Building Re-Tuning Training Guide: Occupancy Scheduling: Night and Weekend Temperature Set back and Supply Fan Cycling during Unoccupied Hours

Summary

The purpose of the occupancy scheduling control guide is to show, through use of examples of good and bad operation, how occupancy scheduling should be utilized and efficiently controlled.

If building systems are properly controlled during unoccupied mode, it can lead to significant cost reductions in commercial buildings. It is very simple to implement, simple to track, and simple to administer. The goal is to shut off systems whenever possible or whenever they are not needed, and refrain from starting up the system for an occasional night-time user or weekend user. Many times the night-time operation can be the most costly, when roughly 5-10% of staff are working with all of the heating, ventilating, and air conditioning (HVAC) equipment running, all fresh air open and lights on. The goal is to have significant consumption reduction for nights and weekends. The difference in consumption between the base load and the peak load should be at least 30% and as much as 80% with aggressive set backs on nights and weekends (will be discussed in detail below). When supply fans operate 24/7 for buildings that have unoccupied periods, these conditions should be detected by reviewing the graphs for further investigation. Failure to investigate or correct/mitigate this situation, in all likelihood, will lead to increased fan, heating and cooling energy consumption.

Data needed to verify the occupancy scheduling control

To analyze and detect deficiencies in occupancy scheduling, night and weekend temperature set back and night and weekend supply fan operation and control, for single-duct variable-air-volume (SDVAV) air-handling units (AHU), the following parameters must be monitored using the trending capabilities of the building automation system (BAS):

- Duct static pressure
- Supply fan status
- Outdoor-air temperature (OAT)
- Outdoor-air damper position signal (OAD)
- Discharge-air temperature (DAT).

The recommended frequency of data collection is between 5- and 30-minutes. When analyzing the night and weekend temperature set back and supply fan cycling, the trends to look for include:

- Is there night set back for unoccupied hours?
- Is there weekend set back if the building is unoccupied on the weekends?
- Does the supply fan cycle frequently during unoccupied hours?
- Does the outdoor-air damper open during unoccupied hours or when the building is in warm-up/cool-down mode?

In addition, this section of the guide provides examples for the following:

- Occupancy scheduling for buildings with “lightly” occupied hours.
- Whole building consumption consequences of poor scheduling.

Is there night set back for unoccupied hours?

Use of night set back can lead to significant energy savings and is easy to implement in buildings. During unoccupied hours, the system should be set back so that the system does not continue to operate. In some building’s BAS, the supply fan status may not be available, but reviewing the plot of the duct static pressure versus time can reveal if there is night set back or not. Figure 1 below shows a 3-day period where the duct static pressure remains at approximately 1.5 inches of water column (in. w.c.) for an office building with an occupancy period of 8:00 AM to 5:00 PM (Monday through Friday, closed on weekends). It appears that there is no night set back for this AHU because when the building goes into an unoccupied mode, the duct static pressure should drop to half of the daily occupied static pressure or lower, but preferably to zero, if night set back is being utilized correctly.

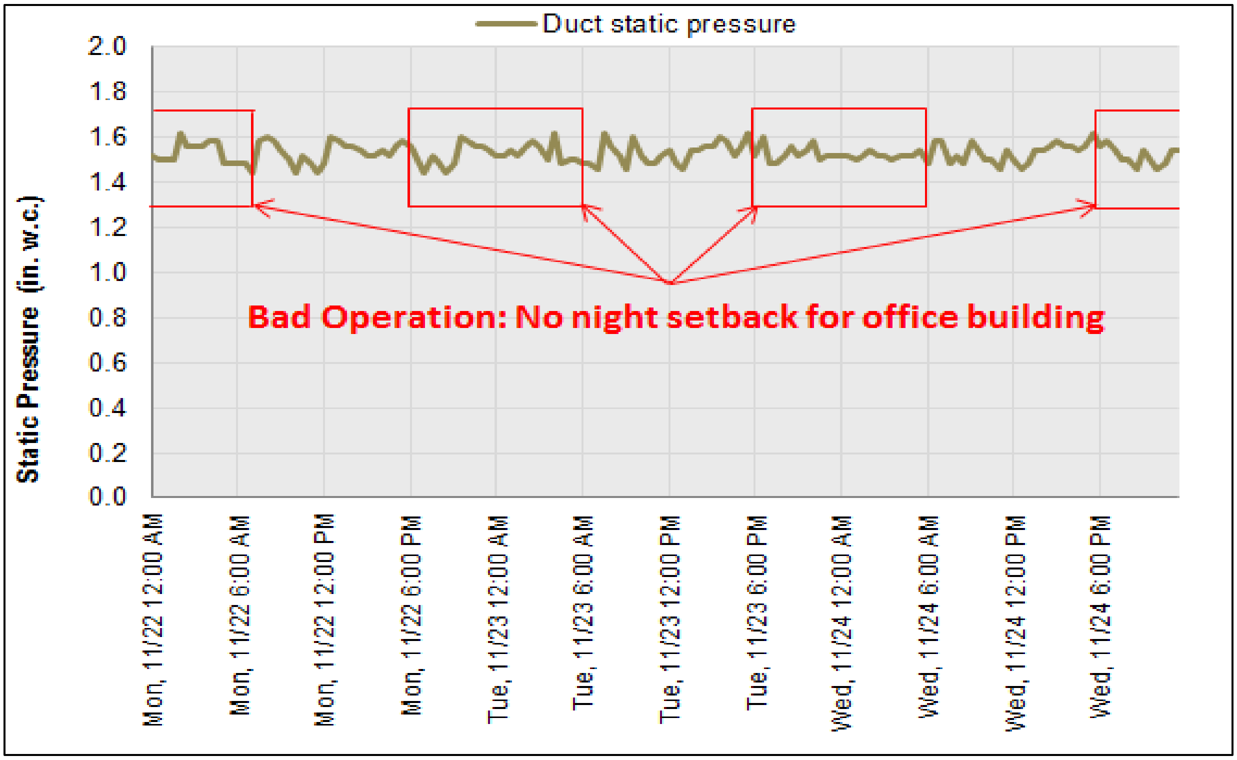

Figure 1: No night set back implemented, constant duct static pressure.

Another chart that can be used to determine if night set back is implemented and how aggressively it is implemented is the fan status or fan speed versus time plots. This plot will tell you if the fan was on or off (or at what speed it is running), and at what time it was on and off. This is very useful because during a night set back, the fan should status should be 0, or off. You can check for aggressiveness of the night set back by checking what time the fan turns on in the morning and comparing it to the building occupancy schedule. The occupancy period from the office building in Figure 1, for example, is 8:00 AM to 5:00 PM, Monday through Friday (closed on weekends). Therefore, the fan status should go to 0 when the building goes unoccupied (or shortly thereafter) and ideally not come back on until the building warm-up the next morning (a few hours before the building is occupied). That is the most aggressive night set back, when the system remains off until the building warm-up/cool-down the following morning. If the fan status goes to 1, or on, in the middle of the night, it could mean two things. First, it could mean that the night set back isn't as aggressive as it probably could be, or it could mean that there were extreme weather conditions that required the system to operate to keep the building from exceeding low/high temperature limits. Figure 2 below shows the chart of fan status versus time for the same building as that shown in Figure 1. You can see that the fan is always on for this example, again reinforcing that there is no night set back for this AHU. Figure 3 shows the same office building when it employed a night set back for this AHU.

