SUBSTRATES: Radiant Heat

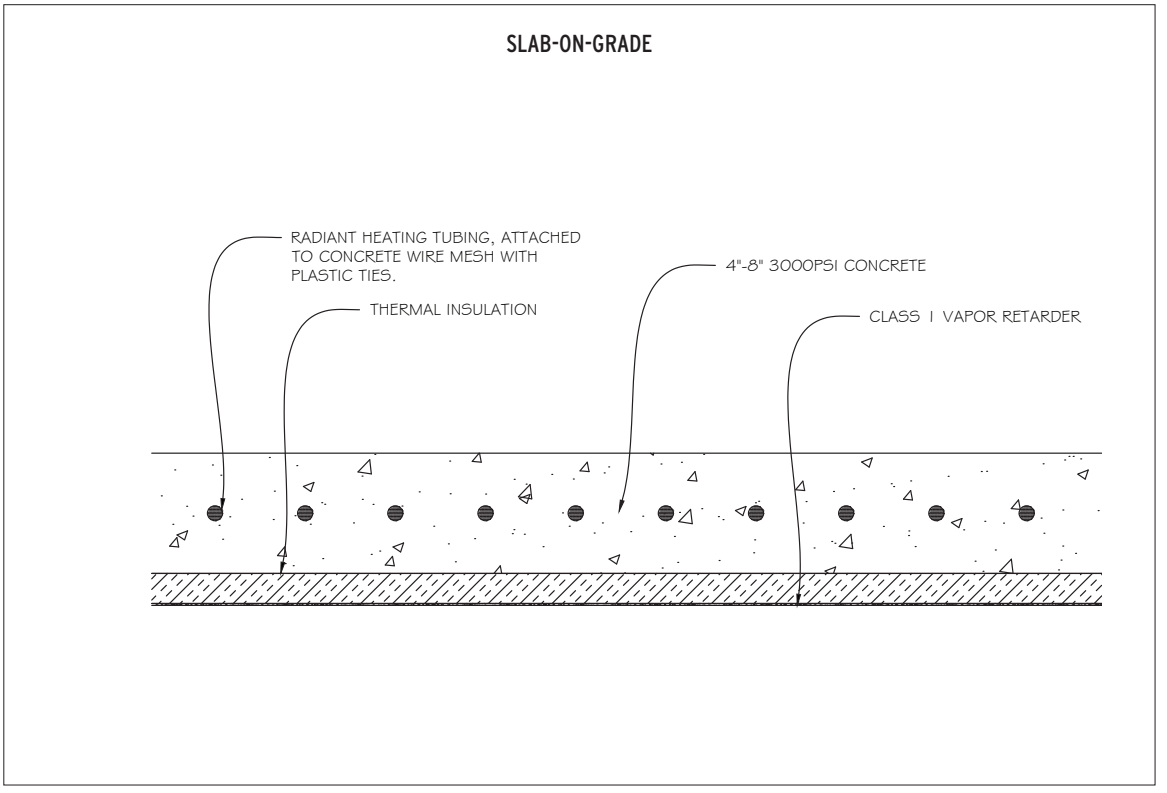
Radiant (underfloor) heating is a type of heating system that is placed below the floor. Radiant heating as a technology is the method of intentionally using the principles of radiant heat to transfer radiant energy from an emitting heat source to an object. Radiant heating may be either hydronic (water/fluid flowing through pipes) or electric (electric resistance heating elements).

PART I
Types of Radiant Heating Systems

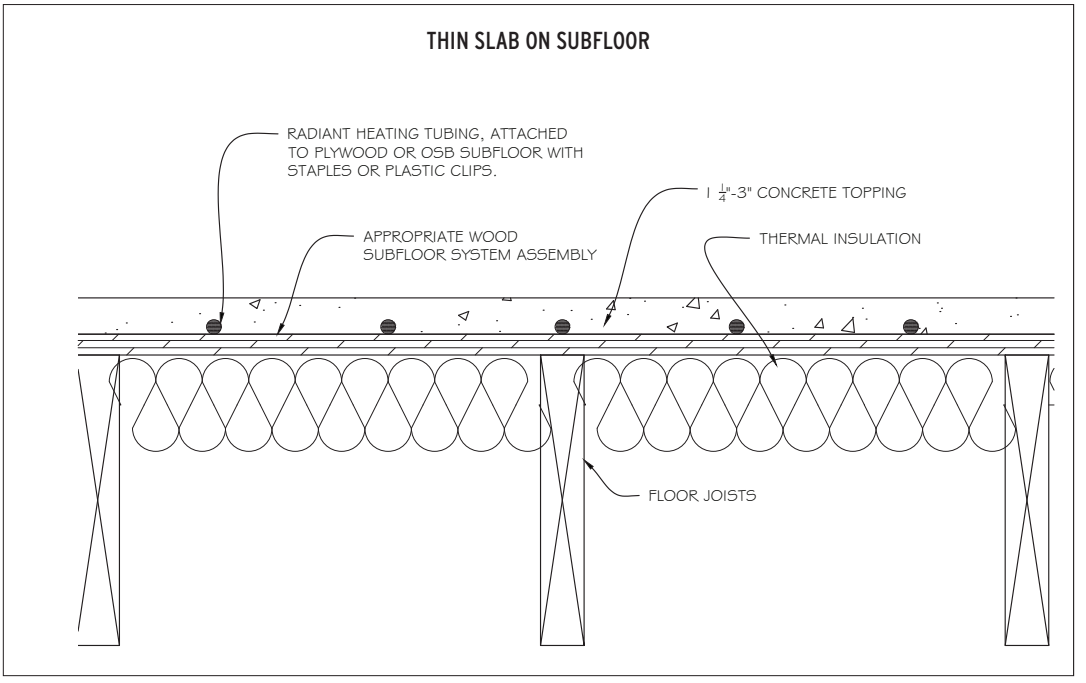
There are many types of radiant heating systems available. The heating system must be approved and properly set up for each specific zone, and for each flooring type being installed over it. Check with the flooring manufacturer for approval, and the recommended installation method over the specific system that is in place. For more-detailed information on any of these systems, visit the Radiant Professionals Alliance (RPA) at www.radiantprofessionalsalliance.org.

A. **Hydronic Radiant Heating:** An underfloor heating or warming system that involves transfer of heat by circulating a fluid (such as water) in a closed system of pipes. Insulation is required below the heat source for most of these systems. Types of hydronic radiant heating systems include:

