CONTROLS FOR A HEAT PUMP WITH SECONDARY HEATING
FOR CONTRACTORS

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WHAT ARE TWO-SYSTEM CONTROLS AND HOW DO THEY WORK?

Two-system controls are single control packages that coordinate between heating systems by switching between primary and secondary heating at a pre-determined condition.

Primary Heat Pump

Secondary Other Heating

Prioritizing the heat pump minimizes the use of fossil fuels or inefficient heating systems which reduces the carbon footprint of the home while maximizing savings and comfort. Installing and configuring controls ensures comfort for the homeowner. Two-system controls allow for "set-it-and-forget-it" operation which simplifies operation for the homeowner and should reduce callbacks related to user error. Concepts addressed for two-system controls also apply to systems with more than two heating types.

Two-system controls consist of a thermostat controller and temperature sensors or a Wi-Fi temperature monitor. Temperature sensors signal the thermostat to activate secondary heating when temperatures fall below the setpoint, while a Wi-Fi monitor can engage secondary heating based on local weather station data.

WHEN SHOULD TWO-SYSTEM CONTROLS BE INSTALLED?

While not essential for heat pump operation, two-system controls are recommended for heat pumps installed with high efficiency secondary heating systems. The controls will manage the two-systems to simplify operation and ensure they work well together.

Two-system controls can be configured with various combinations of heat pumps and other heating systems. Some heating systems, such as radiant floor heating, take time to heat up which may cause a delay in secondary heating. It is suggested that secondary heating systems which require time to warm up be engaged without turning off the heat pump system to reduce the impacts of secondary heating delay.

TWO-SYSTEM CONTROL STRATEGIES AND WHEN TO USE

Controls should be configured to prioritize the heat pump as the primary heating source, then supplement with or switch to the secondary heating system when pre-set conditions are met. Two common strategies for dual system controls rely on indoor and outdoor air temperature.

Strategy One: **Indoor Temperature**

Use this method when:

- Homeowner priority is ease of use, energy efficiency, and carbon reduction.
- A heat pump is sized for 100% of the heating load.
- The thermostat is capable or it is a two thermostat system

Indoor Temperature Benefits:

- Maximizes heat pump use
- Only employs secondary heating when needed
- Does not require annual re-calculation
- Temperature should not drop enough for homeowner to notice
- Reduces effect of mismatched zoning, excess cycling, and secondary heating delay

Indoor Temperature Controls

The indoor temperature method maximizes heat pump operation and uses secondary heating to supplement the heat pump as needed. Maximizing the use of the heat pump minimizes carbon production by only engaging secondary heating when needed to maintain the indoor temperature. It is suggested this method be used whenever possible.

How to Set Indoor Temperature Controls

Configure controls to activate secondary heating solely when indoor temperature falls below a specified threshold, with the heat pump maintaining operation while the secondary system supplements heating until the setpoint is regained. Ensure that the chosen activation temperature for second stage is outside the heat pump's ±2-4 degree temperature float to prevent overlap.

HOW TO SET CONTROLS FOR SYSTEMS WITH TWO THERMOSTATS

It is suggested two-system controls be installed when possible. However, for systems incompatible with advanced controllers, a basic way to simulate advanced controls involves setting the heat pump setpoint as usual and placing the second stage heating system at a setpoint 2-4 degrees lower. Careful monitoring is required to adjust setpoints if the system behaves unexpectedly, as improper operation could lead to energy waste, high bills, and unnecessary emissions.

Strategy Two: **Outdoor Temperature**

Use capacity balance point when:

- Indoor temperature method is unable to be used.
- Homeowner priority is carbon reduction and ease of use.
- The installed heat pump is not sized to 100% of the heating load.
- The system and thermostat allow temperature switchover.

Use economic balance point when:

- Homeowner priority is cost reduction. They should be aware that cost savings are difficult to predict and may be small.
- The operating cost of the heat pump is higher than the secondary heating at temperatures well above the design temperature.

The economic balance point must be re-evaluated annually with changing fuel and electricity prices.

Outdoor Temperature Controls

The outdoor temperature method switches from heat pump to secondary heating at an outdoor temperature called the switchover temperature. This temperature can be determined based on the heating capacity of the heat pump or the cost of running the two heating systems. The economic balance point is not recommended because it is difficult to calculate, frequently changes with prices of electricity and fuel, and does not account for the cost of carbon production.

