Building Re-Tuning Training Guide: AHU Minimum Outdoor-Air Operation

Summary

The purpose of the air-handling unit (AHU) minimum outdoor-air operation control guide is to show, through examples of good and bad operations, how AHU outdoor-air operations can be efficiently controlled.

As specified in American Society of Heating, Ventilation and Air Conditioning Engineers (ASHRAE) Standard 62.1, there is a minimum amount of ventilation that must be supplied to the space being served by the AHU. This will usually be reported as a cubic foot per minute (CFM) per square foot (sf) value and CFM per person in the space. The outdoor-air fraction (OAF) is the ratio of the outdoor-air intake and the total supply air flow rate. It can be used to determine the percentage of outdoor air being brought into the building and also can be used to diagnose over- or under-ventilation when the AHU is not in economizer mode, and failures of the economizer mode (i.e., the AHU is in economizer mode but the OAF shows a smaller fraction of outdoor air than expected). Because the outdoor-air intake air flow rate is hard to measure, the OAF can be calculated as a ratio of the difference between the mixed-air temperature (MAT) and return-air temperature (RAT) and the difference between outdoor-air temperature (OAT) and RAT:

OAF = [(MAT - RAT)/(OAT - RAT)]

This calculation, however, is only meaningful when the OAT is significantly (i.e., ± 5^{o}F) different than the RAT. A common misconception is that the building automation system's (BAS's) outdoor-air damper position signal (% open) corresponds to the outdoor-air fraction, when in fact this is rarely the case. If there are no sensor errors, the OAF is the only true indicator of the percentage of outdoor air entering the building. When AHU minimum outdoor-air operation is not correctly controlled, it may go unnoticed (masked) because of the AHU's ability to heat and/or cool the air stream to meet the discharge-air temperature set point before entering the space. Failure to correct/mitigate this situation, in all likelihood, will lead to increased fan, heating and cooling energy consumption and may also lead to poor ventilation.

Data needed to verify the minimum outdoor-air operation

To analyze and detect deficiencies in the minimum outdoor-air operation, for single-duct variable-air-volume (SDVAV) AHU(s), the following parameters must be monitored using the trending capabilities of the building automation system (BAS):

- Outdoor-air damper position signal (OAD)
- Occupancy mode
- Outdoor-air fraction
- Supply fan speed
- Outdoor-air temperature
- Return-air temperature
- Mixed-air temperature

The recommended frequency of data collection is between 5- and 30-minutes. If the OAF is not found in the BAS, it should be calculated using the above equation and added in the trend logs. When analyzing the minimum outdoor-air operations of the AHU, the trends to look for include:

- Is outdoor air sufficient for ventilation or is over-ventilation occurring?
- Does the outdoor-air damper close during unoccupied times?

Is outdoor air sufficient for ventilation or is over-ventilation occurring?

To determine if sufficient outdoor air is being supplied for ventilation, the outdoor-air fraction should be calculated and checked during times when the AHU is not economizing. If the OAF is calculated in the BAS, it should be plotted with the outdoor-air damper position signal, occupancy mode, and outdoor-air temperature versus time. This plot will show the building operator if the OAF is greater than the minimum OAF required for ventilation during times when the AHU is not economizing. Figure 1 below shows an example where the OAF tracks the OAD position signal between 0% open to 100% open during a 2-day period in May. The outdoor-air temperature varies between 40^{o}F and 60^{o}F, and the building is occupied from 6:00 AM to 6:00 PM (1 corresponds to occupied, and 0 corresponds to unoccupied from the occupancy mode).

