# HELP, IT'S RUNNING AND I CAN'T TURN IT OFF!
## AN INVESTIGATION OF HUMIDITY CONTROL AND TIMER OPERATED FANS

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ABSTRACT

Bathrooms at the Spencer View Apartments in Eugene, Oregon are equipped with exhaust fans controlled by timers set to run four hours per day. This study examines the relative humidity (RH) at key locations in the apartment. It is our hypothesis that the fans' run time is longer than necessary to control humidity in the apartment, and therefore wastes energy. After logging the conditions created by the timer-controlled fan, we determined that fan run time did not always correlate with humidity-causing events in the apartment. In a second phase of testing, a dehumidistat replaced the timer to control the fan, aiming to maintain the bathroom ceiling below 70% RH, the maximum RH recommended for controlling mold growth. The dehumidistat-controlled fan disproved our hypothesis by significantly increasing fan run time. In addition, bathroom RH remained above 70% for more time than with the timer-controlled fan. We also researched factors regarding fan design intent and mold growth control measures.

## 1. INTRODUCTION

The apartment studied is the current residence of one of the authors of this study, Chris Deel, and his wife Colleen. They live in a two-bedroom, one-bath, 700-square foot apartment on the second floor in University Housing at the Spencer View Apartments (Fig. 1.) This housing is designed for graduate students and students with families. Located about a mile from campus (near Amazon Park), the housing complex was built in the mid-1990s in a style common to this area, with buildings clustered around common green space sharing facilities such as playgrounds and community gardens. There are 272 units of varying sizes; Chris's building consists of eight units.

Fig. 1: Spencer View Apartments

Each unit is supplied with an extensive tenant handbook upon move-in. Mold and mildew are a big concern throughout the Northwest, and thus a special notice on "Preventing Moisture Problems in Your House or Apartment" is supplied. This notice gives several instructions about the bathroom extractor fan:

- Allow the fan to run 20 minutes after showers/baths.
- Automatic timers in each unit turn the bathroom fan on automatically, "periodically" each day; notify the office if this does not happen.

- Leave the bathroom door open whenever possible, so the automatic ventilation system can have "better air circulation."

These instructions led us to believe that the intent of the bathroom fan/automatic timer system is to control mold/mildew growth in the bathroom (and possibly the rest of the unit) by reducing humidity. Casual observation indicates that the automatic ventilation timer runs the fan about 2 hours in the morning, and another 2 hours at night (as well as anytime the bathroom light is switched on). We wondered if this might be an excessive amount of ventilation time for such a small apartment, and whether the system might be wasting energy.

The timing of this project (February) is fortunate because the winter months (November - February) represent the highest levels of relative humidity throughout the day in Eugene. In February the average afternoon (low) RH in Eugene is 73% according to cityrating.com, making this time period a good time to study humidity conditions at their highest.

There are many standards for humidity in buildings. According to *Mechanical and Electrical Equipment for Buildings* (p. 141), maintaining a relative humidity beneath 60% is ideal for preventing indoor air quality issues associated with mold growth. *Healthy Housing*, by Ray Ranson states, "Mould (sic) growth occurs when RH exceeds 70% for long periods or about 12 hours a day." After examining the existing conditions in Chris and Colleen's apartment as well as the outdoor conditions in Eugene during this time of year, we determined that our goal would be too keep the RH in the bathroom under 70%.

## 2. HYPOTHESIS

The bathroom fan's automatic daily run-time is more than is required to control wintertime humidity in the apartment with 2 occupants.

## 3. METHODOLOGY & EQUIPMENT

To test our hypothesis, we decided to record existing apartment conditions, then install a dehumidistat to run the fan when relative humidity reached a certain level. By establishing existing conditions, we could compare the current fan run time to a humidity-controlled run-time, thus proving or disproving whether the fan ran more than enough to adequately control relative humidity in the apartment.

