THERE'S MOLD IN MY BATHROOM!
A STUDY OF RH, TEMPERATURE, AND THE GROWING CONDITIONS OF MOLD

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ABSTRACT

The bathroom of the house at 1740 East Ave in Eugene Oregon has a consistent mold problem. According to Healthy Housing (Ray Ranson, pg 140) mold will grow if the relative humidity exceeds 70% for more than 12 hours per day. This study examines the temperature and relative humidity (RH) conditions in the bathroom to determine if the bathroom meets the standards for a healthy bathroom as outlined in Healthy Housing. It is our hypothesis that the data will not meet the above standards. To test this, temperature and humidity readings were taken in the bathroom, as well as heat flux transducer measurements between the bathroom ceiling and the attic. Data collected shows readings above 70% RH for more than 12 hours per day, confirming our hypothesis.

1. INTRODUCTION

The house studied is an older rental home in Eugene, Oregon, (see Fig. 1) and is the current residence of one of the authors of this study, Brita Carlson. As is seemingly typical with older rental houses, there are heat and humidity issues. The occupants informed us that the ceiling in the bathroom is a constant breeding ground for mold and needs to be cleaned regularly. We quickly realized this could be a good case study that would force us to look at a number of factors that might lead to this "moldy" environment.

The bathroom is on the second floor of the house. It is the only bathroom in the house and is shared by the three occupants. Its ceiling is shared by the roof, as well as the attic (which is partially finished and has no insulation in the roof). There is an operable window in the bathroom that is left closed in the winter, as well as a fan that blows air outside through an exhaust pipe.

Mold will only grow under certain conditions. There are many contributing factors, of which an easily measured factor is RH. According to Healthy Housing, "mold growth occurs when RH exceeds 70% for long periods, or about 12 hours per day" (pg 140).

Condensation in bathrooms can also contribute to mold growth. Also from Healthy Housing, "Where water vapor levels are high, condensation can encourage mold, fungi, and other micro-organisms to grow on moist surfaces" (pg 140). Condensation can occur when the surface temperature reaches the dew point. The dew point is a function of the RH and air temperature. If the dew point of the air reaches the surface temperature of the ceiling, for instance, condensation would form on the ceiling.

Fig. 1: Brita's home in Eugene, OR

In general, mold growth in the home is not a promoter of good health. Per the Healthy Housing book, the types of molds that often grow in homes, "…are known to be associated with elevated rates of respiratory illness and certain allergies: many molds in damp houses are allergenic and provide food supply for house mites, which are also potential allergens" (pg 140).

2. HYPOTHESIS

According to The Healthy House, the thermal environment in Brita's bathroom does not meet temperature and RH standards for residential bathrooms, where RH should not exceed 70% for more than 12 hours per day (pg 140).

2.1 Inquiry Questions

What are the ASHRAE standards for residential bathrooms?
What were the standards/regulations when the house was built?
How much cfm of air does the bathroom fan ventilate?
What are the thermal properties of the window (U-value)?
How much airflow is there through the old vent for the gas furnace?
How much/what kind of insulation is in the ceiling?
What is the heat flow through the ceiling?
Where is the output for the vent?

3. METHODOLOGY

To test the hypothesis data was collected on air temperature, RH, and ceiling surface temperature using two dataloggers over a 48 hour time period. This data was compared to RH standards for residential bathrooms as outlined in the Healthy Housing book (pg 140).

3.1 HOBO Dataloggers

Our team used two data loggers to measure temperature and RH in Brita's bathroom. The data was recorded at two-minute intervals between 8:00 AM on February 16th through 8:30 AM on February 18th.

The data loggers were placed on the walls at a height of 7 feet in two locations (see Fig. 2). After logging the data it was extracted, analyzed, and compared to standards.

3.2 Heat Flux Transducer

The flow of heat through the ceiling was then measured using a heat flux transducer. The transducer was located directly above the shower (see Fig. 2) and programmed as per included instructions. Data logging was performed using a Campbell Scientific micrologger 21x. Additionally, two thermocouples were installed to measure temperature on either side of the bathroom ceiling.