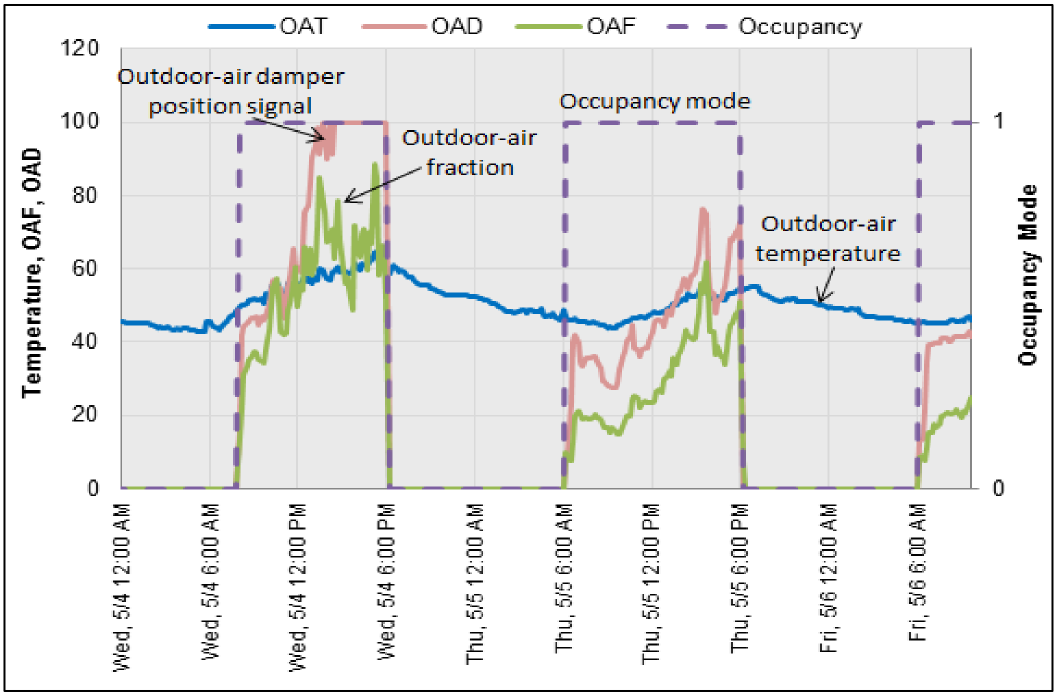

Figure 1: Plot of outdoor-air temperature, outdoor-air fraction, occupancy mode, and outdoor-air damper position versus time. This plot is used to verify that the outdoor-air fraction and outdoor-air damper position signal match.

From Figure 1, it appears that the OAF tracks the OAD position signal fairly well, although when the damper is fully open, the OAF is not 100%. There are number of possible reasons for this difference: 1) accuracy of temperature sensors, 2) location of temperature sensors and possibility that the damper may not be fully open even signaled to open 100%. In most case, if the OAF is within +/- 10% to 15% of expected value, it should be considered reasonable. In Figure 1, the outdoor-air temperature range is favorable for economizing, so further investigation is needed to determine if the minimum OAF is being supplied as required for ventilation (when the conditions are not favorable for economizing). This can be investigated by generating the same plot when the outdoor-air temperatures are high (>65°F) or low (<35°F). Figure 2 below shows a plot that is similar to Figure 1, except now the outdoor-air temperature ranges from 75°F to 100°F. As you can see, the OAF and OAD position signal both indicate roughly 20% outdoor air being utilized during occupied hours. This would indicate that the minimum outdoor-air damper position to satisfy ventilation for this building is 20%. Because the outdoor-air temperature never gets below 75°F during this time period, this corresponds to good operation. Figure 3 below shows an example of a bad operation, where the outdoor-air temperature varies between 75°F and 100°F, and the OAF and OAD position signal indicate roughly 50% outdoor air being used during occupied hours. This means the signal controlling the OAD is set in the BAS at 50% open for these conditions, which is high and may be incorrect. The outdoor-air damper position signal should be set at the minimum position required to satisfy ventilation requirements during outdoor-air temperatures that are not appropriate for economizing. Figure 4 shows another example of bad operation, where the minimum damper position is too low during occupied times (2% for occupied periods).