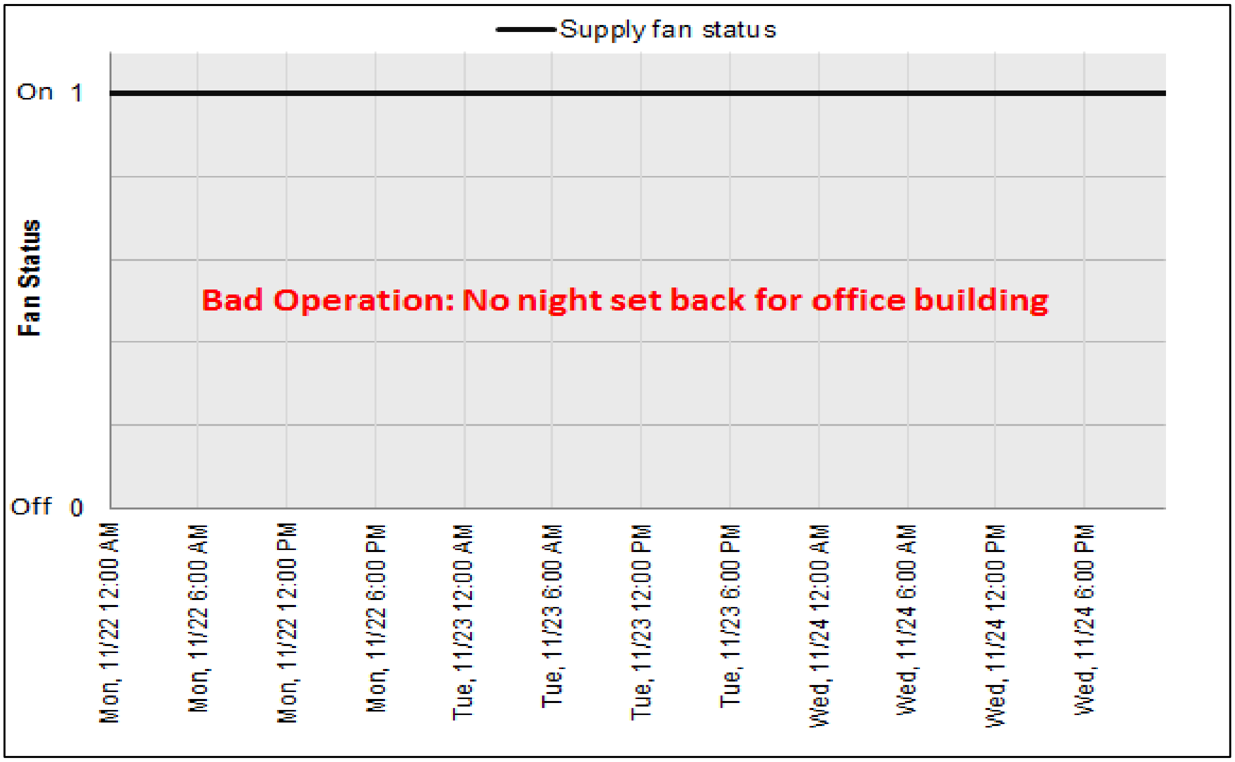

Figure 2: Supply fan status always "on"; no night set back implemented.

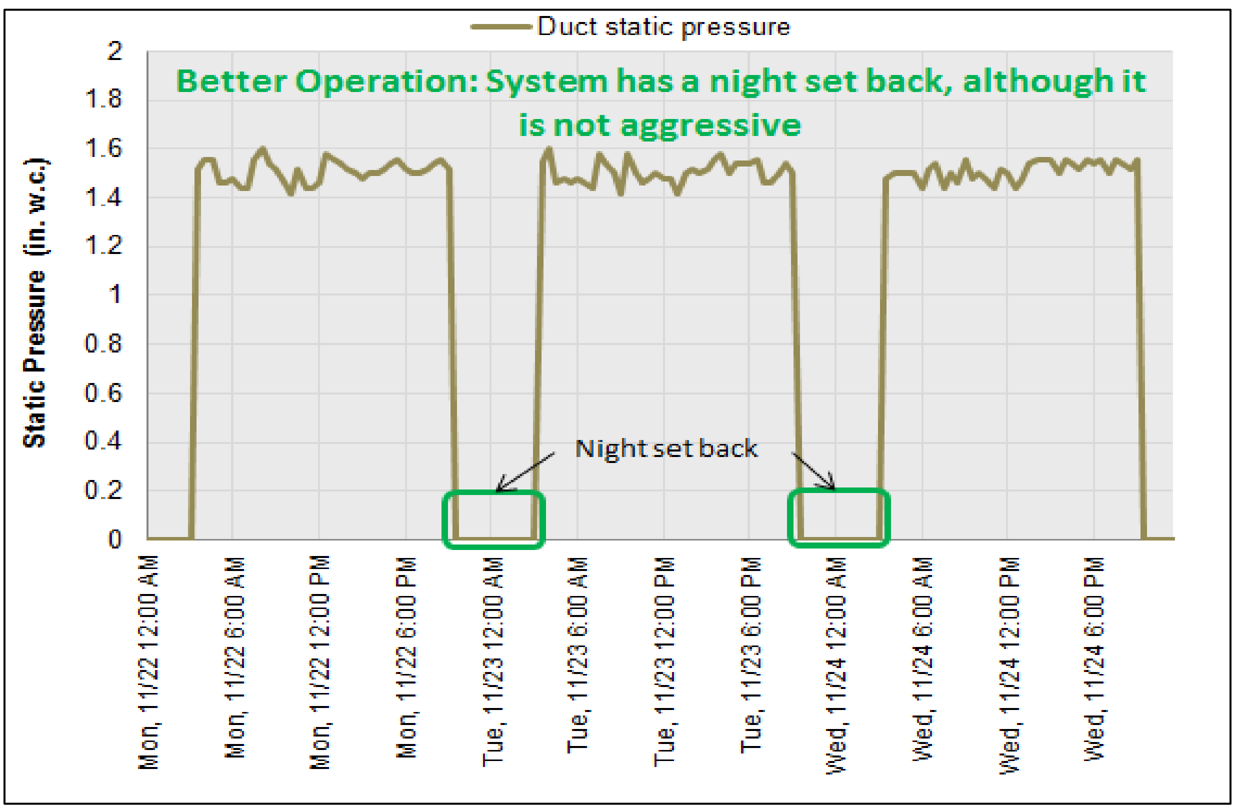

Figure 3: Night set back implemented, but not very aggressively.

The occupancy period in Figure 3 is still 8:00 AM to 5:00 PM (Monday through Friday, closed on weekends), and it appears that the set back does not begin until 9:00 PM at night. Then, the system comes back on around 3:00 AM every day. Although this set back will help to save energy, and is an improvement from the operating condition in Figure 1 and Figure 2, it is still not as aggressive as the building operator should be. Figure 4 shows the corresponding fan status versus time chart for the operating condition depicted in Figure 3. You can see by comparing Figure 4 and Figure 3 that the fan status changes from 0 (off) to 1 (on) as the duct static pressure goes from 0 to roughly 1.5 inches.