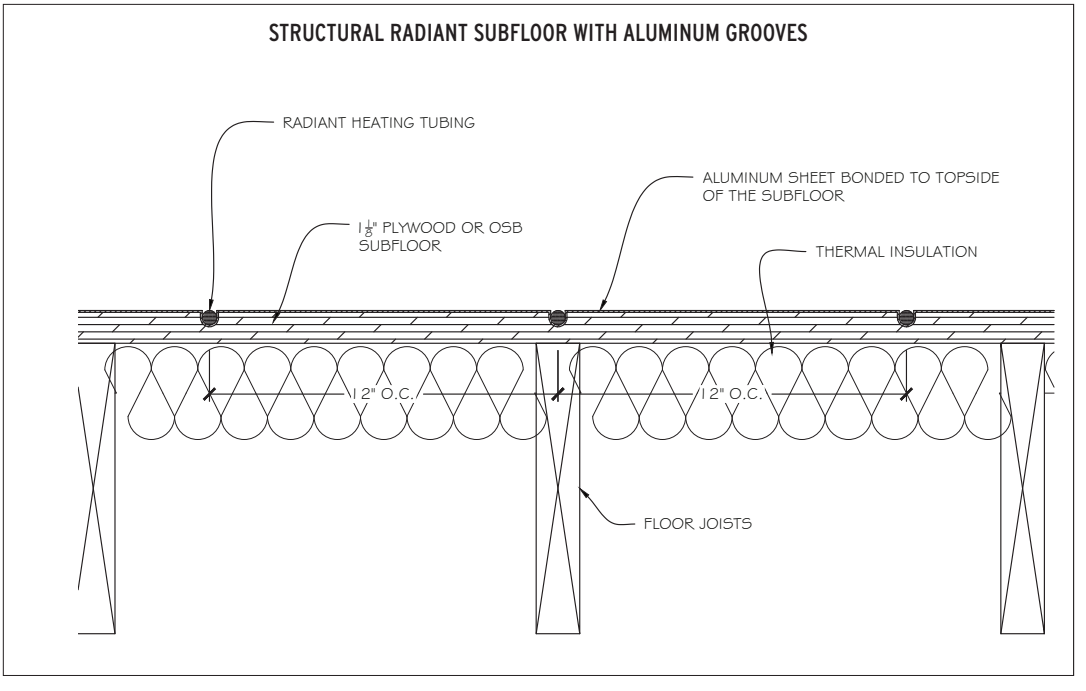
   1. **Slab-on-Grade:** Radiant tubing is embedded in concrete. The tubing typically is attached to metal mesh with plastic ties. A 4" slab is most typical. The tubing is normally placed in the middle of the slab. Full under-slab insulation and moisture control is required for most residential applications. Slabs have a large thermal mass, which stabilizes temperature swings, but slows response.



2. **Thin Slab on Subfloor:** Radiant tubing is attached on top of the wood subfloor with approved staples or plastic clips. A thin topping of self-leveler underlayments, trowelable underlayments, floor fills, or lightweight concrete is poured over the tubing. Typical slabs are a minimum of 1 ½" thick (when using ½" tubing), but may be as thin as 1 ¼" thick (when using 3/8" tubing). The maximum thin slab thickness is 3". Gypsum concrete is lighter than cement, but a little less conductive.

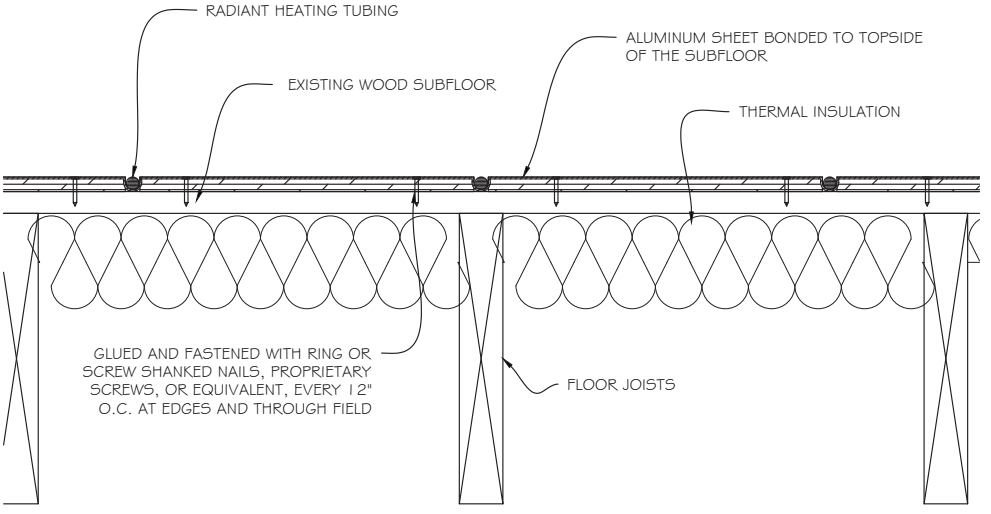


3. **Structural Radiant Subfloor with Aluminum Grooves:** Premanufactured 1 1/8" thick wood subfloor panels that have grooves for tubing and an aluminum sheet bonded to the panel. In this case, the premanufactured panels serve both as the structural subfloor and as the channel into which the tubing is installed. The aluminum sheet makes the system accelerate rapidly and spreads out the heat. Tubing normally is installed 12" on center in the grooves.



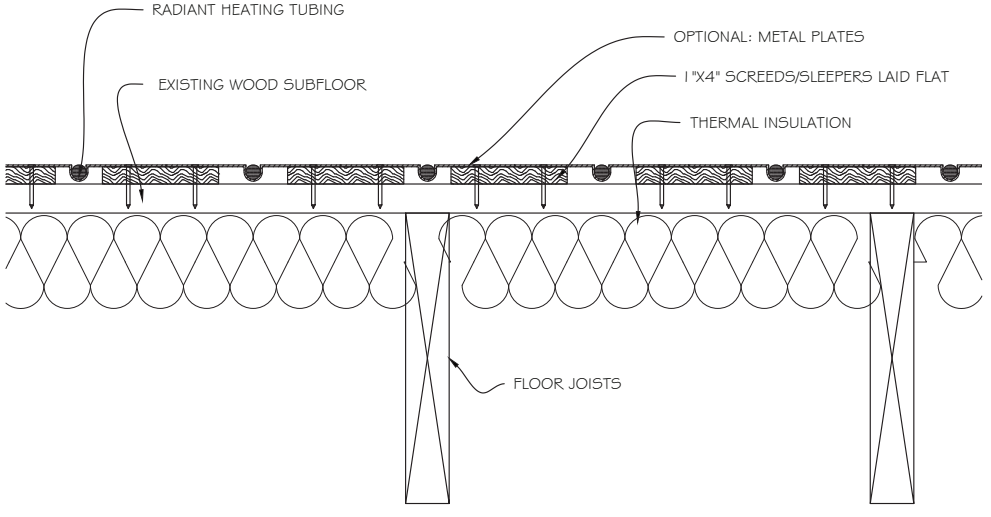
4. **Boards with Grooves and Metal, Attached to Top of Subfloor:** Several varieties currently exist. One board has metal on the bottom and another on the top. Both serve to spread the heat laterally. Normally, they are glued and screwed, or stapled, to the top of a wood subfloor panel. Under some conditions, they may be attached on top of existing slabs. Different products use different pipe sizes.

