SEALING IN THE HEAT

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ABSTRACT

This case study is set up to measure infiltration through cracks in the wall of a residential bedroom. The room being studied experiences much colder temperatures than the rest of the house. The point of the case study is to help increase the thermal comfort of the room by exploring heat loss and ways to fix it. The cracks in the wall of the bedroom will be caulked in an attempt to lower levels of infiltration. If caulking the walls lowers infiltration levels, an expected drop in heat loss will occur. If the room's thermal comfort does not increase, it should be noted that poor insulation is the main cause of heat loss rather than infiltration through cracks. Any outcome of this case study, whether the hypothesis is proven or not, will help give insight to why the room temperature is so much lower than the rest of the house, and as such, will help create solutions for improving thermal comfort.

1. INTRODUCTION

The space being studied is a small bedroom on the lower level of a single-family house. The room was chosen for the study because it is much colder than the other rooms of the house. The room leaves a lot to be desired thermally, with a large wall of windows on one face of the room and a non-insulated concrete masonry unit (CMU) wall on another. Large cracks in the CMU wall appear to be a significant source of heat loss in the space. When a hand is placed near a crack, the movement of cold air can be felt. Although there are many other possibilities for heat loss in the room, the case study being presented is attempting to isolate the effects of infiltration. Infiltration levels will be tested by using the Minneapolis Blower Door. The solution proposed to lower infiltration is to caulk the large cracks, which appear to be a main source of infiltration. If the blower door test shows that infiltration levels are decreased as a result of caulking, subsequent analysis of room temperatures will be made. Through the measurement of interior and exterior temperature, the data can be used to help show whether or not the caulking had an impact on the temperature of the space. If it is shown that caulking does not make any measurable increase in temperature, the study will focus on infiltration and its implications.

2. HYPOTHESIS

Caulking cracks in the exterior masonry wall will reduce infiltration through the cracks and increase wintertime room temperatures by an average of three degrees Fahrenheit throughout a week.

3. METHODOLOGY

Before caulk is applied to the exterior masonry wall of the room, preliminary temperature readings will be taken and a Blower Door test will be completed.

Temperature Readings:

- Two HOBO U12 Dataloggers will be used to measure temperatures within the house. The first will be set up in a central location of the bedroom in order to measure the temperature of the room. The second will be set up in the main floor hallway, which contains the thermostat. This HOBO will measure the temperature in order to reveal the ideal temperature of the room being studied.
- One HOBO Weatherproof Pendant Datalogger will be placed on the exterior of the house. This will find the exterior temperature, revealing whether any thermal changes noted after caulking are related to actual decreases in infiltration or if it is just because exterior temperatures are notably higher.
- The temperature readings will be taken every ten minutes for four days before caulking the room, and for four days after caulking the room. This will give a

broader spectrum of readings in order to better understand how decreased infiltration levels correlate to heat loss.

A Minneapolis Blower Door will be used to complete a depressurization test both before and after the exterior wall of the case study room is sealed off. The Blower Door will be set up on the door to the bedroom being studied, while exterior doors of the house will be opened in order to simulate exterior pressure on the interior walls of the room being studied. The blower door will depressurize the room to 50 Pascals, a pressure used to discover the CFM 50 level. CFM 50 is the amount of airflow in cubic feet per minute that it takes to change the pressure of the room by 50 Pascals. By subtracting the CFM 50 taken after caulking from CFM 50 taken before caulking, it will be possible to find the relative change of airflow/infiltration levels before and after the caulking.

4. DATA

Collecting data from the case study revealed that caulking made a larger impact on infiltration rates in the room than on internal temperature. Data collection revealed that temperatures before and after caulking stayed nearly identical. However, the blower door test proved that caulking reduced airflow into the room. Because caulking had no effect on temperature in the room, the study changed focus to infiltration and its implications on the room. Those include heat loss (Btu/hr), air changes per hour (ACH), and monetary savings due to reduced energy usage. While conducting the temperature studies, a malfunction occurred in the exterior HOBO Datalogger. As a result, data from a local weather station was used for exterior temperatures.

4.1 TEMPERATURE DATA

It was hypothesized that caulking the wall would reduce the rate of infiltration and subsequently raise internal temperature within the study room. The following graph represents the data collected from the HOBO U12 Dataloggers used in the experiment.