Fig. 2: HOBO data logger locations (pink bubbles)

Equipment

- Onset HOBO U12-012 data loggers in the following locations (Fig. 2):
  - bathroom east wall, just below ceiling ~7'10" high; this is assumed to be the point of maximum humidity in the apartment. (Bathroom High)
  - bathroom east wall, mid-height ~4'0" high (Bathroom Mid)
  - bathroom east wall, low ~1'6" high (Bathroom Low)
  - living room north wall, mid-height ~5'0" high (Living Room)
  - outside apartment front door, on a building column ~4'3" above second floor finish floor (Outdoors)
  - kitchen north wall, just below ceiling ~7'10" high (Kitchen)
- Honeywell model H46C1166 wall-mounted dehumidistat (voltage 240/120/24V, differential 4% to 6% RH, operating range 20 to 80% RH)
- Light fixture: standard exterior wall-mount type with compact fluorescent bulb
- Length of 2-conductor extension cord - used for connecting the dehumidistat (purchased used from BRING recycling)
- Wire nuts (purchased used from BRING recycling)

Step One: Recording Existing Conditions

In order to understand the existing humidity conditions and performance of the timer-controlled fan (Fig. 3) in the apartment, a log of temperature, relative humidity, and light was recorded at 5-minute intervals using the HOBO data loggers. Chris and Colleen kept a written log of fan run times, as well as the times of activities likely to affect apartment humidity. This data was logged from 12:00 AM on Tuesday February 16 until 11:59 PM on Saturday February 20.

Fig. 3: The bathroom fan timer control

Fig. 4: Removing the bathroom fan timer

Step Two: Selecting a Set Point

Based on our research, we determined a set point to maintain a relative humidity that seemed ideal for controlling mold growth while being reasonable in this season and climate. We knew from our preliminary data logging that there was an RH differential of approximately 5% between the highest point in the bathroom and the vertical midpoint (where we would mount the dehumidistat). Therefore we chose a set point of 65% in order to keep the highest humidity location (at the ceiling) below 70%.

Step Three: Installing the Dehumidistat

Following safe electrical working practices, we:

1. Disabled and removed the timer device (mounted inside Chris and Colleen's bedroom closet – Fig. 4)
2. Replaced the timer with the dehumidistat. Because the device needed to by physically in the bathroom, we re-used some heavy-gauge extension cord cable to extend the circuit by several feet. To simulate a realistic installation, we mounted the dehumidistat at hand height (approximately 4 feet from the floor).
3. Temporarily added the light fixture to the circuit (Fig. 6), and placed the bulb near one of the HOBO data loggers. The light is switched on whenever the fan is activated, so that intense light logged by the HOBO creates a record of the fan run times (Fig. 7).

Fig 5: The Dehumidistat

Fig 6: Testing the indicator light

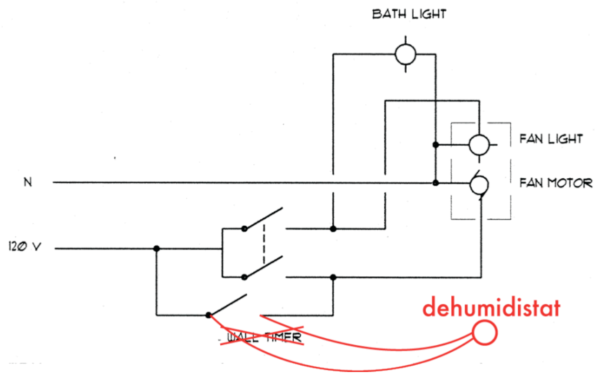


Fig 7: Wiring diagram with dehumidistat

Step Four: Revisiting the Set Point
After logging data for several days, we determined our initial set point of 65% was incorrect, as the bathroom ceiling humidity was remaining above 70% for long periods. To address this, we lowered the dehumidistat to 60% and restarted data collection.

Step 5: Recording Modified Conditions
Data logging for the fan controlled by the Dehumidistat set at 60% RH ran from 12:00 AM on Tuesday March 2 until 11:59 PM on Saturday March 6.

