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Control Strategies for Building Space Heating

E 004
03/01

A building space heating system can be controlled in many ways. The strategy used to control the heat input can make a great difference in the efficiency, comfort, and durability of the heating system. In order to provide accurate indoor temperatures, the heat supplied to the building must equal the heat loss from the building. The heat loss from a building to the outdoors is dependent on the outdoor temperature. As the outdoor temperature drops the heat loss from the building increases. If the heat supplied to the building is greater than the heat loss from the building, the indoor temperature will rise. On the other hand, if the heat supplied to the building is less than the heat loss from the building, the indoor temperature will fall.

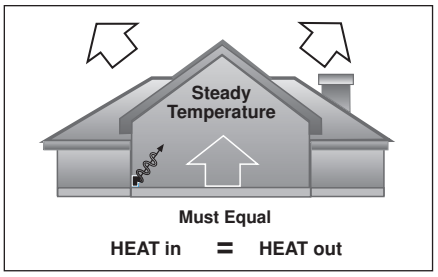

Figure 1

METHODS OF CONTROLLING HEAT SUPPLIED TO THE BUILDING

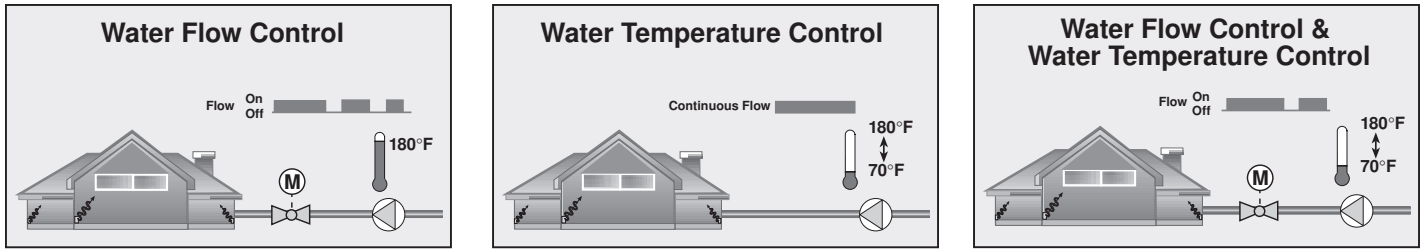

Figure 2

WATER FLOW CONTROL (NO WATER TEMPERATURE CONTROL)

Water Flow Control consists of varying the flow rate of constant temperature water in the heating system. Flow control can be achieved by cycling a valve or pump on and off, or by modulating the position of a valve or speed of a pump. This control strategy section will examine only on / off flow control. Water Flow Control requires the system water to be maintained at high temperatures (typically 180°F (82°C)) in order to satisfy the heating load during design outdoor temperatures. When there is flow present in a zone, 100% of the heat will be supplied, and when there is no flow, 0% of the heat is supplied. During the majority of the heating season, less than 50% of the heat is required, however, the system can only provide 100% or 0% of the available heat. These conditions may cause room temperatures swings and short cycling of equipment. Due to the constant high temperature of the boiler during the heating season, greater distribution, stack and jacket losses results. Also, expansion noises in the terminal units are common as the flow of high temperature water through the terminal unit is turned on and off.

A. Stand Alone Water Flow Control (Thermostats)

Stand Alone Water Flow Controls cannot communicate with other controls in a heating system. Typical Stand Alone Controls are mechanical or electronic room thermostats. In multiple zone systems, whenever a thermostat calls for heat, the boiler fires and operates at a temperature equal to the boiler's aquastat setting. Thermostats provide easy zoning capabilities; However, since there is no communication between controls, random operation of the zones will occur. The random operation of zones causes large fluctuations of system flow rate as shown in figure 3. These flow rate fluctuations can cause boiler short cycling and subsequent decrease in system efficiency.

