COMMERCIAL HVAC EQUIPMENT HOURLY OPERATION – INITIAL OBSERVATIONS

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1 Introduction

Heating, Ventilation and Air Conditioning (HVAC) equipment is the most common sound source associated with commercial buildings, yet the building owners and operations staff that own or operate the equipment know little about how much the units operate. More specifically, the amount of time that the condenser fans operate in a predictable worst-case hour or day is unknown or inaccessible information. This is notably the case for smaller commercial businesses. The operation of a commercial HVAC unit becomes significant when it operates in proximity to noise-sensitive spaces. Commercial land uses are commonly used as a buffer space between louder industrial uses and noise-sensitive uses such as residential. This places commercial HVAC equipment in close proximity to the noise-sensitive uses, especially in cities with strong urban densification trends. Good engineering practice dictates that sound at the sensitive spaces should be limited to an acceptable level. Commonly the sound is evaluated on the basis of a one-hour average. Determining the amount of sound at sensitive locations depends on knowing how loud the sound is and how long it operates in any given period of time.

Assumptions are commonly made to evaluate the sound levels in the absence of known information. One of these assumptions is the amount of time that an HVAC unit's condenser fans operate in a predictable worst-case. A predictable worst-case could be described as a normal maximum and would exclude upset conditions or equipment failure. Under predictable warmest conditions the condenser fans are generally assumed to operate continuously during daytime, and at reduced capacity on the warmest nights. The range of assumed nighttime reductions drops from the usual 50% per hour down to as little as 25% per hour. In some cases, the HVAC units are assumed to be silent when a business is closed, or a space is not open to the public. This paper presents the results of initial investigations into the validity of assumptions about HVAC condenser fans on the warmest days (7 am to 11 pm) and nights (11 pm to 7 am).

2 Background

Where the HVAC unit provides cooling, the primary source of sound is the condenser fans. The sound levels for newer units are commonly available on manufacturer data sheets. The data usually only describes the loudest operating condition. When the unit addresses the heat load of the building by cycling the condenser fans between on and off, a calculation of hourly sound emissions only requires the operating time per hour. If the unit has condenser fans that operate at multiple speeds, such as with Variable Frequency Drives (VFDs) the calculation of hourly sound levels becomes more complex. For simplicity this study will be limited to HVAC units with condenser fans that achieve the necessary cooling capacity by on/off duty cycles.

Figure 1: Typical Commercial HVAC unit

Sources of data for on/off duty cycles are frequently difficult to obtain, as illustrated in the following cases. A larger business is more likely to control the HVAC units with a Building Automation System (BAS). Where the BAS collects a history of the unit functions, the status of the cooling system components is frequently available only as a percent load or temperature. Neither of these parameters translates clearly to a duty cycle of the condenser fans. If data on cooling stage status is available, it can often be correlated to fan operation. In cases where a business is the local outlet for a large corporation with many outlets, the HVAC equipment for all locations is likely to be controlled from a centralized remote site. In such the data is usually not readily accessible. Another group of users does not monitor the HVAC units' operation other than observation of the thermostat. The information from this group is a vague knowledge of how the units operate, with no knowledge of specific fans. Useful data for duty cycles of the cooling system on specific commercial HVAC units is therefore often not readily available.

Determining an actual hourly or daily duty cycle for an HVAC unit from design calculations is similarly impractical. The selection of HVAC unit cooling capacity is based on calculation of expected or probable heat load from activity in the building, building envelope design and construction, as well as geographic parameters.

3 Method

The duration that the HVAC condenser fans were operating was determined from time series data measured on individual fans. Fan operation was recorded twice per minute and aggregated to one-hour periods. A total of 27 fans, distributed over 19 pieces of HVAC equipment were evaluated. These

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included medium and small packaged units as well as split condenser units ranging up to 3 fans per unit. The use cases included hotel, retail, convenience store, and food service (i.e., restaurant or take-out) within the Guelph, Ontario area. Figure 1 shows one of the HVAC units that was measured.
HVAC condenser fans operate to dissipate the building's heat load. The heat dissipation is less efficient at warmer temperatures, so that condenser fans operate more on warmer nights than on cooler nights. To find the target periods of predictable worst-case operation, hourly summer nighttime temperatures in Guelph, Ontario were reviewed for a five-year period. Nights with the highest minimum temperature were selected to conduct measurements of condenser fan operation. The periods selected for evaluation had nighttime minimum temperatures of 20 to 21°C and maximum temperatures of 21 to 23°C.

4 Results

The HVAC condenser fans had notable differences in operation on the warmest nights. Figures 2 and 3 illustrate how two matching units operated over the same week.