## 4. DATA AND ANALYSIS

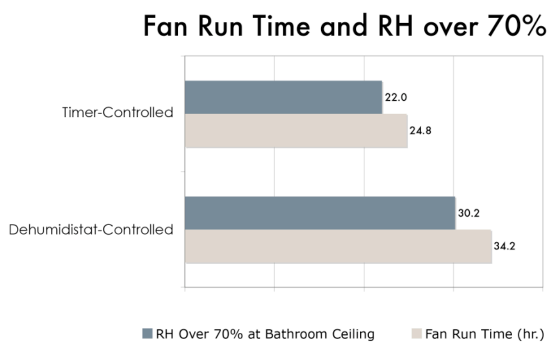


Fig. 8: Total fan run time and time spent over 70% RH

The timer-controlled fan ran for a total of 22 hours during the logging period (Fig. 8.) Since the fan runs 4 hours per day, this means that the fan ran for 2 additional hours during this five-day period. The RH in the apartment remained above 70% for nearly 25 hours, although the events that caused these RH spikes, such as showers and baking, took place for only approximately 8 hours. The fan controlled by a dehumidistat set to activate at 60% RH ran for a total of 30.2 hours during the logging period. This additional run time came as a surprise to our group, as did the 34.2 hours that the RH spent over 70%. Events causing RH spikes took place for approximately 6 hours.

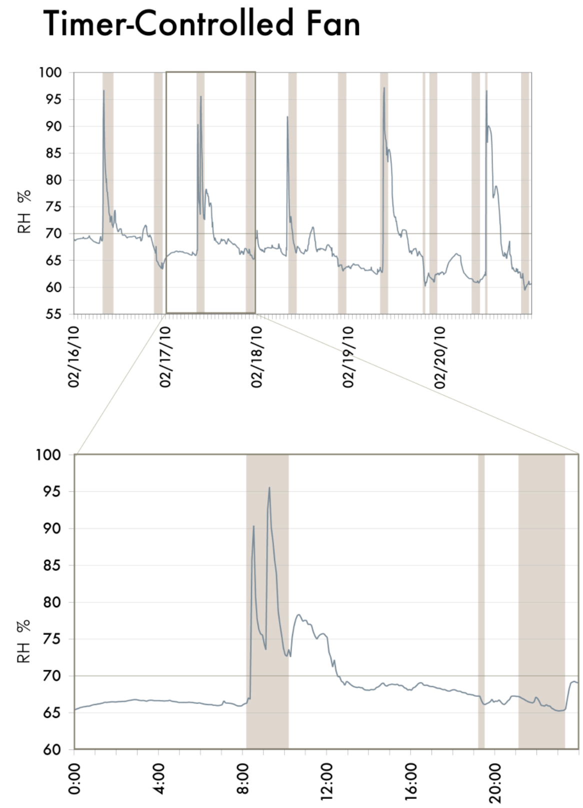


Fig. 9: Weekly and daily conditions with the timer-controlled fan.

The data collected (Fig 9) may indicate that the morning timer-controlled fan run times (8:00-10:00 AM) are well-timed for Chris and Colleen's weekday habit of taking showers in the morning. The evening (9:00-11:00 PM) timer-controlled fan run times could also address humidity in the apartment that may have accumulated earlier due to cooking projects, although it is not an exact match. The fan run times do not correlate well to weekend showers. These two-hour run periods consistently correspond to a drop in RH in the apartment. This initial data set informed our design of the humidistat-controlled fan system studied in the second logging period.

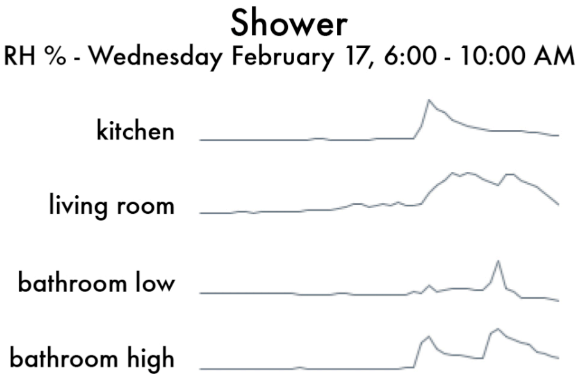


Fig 10: Morning showers' effect on apartment RH

On a typical weekday morning, Chris and Colleen take showers between 8:00 and 10:00 AM. Although the bathroom fan is running during this period, rise in humidity has a global effect on the apartment (Fig. 10), spreading to the lower parts of the bathroom, the living room, and kitchen.

