tekmar® - Essay

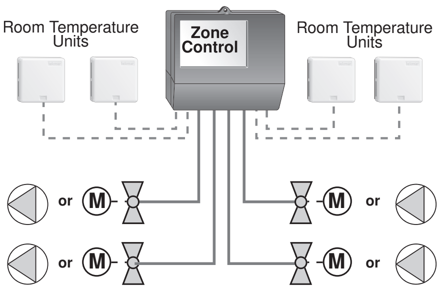
Control of Radiant Floor Heating Zones

E 006

01/02

This essay focuses on the selection of the proper type of thermostat needed to control a radiant floor heating zone. The proper type of thermostat is an important part of controlling a hydronic radiant floor heating zone. However, an equally important part of controlling a hydronic radiant floor heating system is outdoor reset. For a detailed discussion of outdoor reset and its impact on the comfort and efficiency of a hydronic heating system, refer to tekmar Control Systems' Essays E 003 "Characterized Heating Curves and Reset Ratios" and E 004 "Control Strategies for Building Space Heating".

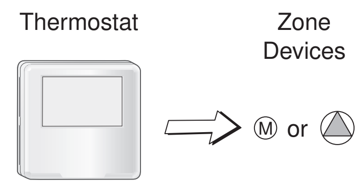
TYPES OF CONTROL SYSTEMS



In general, there are two types of control systems that are used to operate zones in a heating system. These two types are individual thermostats or an integrated zone control with room temperature units (RTUs).

An integrated zone control is a microprocessor driven control that coordinates the operation of several zones in a system. The zone control uses RTUs to sense the temperature in various areas. The RTU is a device that allows the user to select a desired temperature and it is a device that relays information regarding the current temperature for the zone back to the zone control. The RTU does not operate the zone directly. The zone control examines the information from the RTUs in order to coordinate the operation of the zones in the system. After examining the information from the individual RTUs, the zone control turns the zones on and off as it requires. An integrated zone control operates on the same basic principles as a pulse width modulation (PWM) thermostat described below.

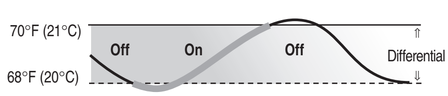
A thermostat is a device that operates an individual zone in a system. A thermostat can be either an electro-mechanical device or it can be a device with a microprocessor. In either situation, a thermostat senses a temperature and responds by turning the zone on or off. With thermostats, typically there is no coordination of the operation of the overall system.



TYPES OF THERMOSTATS

In the heating industry, there are two basic types of thermostats in use. These two types are on / off thermostats and Pulse Width Modulation (PWM) thermostats.

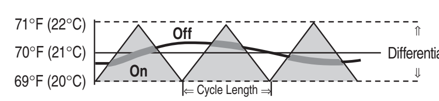
On / Off Thermostat



On / off thermostats work based on a setpoint and a temperature differential. This differential is typically below the desired setpoint. Once the temperature drops the differential below the setpoint, the thermostat turns on. Once the temperature rises to the setpoint, the thermostat turns off. This operation can be changed with mechanical or electronic anticipators in order to minimize overheating, however the operation is very similar.

Pulse width modulation (PWM) thermostats work on a setpoint and a cycle length. The cycle length is measured in either minutes or in cycles per hour (CPH). A PWM thermostat also uses a differential that is centered around the desired setpoint. Typically, the thermostat operates once per cycle. The on time in each cycle is determined by the degree of error in the actual temperature. If the error is positive (the actual temperature is below the desired when heating) the on time is increased from 50%. If the error is zero (the actual temperature is equal to the desired temperature) the on time is 50%. If the error is negative (the actual temperature is greater than the desired temperature when heating) the on time is decreased from 50%. A PWM thermostat usually includes Proportional and Integral (PI) logic in its operation. This allows the thermostat to adjust the amount of error in order to eliminate temperature offsets, or temperature droops, that can occur with a PWM thermostat that only uses Proportional (P) logic.