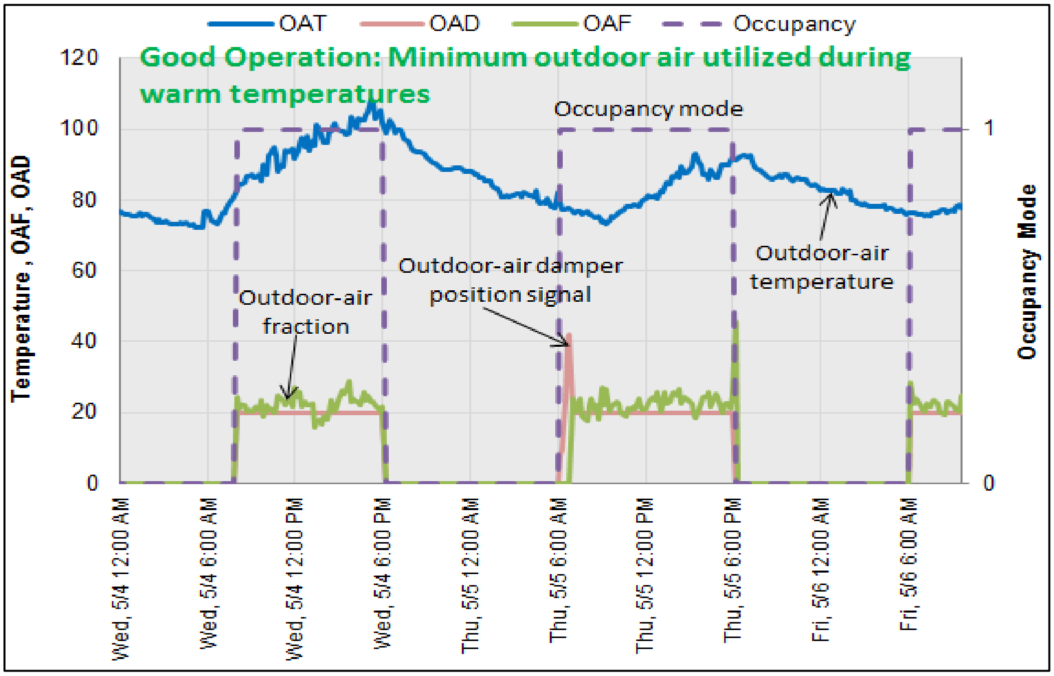

Figure 2: Plot of outdoor-air temperature, outdoor-air fraction, occupancy mode, and outdoor-air damper position versus time. This is an example of good operation, when the outdoor-air damper and outdoor-air fraction track closely together around 20% open during occupied hours. This is assumed to be the minimum damper position used for satisfying ventilation requirements.

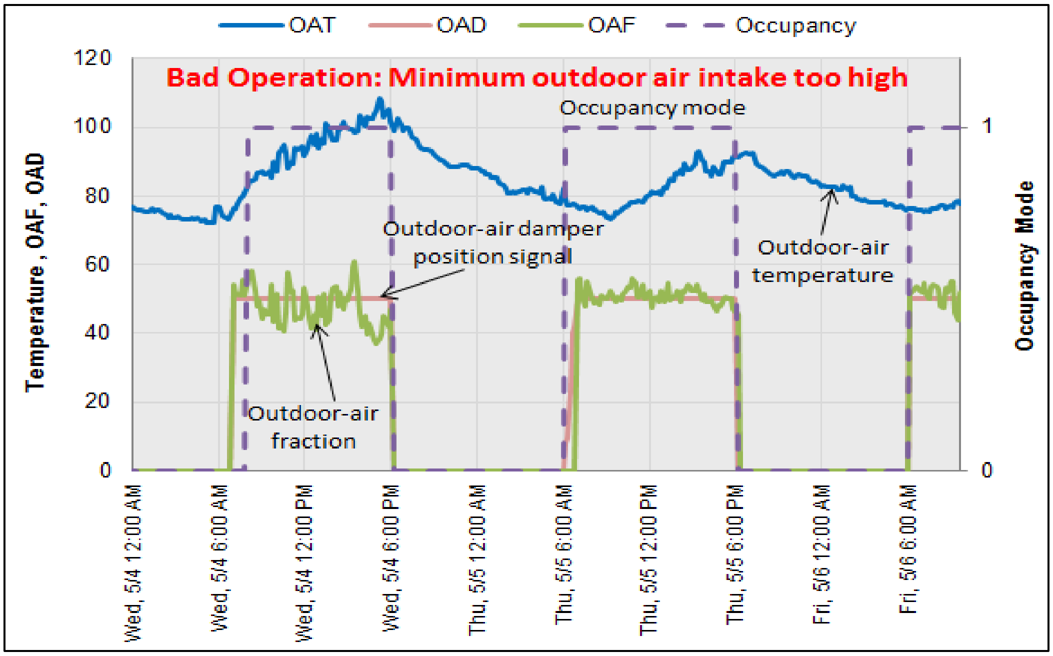

Figure 3: Plot of outdoor-air temperature, outdoor-air fraction, occupancy mode, and outdoor-air damper position versus time. This is an example of what could be bad operation, when the outdoor-air fraction and outdoor-air damper position signal indicate roughly 50% outdoor-air intake during temperature outside of economizing conditions.