Figure 3. Stand Alone Water Flow Control (Thermostats)

B. Integrated Water Flow Control (Central Zone Control)

Integrated Water Flow Control consists of a Central Zone Control that operates and coordinates several zones. Indoor Sensors or Room Temperature Units (RTU), located in each zone, communicate indoor temperature information back to the Central Zone Control. The Central Zone Control then calculates the on time of each zone and coordinates zone operation. As shown in figure 4, zone load coordination provides steadier flow rates in the system, which improves system efficiency by decreasing boiler short cycling. Central Zone Controls also provide more accurate indoor temperature control by using PID (Proportional, Integral, Derivative) control logic. This logic allows the control to predict the response of the room by measuring the room temperature error, how long the error has persisted, and how fast it is changing.

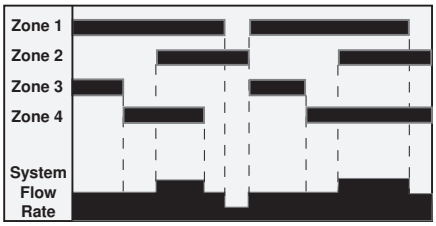

Figure 4. Integrated Water Flow Control (Central Zone Control)

WATER TEMPERATURE CONTROL

Heat flows from a hot body to a cold body and the rate of heat transfer is dependent on the temperature difference between the two bodies. In a heating system, if the temperature of a heating terminal unit such as a baseboard is increased, the temperature difference between the room and the terminal unit also increases. The heat delivered by the terminal unit is directly related to the supply water temperature. With this in mind, the heat transfer into the room can now be matched to the heat loss from the room simply by modulating the water temperature to the terminal unit.

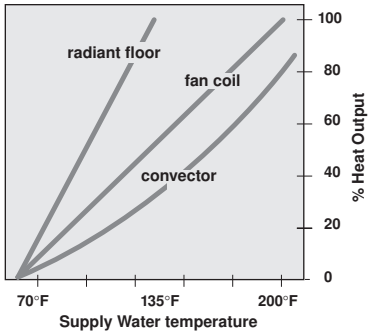

Figure 5

Outdoor Reset

Since the building heat loss depends on the outdoor temperature, regulation of the supply water temperature to the terminal units should be based on the outdoor temperature. The modulation of supply water temperature based on the outdoor temperature is call Outdoor Reset. An Outdoor Reset control utilizes a heating curve to set the relationship between outdoor temperature and supply water temperature. The heating curve determines the amount the supply water temperature is raised for every 1° drop in outdoor air temperature. During mild outdoor temperatures the supply water temperature will be low, while during the coldest day of the year the supply water temperature will be at design conditions. Outdoor Reset reduces indoor temperature swings by more closely matching the output of the terminal units to the load. It also increases system efficiency by minimizing distribution losses.

Depending on the heat source used, different Outdoor Reset strategies are permitted:

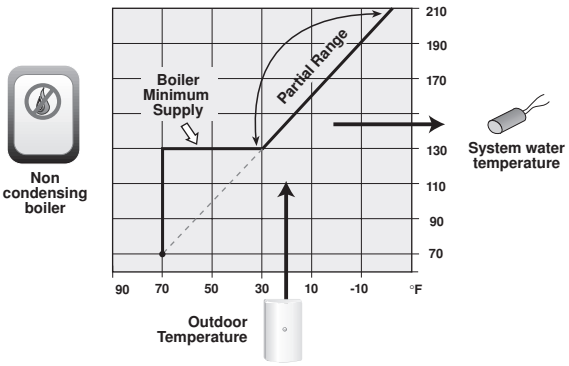

Figure 6. Partial Outdoor Reset

Partial Outdoor Reset

Most boilers, such as non-condensing boilers, require a minimum supply water temperature in order to prevent corrosion from flue gas condensation. The control should therefore only modulate the boiler supply water temperature down to the boiler manufacturer's minimum recommended operating temperature, as shown in figure 6.

