kanmor® - Essay

Control Strategies for Building Space Heating

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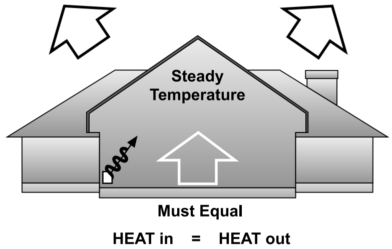
06/03

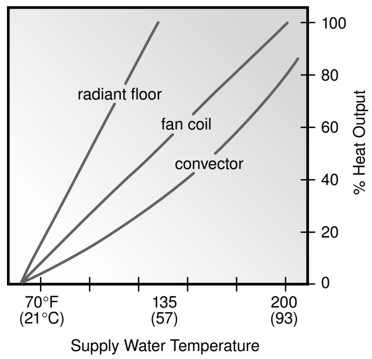
BACKGROUND

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.



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.

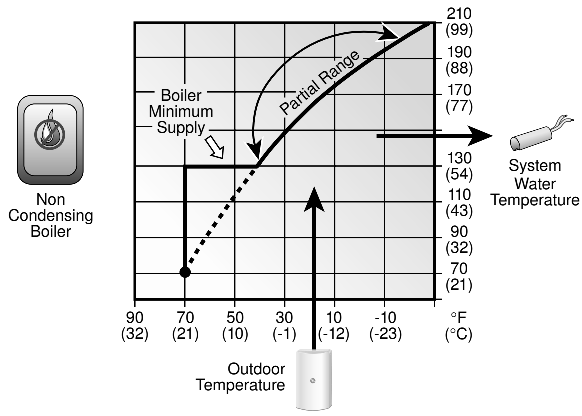


OUTDOOR RESET

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 called Outdoor Reset. An Outdoor Reset Control utilizes a heating curve to set the relationship between the outdoor temperature and the supply water temperature. The heating curve determines the amount the supply water temperature is raised as the outdoor air temperature drops. 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:

Partial Outdoor Reset

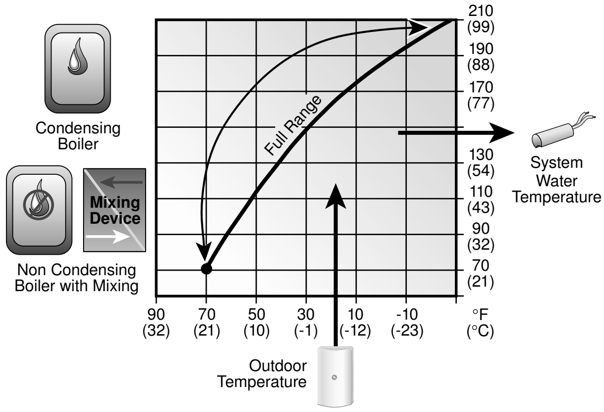
Most boilers, such as non-condensing boilers, require a minimum supply water temperature in order to prevent corrosion from flue gas condensation. The control should therefore only modulate the boiler supply water temperature down to the boiler manufacturer's minimum recommended operating temperature.



Partial Outdoor Reset

Full Outdoor Reset

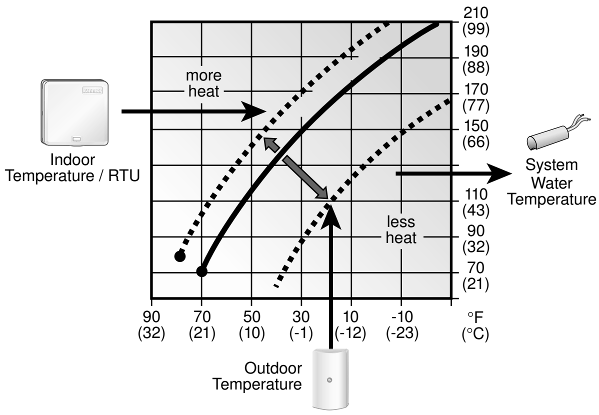
The full range of water temperatures required through a heating season can be provided using a condensing boiler, or a mixing device together with a non-condensing boiler. Full Outdoor Reset can modulate the supply water temperature down to room temperature. This strategy minimizes distribution losses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