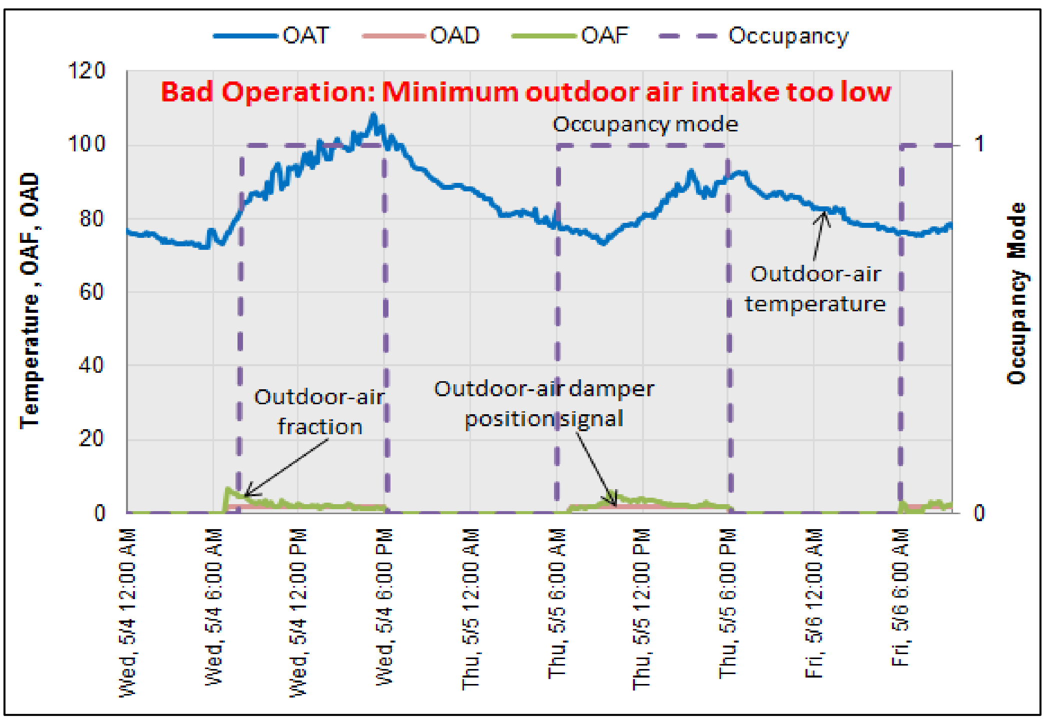

Figure 4: Plot of outdoor-air temperature, outdoor-air fraction, occupancy mode, and outdoor-air damper position versus time. This is an example of bad operation, where the minimum damper position is too low.

Another example of bad operation occurs when the outdoor-air fraction and the outdoor-air damper position signal are widely different from each other, indicating a much different outdoor-air intake. An example of this can be seen in Figure 5 below. In this example, the outdoor-air temperature ranges from 75°F to 100°F, and the damper position signal is 20% open during occupied hours. The OAF during occupied hours, however, indicates roughly 50% outdoor-air intake. This would indicate that the BAS is calling for the minimum amount of outdoor air required to satisfy ventilation, but the damper is not responding. There are several possibilities for this, including a stuck damper or a failed actuator, damper or linkage calibration errors, failing or failed damper seals, or return fan variable frequency drive (VFD) control issues (i.e., the return fan is not matching the supply fan in terms of volumetric flow rate control).