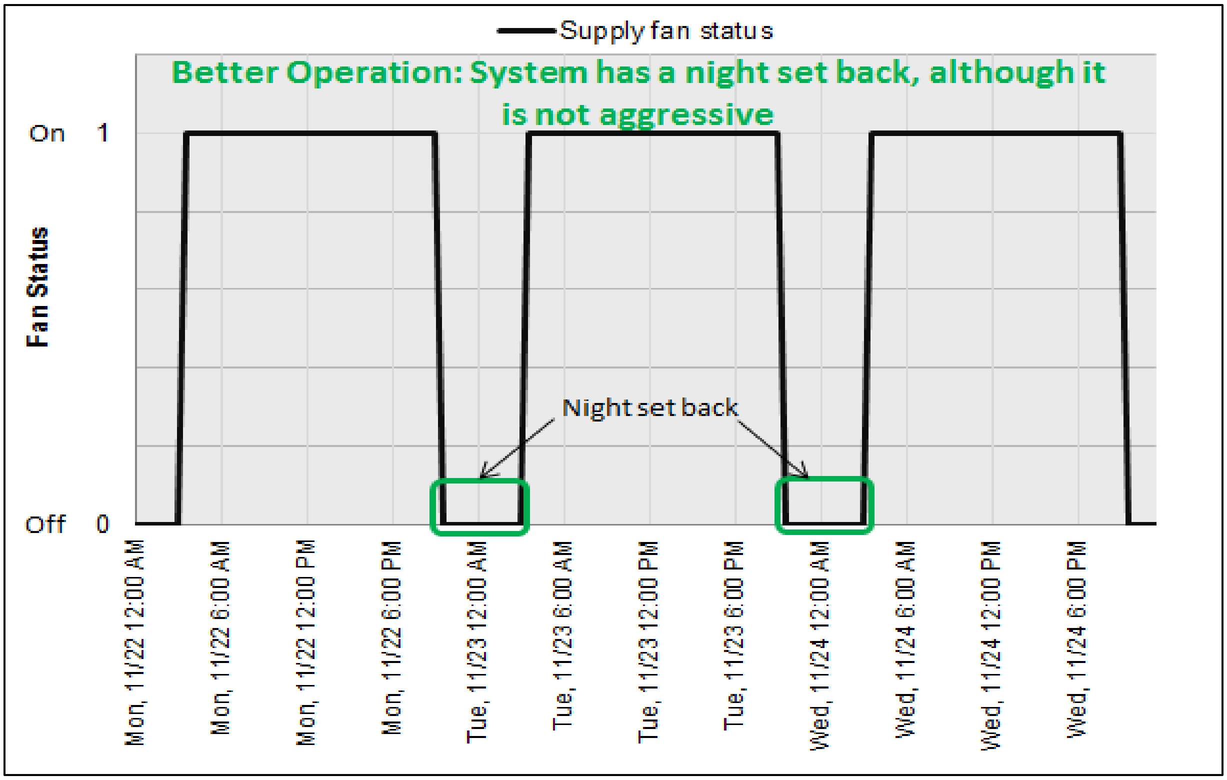

Figure 4: Supply fan status vs. time for unaggressive night set back.

The more aggressive the night set back, the more energy savings can be achieved. Figure 5 below shows the same office building again, but this time with an aggressive night set back implemented. Here, the system is off by 6:00 PM and remains off until 6:30 AM the following morning. This chart lets the building owner and operator know that the building really is shutting down by 6:00 PM on weeknights and starting up at 6:30 AM for building warm-up/cool-down. Figure 6 shows the fan status versus time for this operating condition, and you can see that this chart matches what we see in Figure 5. The difference between Figure 3 and Figure 5 is an additional 6.5 hours of system off time, which will result in significant additional energy savings each day.

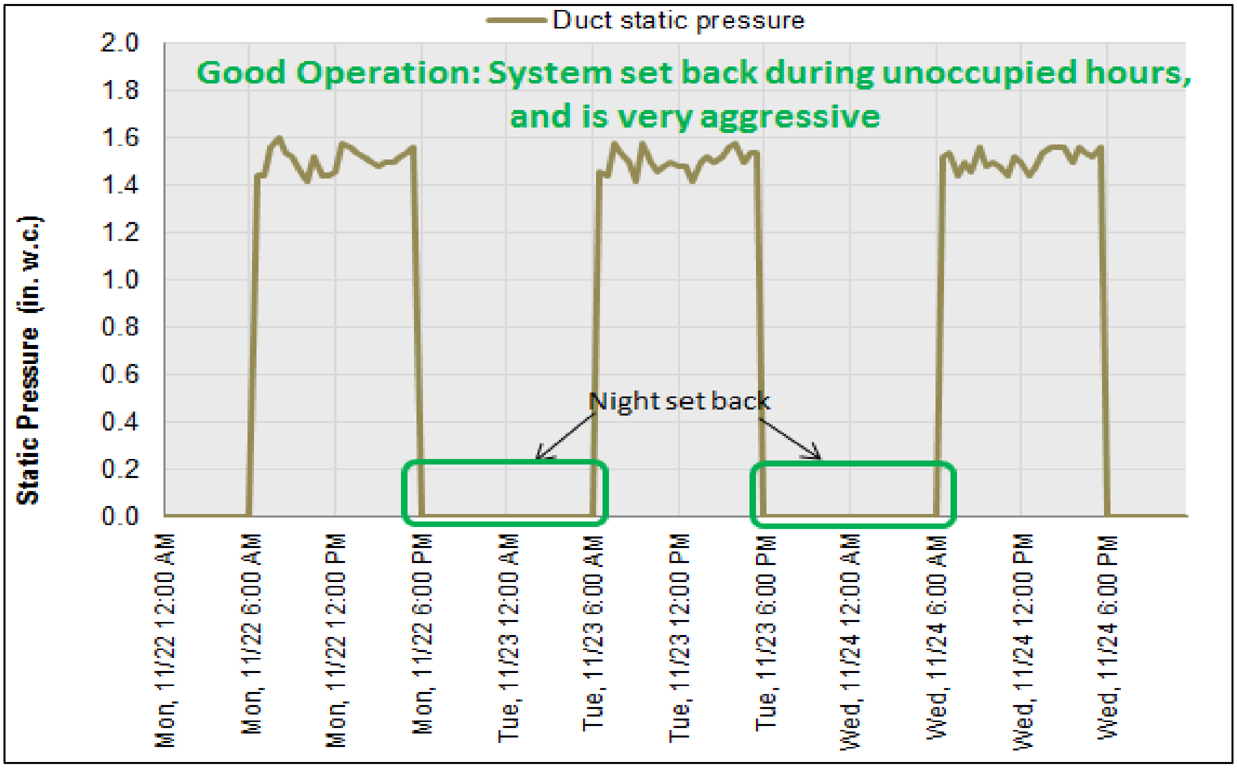

Figure 5: Duct static pressure vs. time for aggressive night set back.

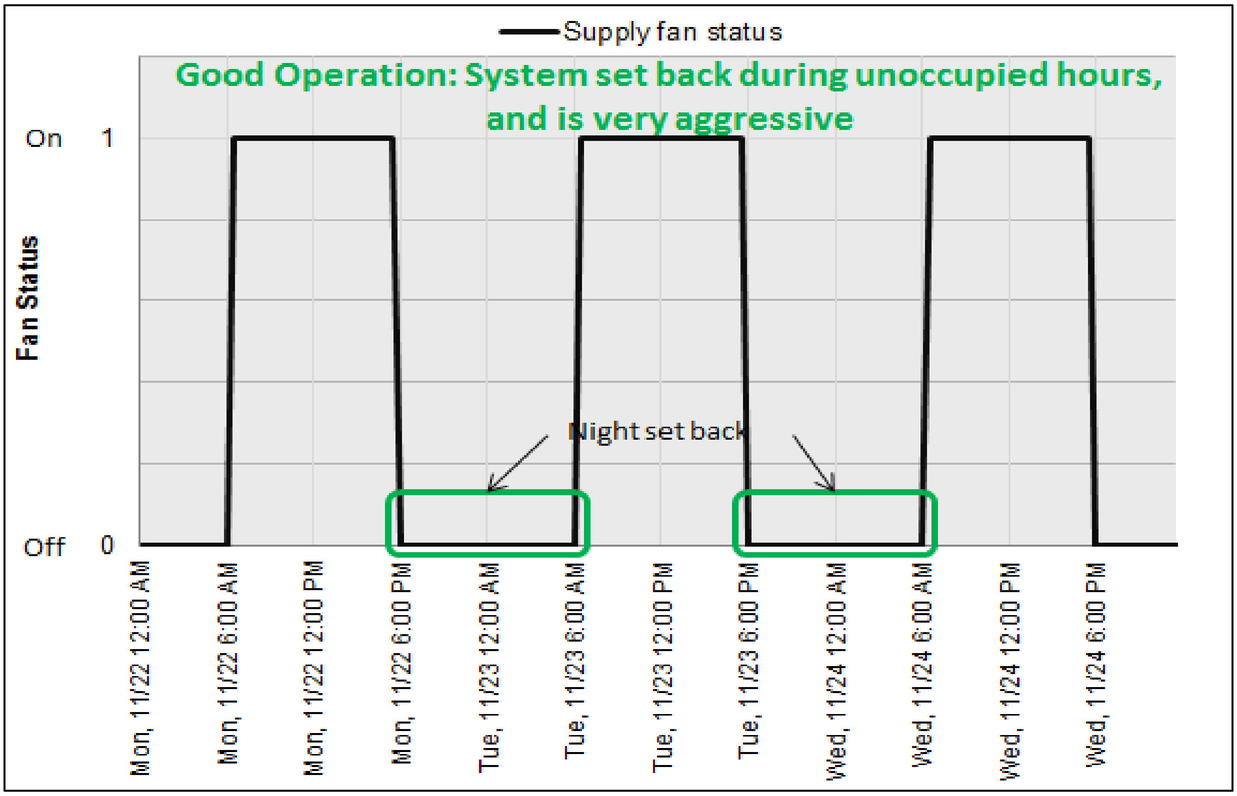

Figure 6: Supply fan status vs. time for aggressive night set back.