Full Outdoor Reset

Outdoor Reset with Indoor Temperature Feedback

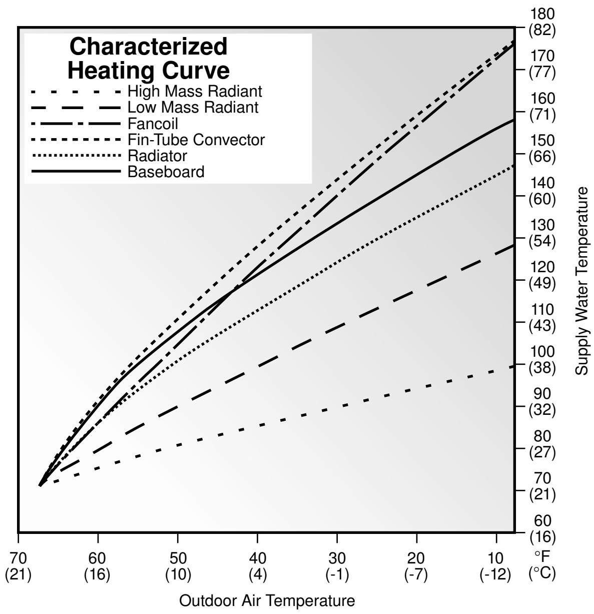
Most buildings have internal heat gains due to people, solar energy, and equipment. If only the outdoor temperature is measured, the control cannot compensate for these gains and overheating will occur. By measuring the indoor temperature, feedback can be provided to the Outdoor Reset Control. This indoor temperature feedback compensates for the internal heat gains by shifting the Outdoor Reset Control's Heating Curve providing an adjustment of the supply water temperature to the system. If the indoor 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 (062e or 063e), or a kanmor Zone Control with multiple Indoor Sensors / RTU's is required to obtain indoor temperature feedback. Outdoor Reset with Indoor Temperature Feedback is more effective when used with Full Outdoor Reset, since the supply water temperature can be fully modulated.



Outdoor Reset with Indoor Temperature Feedback

CHARACTERIZED HEATING CURVE

The Characterized Heating Curve method of controlling the supply water temperature is based on both the outdoor air temperature and the type of heating system that is installed. When using a Characterized Heating Curve, four pieces of information are required. The Indoor Design Temperature, Outdoor Design Temperature, Supply Water Design Temperature and the type of Terminal Unit used by the heating system. This method of outdoor reset is more accurate than traditional outdoor reset methods since the control takes into account the type of terminal unit that the heating system is using and the specific way in which that terminal unit transfers heat to the building. The type of terminal unit that is used has a large impact on the supply temperature to the system since each type of terminal unit delivers heat to the space in a different manner. As can be seen by the figure of the Characterized Heating Curve, the supply temperature during mild weather varies by a large degree depending on the type of terminal unit that is being used.



Indoor Design Temperature

The Indoor Design Temperature is the indoor air temperature that was used when the heat loss calculations for the building were performed. This setting establishes the beginning of the Characterized Heating Curve.

Outdoor Design Temperature

The Outdoor Design Temperature is the outdoor air temperature that is used in the heat loss calculations for the heating system. This is the typical coldest day of the year for the area in which the building is located. This temperature is used when doing the heat loss calculations for the building.

Supply Water Design Temperature

The Supply Water Design Temperature is the supply water temperature that is used in the heat loss calculations for the heating system. This is the supply temperature that is required to heat the building at the Outdoor Design Temperature.

Terminal Unit

When using a Characterized Heating Curve, the control requires the selection of a Terminal Unit. The Terminal Unit determines the shape of the Characterized Heating Curve according to how the Terminal Unit delivers its heat into the building space and how the Terminal Unit responds to changes in the supply water temperature. There are six common types of Terminal Units used in the hydronic heating industry. These six types of terminal units are discussed later.

