect of the acrylic sheet was subtracted off the measured sample R-value.

CONCLUSIONS

The results of the testing show that when properly installed, there is little difference between the thermal performance of a wall construction insulated with fiberglass batts and a wall construction insulated with blown insulation. This is true even with a significant amount of electrical and plumbing fixtures present in the wall cavities.

The thermal performance of a wall construction insulated with fiberglass batts is not affected by the addition of electrical and plumbing fixtures, even when the batts are simply compressed behind the fixtures. The presence of severe installation abnormalities, a 4 in. (101.6 mm) void in one cavity and a 1 in. (25.4 mm) void completely around the electrical outlet, resulted in only a 5% reduction in the overall thermal performance of the wall construction.

The thermal performance of the wall constructions insulated with blown materials was not evaluated with installation abnormalities. In fact, the installation quality of the blown samples tested was better than could be expected in actual constructions. The better installation resulted from the correction of baseball-sized voids which were not visible from the netting side of the cavities, but which were detected by viewing through the clear acrylic sheet that formed the back of the cavities.

This testing shows that when normally accepted installation practices are followed, the thermal performance of a wall construction is not dependent on whether the insulation is in the form of batts or blown products. An exception to this conclusion would be any degrading of thermal performance which may have occurred if the voids detected on the back side of the blown materials had not been corrected.

APPENDIX A

Heat Flowmeter Tests of Construction Materials

All testing was performed in accordance with ASTM C518 with a 75°F (23.9°C) mean temperature. In all cases several specimens were tested and the results were averaged. When testing materials with thicknesses less than 1 in. (25.4 mm), the material was layered up and the resulting R-value calculated based on the material thickness as used in the sample construction. The accuracy of all reported values is +/- 2%.

MATERIAL	R-VALUE hr.·°F·ft.^{2}/Btu	R-VALUE m^2·K/W
Gypsum Board - 1/2 in. (12.7 mm)	.45	.079
Wood Fiber Sheathing - 1/2 in. (12.7 mm)	1.20	.211
Acrylic Sheet - 1/4 in. (6.4 mm)	.25	.044
2 X 4 Studs - 3.5 in. (88.9 mm)	5.30	.932
Fiberglass Batts - 3.5 in. (88.9 mm)	12.43	2.185

APPENDIX B

Sample Calculation of ASHRAE Parallel Path Analysis

Calculation was made on test samples containing gypsum board, acrylic sheet, studs, fiberglass batts, and wood fiber sheathing. Based on the fact that the acrylic sheet has a relatively high thermal conductivity, the Isothermal Plane Calculation method was used. Only one heat transfer path existed through all sample layers except the cavities where heat flow followed parallel paths through the studs and the fiberglass-filled cavities.

The total surface-to-surface resistance to heat flow is then:

$$R_T = R_1 + R_2 + R_3 + R_4 \tag{1}$$

where

R_T = Surface-to-surface R-value
R_1 = R-value of gypsum board
R_2 = R-value of acrylic sheet
R_3 = R-value of stud/fiberglass batt composite
R_4 = R-value of wood fiber sheathing

R-value of stud/fiberglass batt composite is calculated by parallel path method as follows:

$$A_T/R_3 = A_S/R_S + A_f/R_f \tag{2}$$

where

A_T = total area of sample
R_3 = R-value of stud/fiberglass batt composite
A_S = area of wood studs
R_S = R-value of wood studs
A_f = area of fiberglass batts
R_f = R-value of fiberglass batts

Substituting the heat flow results given in Appendix A into Equation 2 along with the following area values:

total area of sample	= 80.0 ft^2 (7.43 m^2)
area of wood studs	= 12.3 ft^2 (1.15 m^2)
area of fiberglass batts	= 67.7 ft^2 (6.29 m^2)

results in a R-value of the stud/fiberglass batt composite of 10.30 hr.·°F·ft^2/Btu (1.81 m^2·K/W). Substituting this value into equation 1 along with the heat flowmeter results from Appendix A gives a surface to surface R-value of 12.19 hr.·°F·ft^2/Btu (2.14m^2·K/W).