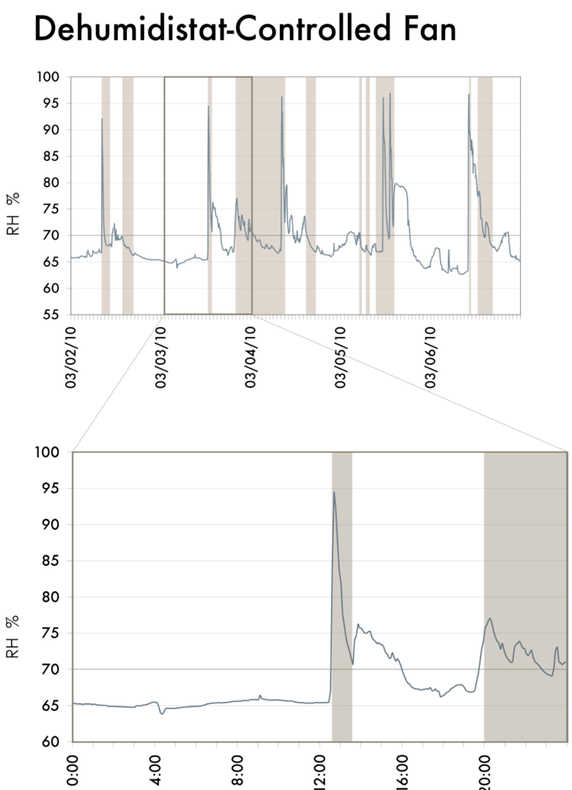


Fig. 11: Weekly and daily conditions with the dehumidistat-controlled fan.

The timing and length of the dehumidistat-controlled fan run times (Fig. 11) were more erratic and lengthy than the timer-controlled fan run times. Showers usually triggered the fan to switch on, but the fan appears to shut off before the RH comes down below 70%. In one case, the fan ran for 12 hours starting in the evening, triggered by cooking activities (which lasted 2.5 hours.) We hypothesized that this irregularity could be caused by a "float" range within the dehumidistat device, which may address a +/-5% variation in conditions rather than an exact RH value.

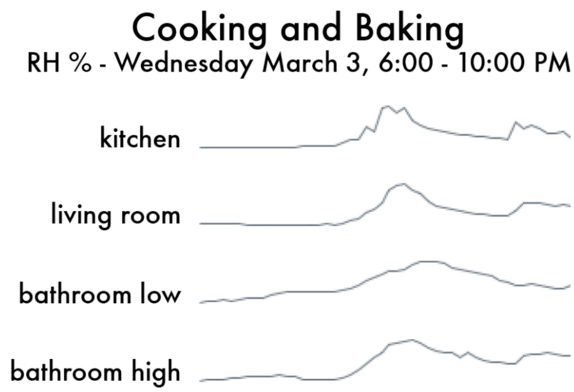


Figure 12: Evening baking's effect on apartment RH

Chris and Colleen do a lot of cooking! The cooking depicted in this graphic (Fig. 12) caused a humidity increase throughout the apartment, causing the dehumidistat to activate the bathroom fan.

We selected the same week days (Tuesday-Saturday) for each logging period to try to get an accurate picture of humidity in the apartment during both days when the residents were home and away. The days logged represent a variety of weather conditions.

## 5. CONCLUSIONS

Our hypothesis was that the timer-controlled fan ran longer than required to control wintertime humidity in the bathroom. Our experiment with the dehumidistat-controlled fan disproved our hypothesis by significantly *increasing* fan run time. Despite the increased run time, however, the bathroom-ceiling humidity remained above 70% even longer than during the timer-controlled phase. This contradiction suggests that the fan was not successfully controlling humidity. If this is the case, it raises a number of questions regarding how the fan system was intended to function and what its actual effects are.