The above figure shows the basic shapes of the Characterized Heating Curves for the six different types of terminal units. The supply water temperature requirements of most terminal units do not vary directly with outdoor air temperature. For this reason, traditional outdoor reset methods are only a good estimation for the supply water temperature and are not an accurate match. When outdoor reset controls were first introduced, the electro mechanical devices used for outdoor reset could not provide a complex reset strategy. However, with today's microprocessor based outdoor reset controls, it is possible to include a number of different Characterized Heating Curves in a single outdoor reset control. The following explains the key differences between the types of terminal units and how they transfer heat to the building and the basic shapes of their Characterized Heating Curves.

METHODS OF HEAT TRANSFER

There are three main methods that are used by terminal units when transferring heat to the building space: radiant heat transfer, natural convection and forced convection.

Radiant Heat Transfer

Radiant terminal units transfer heat directly by infrared radiation from the terminal unit and warms the people and objects in the space. The amount of heat that a radiant terminal unit delivers is related to the surface temperature of the radiant unit.

Natural Convection

Natural convection terminal units rely on the natural movement of air as it is heated. The air around the unit is heated and rises. As the heated air rises, it is replaced by cooler air that is then heated. The heated air moves through the room and warms the people and objects. The rate at which the air moves across the terminal unit depends on the temperature of the unit. The hotter the unit, the greater the rate of natural convection.

Forced Convection

In a Forced Convection terminal unit, air is moved across a heating element at a constant velocity by either a fan or a blower. This allows the terminal unit to be smaller. However, people may feel uncomfortable due to the cooling effect of air moving across their skin. In order to overcome this sensation, air in a forced convection system may be heated to a higher temperature than air in a natural convection system.

THERMAL MASS

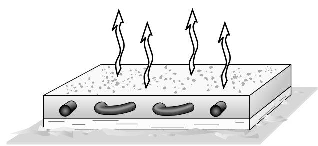
Each type of terminal unit has a different thermal mass. Thermal mass determines how much heat a terminal unit can store, and affects how long it takes the terminal unit to heat up and cool down. A terminal unit that has a high thermal mass takes a long time to heat up and continues to provide heat for a long period after water flow to it is shut off. Proper control of the supply temperature to a high mass terminal unit is required to prevent overshooting and undershooting of the room temperature. A terminal unit with a low thermal mass is relatively fast to heat up and cool down. This type of unit can provide heat very quickly when required. It also stops providing heat shortly after it is turned off. This type of terminal unit requires proper control of the supply temperature to prevent potential short cycling problems.

TERMINAL UNITS

There are several different types of terminal units that are commonly used in the hydronic heating industry. Each of these terminal units behaves differently based on their method of heat transfer and their thermal mass. Because of this fact, the supply water temperature that is supplied to each type of terminal unit should be tailored, or characterized, to match its needs. In order to provide the best control of the heating system, the control should take this into account when adjusting the supply temperature. Only a control that operates with a Characterized Heating Curve is capable of doing this. A control that operates using a traditional outdoor reset method cannot take into account the type of terminal unit that is being used in the heating system and therefore does not provide the same level of comfort and efficiency.

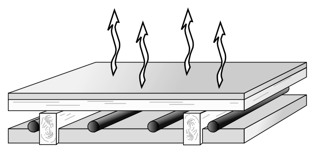
High Mass Radiant

A high mass radiant heating system consists of tubing that carries the heated supply water embedded in a heat transfer material. Commonly, the tubing is embedded in either a thick layer of concrete or gypsum. The concrete or gypsum, tubing and water make up the thermal mass of the terminal unit. Because of the large amount of material that is heated, this type of system changes temperature relatively slowly. A radiant floor heating system transfers heat from the terminal unit to the building using 50% radiant heat transfer and 50% natural convection. Because of the large surface area associated with this type of system, the supply water temperature required to provide adequate heat to the building is quite low. Such a terminal unit has a heating curve that is relatively straight with a low design supply water temperature.



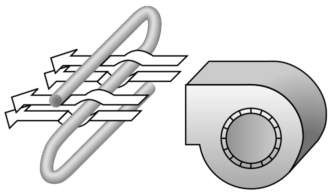
Low Mass Radiant

The tubing of a low mass radiant heating system can be attached directly to the underside of the floor with or without metal heat transfer plates. This is commonly referred to as a ‘staple-up’ radiant system. Alternatively, the tubing can be suspended in the joist space below the floor and used to heat the air on the underside of the floor. Another common method is to sandwich the tubing between the subfloor and the surface covering. Or the tubing can be embedded in a thin layer of gypsum or concrete. The thermal mass of this radiant system is substantially smaller than a high mass radiant heating system. A plated underfloor heating system is capable of responding faster than a high mass radiant heating system and is often required to operate with higher supply water temperatures. Such a terminal unit has a heating curve that is very similar to a high mass radiant heating terminal unit only with a higher design supply water temperature.



