**Building Science Education Solution Center – Cold Climate Heat Pump Sizing**

Proficiency Level 2: Understand

**Learning Objective 2.1:**

* Understand the traditional approach to sizing heat pumps.

**Lecture Notes 2.1:**

Heat pumps, unlike furnaces, air-conditioners, boilers, or baseboard heaters, provide both heating and cooling from the same piece of equipment. This presents a unique challenge to the HVAC designer and installer: Should the heat pump be sized to meet the heating or cooling needs of the client?

The heating capacity of a traditional single-stage heat pump is related to its cooling capacity: the higher the cooling capacity, the higher the heating capacity. Because of this, it can be very difficult to match a heat pump’s size to both the heating load and the cooling load of a house.

Consider a home in a climate zone 7, a very cold climate zone. It will have a large heating load but a small cooling load. A heat pump which has enough capacity to meet the heating load will likely have a cooling capacity which is much larger than the house’s cooling load. The unit will be oversized in cooling. However, if the heat pump is sized properly to meet the cooling load, it will then be significantly undersized for the heating load.

In any case, usually either the heating or the cooling capacity must be oversized or undersized. The following considerations must be made when under- or oversizing a system for heating or cooling:

* Oversized cooling capacity: The system will cycle on and off more frequently, causing wear and tear and uneven comfort. It will also not provide good humidity control.
* Oversized heating capacity: The system will cycle on and off more frequently causing wear and tear and uneven comfort.
* Undersized cooling capacity: The system will not be able to keep the house cool enough during the hottest times, but it will usually dehumidify more effectively.
* Undersized heating capacity: The system will not be able to keep the house warm enough during the coldest times. The auxiliary or backup heat will make up the difference, but at a much lower efficiency.

In many areas of the United States, right-sizing a heat pump for cooling will result in an undersized heating capacity. Conversely, right-sizing for heating will usually result in an oversized cooling capacity. Traditionally, heat pumps were right-sized for cooling because heat pumps were more commonly installed in warmer climates. Often this meant that the heating capacity was undersized, but the system would make up for any lack of heating capacity with auxiliary heat. A system sized this way will provide enough cooling during design conditions, will properly dehumidify, and will not cycle on and off too frequently. Meanwhile comfort is not compromised on the heating side due to the auxiliary heat. This approach works well in the warmer regions of the United States because the heating loads are not high, and the use of auxiliary heat is not excessive.

However, in cooler climates this approach would be problematic. Right-sizing a heat pump for cooling means the heat pump will be sized smaller in cooler climates. This will result in more significantly undersized heating capacities. For these climates, heating demands will be higher and selected heat pump heating capacities will be lower. Consequently, traditional heat pumps and traditional sizing methods may no longer apply to such scenarios because most of the heat for the home will come from the lower efficiency auxiliary heat source rather than from the heat pump compressor itself.

**Problem Set 2.1:**

1. What approach to sizing single-stage heat pumps has been recommended traditionally?
   1. Oversize the cooling capacity and right-size the heating capacity.
   2. Undersize the cooling capacity and undersize or oversize the heating capacity.
   3. Right-size the cooling capacity, even if it means the heating capacity is undersized.
   4. Oversize the cooling capacity and oversize the heating capacity.

**Learning Objective 2.2:**

* Understand the approaches to sizing heat pumps in cool and cold climates.

**Lecture Notes 2.2:**

Variable-capacity air source heat pumps (ASHP) entered the US market in the early 2000s, and their popularity has grown throughout the 2010s and 2020s. The technology allows increased flexibility in how heat pumps are sized. These heat pumps can modulate their output and operate at lower capacities than their rated maximum capacity. Turndown ratio is a term used to describe how much a unit can modulate its capacity. Specifically, turndown ratio equals the unit’s maximum capacity divided by its minimum capacity. If a unit can modulate to a very low capacity compared to its maximum capacity, it is said to have a high turndown ratio. This means that if a system is oversized it can still operate at a lower capacity without needing to cycle on and off as frequently, decreasing system wear. In cooling mode, this also results in improved dehumidification.

Heat pumps can now be right-sized for heating and oversized for cooling with less concern about comfort and efficiency. This makes heat pumps in colder climates much more attractive.

There are a few different approaches to sizing heat pumps in cold climates. Which approach to use depends primarily on the goals of the homeowner. Most applications will fall into one of these four categories:

* Size to the design cooling load. The heating capacity will almost certainly be undersized. A traditional heat pump may meet the needs of this application.
* Size the unit such that the mid- or low end of its cooling capacity range will meet the design cooling load. This approach allows a larger unit with more heating capacity to be selected. A variable-capacity heat pump should be selected. The unit will technically be oversized for cooling, but the modulating or staged capacity will mitigate oversizing issues.
* Size the heat pump to meet most of the heating demand (for example, 80% of the design heating load). A variable-capacity heat pump should be selected. The unit will be oversized for cooling, but modulating or staged cooling capacity will mitigate oversizing issues.

* Size the heat pump to the design heating load. A variable-capacity heat pump should be selected. The unit will be oversized for cooling, but modulating or staged cooling capacity will mitigate oversizing issues.

**Problem Set 2.2:**

1. Why are variable-capacity heat pumps more appropriate for cold climates than single-stage heat pumps?
   1. Single-stage heat pumps cannot provide heating.
   2. Variable-capacity heat pumps can be oversized for cooling, but modulate down to prevent short-cycling and provide better cooling and dehumidification.
   3. Variable-capacity heat pumps provide more heating and cooling than single-stage heat pumps, regardless of climate.
   4. Variable-capacity heat pumps cannot operate in warm weather.

**Learning Objective 2.3**

* Understand the balance point temperature
* Understand heat pump cycling

The colder outside conditions are, the more heat a building will need, and the less heat a heat pump can produce. At a certain temperature, the heating needs of the building will start to become greater than the output of the heat pump. This crossover point is known as the balance point temperature. A heat pump’s balance point temperature is the outdoor air temperature where the maximum heating output of the heat pump exactly matches the building’s heating load. The ASHP’s heating capacity decreases as the outdoor temperature drops, so at outdoor air temperatures below the balance point, the heat pump capacity falls short of the building’s heating load and it must use supplemental heat to maintain the desired indoor temperature. In some residences this supplemental heat will come from electric resistance or a dual fuel system that contains both a heat pump and a gas furnace, but may also come from an existing system left in place. In dual fuel systems, the balance point temperature is known as the switch-over temperature, which is the point where a dual-fuel system switches from using the ASHP to the backup heating system. The module on **Smart Thermostats and Dual Fuel Controls** discusses dual fuel control schemes in more detail.

Heat pumps operate in cycles of on-off operation. Variable-speed units can operate at different speeds while they are on, while single-stage units are either on or off. For either type, the heat pump should operate for a period, then turn off for a period, and the cycle continues. When the load of the house is low, such as in mild conditions, the heat pump may run at its minimum speed for a shorter time than normal. This is called short-cycling and should be avoided. Wear and tear on the equipment increases, as do comfort issues and energy use.

**Problem Set 2.3**

1. Which best describes the balance point temperature of a heat pump?
   1. The temperature at which the maximum heating capacity matches the heating load of the house
   2. The temperature at which the maximum heating load of the house occurs
   3. The temperature at which the heat pump begins short-cycling to match the load of the house
   4. The temperature at which the house requires no mechanical heating or cooling