Measurements were gathered by the micrologger on 5-second intervals, and stored as averages on one-minute intervals. The transducer collected heat flow data for a twenty-four hour period, from which we calculated an average U-value for the ceiling using the formula $Q = U(Tf-Ti)$.

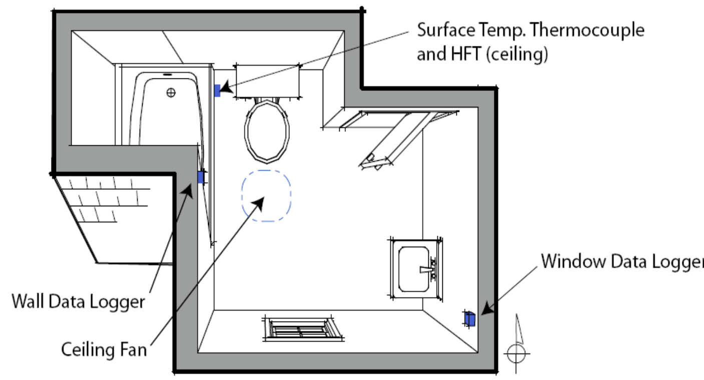

Fig. 2: Plan of Brita's bathroom showing data logger locations

4. DATA AND ANALYSIS

Ray Ranson gives a recommended maximum value for RH on page 140 of the Healthy Housing book:

> "Mold growth occurs when RH exceeds 70% for long periods, or about 12 hours per day"

In concurrence, The Healthy House by Sydney and Joan Baggs states on page 127:

> "In buildings, the RH should not fall below 40 per cent or exceed 70 per cent."

4.1 RH Data and Analysis

RH levels in Brita's bathroom did indeed exceed the 70% maximum for extended periods. The data logger near the window showed an average RH of just under 70%, with several large peaks approaching 95% RH (see Fig. 3). The data logger located at the wall had a slightly lower mean RH but still only 4% below the recommended maximum (see Fig. 4). Both data loggers recorded RH measurements that exceeded the 70% threshold for more that 12 hours in a given 24-hour period.

