PRODUCT APPLICATION

A technical bulletin for engineers, contractors and students in the air movement and control industry

Designing Air-Source Heat Pumps

Because of environmental concerns and local regulations around natural gas, many commercial building owners are taking a closer look at heat pump technology. In the past, technological limitations with air-source heat pumps (ASHPs) meant they could only be used as the main source of heating for a building when the outdoor air temperature was 30°F or higher. However, with recent engineering improvements, ASHPs can operate effectively down to 0°F.

With this evolving capability, many engineers may not be familiar with how to most effectively design air-source heat pumps in commercial buildings or their risks and benefits, which this guide will address.

Benefits of Air-Source Heat Pumps

Small Footprint

- An ASHP utilizes energy from ambient air, so it does not need the land footprint of a geothermal heat pump, which uses a large closed-loop pipe system to harness geothermal energy.
- As all-electric equipment, an ASHP has a smaller carbon footprint than a natural gas boiler or furnace.
- Greenheck ASHPs use R-454B refrigerant, which has no potential to deplete the ozone layer and is four times less likely to contribute to climate change than previously used refrigerants.

Regulatory Trends Toward Decarbonization

According to the Air Conditioning, Heating, and Refrigeration Institute (AHRI), heat pumps outsold gas furnaces in new homes in 2023.[1] But as of the time of writing, less than 15% of commercial buildings in the U.S. use heat pumps, according to Canary Media.[2] A Department of Energy initiative calls for a 65% reduction in carbon emissions from commercial buildings by 2035 and has partnered with manufacturers to move heat pump technology for rooftop units further.[3] Considering that many jurisdictions regulate the use of natural gas in commercial buildings already, heat pumps are becoming more viable alternatives.

More Efficient than Other Electric Options

Compared to electric resistance heat, ASHPs can be over three times more efficient because they use ambient heat energy from the atmosphere rather than simply consuming electricity to produce heat.

How Air-Source Heat Pumps Work

Cooling and Dehumidification Mode

See Figure 1 on the next page for a diagram of an ASHP operating in cooling mode. An ASHP has an indoor and an outdoor coil. In cooling mode, the indoor coil is the evaporator coil and the outdoor coil is the condensing coil. When the cooling cycle is activated, the compressor(s) are staged on to maintain supply temperature, with the lead compressor operating at a variable speed based on the current load demand. The outdoor fan(s) are also staged on, with the lead outdoor fan serving as a modulating fan. The system is controlled by the discharge air sensor. The only difference between an ASHP and a typical rooftop unit in cooling mode is the presence of a reversing valve.

In dehumidification mode, the compressor(s) are staged on to maintain the discharge coil temperature, and the outdoor fan(s) are staged on. If applicable, the hot gas reheat (HGRH) valve modulates between 0–100% to maintain the supply temperature.