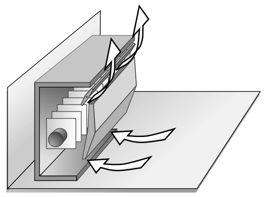
Fancoils

A fancoil incorporates a hydronic heating coil and either a fan or a blower. Air is heated when it is forced across the heating coil by the fan or blower. This type of unit uses forced convection as its method of heat transfer to the building. Since the heating coil is usually as small as possible, a fan coil must operate with a high supply water temperature. This is also required in order to keep the occupants of the building comfortable. Fancoils have a very low thermal mass and respond very rapidly. A fancoil's heating curve is relatively straight with a high design supply water temperature.



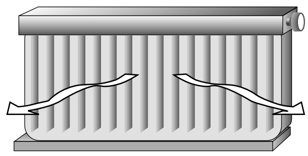
Fin-Tube Convectors

A fin-tube convector consists of a tube carrying the supply water encased in fins. This is also commonly referred to as just "fin-tube". As the water passes through the tube, heat is transferred to the fins. As the fins increase in temperature, the air surrounding the fins is heated which causes it to rise. The heated air is then replaced by cool air. Convectors use this natural convection to heat the air in the room which in turn heats the objects and occupants. Convectors are a low mass terminal unit and require supply temperatures that are high enough to produce the necessary amount of natural convection. The heating curve for a convector is relatively steep at low supply water temperatures and gradually flattens out as the amount of natural convection increases with higher supply water temperatures.



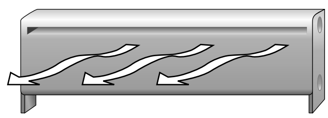
Radiator

A radiator is typically a free standing or wall mounted terminal unit. Because of their design, radiators have a large amount of exposed surface area for their size. Some of the heat that a radiator delivers to a room is through radiant heating. However, due to the design of the radiator, there is a large amount of natural convection. Because of the metal and water content, older cast iron radiators have a relatively high thermal mass when compared to convectors or baseboards. Even after a radiator has been turned off, it continues to provide heat into a room for a period of time as the thermal mass cools. Radiators also have a relatively steep heating curve during mild conditions. Due to the additional heat transfer from natural convection at higher supply temperatures, the heating curve flattens out as it nears the design conditions.



Baseboard

A baseboard terminal unit is characterized by its low profile and flat surface. Baseboards have a relatively small water content. This type of terminal unit is typically mounted around the perimeter of a room with only its front and top exposed to the room. A baseboard provides heat to the room through radiant heat transfer but the majority of the heat transfer is still through natural convection. The shape of the heating curve for a baseboard is very similar to that of a radiator. However, since a baseboard has a relatively small surface area, it is often designed to operate with higher supply temperatures.



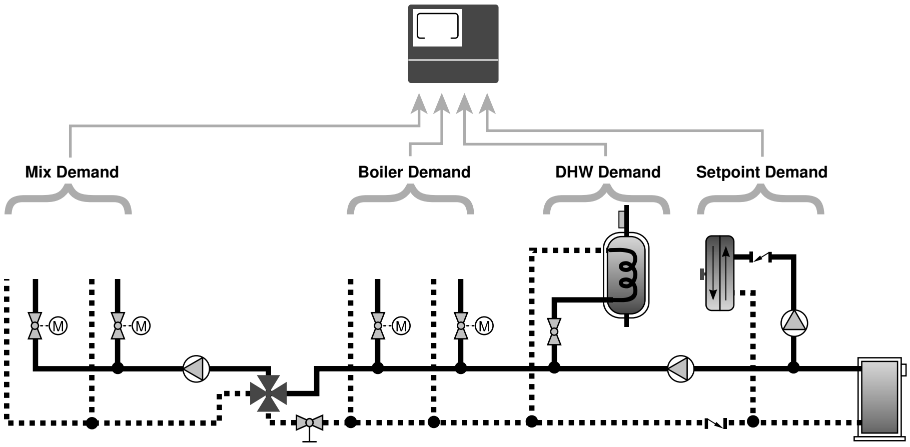
Not all heating terminal units behave in the same manner. Because of this fact, applying a generic outdoor reset strategy cannot provide the maximum performance and comfort from the heating system. An outdoor reset strategy that is customized to the heating system, such as a Characterized Heating Curve, will provide better performance and comfort.