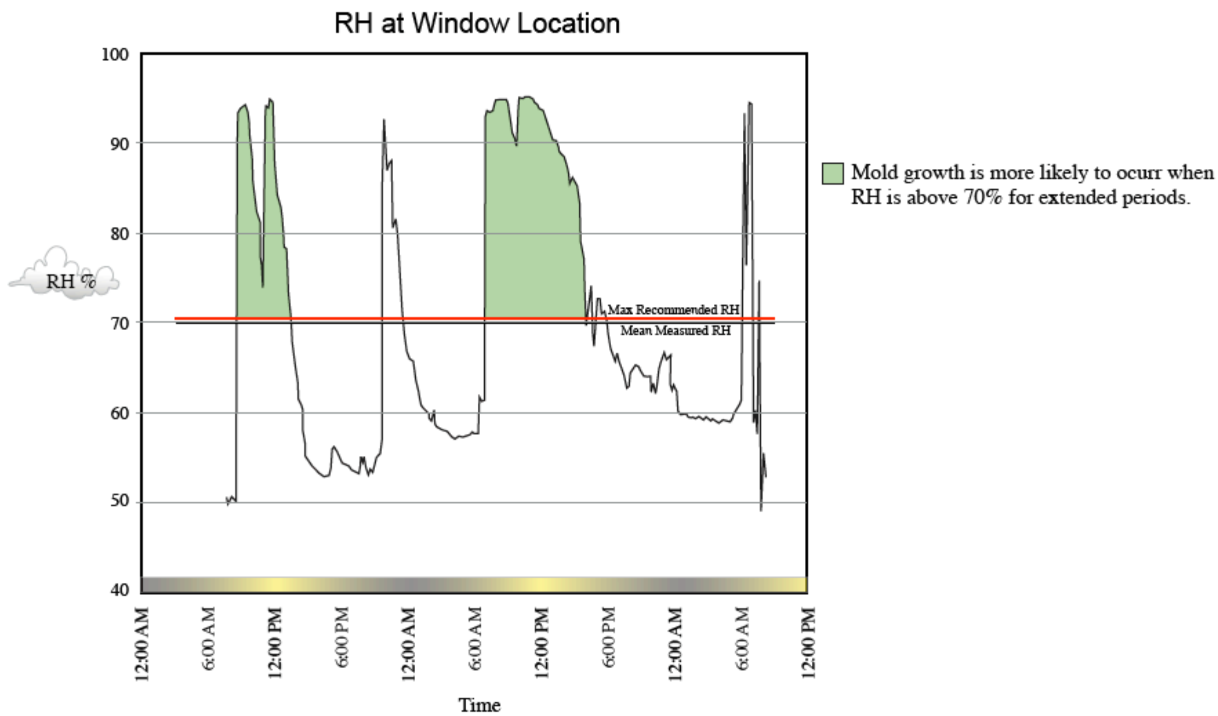

Fig. 3: RH over time from the window data logger

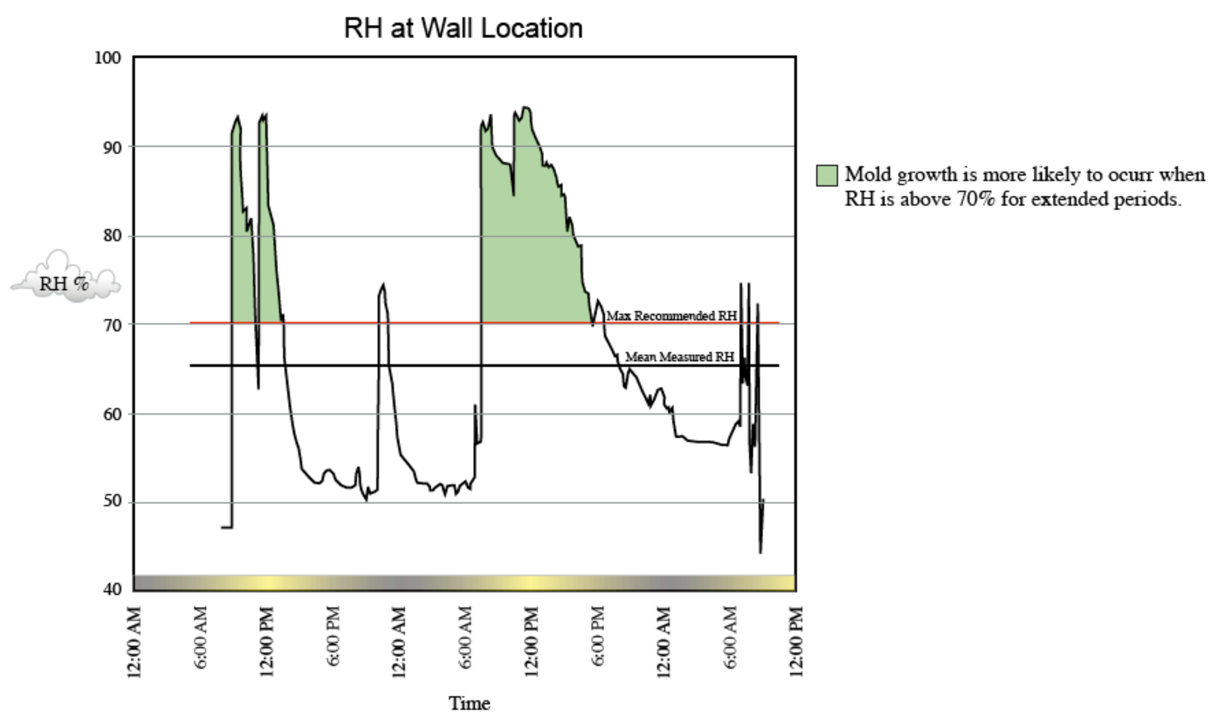

Fig. 4: RH over time from the wall data logger

4.2 Heat Flux Transducer Results

Measurements from the HFT (see Fig. 5) did not yield consistent values for the insulating properties of the bathroom ceiling. One possible explanation for the change in heat flow despite a consistently positive value for delta T is that the attic floor boards behaved more like isolated thermal mass than a thermally connected piece of the bathroom ceiling. Large gaps between boards in the attic allowed significant air flow around each board, creating heat exchange independent of heat flow through the ceiling. A better location for the HFT would be the interior surface of the bathroom ceiling. Because the measurements did not yield meaningful data for our purposes, we show it only as auxiliary data.