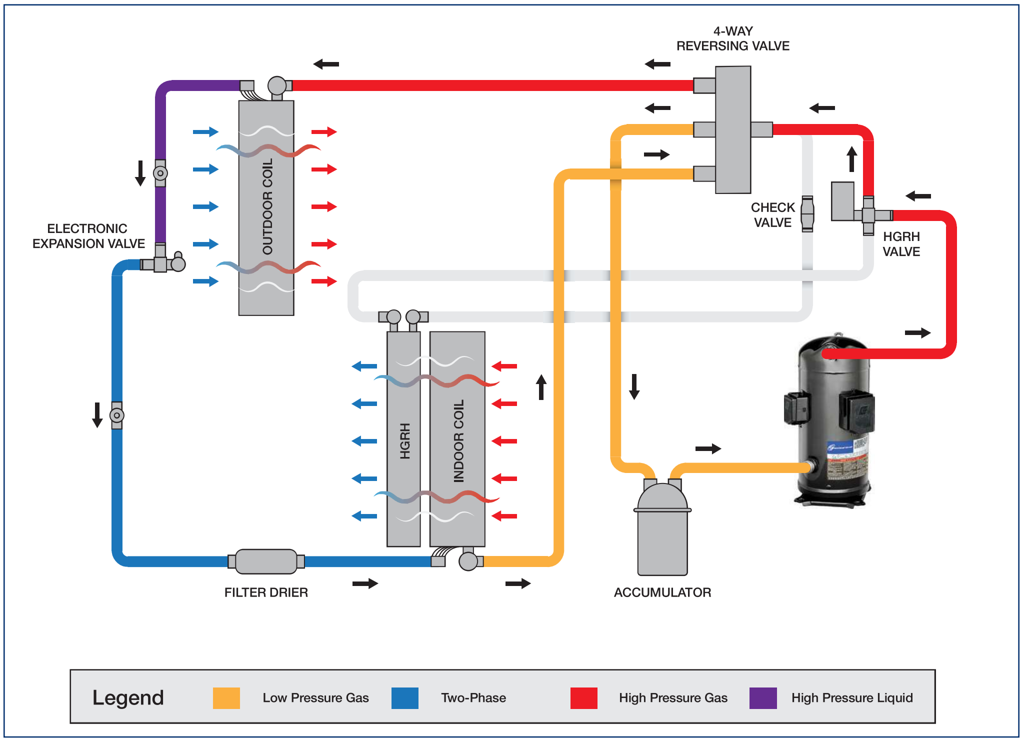

Figure 1: ASHP Refrigeration Circuit with Hot Gas Reheat in Cooling Mode

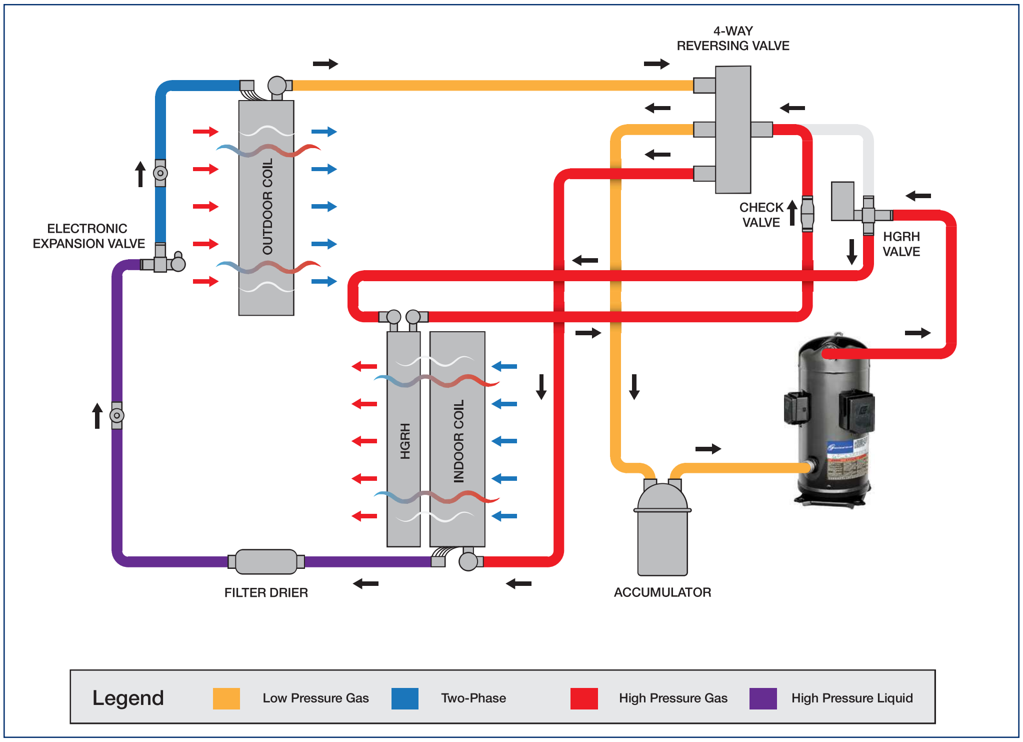

Figure 2: ASHP Refrigeration Circuit with Hot Gas Reheat in Heating Mode

Heating Mode

In heating mode, shown in Figure 2 on the preceding page, the outdoor coil is the evaporator coil and the indoor coil is the condensing coil. When the heating cycle is activated, the reversing valve is energized and the compressor(s) are staged on. The outdoor fan(s) are staged on. The HGRH valve is staged to 100%. The system is controlled by the discharge air sensor.

Additional heat can be added as necessary, sized either for supplemental or backup depending on the need for the secondary heat source to operate simultaneously with the ASHP. The next sections provide more detail.

Air-Source Heat Pump Design Challenges and Solutions

Dealing with Frost on the Outdoor Coil

When the ASHP is in heating mode at certain outdoor conditions, frost can accumulate on the outdoor coil. This prevents the ASHP from operating as intended. Providing an effective defrost mode can help. During defrost mode, the heat from the compressor and the indoor coil are directed toward the outdoor coil to melt the frost, cooling the indoor supply air, which can make building occupants uncomfortable.

During the design phase, it is important to plan what will trigger the defrost cycle. This should not only be a consideration in very cold applications, but temperate ones as well. The moisture in the outdoor air is a better indicator of frost potential than the temperature of the air. The outdoor coil is more likely to frost on a misty 40-degree day than a dry 5-degree day. Therefore, if defrost is triggered by the outdoor air temperature, excessive defrost cycles may occur. In fact, the outdoor air dew point is a more effective indicator of frost. The ASHP should compare the dew point to the saturated suction temperature as the basis for transitioning to defrost. When frost appears on the coil, the saturated suction temperature drops, which indicates less heat rejection.