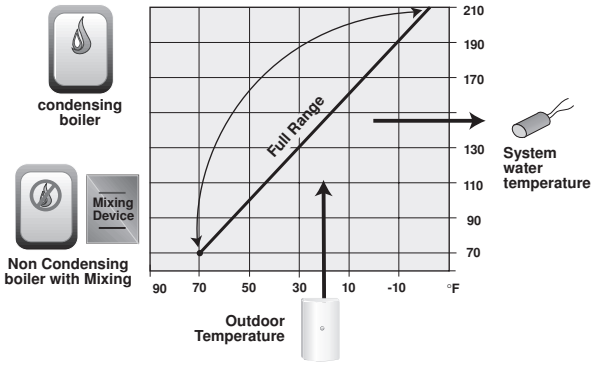

Figure 7. Full Outdoor Reset

Full Outdoor Reset

The full range of water temperatures required throughout the heating season can be provided using a condensing boiler, or a mixing device together with a standard (non-condensing) boiler. Full Outdoor Reset can modulate the supply water temperature down to room temperature. This strategy minimizes distribution losses by always supplying the lowest possible water temperature (see figure 7). Indoor temperature swings are also minimized since the heat supplied to the building can always be matched to the heat loss from the building.

Outdoor Reset with Indoor Temperature Feedback

Most buildings have internal heat gains due to people, solar energy, and equipment. If only the outdoor temperature is measured, the control cannot compensate for these gains and overheating may occur. By measuring the indoor temperature, feedback can be provided to the Outdoor Reset Control. This indoor temperature feedback compensates for the internal heat gains, by shifting the Outdoor Reset Heating Curve providing an adjustment of the supply water temperature to the system. If the room temperature is too cold the control will automatically shift the heating curve up, and if the indoor temperature is too warm it will shift the heating curve down. A single Indoor Sensor / RTU, or a Central Zone Control with multiple Indoor Sensors / RTUs is required to obtain indoor temperature feedback. Outdoor Reset with Indoor Temperature Feedback is more effective when used with Full Outdoor Reset (as shown in figure 8), since the supply water temperature can be fully modulated. In Partial Outdoor Reset applications, the control system used must take the boiler minimum into account.

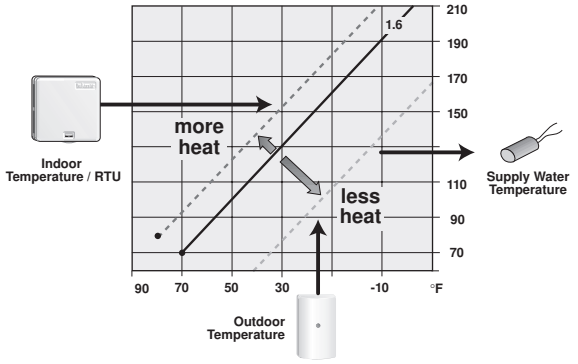

Figure 8. Outdoor Reset with Indoor Temperature Feedback

C. Full Outdoor Reset with Indoor Temperature Feedback

The ideal method of controlling the heat supply to a building is to maintain constant circulation, and to continuously modulate the supply water temperature to match the heat loss from a zone. This type of strategy is Full Outdoor Reset with Indoor Temperature Feedback, and is most cost effective when used in single zone systems. Since the heat input is constantly matched to the heat loss by the building, there are virtually no indoor temperature swings. Heat distribution losses are also kept to a minimum due to the lower water temperatures in the system, and expansion noises are eliminated, since there is constant circulation through the heating terminals at all times.

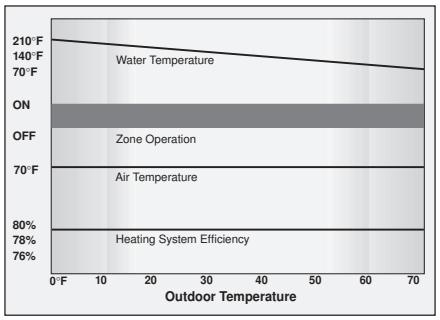

Figure 9. Full Outdoor Reset with Indoor Temperature Feedback

WATER FLOW CONTROL WITH WATER TEMPERATURE CONTROL

Unfortunately, Full Outdoor Reset with Indoor Temperature Feedback is too expensive for every zone in a building, therefore it is necessary to combine Water Flow Control with Water Temperature Control. Thermostats or Central Zone Controls can be used together with an Outdoor Reset Control to provide water flow control and water temperature control. By combining water flow control with water temperature control, expansion noises and indoor temperature swings can be minimized, as a result of the increased on time of the zone valves / pumps at lower water temperatures.