BOARDS WITH GROOVES AND METAL, ATTACHED TO TOP OF SUBFLOOR

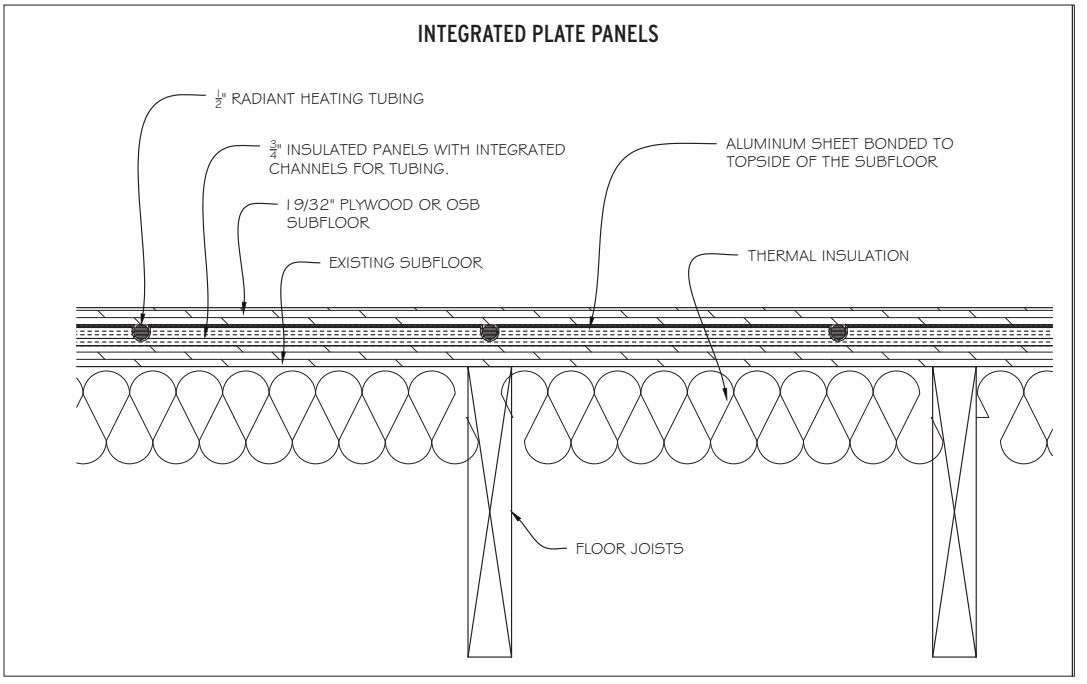


5. **Sandwich Method with or without Plates on Top of Subfloor:** Typically, 1"x4" screeds/sleepers are attached to the top of the subfloor, and pipe is laid between the screeds/sleepers with or without the addition of the metal plates. Metal plates typically cover about 80% of the outside diameter of the pipe, adding significantly to the even dispersion of heat.

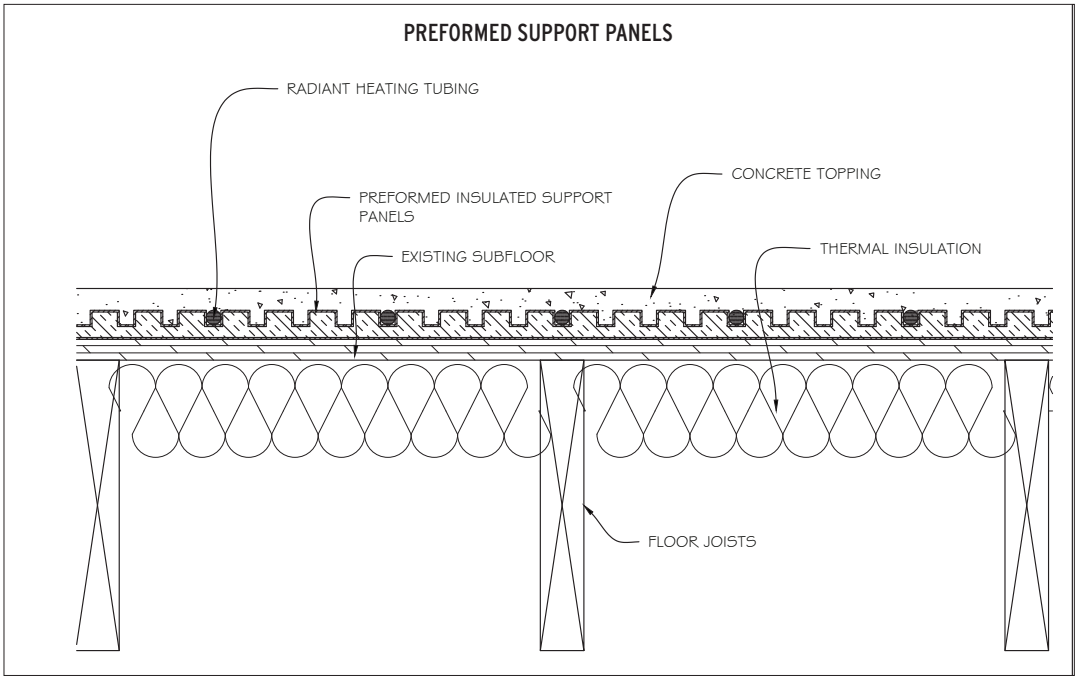
SANDWICH METHOD WITH OR WITHOUT PLATES ON TOP OF SUBFLOOR



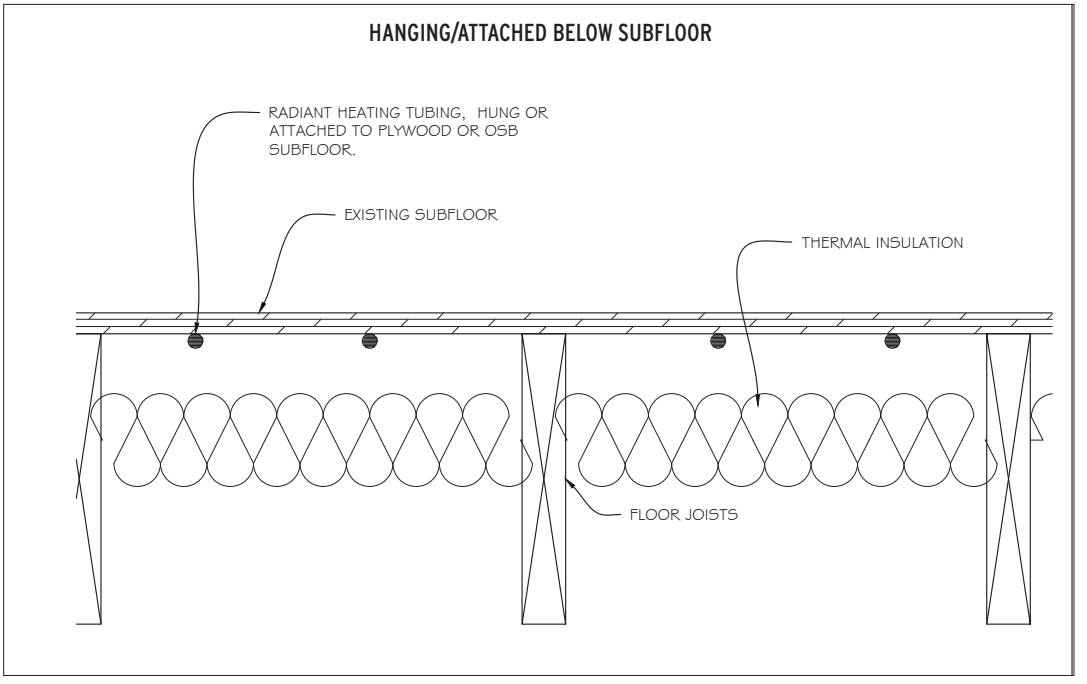
6. **Integrated Plate Panels:** The integrated plate panel system is designed to install over an existing subfloor. The ¾" panels are pre-insulated and water-resistant. The use of ½" pipe allows for greater circuit lengths and is 100% covered by metal. The integrated plate panels are sandwiched between the wood subfloor and wood nailing surface for hardwood flooring.



