Building Science Education Solution Center – Introduction to Heat Pumps

Proficiency Level 3: Apply

Learning Objective 3.1:

- What should a person consider before installing an air source heat pump?

Lecture Notes 3.1:

There are several aspects to understand and consider before installing an air-source heat pump (ASHP) instead of a furnace. The first of these is that, while a heat pump can eliminate the need for on-site fuel storage or a connection to a natural gas line, it will significantly increase the electrical load on the house. If the house is new, then the service capacity and electric panel will need to be properly sized to accommodate this load. If the house is an existing one, the panel and service capacity will need to be assessed and possibly expanded. The Assessment of Electrical Panel and Options training module provides more information on this topic.

A second consideration is that ASHPs require space for the outdoor unit (commonly called a condensing unit or condenser). A typical outdoor unit is about 3 feet wide, 3 feet deep, and 3 or 4 feet tall. They generally require clearance on all sides of at least 1 - 3 feet for airflow. Further, outdoor units produce noise and should be located as far away from bedroom windows as possible. Note that these same issues apply to the outdoor unit for an air conditioner if one is installed along with a furnace rather than a heat pump.

Heat pumps also operate differently from furnaces from the user's standpoint. Because heat pumps do not generate heat through combustion, but rather move heat from the outdoors to indoors, the air coming from a heat pump will not typically be as warm as the air from a furnace. For this reason, heat pumps tend to run and will cycle on and off less than a furnace. This allows heat pumps to maintain more even space temperatures than furnaces. However, if occupants are used to warming up next to the heating vent from a furnace, they may find that the air from a heat pump's vent feels cooler.

Another major aspect of a heat pump is efficiency. Heat pumps are typically 3 to 4 times more efficient than normal electric resistance heat (e.g., electric baseboards). They are also 3 to 4 times more efficient than the most efficient natural gas or propane furnaces. Because of this high efficiency, heat pumps often cost less to operate than fossil fuel furnaces. However, this is highly dependent on local utility costs and the significant fluctuations in the cost of natural gas, propane, and other heating fuels. In general, in order for utility rates to favor heat pumps over an 80% AFUE gas furnace, the electric rates would need to be no more than 0.12 times the gas rate.

Problem Set 3.1:

1) Which of the following should be assessed before installing a heat pump?

a. Is the electrical panel sized to accommodate the heat pump?
b. Is there space to locate the outdoor unit so it gets proper airflow?
c. Does the difference between the gas and electric utility rates in the area favor heat pump installation?
d. All of the above

Learning Objective 3.2:

- What should an HVAC installer consider about the ductwork and condensate drain in an existing home before installing a heat pump?

Lecture Notes 3.2:

Before installing a ducted heat pump to replace a ducted furnace, it is necessary to ensure that the existing ductwork is adequately sized to handle the supply and return airflow of the new unit. Because heat pumps tend to operate under higher supply flowrates, upsizing of ductwork may be needed.

Example 1:

Sarah wants to replace her ducted gas furnace with a ducted heat pump.

The ductwork should also be assessed to ensure that it is properly insulated to reduce energy losses and condensation risk. Properly insulated and sealed ductwork becomes particularly important when moving from a heating-only system to a heat pump which can heat and cool. When in cooling mode, uninsulated or improperly insulated ducts invite condensation, resulting in potential mold, decay, and property damage (via dripping water). Insulating the ducts using a product with a vapor barrier jacket on the outside greatly reduces this risk.

If existing ductwork is inadequate or too many modifications are necessary, new ductwork is another option that could be considered as part of the HVAC upgrade. If new ductwork is installed, a compact layout should be designed in accordance with ACCA Manual D: Residential Duct Systems.[1]

It should be noted that if the existing system has no air conditioning, then provision will need to be made for condensate removal at the indoor coil. This can be accomplished via a simple gravity drain system or a condensate pump system. Both are common and straightforward methods. Finally, if the furnace or boiler is to be removed, the existing flue or chimney should be capped off at the top and the bottom or repurposed.

Problem Set 3.2:

1) Which of the following statements is not true when replacing a ducted furnace with a ducted heat pump?

    a. The ductwork should be assessed to ensure it is properly sized for the new equipment

---

[1] https://www.acca.org/store#/productDetail/71E94104-BC20-E511-80F8-FC15B428DD54/

b. Air conditioning will not increase the risk of condensation on the ducts
c. The existing ductwork should be assessed to ensure it is properly insulated and sealed
d. Properly insulating ductwork will reduce the risk of condensation on the ducts

Learning Objective 3.3:

- Be able to compare the operating costs of ASHPs and fossil fuel heating systems.

Lecture Notes 3.3:

Depending on the climate and utility rates, ASHPs can be more cost effective than fossil fuel heating systems.