How to Determine a Switchover Temperature

The switchover temperature selection depends on homeowner or governing body priorities and can be aligned with either **capacity or economic balance points**, with capacity chosen for emission reduction and economic balance for cost minimization.

Capacity Balance Point: If the customer's goals are to minimize carbon production and maximize heat pump use, this method should be selected. The capacity balance point is the temperature at which the heat pump no longer has the capacity to cover the load of the home. The heating load of the home increases as the outdoor temperature drops. The maximum capacity of the heat pump also declines as outdoor temperature drops, although slowly for cold climate heat pumps. When the maximum capacity of the heat pump is no longer higher than the heating load of the home, second stage heat will need to be engaged. This point can be determined using tools like NEEP's Cold Climate ASHP List (https://ashp.neep.org/#!/) or calculated using the manufacturer provided performance specifications and the Manual J heating load.

Economic Balance Point: The economic balance point, when heat pump and secondary heating costs match, happens because a heat pump's efficiency decreases with outdoor air temperature unlike a secondary system. This balance point must be calculated using the efficiency of the heat pump, efficiency of the secondary system, electricity cost, and fuel cost.

The economic balance point method should minimize utility costs for the homeowner, but the balance point fluctuates as costs of fuel and electricity change. Typically, the cost savings of using the economic balance point are minimal. Because of the changing point and typically small cost savings, many homeowners elect to use the capacity balance point.

CALCULATE THE ECONOMIC SWITCHOVER TEMPERATURE

To calculate when the secondary system is cheaper to run than your heat pump, you will need to gather the efficiency of both systems and the cost per unit delivered of electricity and the fuel. This method can be difficult to calculate but accurate at time of sizing, design, and installation. However, fluctuating costs of fuel and electricity require the economic switchover temperature be re-evaluated every heating season. The savings realized by using this method are often minimal. This method also ignores the cost of carbon production by the fossil fuel system. Because of these reasons, it is suggested other methods be selected when possible.

Natural Gas Switchover

Natural gas is most commonly used in dual fuel systems as it is an inexpensive and available fuel. To find the economic balance point when using a natural gas system, use the heat pump's manufacturer specifications to find the temperature that matches with the switchover COP.

$$\text{Economic Switchover COP} = \$/\text{kWh} \times 29.31\ \text{kWh/Therm} \times \text{AFUE} \div \$/\text{Therm of Gas}$$

$$\$/\text{therm} = \$/\text{CCF} \times 1.038$$

Other Fuel System Switchover

For all other systems, use the below method to find the economic balance point for the fuel and heat pump systems.

$$\text{Fuel Heating: Cost per Btu} = \$/\text{unit} \div \text{Fuel Heating Value} \div \text{Efficiency}$$

Because the fuel heating system does not rely on the outside air for heat, the efficiency of the system typically stays level. Calculate the cost of running the fuel heating system, then find which COP the heat pump requires to equal that cost. Use the manufacturer specifications to find which temperature aligns with the calculated COP. This temperature is the economic switchover point of the system.

$$\text{Heat Pump: Heat Pump Switchover COP} = \$/\text{kWh} \times 0.293 \div 1000 \div \text{Cost per Btu}$$

It should be noted that COP of a single-speed heat pump varies by outdoor air temperature and COP of a multi-speed heat pump varies by compressor speed and outdoor air temperature. Because the COP varies at any outdoor temperature, it should be estimated carefully depending on the output of the system at the temperature in question. Use the manufacturer specification or the NEEP ASHP Tool (ashp.neep.org/#!) to determine the COP of your heat pump.

Fuel cost and heating value

Fuel Type	Typical Efficiency	Average Cost	Heating Value
Natural Gas	0.8-0.95	$1.06/therm	100,000 (BTU/therm)
Propane	0.9-0.98	$2.03/gallon	92,500 (BTU/gal)

Fuel source costs based on U.S. national average. Data from U.S. Energy Information Administration. www.eia.gov

For more rates and information on data assumptions, please visit https://www.mnashp.org/cost-heat-comparison.

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