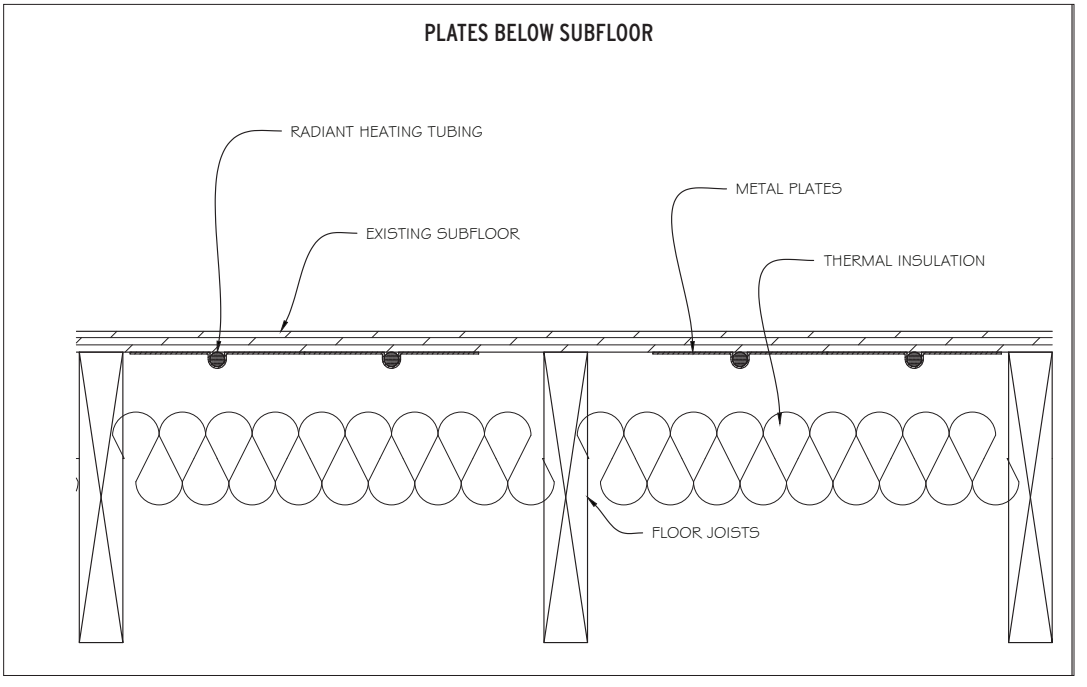
7. **Preformed Support Panels:** Molded panels designed to hold the radiant tubing cover the entire subfloor surface. This system may incorporate insulation molded as part of the panel. Some systems are designed to be embedded in cement, while others have dense, stone-like tiles that are supported by the molded pedestals. They may also include metal heat transfer plates to help disperse the heat evenly.



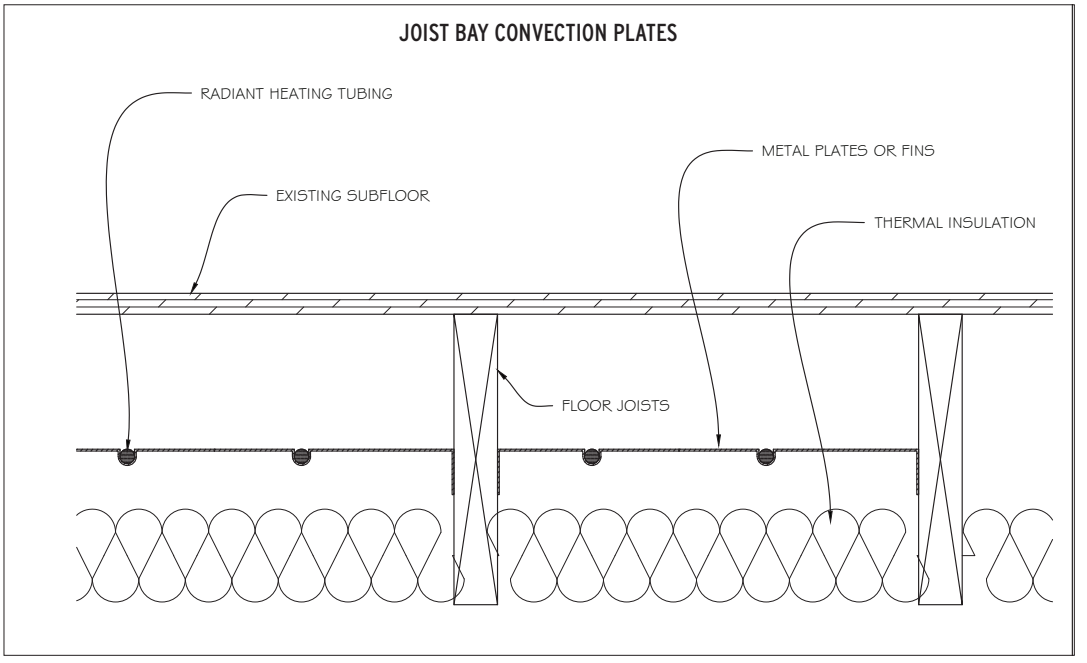
8. **Hanging/Attached Below Subfloor:** Radiant tubing is hung or attached to the underside of the subflooring in an airspace with insulation below. This requires higher water temperatures and has more-limited heat output than other systems. It is often used for retrofitting when access from below is possible. Suspended systems have more-even joist cavity temperatures than when the pipe is attached in direct contact with the subfloor joists.



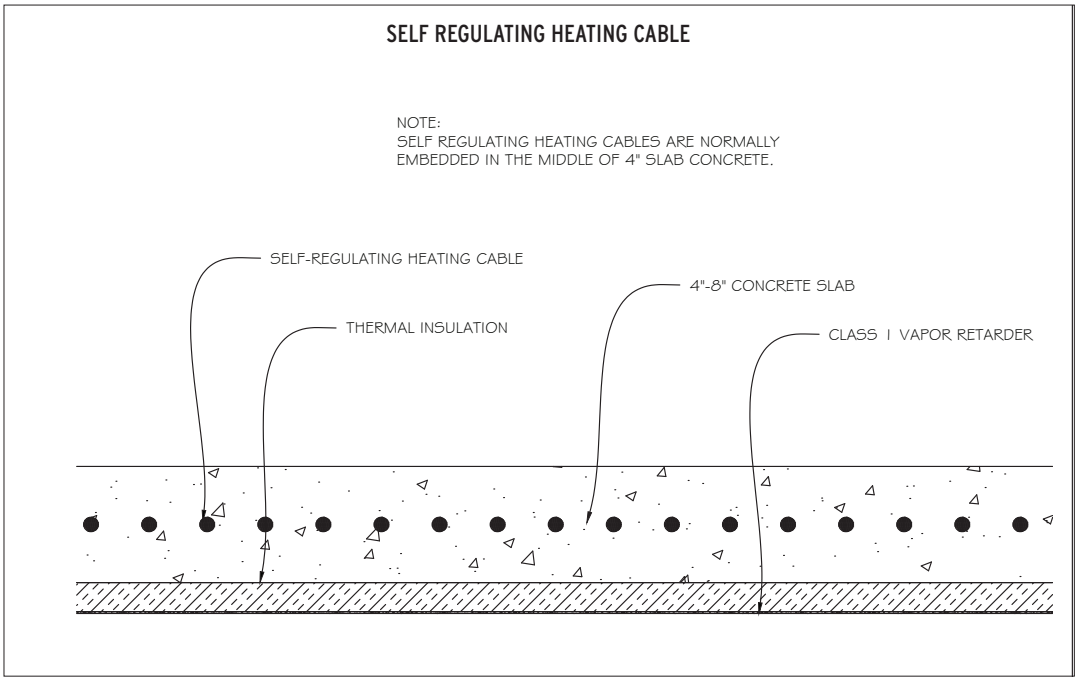
9. **Plates Below Subfloor:** Radiant tubing is attached to the underside of the subfloor with metal plates to diffuse the heat. This type of system has higher water temperatures and more limited heat output than above subfloor systems, but plates make it more effective than suspended pipes under the joists. It is often used for retrofitting when access to joist space is available.