FIG. 1: GRAPH OF TEMPERATURE VERSUS TIME, OVER THE COURSE OF THE CASE STUDY

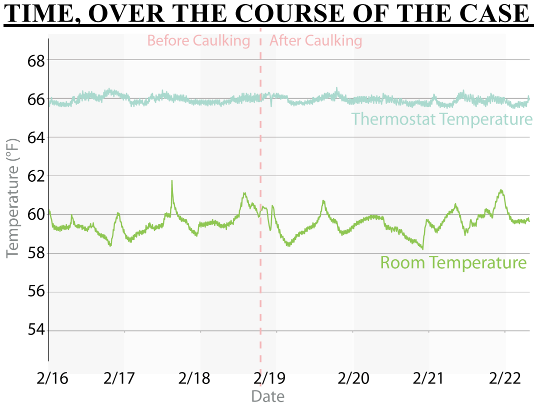

Fig. 1 shows the room temperature before and after caulking the wall. The temperature recorded near the thermostat in the main room of the house stays constant over the course of the study, indicating that the study room is not staying at the ideal temperature of the house. **Fig. 1** also shows that the study room has larger fluctuations in temperature, while the room containing the thermostat remains nearly constant. The temperature trends before and after caulking remain unchanged.

TABLE 1: AVERAGE TEMPERATURES, BEFORE AND AFTER CAULKING

	Interior	Exterior*
Average Temperature Before (°F)	59.52	38.75
Average Temperature After (°F)	59.57	39.00

The findings in **Table 1** show that even though the exterior average temperatures were nearly identical before and after caulking, the interior temperature did not increase by any reasonable margin.

The combined data from **Table 1** and **Fig. 1** disprove the hypothesis that caulking the walls will increase the room's temperature. The constant temperature could be attributed to a reduction in the run time of the heater. Infiltration may also be a small portion of the room's total heat loss, and as such, caulking the walls may make a very miniscule impact on total heat loss. Those two ideas will be further analyzed when heat loss is explored within the results of the blower door test.

*Exterior temperature data was gathered from a local weather station (4).

4.2 INFILTRATION TEST RESULTS

The blower door test showed that caulking improved the air-tightness of the study room. The blower door was used to find the cubic feet per minute of air change at 50 Pascals (CFM50) before and after caulking. The resulting information can be used to find heat loss and natural infiltration rates in the room.

TABLE 2: BLOWER DOOR TEST RESULTS

CFM50 Before Caulking	1200 CFM50
CFM50 After Caulking	1100 CFM50
ΔCFM50 Due to Caulking	100 CFM50

Caulking reduced airflow in the room by 100 CFM50. This data indicates that caulking the exterior wall has a large impact on infiltration levels within the room.

5. ANALYZING DATA

Although caulking cracks in the wall had little effect on the room's temperature, it had a large effect on infiltration levels. Because the reduction in infiltration levels was so prominent, analysis will focus on the results of the blower door test.

5.1 CHANGING CFM50 TO CFM

CFM50 is the air change of the room in cubic feet per minute at 50 Pa of pressure. In order to use the CFM50 for further calculations, it must be adjusted to the natural CFM. That is accomplished by dividing CFM50 by the N-Factor for Eugene. N is a correction factor that makes a correlation between the blower door pressurization test and average infiltration rates. The value of N is based on local weather conditions and varies by region. The N-factor is based on wind levels, stack affect, types of leaks, and numbers of levels. Eugene's N-factor is 23. (Meier)

CFM50 to CFM:

$$\text{CFM} = \frac{\text{CFM50}}{\text{N - factor}}$$

$$\text{CFM} = \frac{100}{23} = 4.4$$

The reduction of air infiltration due to caulking is 4.4 cubic feet per minute. This value can be further extrapolated to find the rooms reduction in air changes per hour (ACH) as well as reduction in heat loss in the room and its subsequent energy savings.

5.2 AIR CHANGES PER HOUR (ACH)

ACH is the number of air changes per hour that a room experiences.

CFM to ACH:

$$\text{ACH} = \frac{(\text{CFM} \times 60\,\text{min/hr})}{\text{room volume in ft}^3}$$

$$\text{ACH} = \frac{(4.4\ \text{CFM} \times 60\text{min/hr})}{1488\text{ft}^3 \times}$$

$$\text{ACH} = 0.18$$

Caulking the wall decreased the room's air changes per hour by 0.18 ACH.

5.3 CHANGE IN DESIGN HEAT LOSS

The q-value, or the change in design heat loss, from caulking the walls can be measured using the design heat loss equation. The ΔT is calculated using Eugene's winter outdoor design temperature and the interior design temperature. (Grondzik et al.) Outdoor design temperatures are lower than normal temperature averages, skewing the results to slightly higher values. The q-value reveals the reduction of heat loss in Btu/hr that the case study room achieved.

$$q = (\text{cfm}) \times 1.1 \times \Delta T \text{ in } ^\circ\text{F}$$

$$q = (4.4) \times 1.1 \times (65 - 25.6^*)$$

$$q = 190.7\text{Btu/hr}$$

*25.6°F is the outdoor winter design temperature for Eugene. The value is found in Appendix B of MEEB. (Grondzik et al.)

*1.1 is a constant derived from the density of air at 0.075 lb/ft^3 under average conditions, multiplied by the specific heat of air (heat required to raise 1 lb of air 1°F, which is 0.24 Btu/lb °F) and by 60 min/h. The units of this constant are Btu min/ft^3 h °F. (Grondzik et al.)