Other elements to consider during design are how long the defrost cycle lasts and how the unit exits defrost mode. ASHPs typically have a timer that can be set to determine how long defrost mode will last. Using this alone may result in defrosts that are too long or too short. The ASHP should actively monitor defrosting based on condensing temperature for the optimum defrost time.

Planning for Low Temperatures

Even as ASHP technology improves, the units can still be challenged by wintry temperatures. In cold starts, where the unit goes from “off” to “on” in cold weather, the compressor may be slow to start up. In most cases, the ASHP will not operate if the outdoor air temperature is less than 0°F. Additionally, higher entering indoor coil temperatures may be required at low outdoor temperatures. Here are some ways to mitigate the effects of low temperatures while designing an ASHP.

- **Recirculation dampers:** Units that have this feature can start in 100% recirculation to allow time for the refrigeration circuit to warm up before the indoor coil is exposed to ambient conditions.
- **Supplemental heat:** This is heat that runs at the same time as the ASHP. It would typically run during defrost mode to prevent the space from getting significantly colder, but can also help meet setpoint during instances where the ASHP cannot meet the desired discharge air temperature on its own.
- **Backup heat:** This is heat that kicks on during an ASHP lockout due to temperature. Electric resistance heat, hot water coils, or a gas furnace could be used as backup or supplemental heat, so long as the electrical power to the unit is sized for it.
- **Energy recovery:** Adding energy recovery to an ASHP can be an effective solution for tempering the air that reaches the indoor coil. During heating mode, energy recovery technology uses exhaust air from the building, which is already heated, to temper cold incoming air. The incoming air that reaches the indoor coil is therefore warm enough for the compressor to start operating. This also increases the amount of time that the ASHP can meet the desired discharge air temperature without the need for supplemental heat.