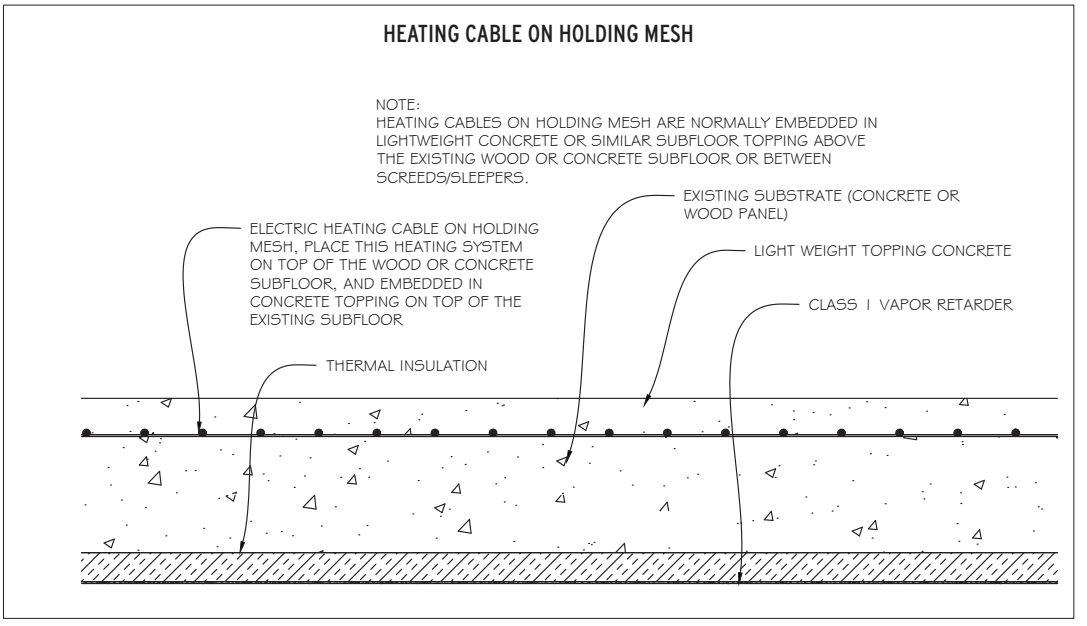
10. **Joist Bay Convection Plates:** The radiant tubing is suspended in a clear airspace beneath the subfloor and between the joists with metal plates or fins attached to the tubing. The tubing and metal fins heat the air within the joist space, which in turn, heats the subfloor. Higher water temperatures are also required than in systems with the plates in direct contact with the floor. Tubing is normally run parallel to the joists or perpendicular when holes are drilled to accommodate the tubing.



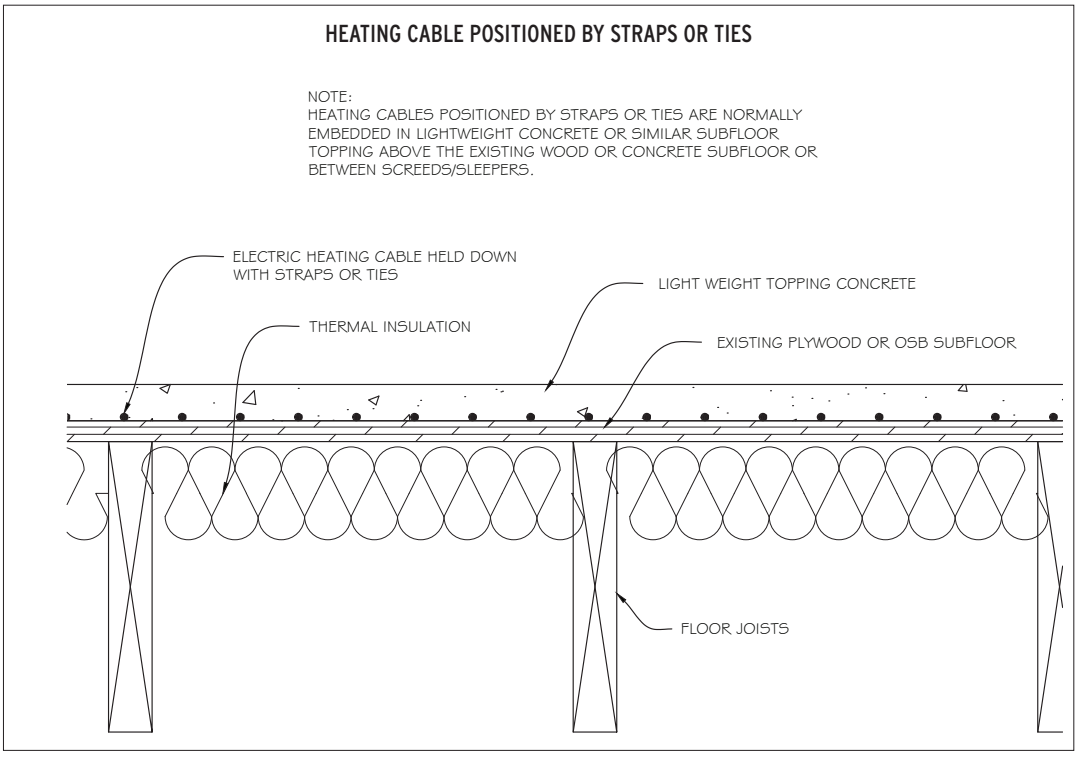
B. **Electric Radiant Heating:** An underfloor heating or warming system that involves the conversion of electrical energy to heat. Types of electric radiant heating systems include:
   1. **Self-Regulating Heating Cable:** This cable is made of a semi-conductive polymer and is self-regulating. It is to be embedded in a concrete slab. This product comes in a variety of voltages including low-voltage, 120V, 208V, and 240V versions.



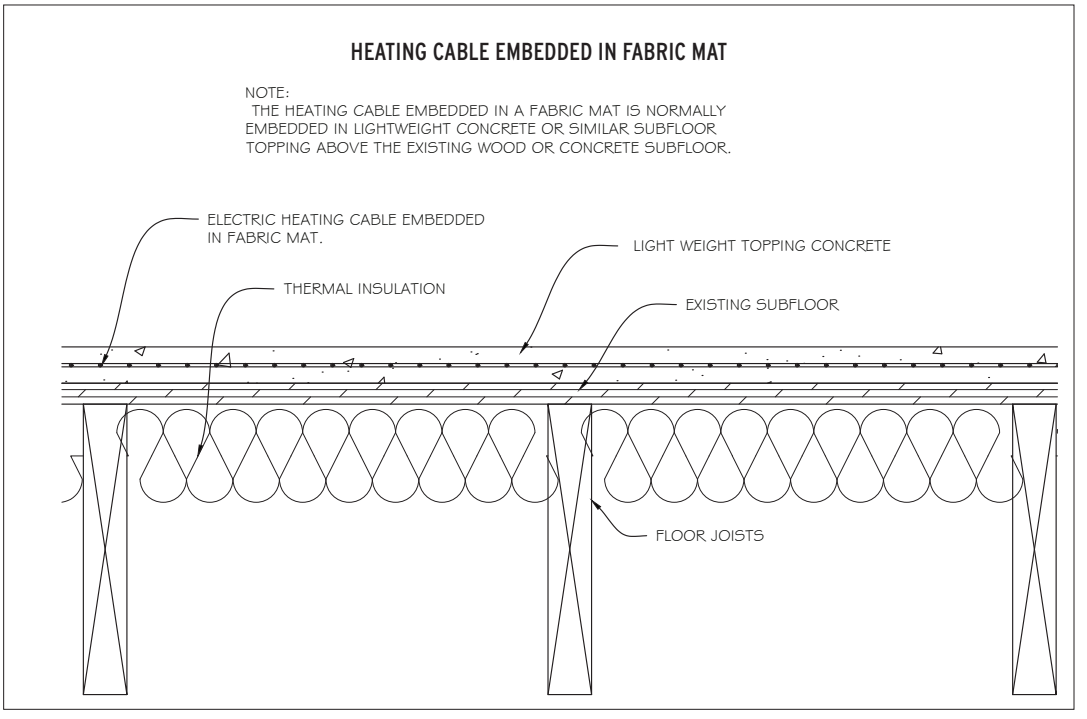
2. **Heating Cable on Holding Mesh:** The constant-wattage heating mat normally is embedded in the slab or in a thin topping of self-leveler underlayments, trowelable underlayments, floor fills, or lightweight concrete set above the subfloor or between screeds/sleepers. These heating mats are available in a variety of voltages including low voltage, 120V, 208V, and 240V versions.