Example 1: Gas furnace versus a ducted whole-home heat pump.

201 Hickory St in Atlanta, GA has a ducted gas furnace. It has an AFUE, or efficiency, or 80%. This means that for every 1 Btu of natural gas that the furnace uses, the home receives 0.8 Btu of heating. The furnace typically uses 700 therms of natural gas per year. Sarah, the homeowner, is considering replacing the gas furnace and air conditioner with a heat pump. The heat pump has a HSPF of 10.5.

First, calculate the home's heating energy use.

$$Annual\ Heating\ Energy\ Requirement\ (Btu/yr)$$
$$= Annual\ Natural\ Gas\ Use\ (therms/yr)\ x\ \frac{100,000\ Btu}{1\ therm}\ x\ efficiency$$

$$Annual\ Heating\ Energy\ Requirement\ \left(\frac{Btu}{yr}\right) = 700\ \frac{therms}{yr}\ x\ \frac{100,000\ Btu}{1\ therm}\ x\ 80\%$$
$$= 56,000,000\ \frac{Btu}{yr}$$

The home's annual heating energy requirement is 56 million Btu/yr. Next, use the proposed systems overall heating efficiency, the Heating Seasonal Performance Factor (HSPF), to determine the electric energy required to provide the same heating energy. Here is the definition of HSPF:

$$HSPF = \frac{Heating\ Energy\ Requirement\ (Btu/yr)}{Electric\ Energy\ Used\ (Wh/yr)}$$

Rearranged, the electric energy used can be found using this equation:

$$Electric\ Energy\ Used\ \left(\frac{kWh}{yr}\right) = \frac{Heating\ Energy\ Requirement\ \left(\frac{Btu}{yr}\right)}{HSPF}\ x\ \frac{1\ kWh}{1,000\ Wh}$$

$$Electric\ Energy\ Used\ \left(\frac{kWh}{yr}\right) = \frac{56,000,000\ \frac{Btu}{yr}}{10.5}\ x\ \frac{1}{1,000} = 5,333\ kWh/yr$$

The current heating use is 700 therms of natural gas, and the proposed heating use is 5,333 kWh of electricity. Now let's apply the utility rates. Sarah pays $0.80 per therm and $0.09 per kWh.

$$Operating\ Cost = Fuel\ Use\ x\ Utility\ Rate$$

$$Gas\ Furnace\ Operating\ Costs = 700\ therms\ x\ \$0.82\ per\ therm = \$574$$

$$Heat\ Pump\ Operating\ Costs = 5,333\ kWh\ x\ \$0.09\ per\ kWh = \$479$$

The gas furnace costs $574 per year and the proposed heat pump would cost $479 per year. That's nearly $100 savings each year.

Problem Set 3.3:

1. Sarah's nephew is considering replacing his natural gas boiler with a multi-zone ductless heat pump system. The boiler has an efficiency of 70% and the ductless mini-split has an HSPF of 11.5. Sarah's nephew uses 1,000 therms per year and pays $0.62 per therm and $0.11 per kWh. How much would it cost to run each system and will her nephew save money by installing the new system? Why else might he install the new system?

Answer:

$$Annual\ Heating\ Energy\ Requirement\ (Btu/yr)$$
$$= Annual\ Natural\ Gas\ Use\ (therms/yr)\ x\ \frac{100,000\ Btu}{1\ therm}\ x\ efficiency$$

$$= 1,000\frac{therms}{yr}\ x\ \frac{100,000\ Btu}{1\ therm}\ x\ 70\% = \mathbf{70,000,000}\frac{\mathbf{Btu}}{\mathbf{yr}}$$

$$Electric\ Energy\ Used\ \left(\frac{kWh}{yr}\right)$$

$$= \frac{Heating\ Energy\ Requirement\ \left(\frac{Btu}{yr}\right)}{HSPF}\ x\ \frac{1\ kWh}{1,000\ Wh}$$

$$= \frac{70,000,000\frac{Btu}{yr}}{11.5}\ x\ \frac{1}{1,000} = \mathbf{6,087\ kWh/yr}$$

$$Operating\ Cost = Fuel\ Use\ x\ Utility\ Rate$$

$$Gas\ Furnace\ Operating\ Costs = 1,000\ therms\ x\ \$0.66\ per\ therm = \$660$$

$$Heat\ Pump\ Operating\ Costs = 6,087\ kWh\ x\ \$0.11\ per\ kWh = \$669$$

Sarah's Nephew will pay slightly more using a heat pump. He may choose a heat pump over a gas furnace due to concern about unstable gas prices or safety concerns over combustion in the home.

Other reasons he may choose the heat pump would be because he wants to have air conditioning available in his home, or wants to run his system off of the solar panels he is installing to lower his carbon footprint.