Suggested actions

To control the night set back on AHUs, reset the discharge-air temperature set point by 5 to 10°F when the supply fan turns off, or when the building goes unoccupied. In addition, set back each zone temperature by 5 to 10°F that is served by the AHU. Start by adjusting the discharge-air temperature set point and zone temperatures by 5°F and trend 1 week worth of data. Analyze the fan status versus time plot in the energy charting and metrics tool (ECAM) and determine how aggressive the set back is. If the fan status versus time plot shows the fan turning on well before the occupants arrive, consider increasing your discharge-air temperature set point and zone temperatures a few more degrees and trend the new data. This strategy is a trial and error approach and will change as the outdoor weather changes, especially during the shoulder months.

Is there weekend set back if the building is unoccupied on the weekends?

If there are no occupants in the building on weekends, most of the HVAC systems should be turned off and should remain off either until preset temperature limits are reached or until the building warm-up/cool-down on Monday morning. The weekend set back strategy can be much more aggressive initially than the night set back strategy on weekdays because there is so much more time when the building is unoccupied during the weekends. In extreme weather conditions the system will cycle a few times on the weekends (to maintain preset limits in the zones), but for the majority of the year, the system will remain off on the weekends if the right weekend set back strategy is employed. Figure 7 below shows a weekend for the operating condition depicted in Figure 1, an office building that is closed on the weekends and doesn't have a night set back implemented. Similarly, the fan status during the weekend is always 1, or on, as shown in Figure 8.

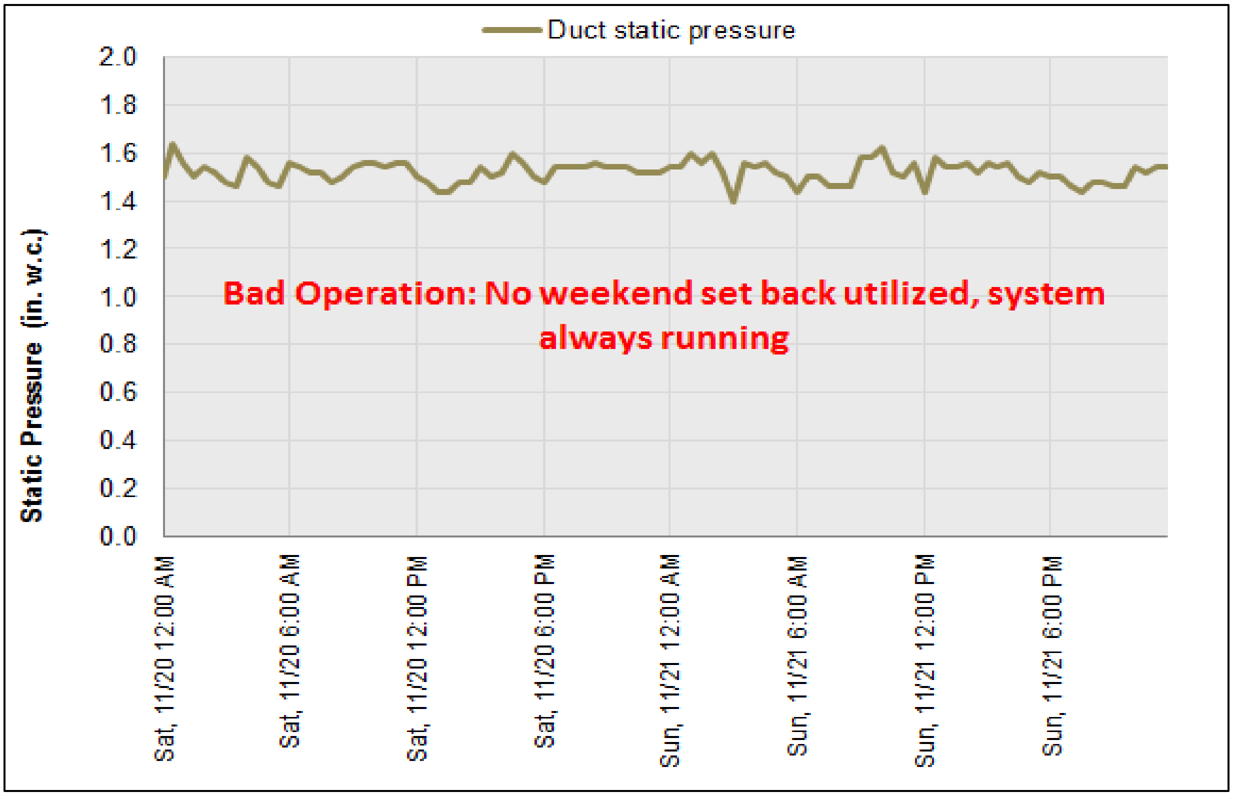

Figure 7: Duct static pressure vs. time for weekend operation with no set back.

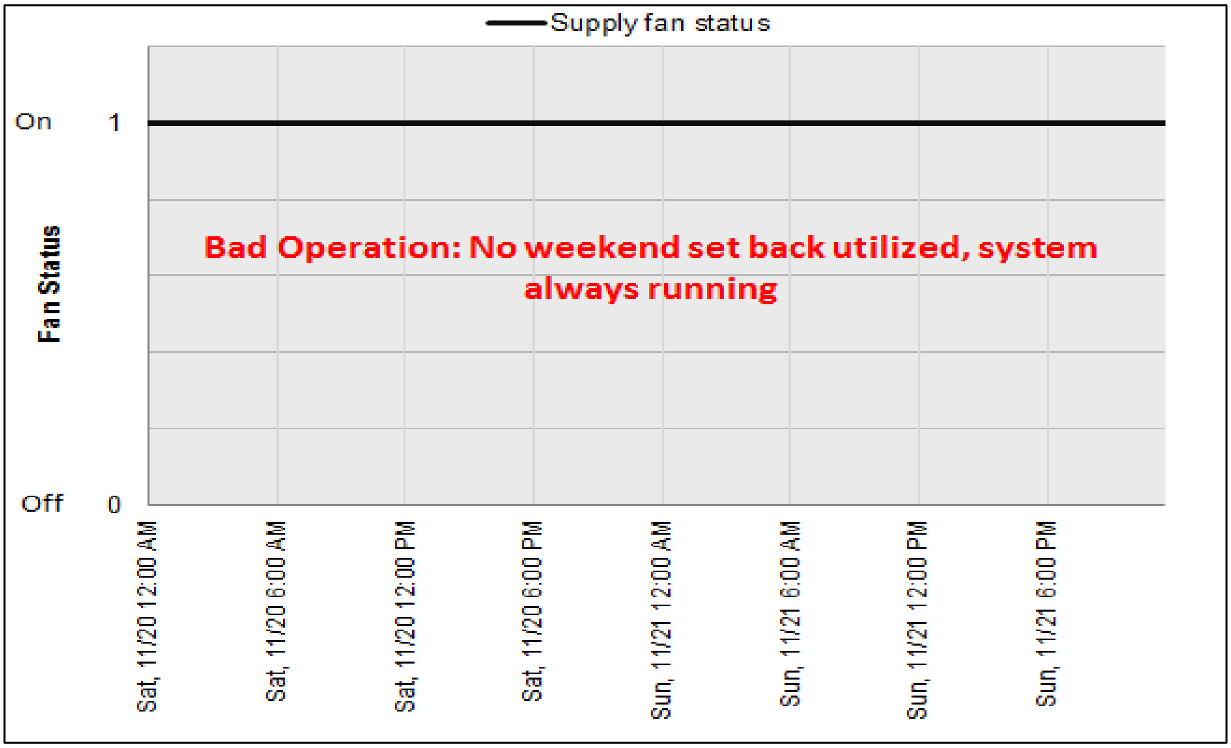

Figure 8: Supply fan status vs. time for weekend operation with no set back.