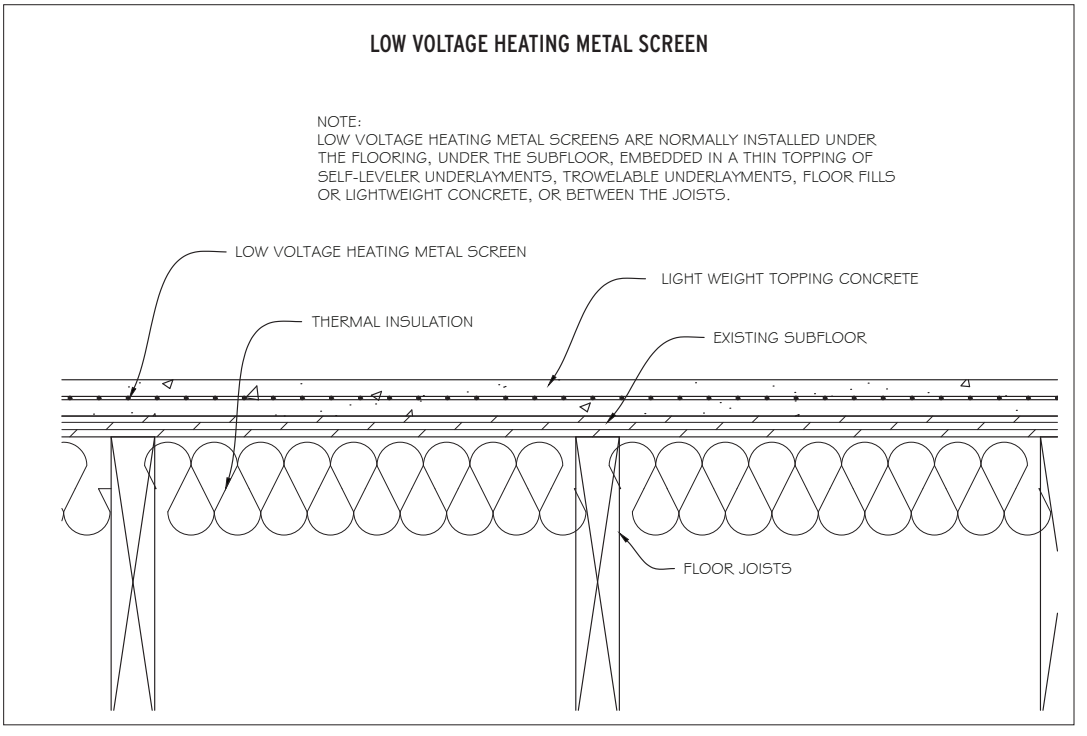
3. **Heating Cable Positioned by Straps or Ties:** The constant-wattage heating cable is held in place by straps, ties, or fixing strips, and embedded in the slab or in a thin topping of self-leveler underlayments, trowelable underlayments, floor fills, or lightweight concrete set above the subfloor or between screeds/sleepers. The heating cable is available in a variety of voltages including low-voltage, 120V, 208V, and 240V versions.



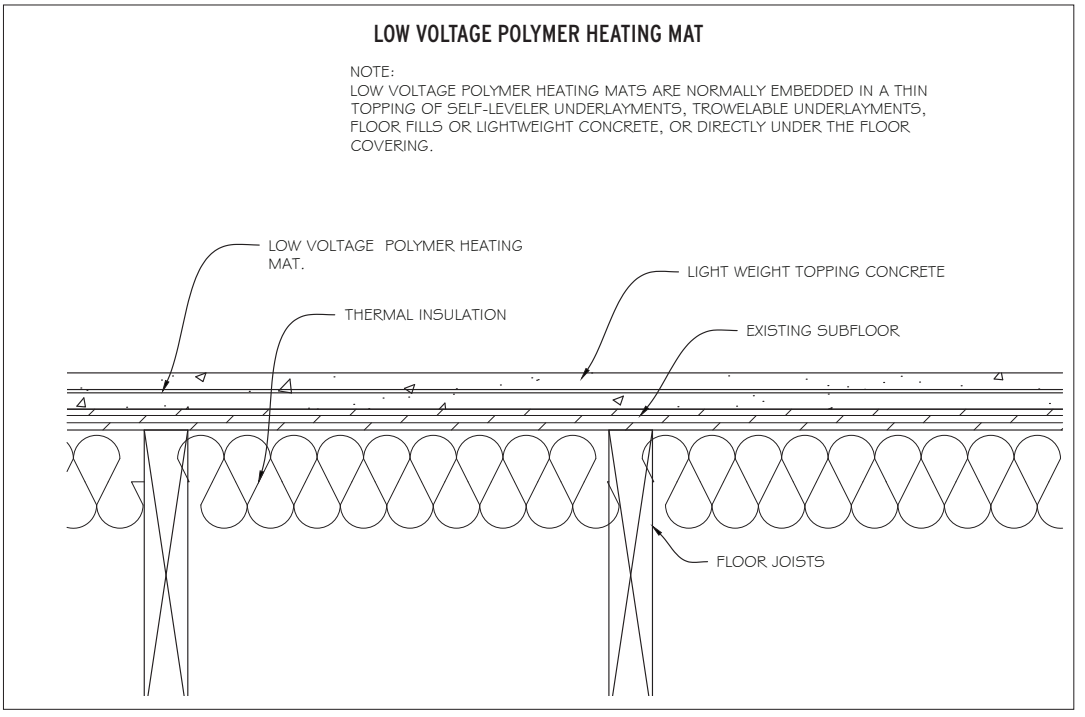
4. **Heating Cable Embedded in Fabric Mat:** Heating cables encased in a fabric carrier mat. The heating mat is embedded in a thin topping of self-leveler underlayments, trowelable underlayments, floor fills, or lightweight concrete set above the subfloor. This product comes in a variety of standard and custom sizes, as well as a variety of voltages including 120V, 208V, and 240V versions.