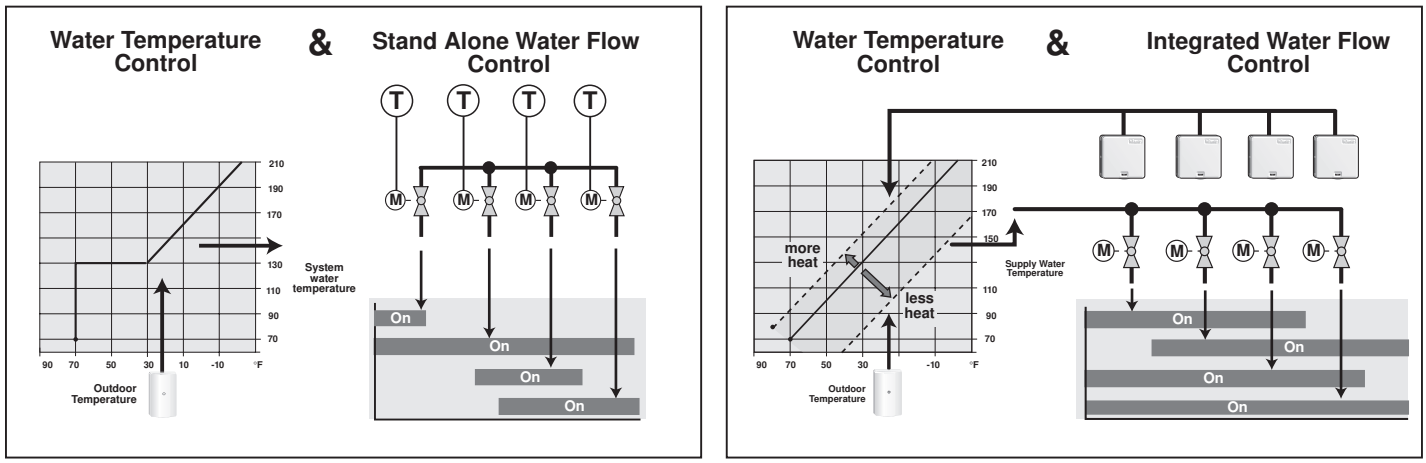

Figure 10

D. Stand Alone Water Flow Control with Partial Outdoor Reset

The performance of a Stand Alone Water Flow Control system can be significantly improved by adding Water Temperature Control. When a thermostat calls for heat, the Outdoor Reset control measures the outdoor temperature and provides the required supply water temperature, based on the heating curve. During mild outdoor temperatures the Outdoor Reset Control maintains the supply water temperature at the boiler minimum temperature. As a result, the supplied water temperature is hotter than required and may cause some indoor temperature swings and zone short cycling. Stand Alone Water Flow Control with Partial Outdoor Reset typically provides energy savings of 10 to 15%. This control strategy is often the most cost effective control solution in retrofit applications.

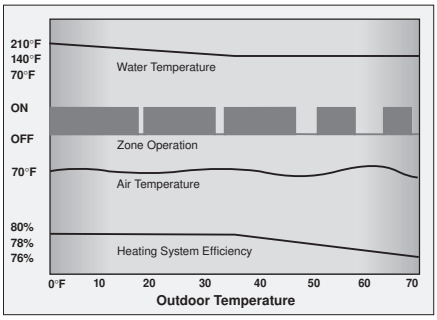

Figure 11. Stand Alone Water Flow Control with Partial Outdoor Reset

E. Stand Alone Water flow Control with Full Outdoor Reset

For systems using a condensing boiler or a mixing device with a non-condensing boiler, Full Outdoor Reset can be used. When a thermostat calls for heat, the Outdoor Reset Control modulates the supply water temperature based on the outdoor temperature and the heating curve setting. During mild outdoor conditions the supply water temperature is modulated all the way down to room temperature. This increases system efficiency by reducing distribution losses throughout the heating season. Since the heat supplied is controlled through the supply water temperature, thermostats tend to stay on longer and the indoor temperature is more stable. Stand Alone Water Flow Control with Full Outdoor Reset provides further improvement in system efficiency and more comfort by minimizing indoor temperature swings during mild conditions.