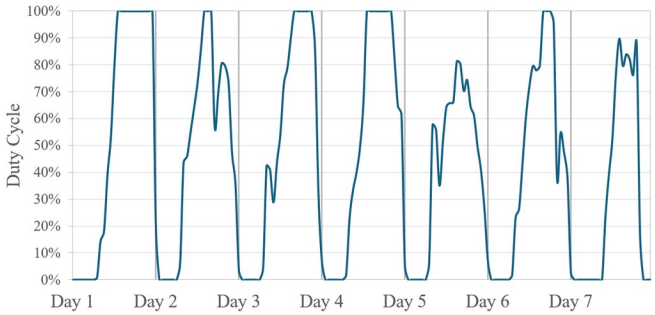

Figure 2: One Week Period with Fans Generally Off at Night

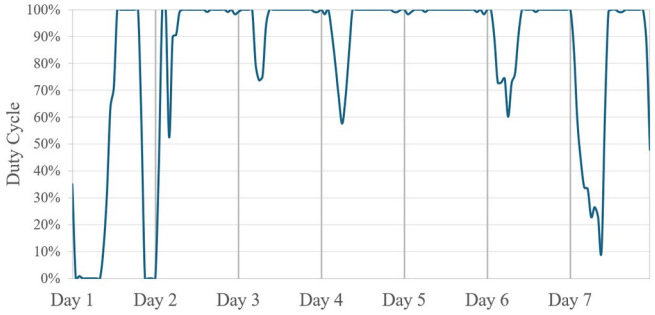

Figure 3: One Week Period with Fans Generally On at Night

Daytime operation at or near 100% of the hour was a common characteristic of 24 of the 27 condenser fans. The remaining condenser fans operated for only a few hours even on the hottest days.
In the nighttime periods there was greater variation between different HVAC units, as shown by the difference between Figures 2 and 3. Overall there were fewer hours of condenser fan operation. However, during the predictable worst-case hours the fans generally operated for the full hour. This is illustrated in Figure 4, where the distribution of worst-case duty cycle operation during nighttime shows that 67% of the fans had periods where they operated 100% of the hour.

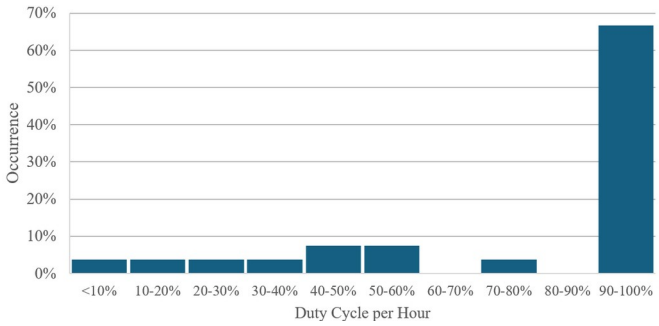

Figure 4: Distribution of Nighttime Predictable Worst-Case Hourly Duty Cycles

Individual fans on multi-fan HVAC units were observed to have similar average and maximum duty cycles. HVAC units also operated independently of each other on businesses with multiple HVAC units. However, the data set was not large enough to identify per-business trends.

Although this evaluation combines the food service, hotel, convenience store and retail uses, each type of use had nighttime hours with 100% HVAC condenser fan operation. Retail and food service businesses, which were not open 24 hours per day, had HVAC condenser fans turned on both before and after the business operating hours. In one case the HVAC condenser fans for a food service business operated continuously for all of the nighttime hours.

5 Considerations for Further Study

These results cumulatively consider a limited set of diverse commercial HVAC uses. Additional data sets would be necessary to demonstrate trends for specific use types, other use types, and how many HVAC condenser fans on a single business would simultaneously operate for 100% of a nighttime hour. Future study should also include correlation between nighttime ambient outdoor temperature and HVAC condenser fan operation. This would be valuable in considering how long-term weather trends would influence how much HVAC condenser fans would operate in the future.

6 Conclusion

This initial investigation, based on a limited data set, shows that the condenser fans of commercial HVAC units can operate for 100% of an hour during the warmest daytime and nighttime periods. During nighttime, operation at 100% occurs less frequently, however two thirds of the fans in this data set had hours of 100% operation at night.

The observations challenge assumptions that have been made about condenser fan operating times. The assumption of full capacity operation during predictable worst-case daytime hours is supported. However, during nighttime, the assumption of reduced hourly operation is not supported. During a predictable worst-case summer nighttime hour, an HVAC condenser fan also operates at full capacity, even if the business is not operating. The assumption of no condenser fan operation when a business is closed is thus not supported. Predictable worst-case HVAC condenser fan operation is a full hour in both daytime and nighttime.