PWM Thermostat



An on / off thermostat works in a fast responding, low mass system. A fast responding system is one such as a furnace, a baseboard or a fancoil. These systems have the common characteristic in which heat is available in a very short time frame once the thermostat turns on. A low mass system is also characterized by the fact that it does not have a large amount of thermal mass in which to store heat. This means that once the system shuts off, any heat in the system is rapidly released.

A PWM thermostat is essential for the proper operation of slow responding systems that have a high thermal mass such as radiant floors. A radiant floor can be heated either hydronically or electrically. A slow responding system is characterized by a long delay between the thermostat turning on and a temperature change being sensed by the thermostat. A high mass system is also characterized by the fact that it has a large amount of thermal mass in which to store heat. This means that the system continues to release heat for a long period after the thermostat has shut off.

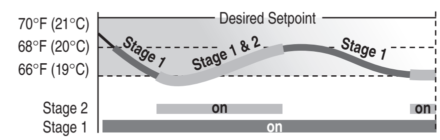
If an on / off thermostat is used in a slow responding system, the system experiences cycles of underheating and then overheating. A steady temperature is difficult to establish and / or maintain. The reason for this is that an on / off thermostat only turns on when the temperature is below the desired setpoint. With a slow responding system, the temperature can continue to drop even after the thermostat has turned on. The heat initially applied to the system is used to heat the mass of the heating system and is not immediately used to heat the space. Conversely, the thermostat can only turn off when the temperature is above the desired setpoint. Once the thermostat turns off, all of the excess heat contained in the mass of the heating system is released causing the temperature to continue to rise after the thermostat has shut off.

A PWM thermostat operates for longer or shorter on times each cycle based on the degree of error in the actual temperature. A PWM thermostat allows heat to be applied to the system even if it is overheated by less than half the differential. This is done in order to maintain the thermal momentum of the heating system.

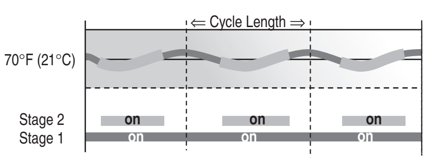
TWO-STAGE HEATING

Both on / off thermostats and PWM thermostats can have two-stage operation. With an on / off two-stage thermostat, the first and second stages of heat operate based on separate temperature setpoints. Typically the first stage operates at the desired temperature. The second stage operates on a second setpoint slightly below the desired temperature. This second setpoint also has a differential. In the basic operation of an on / off two-stage thermostat, the first stage cycles to maintain the desired temperature. When the load increases to the point where the first stage can no longer maintain the desired temperature, the actual temperature begins to drop. Once the temperature has dropped far enough, the second stage turns on. With this operation, the temperature must be below the desired temperature in order for the second stage to turn on. Also, the second stage turns off before the desired temperature is reached. The net result is that under heavy loads, there is a temperature offset.

Two-stage On / Off Thermostat



Two-stage PWM Thermostat



With a PWM two-stage thermostat there is only one setpoint. Both the first and second stages operate based on a single temperature setpoint. In each cycle, an on time is calculated for both the first and second stages. For proper operation of a two-stage system, the second stage should only operate when the first stage is operating at 100% of its allowed on time. Once the first stage is operating at 100% of its allowed on time, the second stage's on time should be increased from 0% in order to supplement the heat of the first stage. The second stage should only operate if it is not possible for the first stage to maintain the desired temperature.

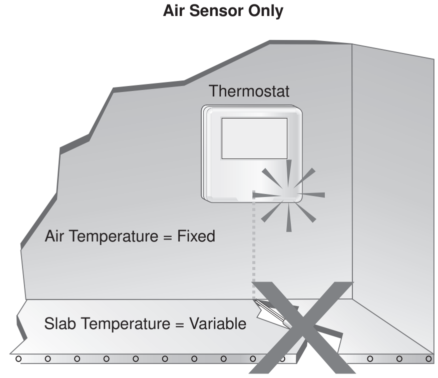
An on / off thermostat provides adequate operation when the first and second stages have fast response times. However, the system still experiences a temperature droop when second stage operation is required. In a system in which the response times vary for the first and second stages, it is possible to have the second stage operating when it is not needed. An example of this is a system in which the first stage is a radiant floor and the second stage is a fancoil or baseboard unit. In this system, the radiant floor may turn on but due to its slow response time, the temperature may droop enough to bring on the second stage. When the second stage operates, it may provide enough heat to turn off both the second stage and the first stage. In this scenario, the second stage essentially overruns the first stage operation under light loads and does not allow the first stage to operate as it was intended.