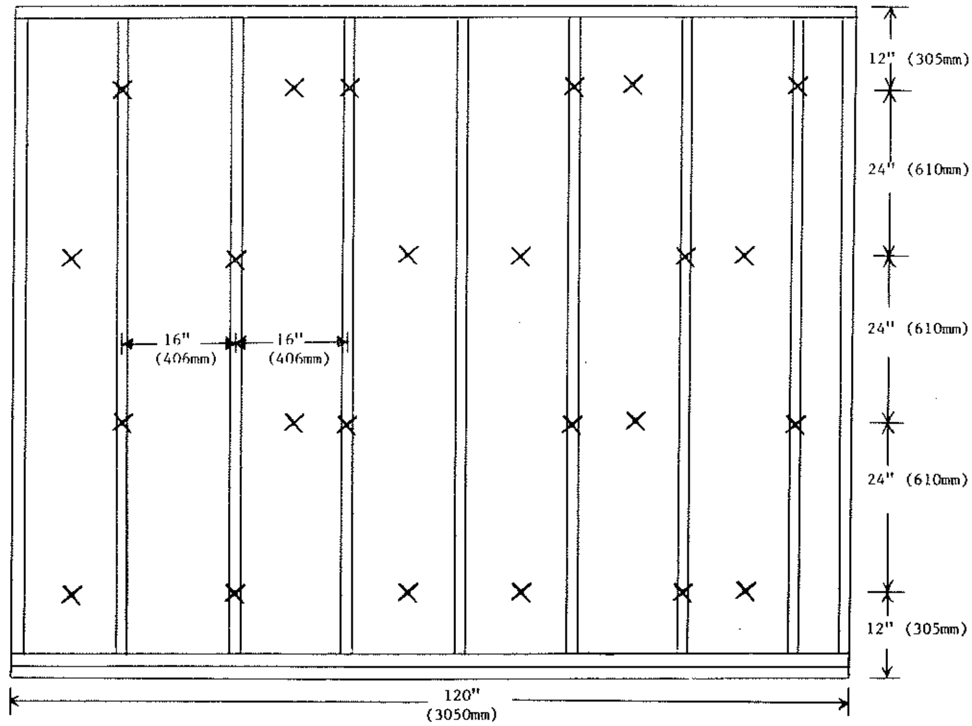

Figure 1. *Sample frame construction and surface thermocouple locations "X". Drawing shows sample viewed from climatic chamber. Thermocouples placed in similar locations on metering chamber side.*

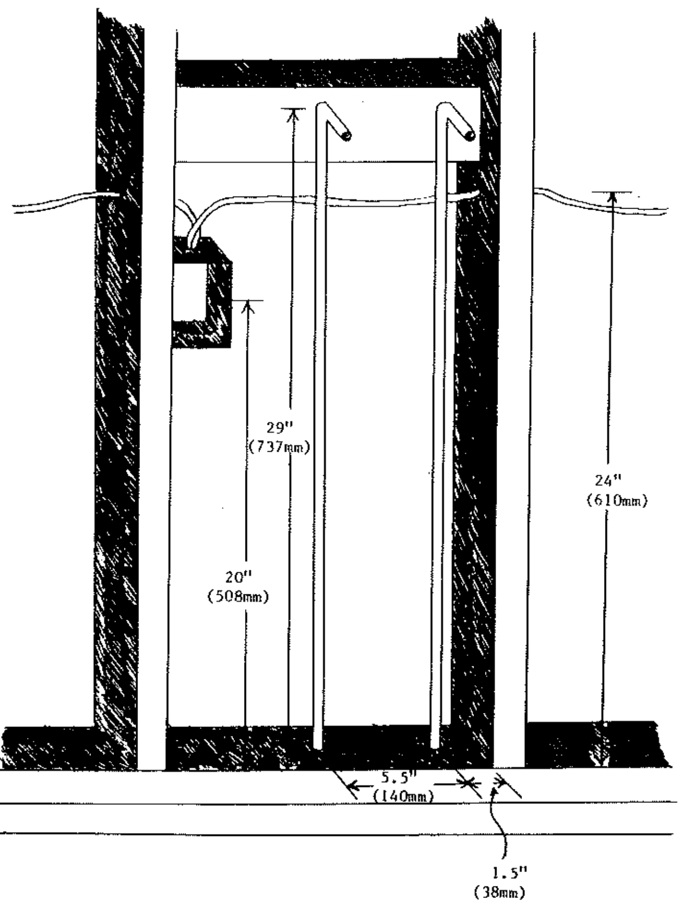

Figure 2. *Electrical and plumbing additions, viewed from metering chamber.*