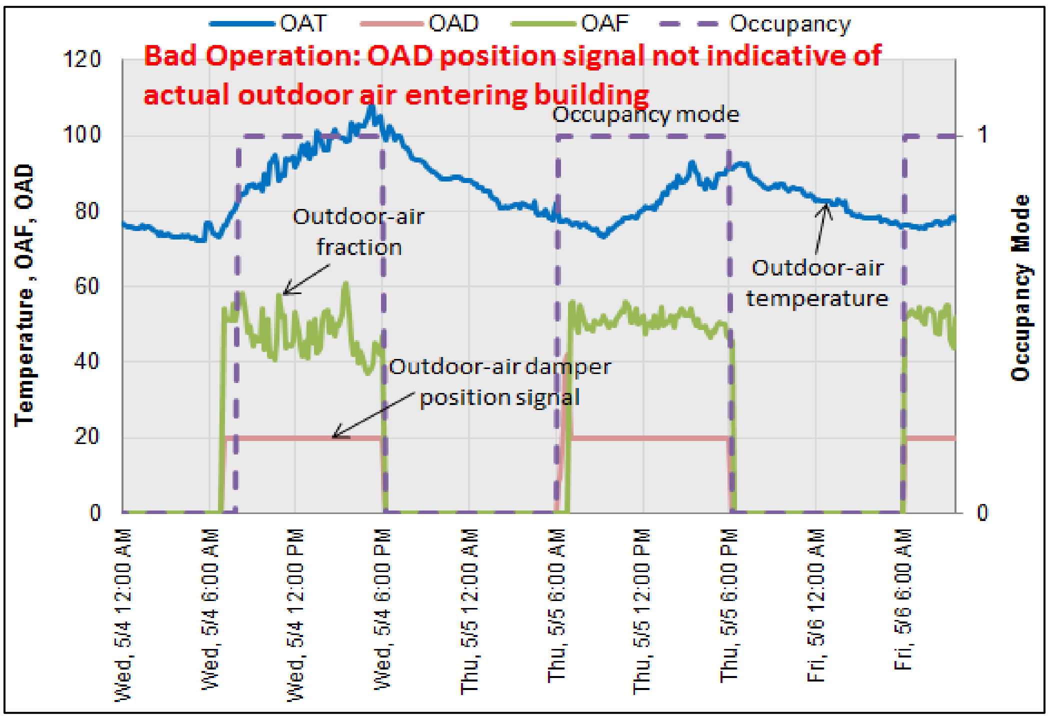

Figure 5: Plot of outdoor-air temperature, outdoor-air fraction, occupancy mode, and outdoor-air damper position versus time. This is an example of bad operation, when the outdoor-air damper position signal is correct for calling for minimum outdoor air, but the actual outdoor-air fraction is greater than the minimum required for ventilation.

Suggested Actions

The minimum outdoor-air intake required to satisfy ventilation should be verified before changing any settings in the BAS. This way, the building operator will know what to look for regarding the OAD position signal when analyzing the plots. For example, some zones in the building will require more fresh air intake, such as dining areas, kitchen cooking areas, chemical storage areas, etc. Once verified, the OAF should be compared to the OAD position signal in the charts. If there are major discrepancies during times when the OAT and RAT are significantly different (± 5°F), then check to make sure the outdoor-air damper is responding to the signal from the BAS. Once verified, check the minimum outdoor-air intake by reviewing the plot of OAT, OAF, OAD position signal, and occupancy mode versus time. During times when the AHU is not in economizer mode and the building is occupied, then the OAD should be commanded to the minimum position required to satisfy ventilation. This is generally between 5% and 20% open depending on the design outdoor air intake for the zone(s) served. If it is not, check the control sequence for the OAD and make sure it is set to open only when the AHU is in an occupied mode.

Does the outdoor-air damper close during unoccupied times?

During unoccupied periods (nights and weekends), when the system is set back, the outdoor-air damper should be closed. It should also be closed for most of the startup period in the morning (with exception to the last 30 minutes). The plot of OAD position signal, OAT, and occupancy mode versus time should be reviewed to check this. Figure 6 is an example of good operation, where the OAD position signal is set to the minimum position (20% open) during occupied hours, and then closed during unoccupied hours. Figure 7 below is an example of bad operation, where the outdoor-air damper is signaled to the minimum position 2 hours before occupancy begins every day. This would indicate that the outdoor-air damper is opening during the startup mode in the morning. The damper should be closed during startup mode because there is no occupancy at this time. Therefore, ventilation is not required, and can waste cooling or heating energy by bringing in warm/humid or cold outdoor air and then cooling/de-humidifying or heating to meet the discharge-air temperature set point. However, if there is need to purge the building odors, the AHU can begin to provide outdoor air 30 minutes before the building is occupied.