Figure 9 and Figure 10 show the same office building as described above, but this time with an aggressive weekend set back implemented. These charts show an entire week's worth of data, and you can see that both night and weekend set back strategies are used. The system shuts down for the entire weekend in this scenario, and starts back up on Monday morning at 6:00 AM.

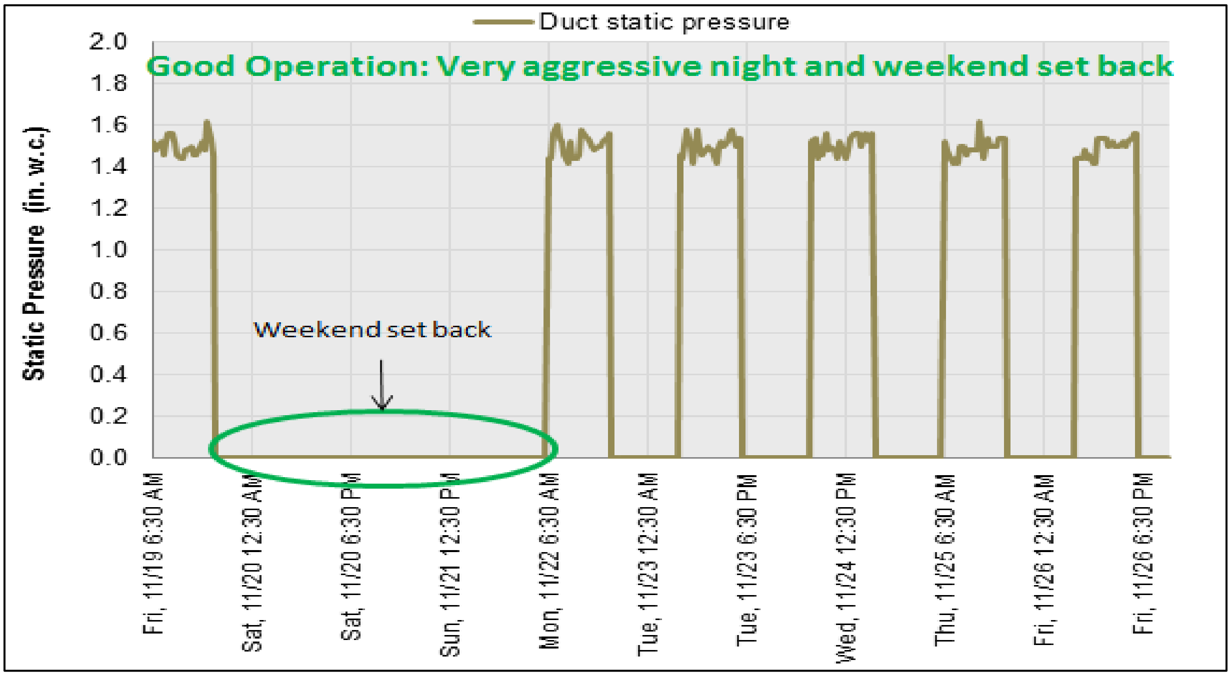

Figure 9: Duct static pressure vs. time for aggressive night and weekend set back.

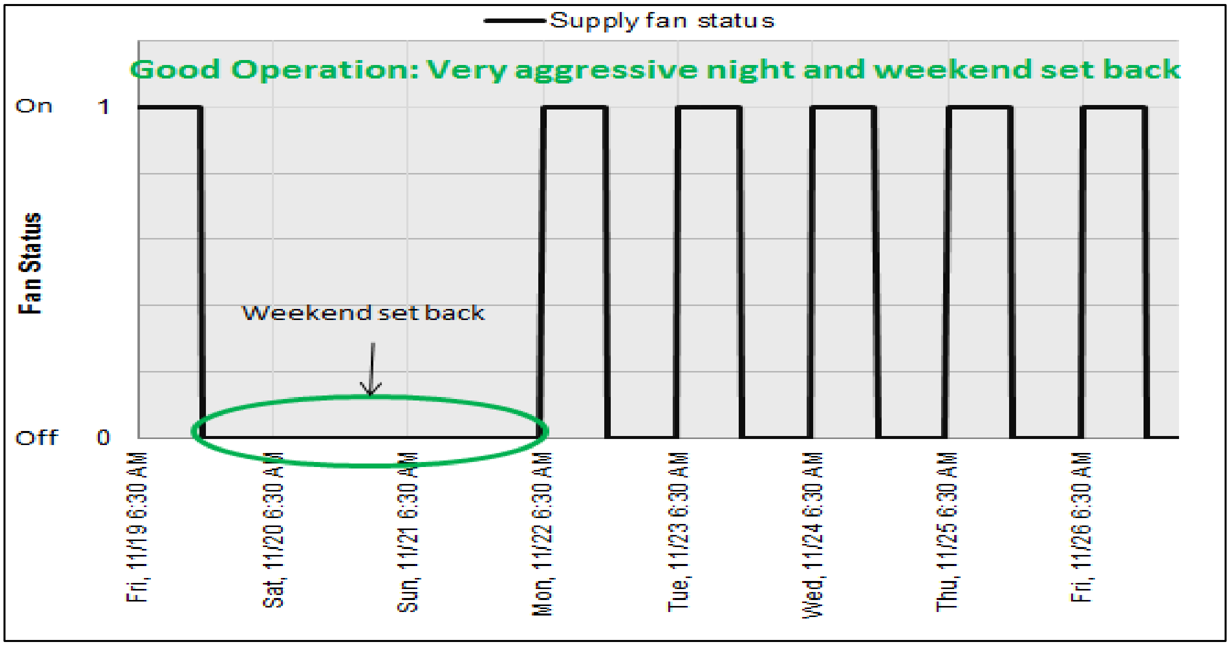

Figure 10: Supply fan status vs. time for aggressive night and weekend set back.

Suggested actions

In addition to the night set back implementation described above, the same approach should be applied for weekends, but initially reset the discharge-air and zone temperature set points by 10°F when the supply fan turns off, or when the building goes unoccupied. Trend the duct static pressure and supply fan status for 1 week. Analyze the supply fan status versus time plot to see if excessive fan cycling is occurring on the weekends. If so, check to make sure all hot water pumps for reheat, reheat converters, hot water boilers for reheat, chillers, towers, chilled water pumps etc. are turning off during the unoccupied period. Once you have verified that all system components are off, continue to adjust the discharge-air temperature set point and zone temperature set points (don't exceed 85°F in the summer time, or go below 60°F in the winter time). It is recommended that you do not solidify the building schedule during the shoulder months, when the weather is changing drastically over a few weeks to a month. Rather, implement the night and weekend set back during summer or winter, when the outdoor-air temperature remains relatively unchanged from one day to the next. For shoulder months, aggressive scheduling can be accomplished, but requires more attention based on large outdoor temperature changes. It is recommended that the building operator be very aggressive during shoulder months to take advantage of large outdoor-temperature swings.

Does the supply fan cycle frequently during the unoccupied hours?

When implementing a night and weekend set back for your building, one thing to be careful of is frequent cycling of the supply fan during unoccupied hours. Figure 11 shows a building that has implemented a night set back, but the plot of fan status versus time shows that the fan cycles frequently between 1:00 AM and 6:00 AM. This could be the result of extreme outdoor weather conditions, where the AHU must run to maintain the temperature limits inside the building, or it could be caused by the night set back not being aggressive enough. This plot should be expanded over several days or weeks, and if this pattern continues, it would be a good indicator that the night set back isn't aggressive enough for the current outdoor conditions.

