Measuring Heat Pump Efficiency

Measuring heat pump efficiencies in the field is often thought to be difficult because measuring air conditioner efficiencies certainly is. But a little trick—using the backup heat—greatly simplifies the measurement. You can actually get an accurate efficiency measurement with equipment as minimal as two thermometers and a stopwatch.

The presence of backup heat (or strip heater) facilitates air flow (cfm) measurement. For air conditioners, air flow is "the hardest thing to measure in the field," according to Bruce Hunn, head of the Building Energy Systems Program at the University of Texas. But for heat pumps, it is possible to measure the air temperature rise between the return and supply air (ΔT, in °F), and the back-up heat plus fan power draw (BW + FW, in watts). This allows the cfm to be calculated.

$$\text{cfm} = \frac{(BW + FW)}{\Delta T} \times 3.16$$

Measuring air temperatures requires care. It is important that the air be well mixed and critical that the thermometer not be in the line of sight of the backup heaters to avoid radiant heating errors. This usually means taking readings a small distance from the heat pump, beyond at least one duct elbow. Longer distances lead to other measurement errors because duct air leakage and heat losses can become significant.

The building's kWh meter is the best way to measure the backup heat plus fan power. Simply time the revolutions with a stop watch, and use the kh factor on the meter to determine power drawn by the equipment as follows:

$$\text{Watts} = \text{kh} \times 3600 \times \frac{\#\ \text{revolutions of meter disk}}{\#\ \text{seconds}}$$

Subtract the power draw when the equipment is not running, and ensure that nobody turns on a microwave oven during the measurements! (John Proctor, President of Proctor Engineering Group, suggests cutting power to the rest of the building at the circuit breakers—with the owners' permission of course.) Take one measurement with the fan and heat on—i.e., set the heat pump control so that only the backup heat and the fan run (BW + FW)—and one with the fan only (FW). The difference between the two is the backup heat only (BW), which will be used in the COP calculation as well.

With the air flow rate, the heat pump efficiency can now be measured. Run the equipment in heat pump mode, with the backup heat on, and again measure the air temperature rise (ΔT). Also measure the total equipment power draw (EW, in watts). (The degree of error from leaving back-up heat on proves to be negligible.

The heat pump coefficient of performance (COP) is:

$$\text{COP} = \frac{((\text{cfm} \times \Delta T \times 1.00) - (BW \times 3.41))}{(EW \times 3.41)}$$

This equation subtracts the backup heat capacity (BW x 3.41) in order to calculate the COP of the heat pump without the backup heat.

To compare the field COP to manufacturers' ratings, one must also measure the indoor and outdoor temperatures, because heat pump efficiency varies greatly with air temperature. If the equipment isn't rated, John Proctor's report provides a good generic chart.

In order to make it easy enough to use in the field, a few minor simplifications have been made in this technique. This technique assumes that:

- air properties such as density are constant (again, for our purposes, leaving on backup heat makes only a minor difference),
- all fan power is converted into heat (some of it is actually still in the form of air pressure where measurements are taken),
- the system is at steady state,
- and—in the case of a heat pump added to an existing furnace—fan power draw of the furnace motor is the same as that of fan coils used in equipment rating.

These simplifications result in errors of less than 1–2% of the final COP calculation.

A simple way to check for air mixing is to move the thermometer around within the duct, waiting at each position for the reading to stabilize. Averaging thermometers are also available. The temperature should be fairly uniform.

For all the measurements, run the equipment for at least 10 minutes before taking readings to allow some stability. However, perfect stability is impossible unless it's in the middle of winter and the building heat load is equal to equipment capacity! To ensure accuracy, double-check measurements with any secondary means available. For example, a wattmeter can be used to check the building meter power measurement. Also, Bruce Hunn reports measuring cfm using both a pitot traverse and a flow hood, with some success. Finally, to avoid erratic readings, consider taking a few measurements and averaging them.

31 houses that received it, but variability in actual cut-out temperatures lowered estimated average real savings to 8%.

Decks and Defrosters

Other frequent heat pump problems included leaks in the refrigerant lines, frequent defrost cycles, and air recirculation to outside coils. Leaks had sometimes been introduced by previous repairs. Project technicians repaired all leaks. Time between defrost cycles was corrected in all affected units (defrost cycles occurring every 90 minutes are sufficient in this climate). Air recirculation usually was caused by the placement of the outside coils in a restricted area, such as under a deck. In one case, the trapped air was 10° F below the ambient temperature. This unit's efficiency was lowered by 11%. Not surprisingly, no one could be convinced to tear down their deck for the sake of lower heating bills.

Overall Savings

The Pilot Project results showed that, if the full program were to be applied to houses of this type, homeowners could expect an average heating-energy savings of 27%. These savings were well above the original goal of 10–20%. The program also projected an average cooling savings of 22%. Under the plan, the utility would pay $400 per site, while it would regain a calculated net life cycle benefit of $459. The program would cost participants from $50 to $350, and would save them an average calculated net lifecycle benefit of $2,597. The lifetime of the duct repair work is considered 15 years. That of the heat pumps is only five years, owing to the likelihood of replacement. Costs and savings for individual retrofits are summarized in Table 1. Because not all the retrofits were needed in each house, the sum of the savings for each of the individual retrofits