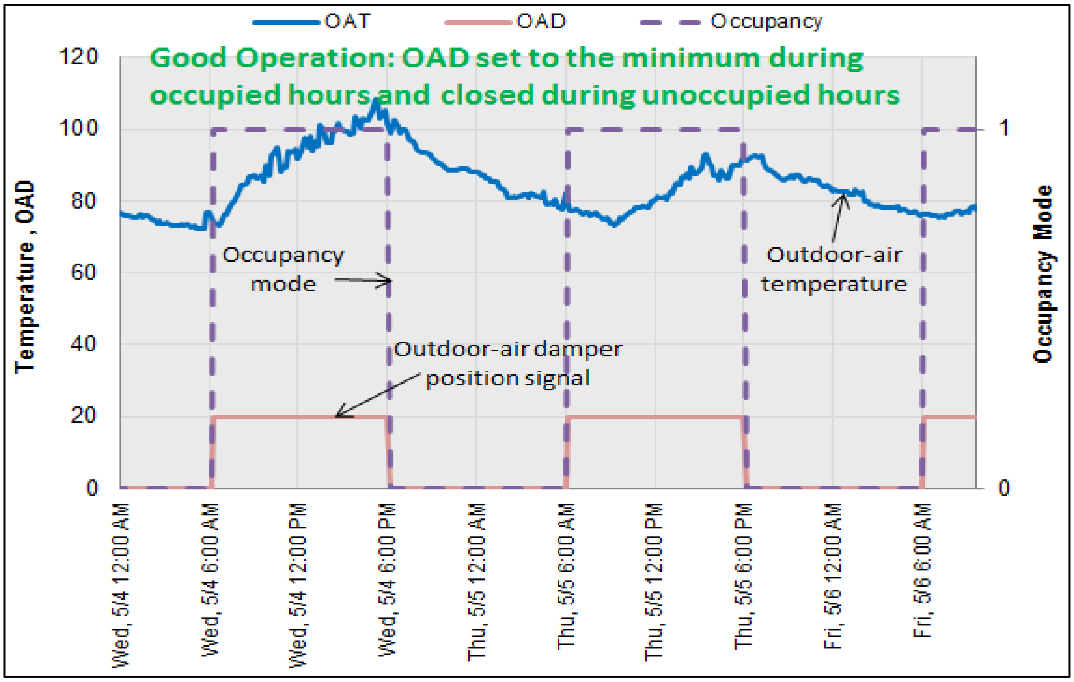

Figure 6: Plot of occupancy mode, outdoor-air temperature, and outdoor-air damper position signal versus time. This is an example of good operation, where the outdoor-air damper is closed during unoccupied hours and at the minimum during occupied hours for warm outdoor-air temperatures.