DEMAND INPUTS

kanmor controls have several different types of demand inputs. A demand input is a powered signal that allows the control to interface with the loads in the hydronic system and allows the control to distinguish between different types of loads. The four common demand inputs for kanmor controls are Boiler Demands, Mixing Demands, DHW Demands and Setpoint Demands. A kanmor control responds in a specific manner to the different types of demands that it receives. By having different types of demand inputs, kanmor controls can be easily matched to a number of different applications for maximum flexibility.

Boiler Demand

A boiler demand is used by any space heating device that is piped directly to the boiler. The control responds to the boiler demand by determining the correct boiler supply temperature and pump operation. The boiler supply temperature delivered for a boiler demand is affected by the outdoor reset setup of the control and the outdoor air temperature. The temperature to the heating system is controlled by cycling the boiler on and off. If the control is in Warm Weather Shut Down (WWSD), it will not respond to a boiler demand. A boiler demand can come from a single thermostat, multiple zone valve end-switches or a wiring center.



Mixing Demand

A mixing demand is used by any space heating device that is piped to the low temperature side of a mixing device. The control responds to the mixing demand by determining the correct mixing supply temperature, pump operation and mixing device operation. The mixing supply temperature for a mixing demand is affected by the outdoor reset setup of the control and the outdoor air temperature. The temperature to the heating system is controlled by modulating the mixing device. If the control is in WWSD, it will not respond to a mixing demand. A mixing demand can come from a single thermostat, multiple zone valve end-switches or a wiring center.

DHW Demand

A DHW demand is used by the DHW tank aquastat. When the DHW tank requires heat from the boiler, the DHW aquastat sends a DHW demand to the control. The control responds to the DHW demand by determining the correct boiler temperature and pump / valve operation for the type of mechanical system used. After a DHW demand is removed, the control will then perform a purging routine to maximize the efficiency of the system. If the control is in WWSD, it will still respond to a DHW demand.

Setpoint Demand

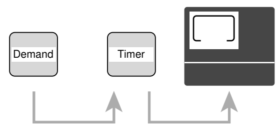
A setpoint demand is used by any hydronic load that is not related to the space heating system or the DHW system. An example of a setpoint load is a pool or hot tub. This type of load may require a specific supply temperature regardless of the outdoor air temperature. The control responds to a setpoint demand by determining the correct operating temperature for the boiler but does not operate any of the pumps in the system. The pumps must be operated independently for a setpoint demand. If the control is in WWSD, it will still respond to a setpoint demand.

TIMED SETBACKS

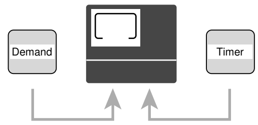
When a timed night setback is required in a system operated by a kanmor Outdoor Reset Control, there are three main methods of setting back the system. 1) Interrupt the demand signal from a given load. 2) Send an unpowered kanmor UnOccupied (setback) signal directly to the control. 3) Feedback from a kanmor Zone Control.