Based on Chris's conversation with Bill Marbella from UO Housing, the design intent of the timed fan system was not only moisture control, but general indoor air quality control (as a mitigation for the building's tight envelope). Intent to ventilate the entire apartment would explain the apparent oversizing of the bathroom fan (ASHRAE standard 62.2.2007, *Ventilation and Acceptable Indoor Air Quality in*

*Low-Rise Residential Buildings* requires exhaust fan capacity of at least 50 cfm for bathrooms, while the Spencer View bathroom fans have a capacity of 110 cfm–closer to the ASHRAE standards for kitchen ventilation). But if it is true that the fan is intentionally oversized, this makes it even more surprising that it fails to keep the humidity below 70% so much of the time.

According to *Mechanical and Electrical Equipment for Buildings*, the design intent of exhaust fans is to remove excessively humid or offensive air before it can spread beyond bathrooms or kitchens, and in doing so, create "a negatively pressured area that further limits the spread of undesirable air" ( p. 134). However, humidity in the kitchen and living room rose in correlation with bathroom moisture events like showers. This suggests the negative pressure created by the fan was not adequate to control the spread of humid air from the bathroom; when the door was opened after a shower, a large amount of water vapor escaped and the air in the rest of the apartment acted as a "sink" to store this escaped moisture for hours. However, the apartment is a small semi-closed system with many variables that influence humidity–cooking, number of people present, air leakage from outside–which always makes causation difficult to determine.

Given a longer experimentation period, we have identified several avenues of inquiry that might deepen our understanding of the results from this experiment. It would be interesting to measure the actual air moved by the exhaust fan (as opposed to its rated cfm). Perhaps this could be done using a blower door, with the bathroom fan turned off, and then turning it on and recording the change in readout. Using the blower door could also tell us about the actual tightness of the envelope. The addition of a third data collection phase with the fan disconnected might be an easy way to better understand the moisture dynamics of the apartment, while providing a gauge of the overall efficacy of the fan. In addition to collecting data while the fan is disconnected, it could be interesting to replace the fan with a dehumidifier, and see how it compares with the fan for effectiveness and energy usage.

## 6. DESIGN LESSONS LEARNED

In designing and implementing this study, our team identified four factors that will impact the design of multifamily residential bathroom ventilation in the Oregon climate: ventilation, envelope, temperature, and outside events.

6.1 Ventilation. Based on materials provided on move-in and knowledge about the Oregon climate, the bathroom ventilation system appeared to be designed primarily to reduce humidity and inhibit mold growth. Ventilation can improve air quality and reduce humidity. However, the dehumidistat experiment does not clearly show that an exhaust fan is effective for reducing indoor humidity.

6.2 Envelope. The Spencer View Apartments were designed with a tight envelope for energy efficiency. The bathroom exhaust fan's large capacity suggests it is intended to improve air quality in the entire apartment. However, no air intake is provided (wall mounted heaters draw air from inside the apartment), meaning that makeup air has to come from under doors, through wall penetrations, etc. A better-designed ventilation system would use an even tighter envelope, but provide a defined inlet for makeup air, such as a heat recovery ventilator.

6.3 Temperature and Condensation. ASHRAE's *Humidity Control and Design Guide for Commercial and Institutional Buildings* provides a range for relative humidity dependent upon the dew point. This is due to the fact that mold growth occurs at the location of condensation, so cold temperatures and a high dew point can mean that mold growth will occur even with a relative humidity below 50%. Since cold surfaces can cause condensation and lead to mold growth, a further step could investigate surface temperature and dew point in the apartment. It may be possible to address these surface temperature variations through insulation. In addition, a dehumidifier could control the level of moisture in the apartment air.

6.4 Outside Events. In the close quarters and closed system of the apartment, activities in the kitchen and bathroom will significantly increase humidity in the entire apartment. It is difficult to isolate these spaces within an open floor plan. As a result, design should address ventilation from a global perspective rather than a room-by room zoned approach. While ventilation efforts should certainly be concentrated at the source, it makes good design sense to size a ventilation system to address the entire living space.

## 7. REFERENCES

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