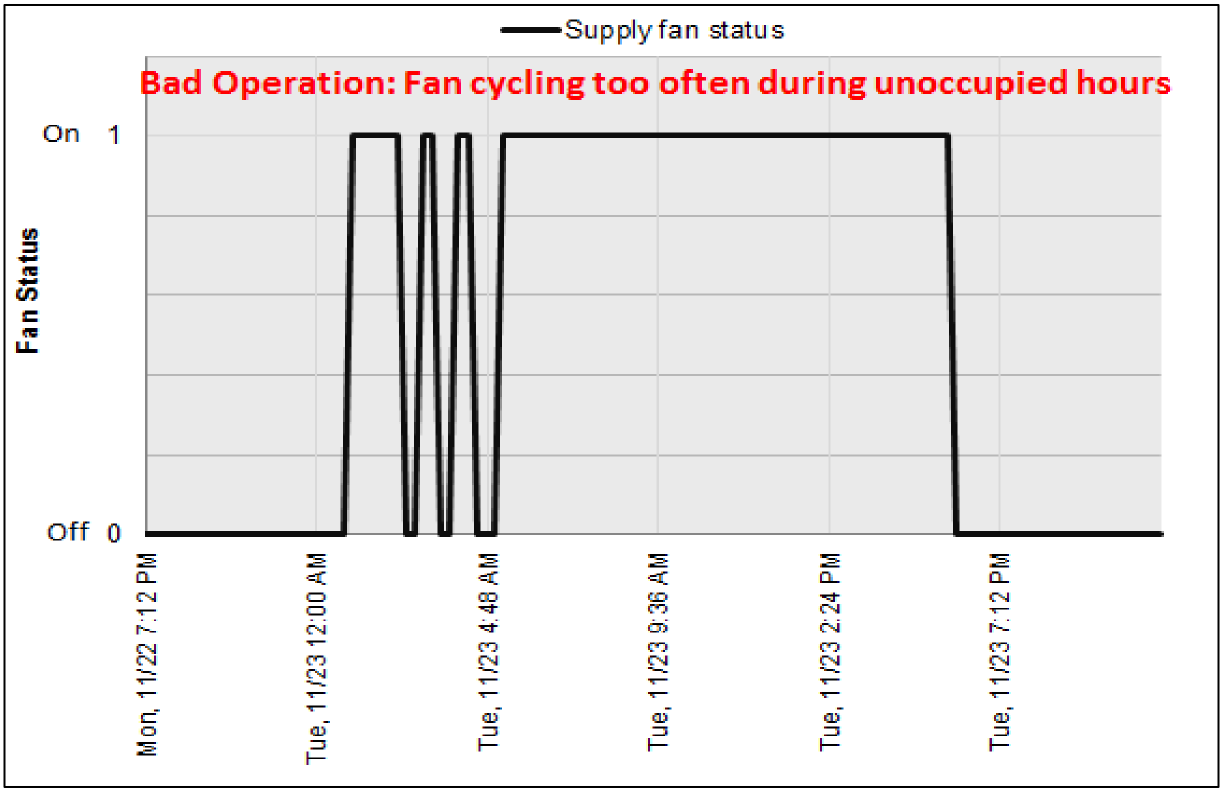

Figure 11: Supply fan status vs. time for 1 day with night set back implemented.

Suggested actions

The supply fan cycling during unoccupied hours could be caused by several things. First, check to see what time the cycling is occurring. If it occurs early in the morning when the building warm-up/cool-down is started, it is possible that the building is being started too early, or that the outdoor-air damper is opening during building warm-up/cool-down. Make sure the outdoor-air damper is closed during unoccupied hours and warm-up/cool-down before adjusting any settings. Once you are sure the damper is closed, try delaying your building warm-up/cool-down by 30 minutes and see if the fan cycling reduces. Another thing to check is that the exhaust fans are shutting down at night. If not, they can cause circulation of cooler or warmer air from building infiltration. This will cause frequent cycling of the supply fan to maintain the building's preset temperature limits.

For excessive cycling at night, check your set back controls and make sure they are implemented correctly, and make sure all systems are turning off during unoccupied hours by enabling the set back controls. Two plots that can be reviewed to aid in determining the cause of the cycling are the outdoor-air temperature, outdoor-air damper position signal versus time and the discharge-air temperature versus time. This will be discussed below in more detail.

Does the outdoor-air damper open during unoccupied hours or when the building is in warm-up/cool-down mode?

During unoccupied hours and warm-up/cool-down, the outdoor-air damper should be closed. The outdoor-air damper should be opened 30 minutes prior to occupancy to flush the building. If this is not the case, the energy savings from implementing night set back will be compromised by infiltration of cold or hot outdoor-air. Figure 12 below was trended for the same time period that Figure 11 above was generated, when the supply fan was cycling excessively in the early morning.

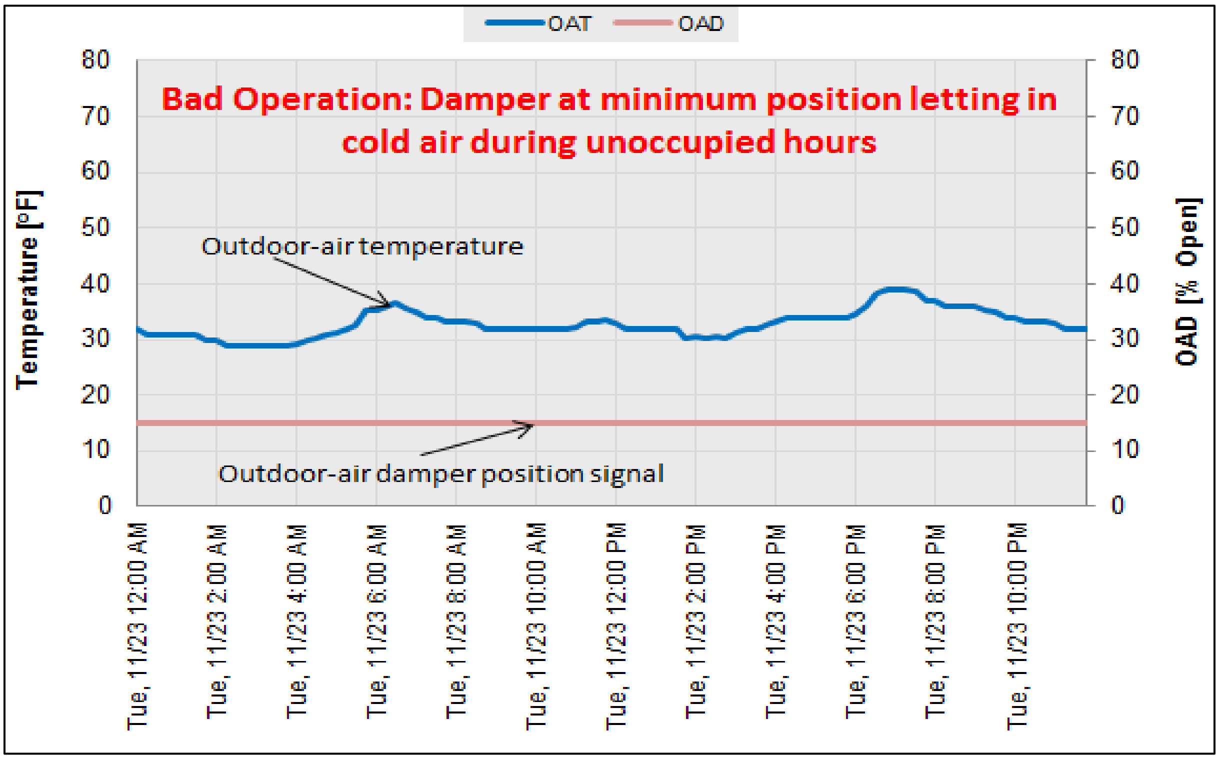

Figure 12: Outdoor-air temperature and damper position vs. time for a building with night set back.

From Figure 12 you can see that the damper signal is at the minimum position (15% open) during both occupied and unoccupied hours. During unoccupied hours, this cold air is causing the building to reach that set back temperature quicker, thus making the fan cycle to keep the building at the set back temperature until occupants arrive, at which point the set back temperature is changed and the system runs for the occupied period of the day. The outdoor-air damper should not open up during morning warm-up/cool-down (unless the weather is appropriate for economizing), and then it should open 30 minutes prior occupancy to flush the building. It should close at the end of the occupied time, and stay closed overnight. See Figure 13 below for an example of a building with the appropriate set back controls and strategy. The building has occupied times from 8:00 AM until 6:00 PM. The morning warm-up/cool-down for this particular building starts at 7:00 AM, which is when the set back temperatures are changed back to set point for the day and the building warms up for the occupants. The outdoor-air damper remains closed during this hour of warm-up, and opens up to the minimum at 8:00 AM to satisfy ventilation requirements. It stays at the minimum position throughout the day as a result of the outdoor-air temperature being less than 40°F, and then closes at 6:00 PM, when the building occupants leave.