Interrupting the Demand Signals

A multi channel timer can be combined with a kanmor control to provide a timed setback in the system. The channel timer can be used to interrupt the demand signal. Since the demand signal is interrupted, the control does not register the demand and does not respond to the system. The thermostats and valves continue to operate as usual, however the control does not provide heat to the system. When using a control with multiple demand inputs, a separate channel on the timer can be used for each demand signal. This gives the operator the ability to have different portions of the hydronic system operating on different schedules.



kanmor UnOccupied (Setback) Signal

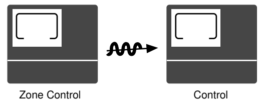


kanmor controls have several built in setback features that are more sophisticated than a simple channel timer. To activate the built in setback capabilities an unpowered switch must be closed on the control. A channel timer can be used to open or close the circuit between the UnOccupied Switch (UnO Sw) terminal and a Common (Com) terminal. The channel timer is used to set the schedule for the system. Once the channel timer closes the switch between the UnO Sw and the Com terminal, the kanmor control is put into an UnOccupied, or setback, mode of operation. When in the UnOccupied mode, several settings in the control will change to an alternate setting. These alternate settings are made when the control is first set up. For many of the Outdoor Reset settings, the installer will select both an Occupied setting and an UnOccupied setting. This also applies to several other settings including DHW tank operation and Setpoint operation. The Occupied settings are used by the control during normal operation. The UnOccupied settings are used when the channel timer closes between the UnO Sw and Com terminals and the control is placed in an UnOccupied mode.

There are several advantages to using the UnOccupied mode of operation. With the UnOccupied mode, an alternate Warm Weather Shut Down (WWSD) can be selected. As well, if a kanmor sensor is used to control the DHW tank, the tank temperature can either be reduced during a setback or it can be ignored. If either a kanmor Room Temperature Unit or kanmor Indoor Sensor is used, the temperature in the building can be reduced to a lower temperature rather than shut off. When the setback period is over, the channel timer will remove the UnOccupied signal. When the UnOccupied signal is removed, the kanmor control is capable of raising the water temperature in the system for a period of time in order to provide a faster recovery. This function is called a system Boost.

Feedback from a kanmor Zone Control

A kanmor Zone Control is designed to provide a feedback signal to the kanmor Outdoor Reset controls. This feedback signal allows the kanmor Outdoor Reset control to fine adjust the supply water temperature to the system. As well, it eliminates the need for a channel timer for the heating zones controlled by the zone control. The zone control incorporates a built in timer function for the zones that it operates. When the zones of the zone control enter into a setback period, the feedback signal is adjusted to reflect this change. The kanmor Outdoor Reset Control responds by adjusting the supply water temperature accordingly. The feedback signal from the zone control is also designed to provide optimization when the system is recovering from a setback.



Zone Controls

SINGLE ZONE CONTROL

Single zone control is achieved by connecting a kanmor RTU (062e or 063e) to the Outdoor Reset Control. The kanmor RTU provides room and outdoor temperature read outs and separate day and night temperature user adjustments. The kanmor RTU also provides Indoor Temperature Feedback to the Outdoor Reset Control for system supply water temperature fine tuning.

MULTI ZONE CONTROL

Multi zone control is achieved by providing a powered Boiler or Mixing Demand to the Outdoor Reset Control by either multiple thermostat controlled zone valve end switches or a Demand output from the wiring center.

INTEGRATED MULTI ZONE CONTROL

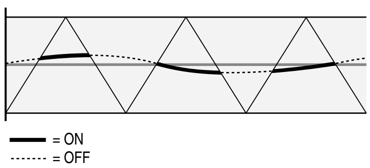
Integrated multi zone control is achieved by connecting one or more kanmor Zone Control to the Outdoor Reset Control. Up to six kanmor RTUs (062e or 063e) can be connected to each kanmor Zone Control. Each RTU provides room and outdoor temperature read out, separate day and night temperature schedules with optimization and user day and night room temperature adjustments.

kanmor Zone Control

When coupled with a kanmor Outdoor Reset Control, a kanmor Zone Control maintains an almost constant system flow rate at the lowest possible supply water temperature. This results in significant energy savings while providing maximum comfort. The kanmor Zone Control offers four remarkable features including: pulse width modulation output, water temperature feed-back, built in timer, zone load synchronization and individual zone night setback with optimization.

Pulse Width Modulation Output

The kanmor Zone Control uses room temperature feedback from up to six Room Temperature Units (RTU's) to operate individual zone valves or pumps. The control utilizes a pulse width modulation (PWM) output to operate the zone valves / pumps. This enables the control to maintain an accurate space temperature with virtually no fluctuations.