A PWM thermostat is essential for the proper operation of a system in which the response time of the first stage is much slower than the response time of the second stage. Since the second stage is only allowed to operate once the on time of the first stage reaches 100% of its allowed on time, it is not possible for the second stage to override the operation of the first stage.

In two-stage systems that combine radiant floor heating with a second stage of heat, proper control of the temperature requires a PWM thermostat.

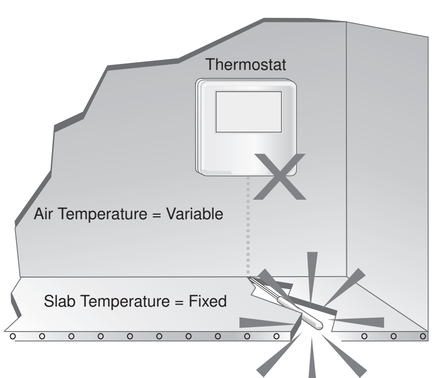
AIR SENSING OR SLAB SENSING

Air Sensor Only



There are two methods of controlling the temperature of a radiant floor. Either an air sensor can be used for space heating or a slab sensor can be used for floor warming. An air sensor measures the air temperature in the space in which the radiant floor is located. The thermostat operates the radiant floor in order to maintain the desired air temperature. The result of using an air sensor is that during certain conditions, the floor may feel warm and under other conditions, the floor may feel cool. However, the air temperature stays at the desired temperature. Typical uses for air sensors include most living spaces such as dining rooms, living rooms and kitchens. In these areas, a steady air temperature is much more comfortable and much more desired than a steady floor temperature.

Slab Sensor Only



A slab sensor measures the slab or floor temperature in the area in which the radiant floor is located. The thermostat operates the radiant floor in order to maintain the desired slab or floor temperature. The result of using a slab sensor is that under certain conditions, the air temperature may overheat and under other conditions, the air temperature may underheat. However, the slab or floor temperature stays at the desired temperature. Typical uses for slab or floor sensors include bathroom floors or tile entranceways. In these areas, a warm floor is much more comfortable and much more desired than a steady air temperature.

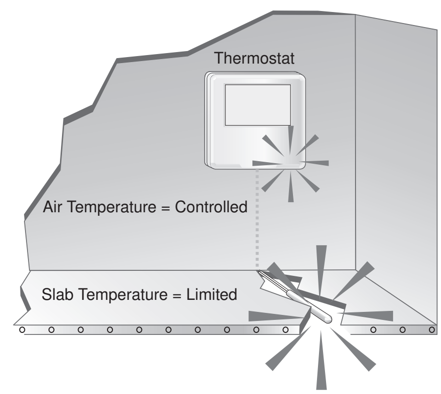
Slab sensing thermostats are also used in systems where limiting the maximum floor temperature is necessary for either occupant comfort, or in order to help protect surface coverings or other flooring materials.

AIR SENSING AND SLAB SENSING

Ideally, a thermostat that is used with a radiant floor should be capable of sensing both the air temperature in a space and the slab or floor temperature in that same space. A thermostat that senses both air and a slab temperature would be capable of satisfying many more operational requirements of a radiant floor than a thermostat that sensed either air or slab temperature only.

This type of thermostat would require setpoints for the desired air temperature, the desired minimum slab temperature and the maximum allowable slab temperature. This thermostat should also be capable of handling the common space conditioning scenarios in today's industry. These scenarios include, but are not limited to, one-stage heating, two-stage heating and heating / cooling.