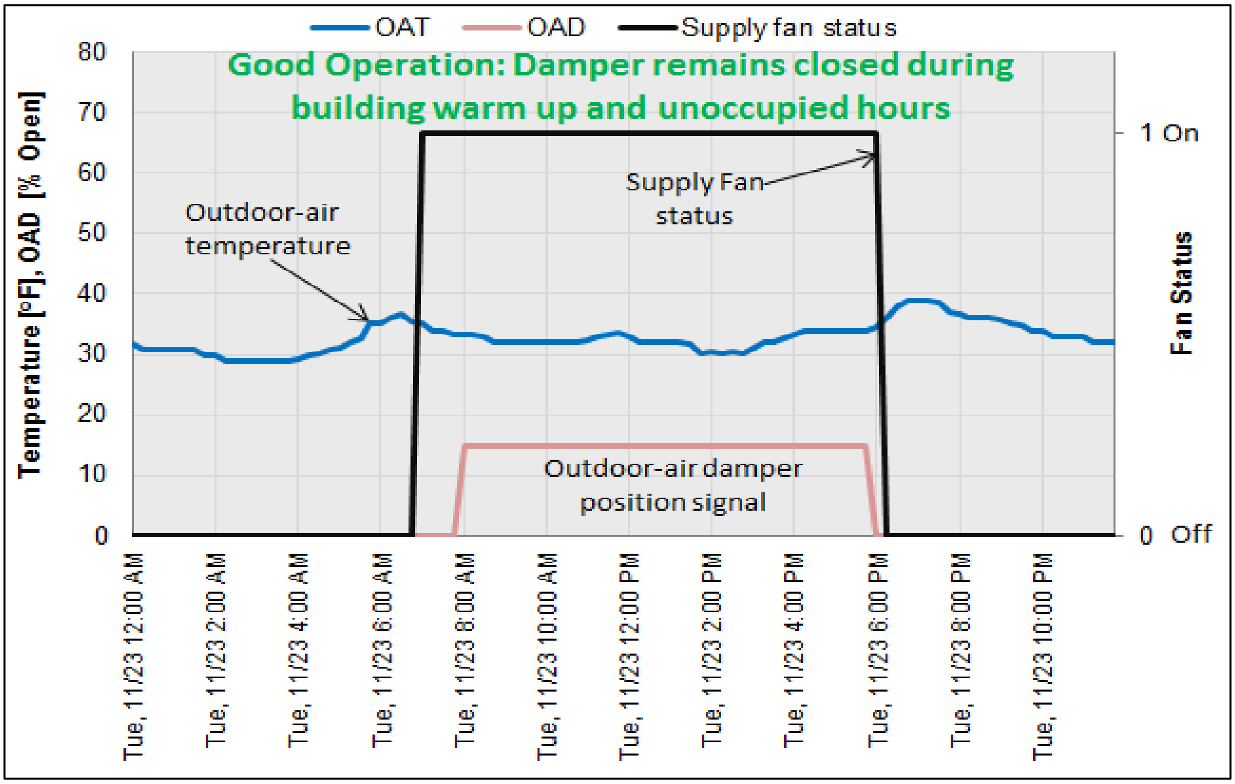

Figure 13: Outdoor-air damper modulating correctly during building warm-up/cool-down and occupied hours.

Suggested actions

Make sure the outdoor-air damper is fully closed during unoccupied hours and morning warm-up/cool-down (except when economizing) to avoid frequent fan cycling. Once verified, try adjusting the set back temperature a few degrees, unless the thresholds for summer (85°F), or winter (60°F) are reached.

Occupancy scheduling for buildings with "lightly" occupied hours.

All of the previous examples are based on an office building where there are well defined occupied and unoccupied hours, but this will not always be the case. Examples of buildings that may have variable schedules include hospitals, medical clinics, schools, retail stores, etc. For these types of buildings, isolating particular AHUs (when the building contains more than one unit) is key in achieving energy savings. For example, certain wings at a medical clinic will have to be served 24 hours by the appropriate unit, but there may be other parts of the clinic that have unoccupied hours or "lightly" occupied hours. "Lightly" occupied hours refer to times when the occupancy is at a minimum, but there are still occupants in the building. For units serving zones with minimal occupants, the demand from the AHU should be reduced to satisfy the smaller load. For example, the duct static pressure should be reset to reduce the air flow while maintaining the same discharge-air temperature. Figure 14 below shows an example of a medical clinic floor with night hours. The system operates at full capacity from 8:00 AM until 7:00 PM, with the duct static pressure at 2 in. w.c. during this time. During all other times the static pressure is reduced to 1 in. w.c., while the discharge temperature remains the same.

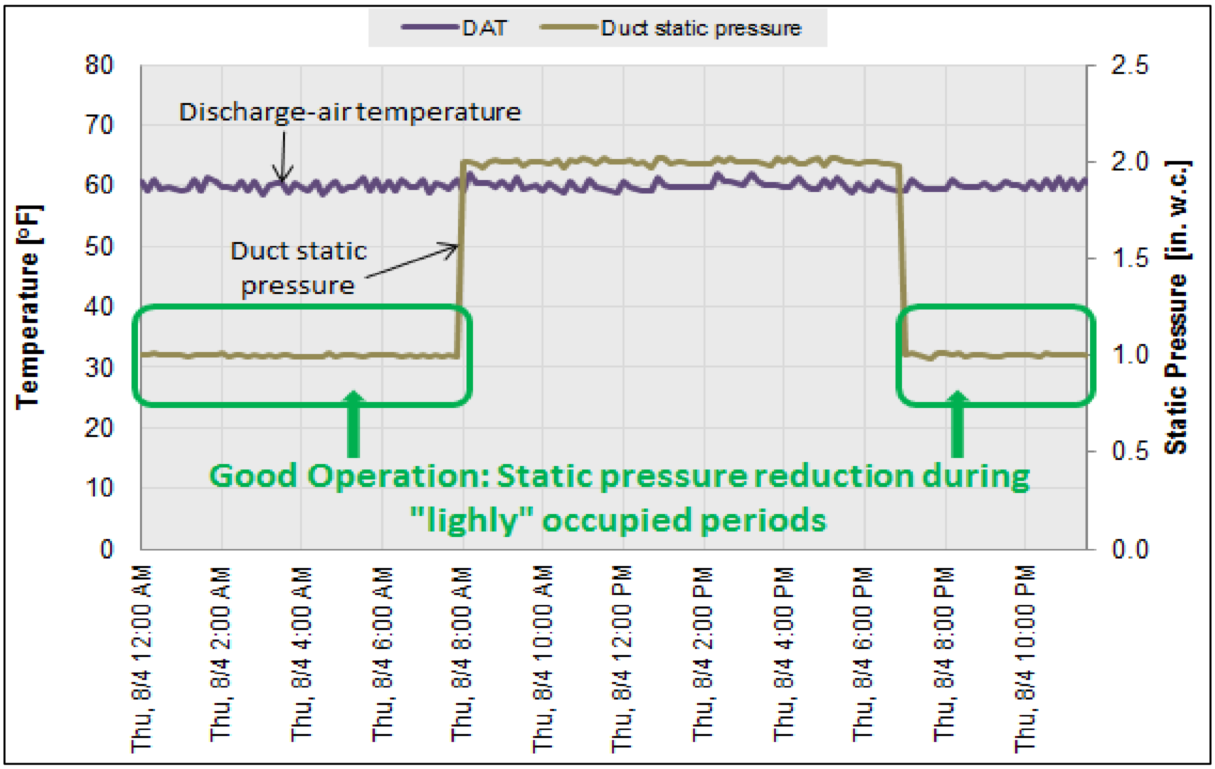

Figure 14: Discharge-air temperature and duct static pressure reset for hospital with light occupancy mode.