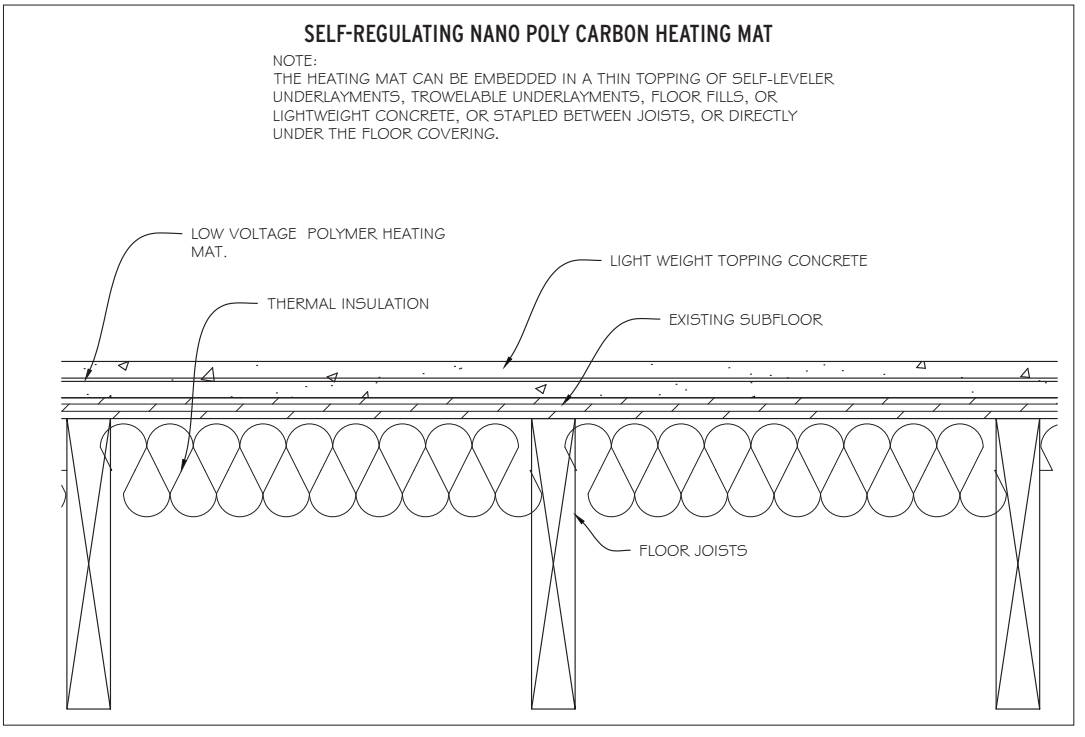
5. **Low-Voltage Heating Metal Screen:**
This mesh heating product is designed to be installed under the flooring, under the subfloor, embedded in a thin topping of self-leveler underlayments, trowelable underlayments, floor fills, or lightweight concrete, or between the joists. The heating mesh can be used in direct nail-down situations (when recommended by the flooring manufacturer). This product comes in low-voltage only.



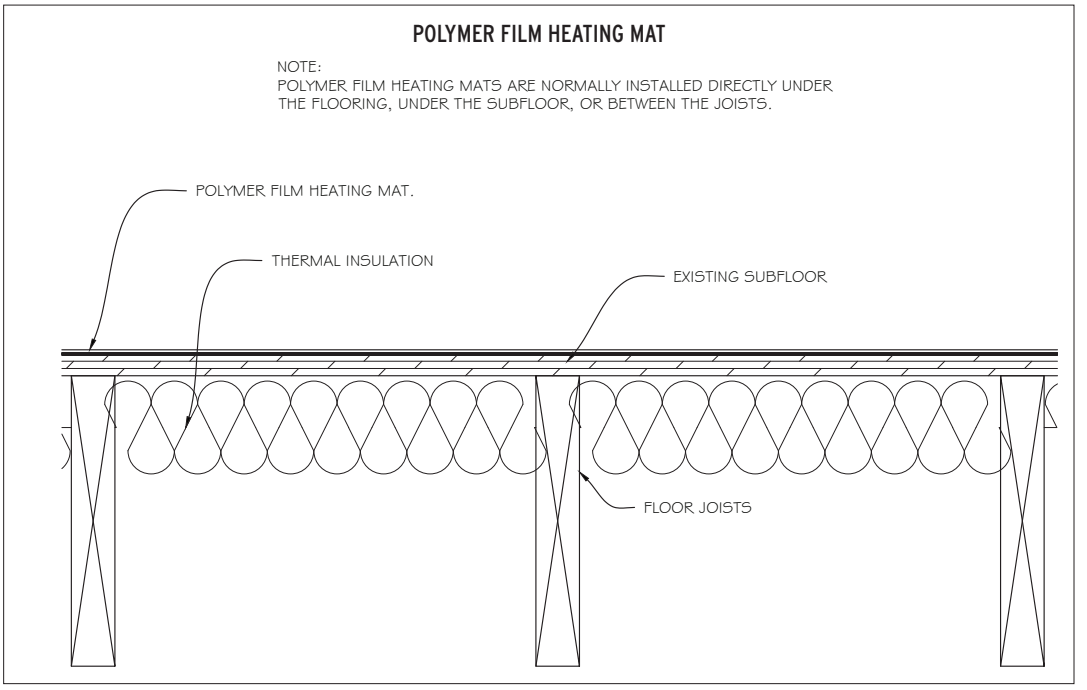
6. **Low-Voltage Polymer Heating Mat:** This mat is made of a semi-conductive polymer and is self-regulating. The heating mat can be embedded in a thin topping of self-leveler underlayments, trowelable underlayments, floor fills, or lightweight concrete, or directly under the floor covering. This product comes in low-voltage only.



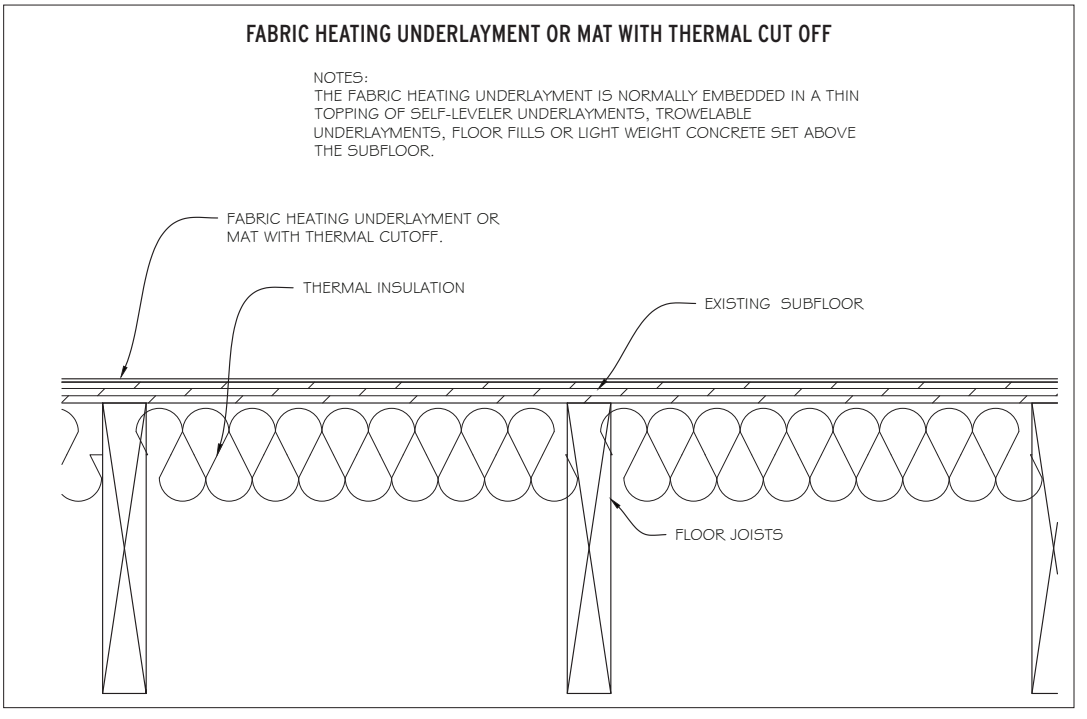
7. **Self-Regulating Nano Poly Carbon Heating Mat:** This mat is made of extruded homogeneous semi-conductive polymer and can be cut to size. Normally low-voltage or powered by solar panels. The heating mat can be embedded in a thin topping of self-leveler underlayments, trowelable underlayments, floor fills, or lightweight concrete, or stapled between joists, or directly under the floor covering.