5. CONCLUSIONS

Brita's bathroom has a serious problem with RH control. The high humidity in Brita's bathroom is likely the reason for moisture condensation, which can lead to mold growth. Per the Healthy Housing book "condensation dampness occurs when air saturated with water vapor condenses onto surfaces as soon as the temperature drops – the warmer the air, the more moisture it can hold".

It is clear that the spikes in temperature and RH in these graphs correspond to showers. When the data is narrowed to look at a smaller time frame one can see the dramatic changes in both RH and temperature due to showers in this space (see Fig. 6 on following page).

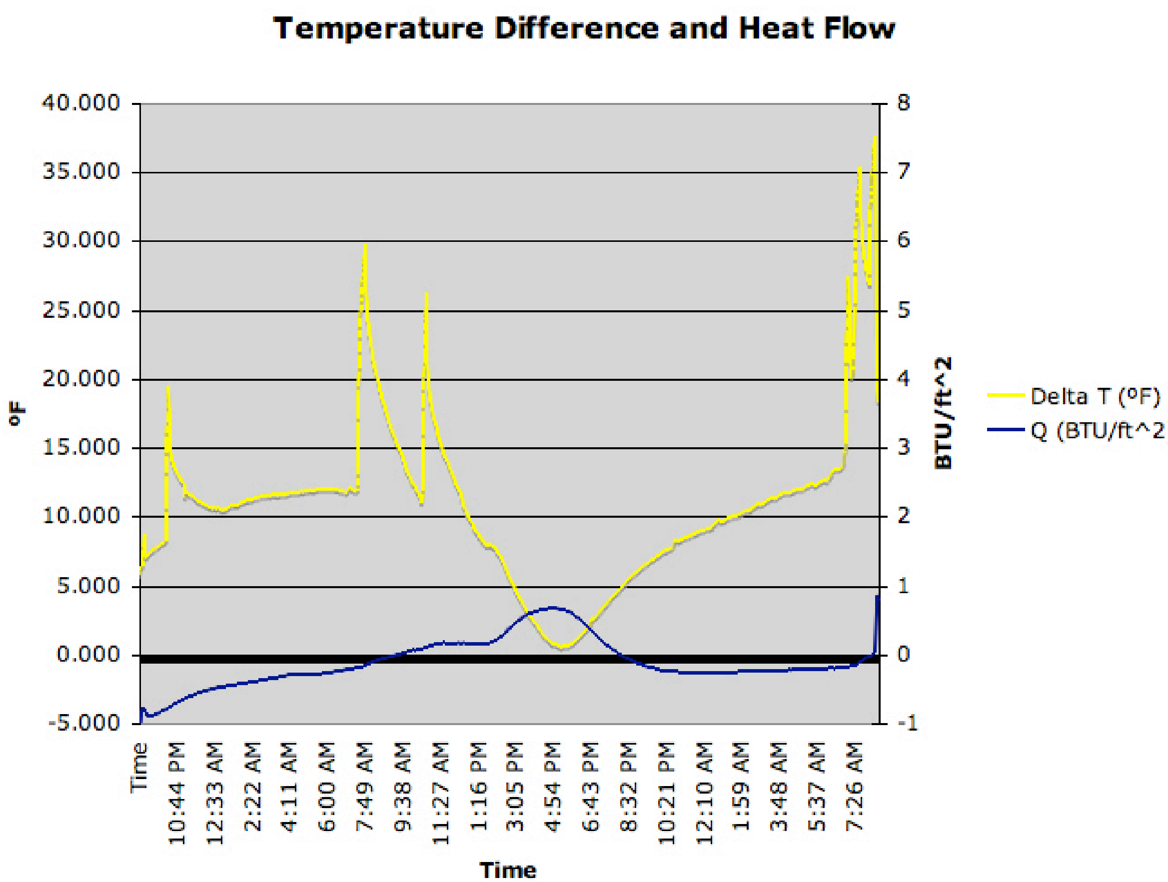

Fig. 5 – Temperature & Heat Flow over time

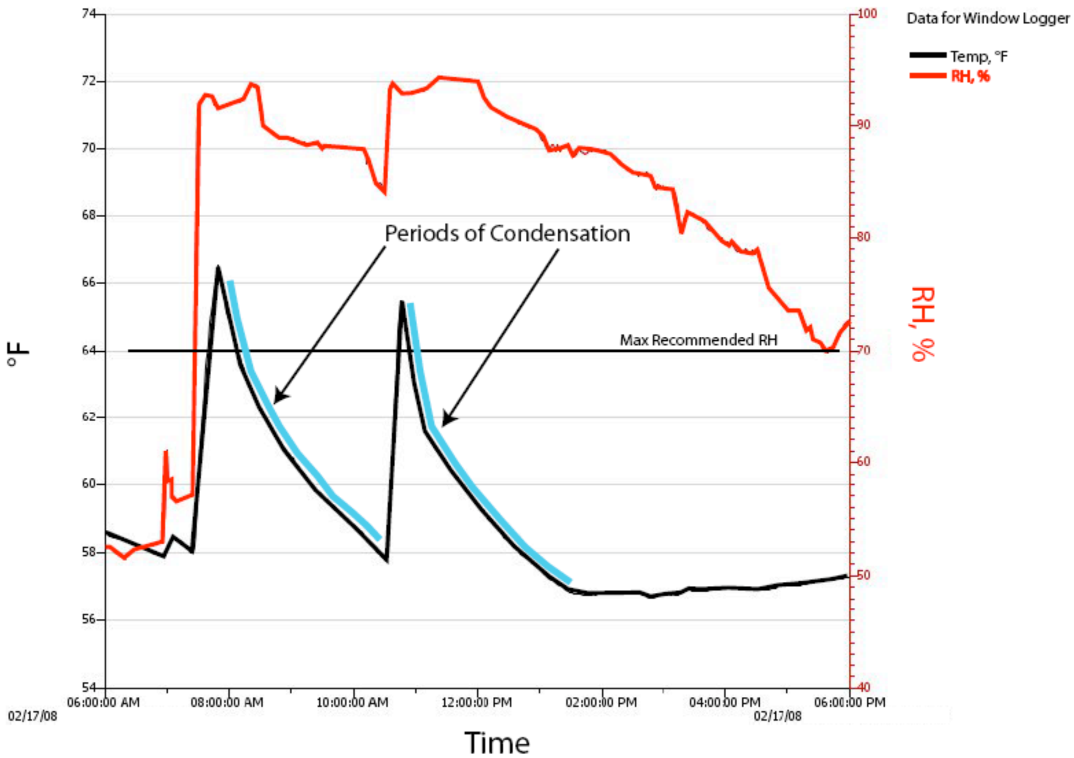

Fig. 6: Temperature & RH plotted from 6:00 AM on 02.17 thru 6:00 PM that same day

At roughly 7:30 AM on Sunday the 17th of February both the temperature and RH are at acceptable levels. The temp in Brita's bathroom is a cool 58 degrees and the RH is an acceptable 53%. At this moment, the shower is turned on and a rapid change takes place for both temp and RH. During this shower the temp spikes up to 66.5 degrees and the RH skyrockets to over 90%. As the Healthy Housing book describes, these are conditions ripe for condensation (warm air that is super saturated with water vapor). But for condensation to occur, the air temperature must drop. By roughly 10:45 AM the air temperature in Brita's bathroom has reset to a cool level of 57.7 degrees. The large amount of water vapor then condenses on bathroom surfaces, especially the ceiling over the shower. After that first shower early in the morning, and aided by a second shower later, the RH does not return below the 70% mark till almost 6:00 PM that night.