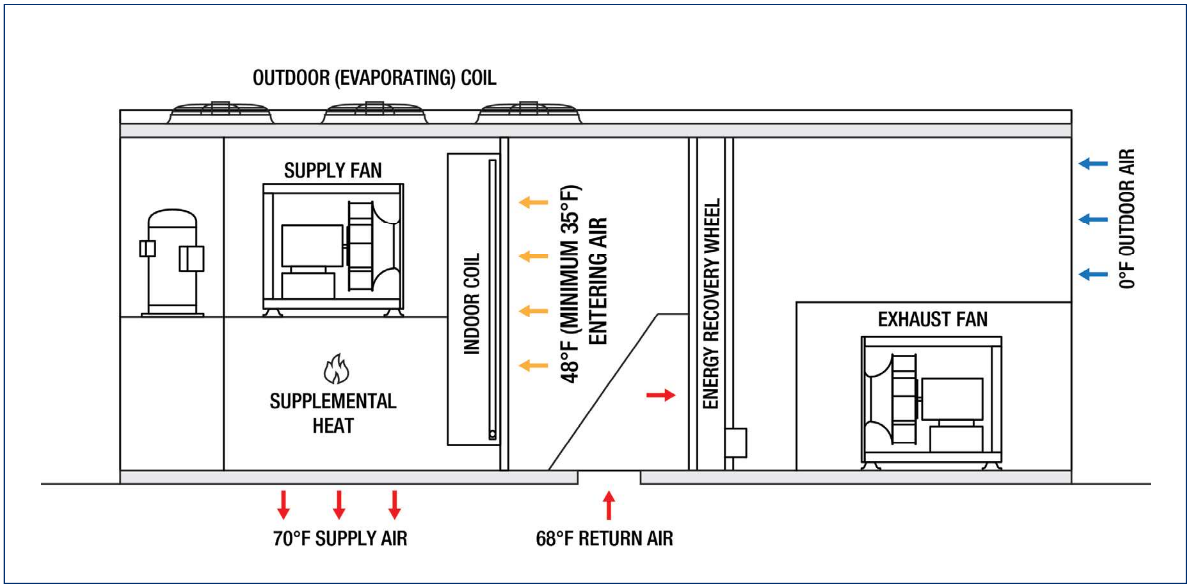

Figure 3: ASHP with Energy Recovery Wheel

In the above diagram, an energy recovery wheel is receiving exhaust air at 68°F, using it to heat up frigid outdoor air coming in at 0°F, and delivering it to the indoor coil at a mild 48°F. With the addition of supplemental heat transmitted by a supply fan, the room's occupants receive the air at a pleasant 70°F, as designed.

Summary

Air-source heat pumps offer many benefits as part of a heating and cooling system for a commercial building. They have a small land and ecological footprint, are more efficient than traditional electric resistance heat, and are part of the Department of Energy's plans for a decarbonized future. It is important to be aware of their challenges as well, such as the potential for a space to lose heat while the unit is defrosting the outdoor coil, and the need for backup heat and energy recovery in applications with subzero outdoor temperatures. Strategic design of an ASHP around elements like defrost cycle triggers, recirculation dampers, and effective control sequences at lower outdoor temperatures will help to ensure comfort for occupants and compliance with local energy codes.

1 Spencer, Regan. "AHRI Releases December 2023 U.S. Heating and Cooling Equipment Shipment Data." AHRI. February 9, 2024. Accessed July 31, 2024. https://www.ahrinet.org/news-events/news/ahri-releases-december-2023-us-heating-and-cooling-equipment-shipment-data

2 Takemura, Alison F. "Better heat pumps for commercial buildings are coming soon." Canary Media. April 15, 2024. Accessed July 8, 2024. https://www.canarymedia.com/articles/heat-pumps/better-heat-pumps-for-commercial-buildings-are-coming-soon

3 Longevin, Jared and Wilson, Eric. ***Decarbonizing the U.S. Economy by 2050: A National Blueprint for the Buildings Sector.*** U.S. Department of Energy. April 2024. Accessed July 16, 2024. https://www.energy.gov/eere/articles/decarbonizing-us-economy-2050