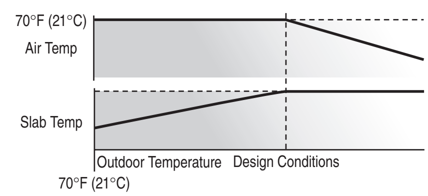
Slab and Air Sensor



One-stage Space Heating with Slab Maximum

In a one-stage heating scenario with slab maximum, the thermostat maintains the desired air temperature with the ability of limiting the floor's surface temperature. This is achieved by setting a desired air temperature and a maximum allowed slab temperature. In this scenario, the radiant floor is cycled to maintain the desired air temperature in the space. As the heating load increases, the slab temperature also increases. This operation continues until the slab sensor indicates that the radiant floor is operating at its maximum allowed temperature. This happens if the system is asked to operate beyond its design conditions. In this instance, the thermostat continues to cycle the floor in order to maintain the maximum allowed slab temperature and the air temperature is allowed to drop below the desired setpoint.

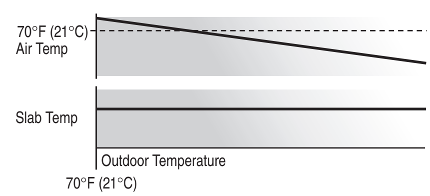
One-stage Space Heating with Slab Maximum



Floor Warming

In a floor warming scenario, the thermostat maintains the desired slab temperature. The desired air setpoint is set to an off setting. The radiant floor is cycled in order to maintain the floor at the set slab temperature. This temperature is maintained as long as there is heat available to the radiant floor when the thermostat cycles.

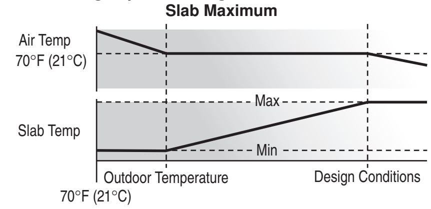
Floor Warming



One-stage Space Heating with Slab Minimum and Slab Maximum

In a one-stage space heating scenario with a slab minimum, the thermostat maintains the desired slab minimum during mild outdoor conditions. This can often be desirable in order to give a warm sensation to a tile floor. During this period, overheating of the space can occur. As the outdoor temperature begins to drop, the air setpoint begins to control the cycling of the radiant floor in order to maintain the desired air temperature. The floor temperature continues to increase with the heating load until the floor reaches the maximum allowed setpoint. At this point, the air temperature begins to drop as the load increases further. However, this only happens if the actual heating load exceeds the designed heating load.

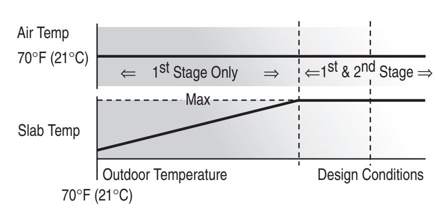
One-stage Space Heating with Slab Minimum and Slab Maximum



Two-stage Space Heating with Slab Maximum

In a two-stage space heating scenario that combines a radiant floor with a secondary source of heat, a maximum allowable slab temperature is desirable. The thermostat cycles the radiant floor under mild conditions to maintain the space temperature. As the load increases, the on time and temperature of the floor increases in order to maintain the space temperature. Under extreme load conditions, the floor temperature may increase to the point where the floor coverings or flooring materials may sustain damage. In systems where this is a concern, a slab sensor should be used and the thermostat should be programmed with a maximum allowable slab temperature. Once the maximum allowed slab temperature is reached by the thermostat, the on time of the radiant floor should be limited to prevent it from overheating. At this point, the second stage begins to cycle in order to maintain the desired space temperature.

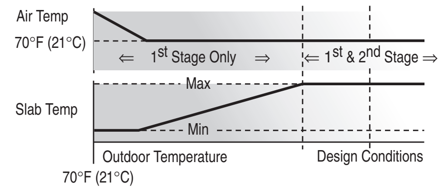
Two-stage Space Heating with Slab Maximum



Two-stage Space Heating with Slab Minimum and Slab Maximum

The aspect of floor warming under light loads can be added to the previous scenario by incorporating a minimum slab temperature into the operation of the thermostat. This allows the system to maintain the comfortable feeling of a warm floor during mild outdoor conditions. However, this will lead to overheating of the space unless some form of cooling is incorporated.