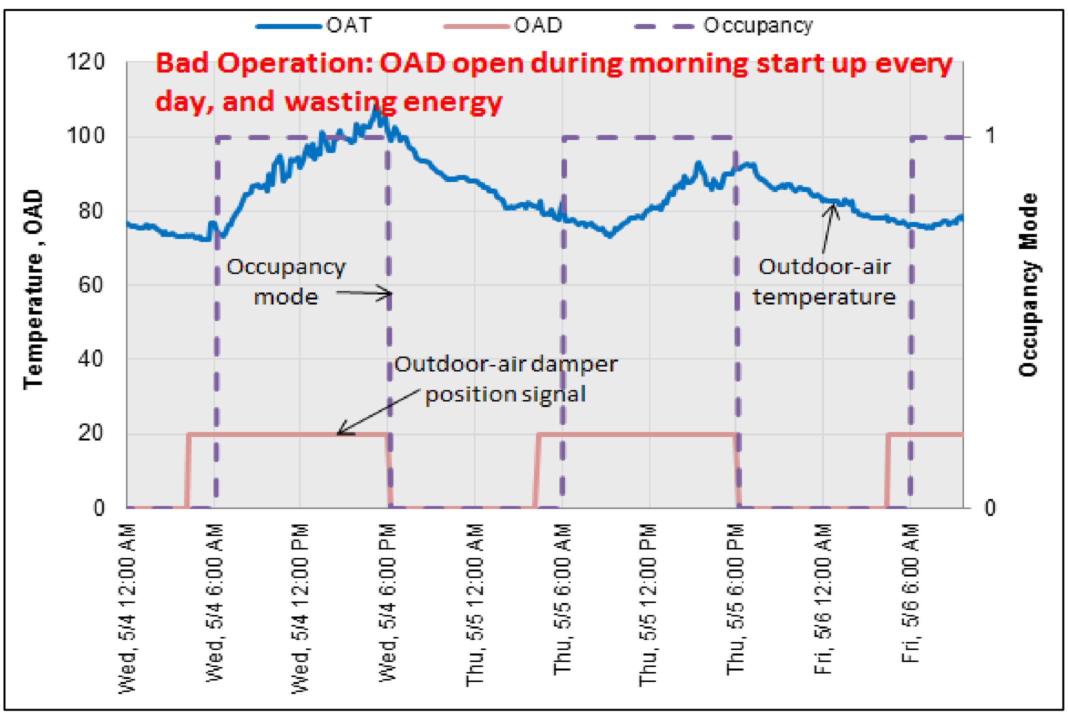

Figure 7: Plot of occupancy mode, outdoor-air temperature, and outdoor-air damper position signal versus time. This is an example of bad operation, where the outdoor-air damper is opening during morning start up and wasting energy.

Figure 8 is another example of bad operation, where the OAD is set to the minimum position during all hours of the day and night. This example has the largest energy impact, because the AHU will either reach the set back temperature faster (caused by exhaust fans running and pulling more outdoor air through the damper), requiring AHU heating or cooling during the unoccupied period, or for the morning start up to occur earlier to get the building to meet set point before occupancy.

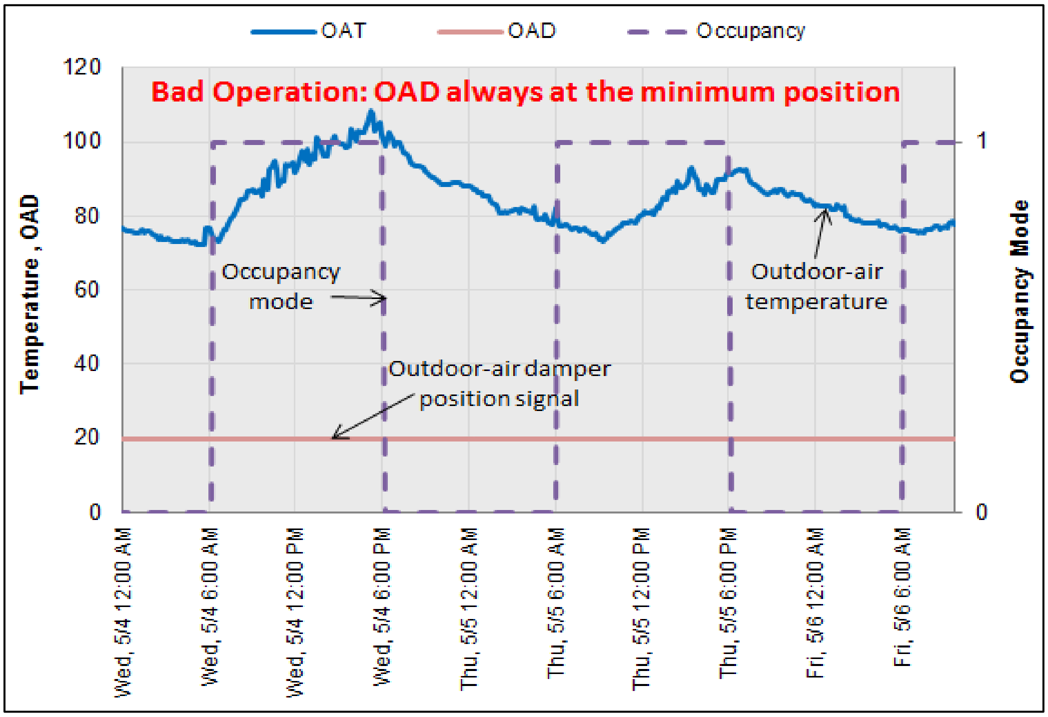

Figure 8: Plot of occupancy mode, outdoor-air temperature, and outdoor-air damper position signal versus time. This is an example of bad operation, when the outdoor-air damper is open continuously, even when the building is unoccupied.

Suggested Actions

Check to make sure that the outdoor-air damper minimum position is configured to be 0% open during all unoccupied periods and reverts to the design minimum position (5, 10, 20% open or as required) during occupied periods.

The best way to configure this is to add a schedule or series of schedules to the AHU minimum damper position data point. The schedule should configure the minimum position set point to be 0% just before the end of scheduled occupancy period and placed back to the required minimum position 30 minutes prior to actual occupancy (i.e. - 7:30 AM, if occupancy = 8:00 AM).