Whole building consumption consequences of poor scheduling

Implementing significant set back strategies in your building will drastically affect the amount of energy consumed by the building, and the monthly utility bill. The difference between the base load to the peak load should be a minimum of 30%, but can be as high as 80% with the proper set back and system control. The ECAM tool has the capability to produce charts for whole building consumption versus time. These charts are described in detail in the "Interval Data Analysis with the Energy Charting and Metrics Tool" (http://www.pnnl.gov/buildingretuning). Figure 15 below shows an example of an office building that only has a 50% reduction from peak and base load. The building is listed as unoccupied on weekends, yet there is some increase in consumption from the base load starting at 8:00 AM on both Saturdays and Sundays. Additionally, the shutdown procedure for this building is too slow. The listed hours of occupancy for this building are Monday through Friday, 6:00 AM to 6:00 PM. At 6:00 PM, the systems should be set back, but instead the system continues to operate over the next several hours.

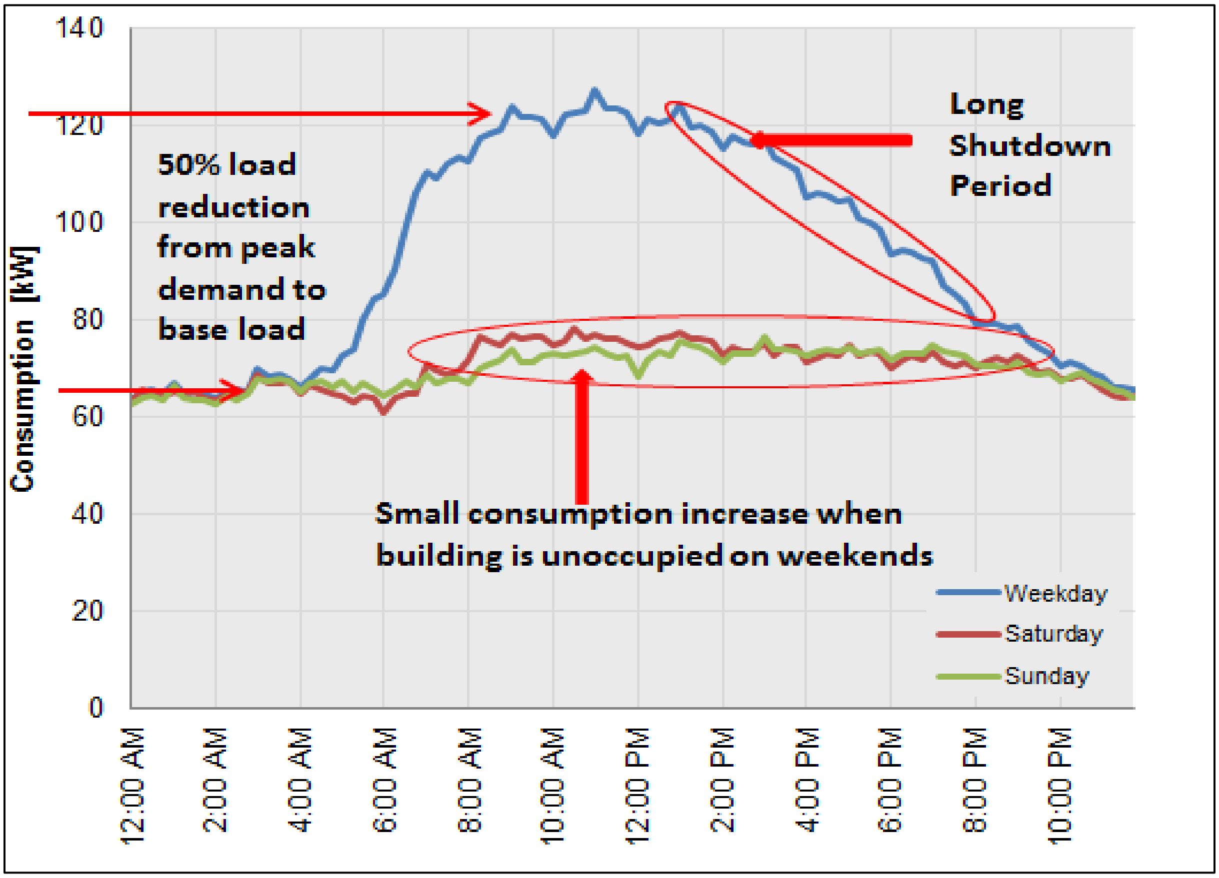

Figure 15: Whole building consumption for office building with passive set back strategies.

Figure 16 shows the same building with an aggressive set back strategy in place. The equipment startup and shutdown times are minimized, and all equipment is either off or set back on the nights and weekends. There is no ventilation during unoccupied hours or during building warm-up until 30-minutes prior to occupancy. Lighting is turned off during unoccupied hours as well.

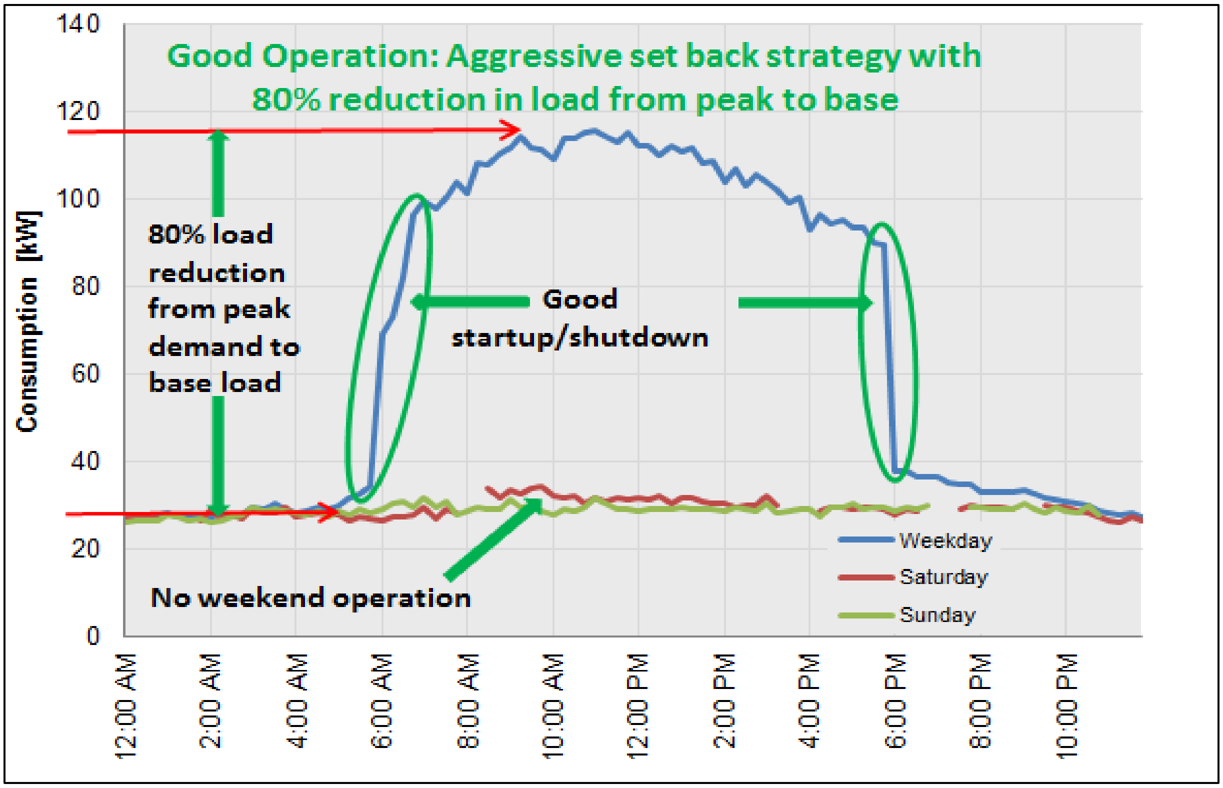

Figure 16: Whole building consumption for office building with aggressive set back strategies.