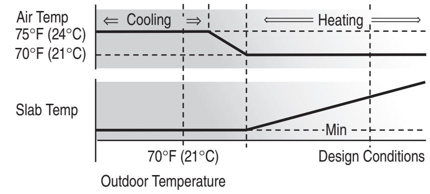
Two-stage Space Heating with Slab Minimum and Slab Maximum



One-stage Space Heating with Slab Minimum and Space Cooling

A unique scenario that is experienced with radiant floor heating systems is the desire to heat the floor and cool the air at the same time. An example of such a system would be an entranceway in which the user desires to have a warm floor to welcome their feet when they remove their shoes. However, under light heating load conditions, this warm floor will overheat the space. In this situation, the user may deem it desirable to operate the cooling system in order to maintain a comfortable air temperature. To operate this system, the thermostat must have a slab sensor and a minimum slab temperature setting. At the same time, this thermostat must be a cooling thermostat that operates based on air temperature. Only a thermostat capable of sensing both the air and the slab temperature at the same time is capable of controlling this type of system. This same thermostat would also control the air temperature during the heating season. As the heating load increased, the floor would be cycled to maintain a comfortable air temperature.

One-stage Space Heating with Slab Minimum and Space Cooling



SCENARIOS UNIQUE TO RADIANT FLOOR HEATING SYSTEMS

There are several heating scenarios that are unique to radiant floor heating systems. These scenarios are extremely difficult to address unless a proper thermostat, capable of sensing both the space and the slab temperatures, is used to control the system.

Slab Minimum for Areas with Large Solar Gains

Some of the most difficult types of radiant floor heating systems to control properly are those that experience large internal heat gains. An example of such a system would be a large radiant floor area that has a large glass area with a solar exposure. If this system were operated with a thermostat that only sensed air temperature there would be wide temperature swings. In the mornings, before there were any significant solar gains, the radiant floor would be operating to maintain the proper space temperature. During the day, as the solar gains increased, the radiant floor would shut off as the space began to overheat. In the evening, the solar gains would stop once the sun was below the horizon. At this point, the space temperature would begin to drop and the radiant floor would turn on. However, due to the slow response time, it could take several hours before the radiant floor started to stabilize the space temperature. This would result in a period in the evening when the space would become cool and would feel uncomfortable to the occupants.

To compensate for the long response time of the radiant floor, the system should either maintain a minimum radiant floor temperature during the entire day or the system should maintain a minimum radiant floor temperature just prior to the solar gains stopping. In order to achieve this, the thermostat must have a slab sensor. The ideal thermostat for this scenario would incorporate air heating, air cooling and slab minimum combined with a scheduling system. During the night, the thermostat should operate to maintain a heated air temperature. During the day, the thermostat should automatically switch between a heating and cooling setpoint as the air temperature dictates. A few hours prior to sunset each evening, a minimum slab temperature should come into effect. At this point, the thermal mass of the slab would begin to heat. When the sun sets and the air temperature begins to cool in the space, the slab is already precharged with heat. This minimizes the period in the evening where the space may become cool due to the fact that the radiant floor system has such a slow response time.

USING SCHEDULES WITH AIR AND SLAB SENSORS

Adding a scheduling system to a thermostat capable of sensing slab and air temperature adds the flexibility needed to accomplish all of the applications required from a radiant floor system.

A proper schedule would allow for air heating and / or cooling setpoints for each scheduled period as well as minimum slab setpoints for each scheduled period. Each of these setpoints would also have an off setting. These schedules would allow for alternate periods of space heating and / or cooling as well as floor warming.

An example of this would be a bathroom. In a certain scenario, the users may desire to have a warm floor in the bathroom during the morning while they are showering and for the remainder of the day, maintain a comfortable air temperature. An easy, temporary override should also be available for the user that periodically wants to have a warm floor in the evening.

Overall, to meet all of the expectations of the applications for radiant floors, these systems need a proper thermostat. A proper thermostat must be able to sense both air and slab temperatures in order to properly control the radiant floor. As well, a proper thermostat for radiant floors should be PWM in order to minimize temperature undershoots and overshoots. If two-stage heating is to be combined with a radiant floor system, proper two-stage logic must be used in order to prevent the second stage from overrunning the first stage of the system.

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