A reduction of 190.7 Btu/hr is encountered as a result of caulking the leaky wall. Because the heat loss is based on wintertime design temperatures, which are lower than the actual average temperatures, the calculated savings in heat loss is higher than the actual savings, but serves as a good estimate.

5.4 MONETARY SAVINGS FROM REDUCED HEAT LOSS

The values obtained from the reduction of heat loss calculation can be used to find the monetary savings attributed to it.
Btu to kWh to Monthly Savings:

$$1 \text{ Btu} = 0.000293 \text{ kWh}$$

$$190.7 \text{ Btu} = (190.7 \times 0.000293) = 0.056 \text{ kWh}$$

$$0.056 \text{ kWh} \times 24 \text{ hr} = 1.341 \text{ kWh/day}$$

$$1.341 \text{ kWh/day} \times 30 \text{ days} = 40.23 \text{ kWh/month}$$

$$40.23\text{kWh/month} \times (\$0.02887 + \$0.04356) = \$2.91/\text{month}$$

Roughly $12.00/year in savings will be achieved as a result of caulking the wall, assuming an estimated four heating months are encountered during winter in Eugene.

5.5 CALCULATING REDUCTION OF ENERGY USE INTENSITY AND CARBON EMISSIONS

The calculated reduction of Btu/hr can be used to estimate reduction of the room's Energy Use Intensity (EUI) and its annual CO_2e.

This figure only takes into account the amount of time that the heater will be in use, an estimated 120 days, rather than a 365-day reading. This is because a heater will not be in use the remainder of the year. The number can only be roughly estimated through these equations.

EUI:

$$1.341 \text{ kWh/day} \times 120 \text{ days/year} = 160.92 \text{ kWh/year}$$

$$\frac{160.92 \text{ kWh/year}}{186 \text{ ft}^2} = 0.865 \text{ kWh/ft}^2\text{/year}$$

$$0.865 \text{ kWh/ft}^2\text{/year} \times 3412 \text{ Btu/kWh} = 2952 \text{ Btu/ft}^2\text{/year}$$

$$\text{Reduction of EUI} = 3011.36 \text{ Btu/ft}^2\text{/year}$$

CO_2e:

$$CO_2e = (1.670 \text{ lbs/kWh}) \times (0.865 \text{ kWh/ft}^2\text{/year})$$

$$\text{Reduction in } CO_2e = 1.44 \text{ lbs/ft}^2\text{/year}$$

In one year the caulking will save 268 lbs of CO_2 ($1.44 lbs/ft^2/yr \bullet 186 ft^2$) According to the EPA on gallon of gasoline emits 19.4 lbs of CO_2 into the atmosphere (Emission Facts). By caulking the walls, emissions savings will be equivalent to the use of 13.8 gallons of gasoline (268lbs/19.4lbs/gallon of gasoline). Furthermore, the U.S. Bureau of Transportation Statistics states the average fuel efficiency of cars in the U.S. is 22.6 mpg (Average Fuel Efficiency). The reduction in CO_2e as a result of caulking the room's walls is equal to the CO_2 emitted from a car on a drive from Portland, OR to Vancouver, British Columbia: 313 miles (22.6mpg•13.8gallons=312miles).

6. ANALYTICAL CONCLUSIONS

As the data showed, there was no temperature change in the study room as a result of caulking the wall. This result disproved the hypothesis that caulking the wall would increase the interior temperature by an average of three degrees over a week. However, a decrease in infiltration was observed. The hypothesis assumed a correlation between temperature and rate of infiltration, but no correlation could be observed. It can be inferred that other conditions may have changed as a result of the caulking. For example, the heater may have come on less frequently as a result of lowered heat loss. As seen in data calculation 5.3, the amount of heat loss was reduced by 190.7 Btu/hr. Because the heat loss was reduced without an increase in temperature, it can be reasonably hypothesized that the heater ran with a parallel reduction in heat output.

Another possible explanation for the lack of temperature gain in the room is that the reduction in heat loss due to caulking was minimal compared to the total heat loss of the room. Heat could be lost through other means, such as poor insulation of CMU wall, low R-value windows, and heat loss through the room's slab-on-grade floor.

7. CONCLUSIONS

Although there was no temperature gain in the room, caulking the wall still proved to be beneficial because of reduced air infiltration rate, reduction in heat loss, and a correlating reduction in energy costs and CO_2 emissions.

Although the hypothesis was disproven, a reduction in rate of infiltration was measured. Nonetheless, caulking the walls still proved to be beneficial because it reduced the overall heat loss of the house. Even small changes can make a large impact over time, as shown in section 5.4, where monetary savings from reduced heat loss were calculated. Caulking is a simple solution to the common problem of high infiltration in houses. Although thermal comfort may not be improved by caulking, benefits such as reduced heat loss, reduced energy costs, and reduced emissions still exist.

8. ACKNOWLEDGEMENTS

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