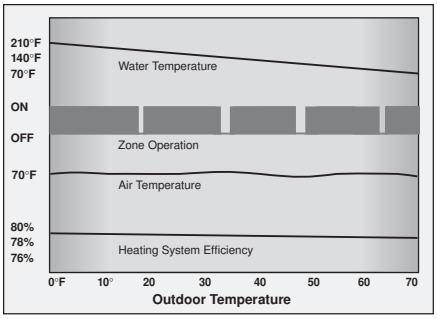

Figure 12. Stand Alone Water Flow Control with Full Outdoor Reset

F. Integrated Water Flow Control with Partial Outdoor Reset

A Central Zone Control can constantly monitor the individual zone space temperatures and feed this information back to the Outdoor Reset Control. The Outdoor Reset Control can then adjust the heating curve to supply the highest water temperature required to satisfy the zone with the highest heat load. During mild outdoor conditions, the supply water temperature will still be limited by the boiler minimum temperature; However, zone load coordination increases system efficiency by minimizing boiler short cycling.

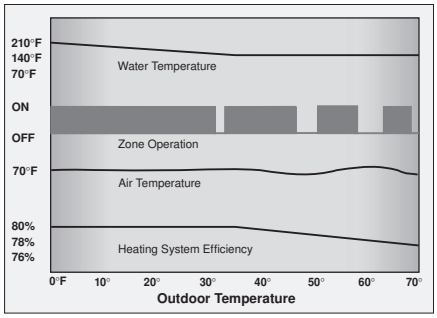

Figure 13. Integrated Water Flow Control with Partial Outdoor Reset

G. Integrated Water Flow Control with Full Outdoor Reset

Combining a Central Zone Control with Full Outdoor Reset provides the best room temperature control and efficiency for a multiple zone heating system. The supply water temperature is continuously modulated to provide the required temperature in the zone with the highest heat load, and therefore constant circulation in this zone will occur most of the time. Other zones will cycle on and off to inject heat into the zone as required. Expansion noises are kept to a minimum since the zone on times are longer. Integrated Water Flow Control with Full Outdoor Reset provides more comfort by minimizing indoor temperature swings during mild conditions, and increases system efficiency by providing the lowest possible water temperature to the system.

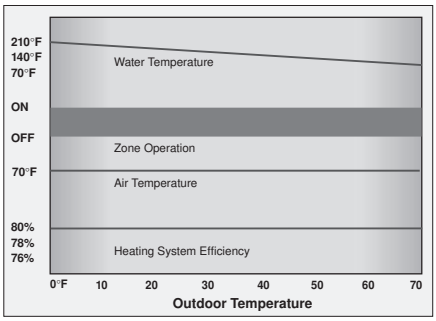

Figure 14. Integrated Water Flow Control with Full Outdoor Reset

Benefit summary

○ Poor ◒ Fair ◕ Good ● Excellent

Control Strategy \ Benefits		Steady Air Temperatures More Comfort	Less Expansion Losses More Comfort High Quality	Lower System Losses Energy Saving	Less Boiler Cycling Energy Saving	Zone Coordination High Quality
Stand Alone Water Flow Control	A	○	○	○	○	○
Integrated Water Flow Control	B	○	○	○	◒	●
Full Outdoor Reset with Indoor Temperature Feedback	C	●	●	●	●	N / A (Single zone)
Stand Alone Water Flow Control with Partial Outdoor Reset	D	◒	◒	◒	○	○
Stand Alone Water Flow Control with Full Outdoor Reset	E	◕	◕	●	○	○
Integrated Water Flow Control with Partial Outdoor Reset	F	◕	◕	◕	●	●
Integrated Water Flow Control with Full Outdoor Reset	G	●	●	●	●	●

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All specifications are subject to change without notice.
Printed in Canada E 004 - 03/01.