Big Fans, Big Pumps Equal Big Energy

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An 11-story, 93,000 ft^2 (8600 m^2) office building owned by the Tennessee Valley Authority (TVA) in Chattanooga, Tenn., achieved an ENERGY STAR label primarily due to a novel upgrade to a 1969 vintage water-loop heat pump system. TVA employee Norman Bookout suggested the replacement of a central 50 hp (37 kW) pump and one 5 hp (3.7 kW) pump with 46 in-line pumps that cycle on and off with each heat pump. Although total pump power is only 8.2 hp (6.1 kW), they "...were found to handle the loads with no problem... and also save maintenance dollars."[1] This relatively simple modification suggests the potential for similar improvements in many existing buildings and possibly even in buildings not yet completed.

Design engineers are faced with many constraints including a plethora of code and standard compliance issues (ventilation, energy, mechanical, etc.), installation costs, and required formalities to obtain building ratings. If standards, codes and ratings do not adequately limit fan and pump size, the good intention and high cost of many other energy-saving features could be compromised. Engineers might make the false assumption that demand and energy use of fans and pumps are acceptable if buildings comply with ASHRAE Standard 90.1-2007[2] and obtain a LEED rating.

One goal of this column is brevity in hopes that the average ASHRAE member may be more inclined to read a document written by a Ph.D. if it is very short. Therefore, no hour-by-hour energy analysis is offered. The simple premise is that if a fan or pump is too big it will use too much energy, even if it has a variable-speed drive.

Fan, Pump Limits in the Standard

While there seems to be no restriction on the head and flow rate of pumps in Standard 90.1-2007, fan motor power is limited to 1.7 hp/1,000 cfm (2.7 kW/1000 L/s) for variable-speed and 1.2 hp/1,000 cfm (1.9 kW/1000 L/s) for constant-speed motors in large air handlers. At first glance, this seems a bit high if one considers a 1,000 cfm (470 L/s) energy-efficient unitary air conditioner likely would have a 0.25 hp (0.2 kW) fan. Therefore, the impact of a 1.7 hp/1,000 cfm (2.7 kW/1000 L/s) air-distribution system is compared with a primary chilling device having a demand of 0.5 kW/ton (COP = 7.0).

The fan limit is converted to a per ton basis using 400 cfm/ton and to power input using a 92% efficient motor.

$$W_{Fan}/\text{ton} = 1.7 \text{ hp}/1000 \text{ cfm} \times 400 \text{ cfm/ton} \times 0.746 \text{ kW/hp} \div 0.92 = 0.55 \text{ kW/ton}$$

Not only is the fan demand 10% larger than the chiller demand, all of this power is converted to heat (motor losses, fan losses, and friction in duct), which results in a significant reduction in net cooling effect.

$$q_{Fan} = 0.55 \text{ kW/ton} \times 3{,}412 \text{ Btu/kWh} = 1{,}880 \text{ Btu/h heat gain per ton (15.6\%)}$$

When fan power and heat are considered, the chiller COP of 7.0 is converted to a system COP of 2.8. If the power input of the chilled water pump, the condenser water pump, and the cooling tower fan are included, the COP likely will be less than 2.4 (EER = 8.2), which is 15% lower than the Standard 90.1 minimum for a window air conditioner.

Properly applied unitary systems tend to minimize auxiliary component power, resulting in high system efficiency. Unfortunately, some buildings are not amenable to this type of equipment. In buildings that are better served by central distribution systems, careful scrutiny of fan and pump power is especially critical to system energy efficiency.

Conclusions

The impact of fans and pumps must be carefully considered in efforts to improve energy performance of buildings.

Standards, codes and rating methods should be modified when loopholes for auxiliary demand and energy consumption guidelines exist.

References

1. U.S. Environmental Protection Agency. 2009. ENERGY STAR Labeled Building Profile: Edney Building (TVA). http://tinyurl.com/mhxvfm.

2. ANSI/ASHRAE/IESNA Standard 90.1-2007, *Energy Standard for Buildings Except Low-Rise Residential Buildings*.

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