Water Temperature Feedback

The kanmor Zone Control feeds the highest room temperature requirement to the kanmor Outdoor Reset Control. When several kanmor Zone Controls are used, the highest room temperature required out of all the Zone Controls is selected and fed back to the kanmor Outdoor Reset Control. This enables the Outdoor Reset Control to modify the system supply water temperature to achieve the following:

- the zone with the highest heat demand receives system supply water of sufficient temperature to satisfy the space temperature requirements.

- the system supply water is always maintained at just the right temperature to satisfy the maximum heat demand with constant water circulation. This allows for a more even load distribution with minimum heat transmission losses.

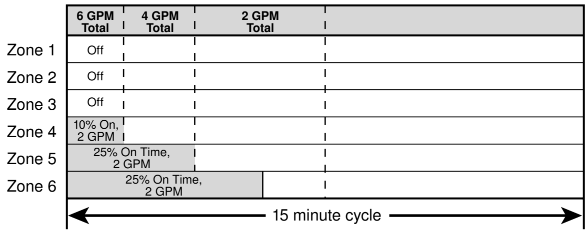
- the Zone Control incorporates a boost for return from night setback. When the control comes out of an unoccupied (night setback) period, the water temperature is boosted for faster recovery of the space temperature.

Zone Load Synchronization

The kanmor Zone Control synchronizes the Pulse Width Modulation signal from all the zones to help even out the system flow rate. This provides the following benefits:

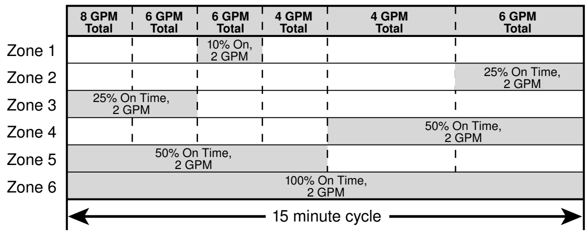
- effective outdoor reset operation is maintained because the supply water temperature can be constantly monitored when the system flow rate is continuous.

- a single boiler is kept from short cycling and multiple boilers are kept from active staging when the required heat output from the boiler(s) is relatively constant.



The majority of a heating season typically requires less than 50% of the design heat output . If the supply water temperature is much hotter than the system presently needs (e.g. when operation on minimum boiler supply) then under light load conditions, the zone valves or pumps operate for short portions of each cycle. The figure above presents an example of such a scenario. Under these conditions, the Zone Control turns on all the zones at the beginning of each cycle in order to maximize boiler efficiency. When the zone with the highest heat demand is near the end of its on time, the Zone Control sends a signal to a kanmor Outdoor Reset Control to turn off the boiler. The Zone Control then purges the residual heat from the boiler by keeping the system pump and zone valve / pump on for a post purge period.

If the heating load increases and / or the supply water temperature approaches the actual temperature the system requires, the zone valves / pumps remain on for longer portions of each cycle. The kanmor Zone Control then distributes the zone on times over the cycle in order to even out the heating load and flow rate for the boiler. The figure at right demonstrates how the kanmor Zone Control distributes the zone on times to maintain the flow rate between 4 and 6 gpm.



Individual Zone Night Setback with Optimization

The kanmor Zone Control gives the user the ability to schedule each zone in the system. Each zone can follow either the control's schedule or its own individual schedule. The user is able to select either a 24 hour schedule or a seven day schedule. Two occupied and two unoccupied (setback) times can be programmed for each day. When using setback, the kanmor Zone Control provides the ability to optimize both the setback and recovery times for the system. Using a feature called Optimum Start / Stop, the kanmor Zone Control determines the heat up and cool down rates for each zone and operates the system to provide the maximum performance and energy savings. With Optimum Stop, the control shuts off the heating system ahead of time and allows the zone to start cooling down in advance of the setback period. With Optimum Start, the control optimizes the start time of each zone to ensure that the zone is up to temperature by the end of the setback period. The indoor temperature feedback signal that is sent from the kanmor Zone Control to the kanmor Outdoor Reset Control allows for precise adjustment of the system supply water temperature. As well, this signal allows for a shorter recovery time from a setback by having the kanmor Outdoor Reset Control provide a higher supply water temperature during the recovery period.

Notes:

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