Per the Healthy Housing book, condensation is considered serious when it is found, "on the surface of walls, floors, and ceilings". This is exactly the case in Brita's bathroom. Direct observation revealed condensation on the bathroom ceiling and on the window, among other locations (see Fig. 7 on this page and Fig. 8 on the following page).

Fig. 7: Condensation on the bathroom ceiling

Fig. 8: Condensation on the bathroom window

This data suggests a strong link between pervasive mold growth and thermal conditions in Brita's bathroom. The combination of high humidity levels and condensation is the fertile soil for mold and an overall unhealthy micro environment.

Another negative effect of RH and condensation is damage and erosion of the building materials themselves. The conditions in Brita's bathroom are ideal for plaster damage and rotting of woodwork. This could be a possible reason for the degraded quality of the insulation in the ceiling above the bathroom (see Fig. 9).

Fig. 9: Exposed insulation in the attic, showing some degradation

6. LESSONS LEARNED

This study leads to three factors that could be improved upon to help reduce the RH and subsequent condensation and mold problems in Brita's bathroom. These are ventilation, heating, and insulation.

6.1 Ventilation

No experiments were done to evaluate the effectiveness of the ventilation fan in Brita's bathroom. ASHRAE standard 62-1989 stipulates a target of 50 cfm intermittent or 20 cfm continuous or operable windows. Brita's bathroom does have an operable window that is rendered useless during the cold fall and winter months. Unscientific interviews revealed that the window is never opened during the winter.

The bathroom has an air grate in the floor that is hooked to the original oil furnace. The oil furnace is now decommissioned and the only source of bathroom heat is from an electric baseboard heater. Therefore the only fresh air that can be circulated into the room is from the window.

The ceiling fan should help with removing the highly moist air. The problem is that the fan is linked to the light switch. When the bathroom is not occupied, the light is off, and so is the fan.

It could be helpful to replace the current fan with one that has a larger capacity and can be operated independent of the light. After showering, the fan could be left on after the occupant leaves to aid in reducing RH.

6.2 Heating

During the winter, Brita's bathroom is a cool place. Temperatures dropped to near 52 degrees and averaged around 55 degrees when the shower was unoccupied. During showers, the average temperature was roughly 68 degrees. The showers are therefore heating events and when the showers are over the temperature rapidly cools to its previous level. These are prime conditions for condensation.

Maintaining a consistently higher temperature would help prevent condensation. Not knowing the effectiveness of the electric baseboard heater, it is difficult to say whether it could help maintain a more steady temperature if it were left on. One possible step towards reducing condensation would be to leave the heater on for longer periods. The potential drawback of this approach is the additional expense incurred via the electric bill.

6.3 Insulation

This is an old home and is not well insulated. There is no insulation in the roof, including the part that forms the ceiling over the shower. The insulation that is in the ceiling of the bathroom is old and thin. It is fair to assume the insulation in the exterior wall is weak as well.

Improving the insulation in this bathroom would help to moderate temperature swings, and thus help the condensation problem.

In conclusion the data that was collected in this study proves the hypothesis that the thermal air quality in Brita's bathroom is not meeting certain specifications. The present conditions involve high levels of RH and pervasive condensation, which creates a prime environment for mold growth. There are several steps that could be taken with regards to ventilation, heating, and insulation that could help alleviate these symptoms and improve the thermal conditions and hopefully reduce the instances of mold growth.

7. REFERENCES

1. Ranson, Ray. Healthy Housing – A Practical Guide. London: E & FN Spon, an imprint of Chapman & Hall, 1991.
2. Baggs, Sydney and Joan. The Healthy House. Sydney, San Francisco: Harper Collins Publishers, 1996.
3. ASHRAE Standard 62-1989 (Table 2.3 – Outdoor Requirements For Ventilation of Residential Facilities)

8. ACKNOWLEDGEMENTS

Thanks go to Brita's housemates for putting up with our intrusion into their bathroom. Thank you to Britni Jessup for getting us set up with the heat flux transducer. And much thanks to Rachel Auerbach, our GTF, who has consistently given us thoughtful comments and suggestions to help us complete this study.