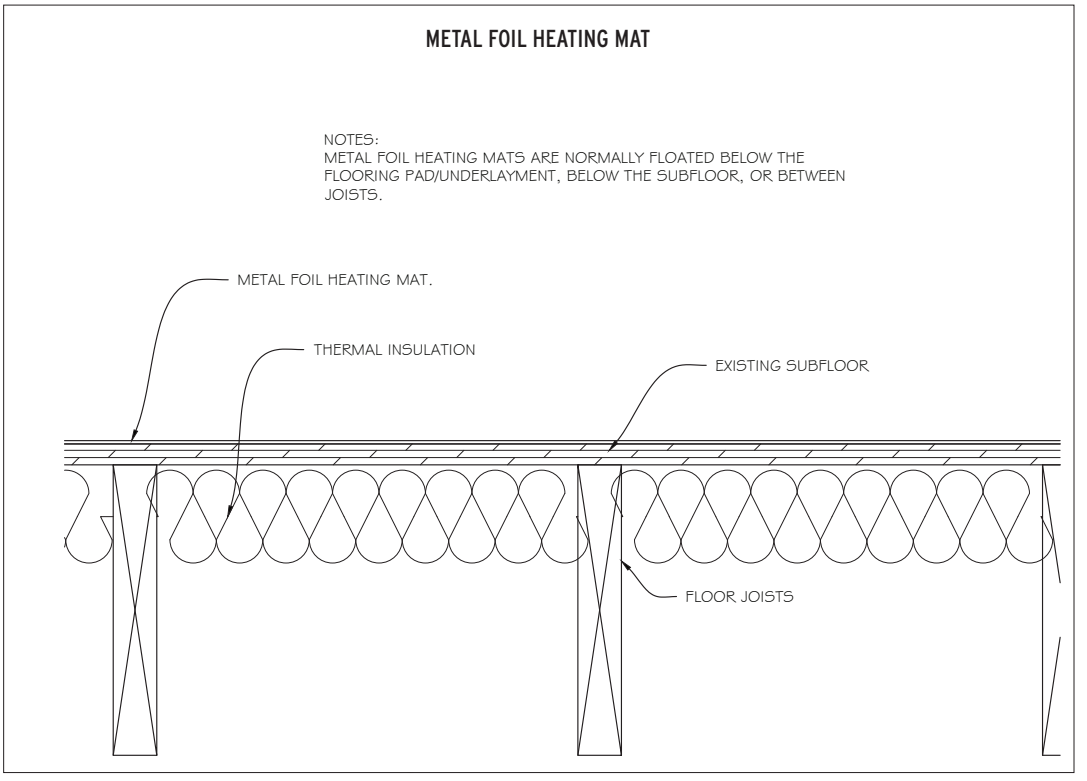
8. **Polymer Film Heating Mat:** These mats consist of a thin and flat printed heater encased between layers of polymer film. The mat is designed for installation directly under the flooring, under the subfloor, or between the joists. The polymer film heating mat comes in a variety of voltages including low-voltage, 120V, 208V, and 240V versions.



9. **Fabric-Heating Underlayment or Mat with Thermal Cut Off:** Thin constant wattage heating element, having thermal-cut-off (TCO) overheat protection is encased between two layers of fabric and/or a breathable underlayment. The fabric-heating underlayment is designed to be in direct contact with the wood floor covering. It provides heating, thermal insulation, and noise reduction. The fabric-heating underlayment may be embedded in a thin topping of self-leveler underlayments, trowelable underlayments, floor fills, or lightweight concrete set above the subfloor. This heating underlayment is offered in a variety of voltages including 120V, 208V, and 240V versions.



10. **Metal Foil Heating Mat:** These products are designed for floating floor installations only. These floor heating products are not embedded, glued down, or glued to. These products are designed to float below the flooring pad/underlayment, below the subfloor, or between joists. This product comes in a variety of voltages including 120V, 208V, and 240V versions.



PART II

Radiant Heating System Requirements

A. Radiant heating systems are designed to either be the sole heating source (floor heating), or a part of a larger heating system (floor warming). Regardless of their intended use, when placed under a wood floor, they must do so without damaging the floor.

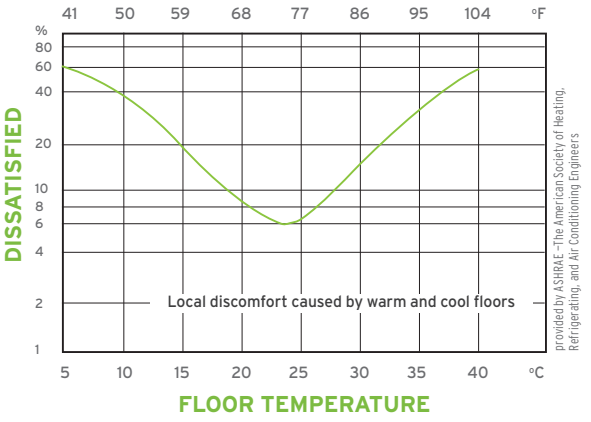
B. To provide an adequate thermal environment for the end-user, many factors must be taken into account, including the size of the room, the construction of the home, R-value of the windows, HVAC systems, the number and age of the occupants, and the interior finishes that may be directly affected by these requirements.

C. The builder, the radiant heating system design engineer, and the radiant heating system installer should be made aware of the type of floor covering being installed over the radiant heating system in order to adequately pair the system with the flooring requirements, based on the facility in which they are being installed. This design coordination should consider whether the heating system is expected to be the sole heating source, or a part of a larger heating system.

D. Radiant cooling systems are never recommended under wood flooring.

E. The radiant heat system design engineer and radiant heating system installer should make available a room-by-room heat-loss calculation based on all of the factors that will affect the heat output of the radiant system. This analysis must establish a maximum operating temperature of the heating system dependent on the floor covering being installed over it.

F. According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), a floor surface temperature that creates optimal human comfort for most people lies somewhere between 70-80°F.



G. Unless otherwise specified by the wood flooring manufacturer, the heat-loss calculations designed for wood flooring installations should restrict the operating temperature of the radiant heat system to never allow the surface of the installed wood floor to exceed 80°F. The entire wood flooring system, including the wood product, the installation method, and the underlayment systems must be taken into account.
   1. Where radiant hydronic heating systems are installed, this heat-loss calculation analysis should establish a maximum heat gain of 20 BTU/hr/sf from the floor heating system, for each room receiving wood flooring. If the ambient conditions of the airspace cannot sufficiently be maintained at 70°F with the radiant heating system operating at a maximum 20 BTU/hr/sf floor load, a supplemental heating system will be necessary.
   2. Where electric radiant heat systems are installed as the sole heating source, the heat-loss calculation analysis should establish a maximum heat gain of 20 BTU/hr/sf from the floor heating system using a maximum 6 watts per sf/hr for each room receiving wood flooring. If the ambient conditions of the airspace cannot sufficiently be maintained at 70°F with the radiant heating system operating at a maximum 20 BTU/hr/sf floor load, a supplemental heating system will be necessary.

H. Separation of heating zones and thermostats, based on flooring type and temperature limitations, is required when multiple floor coverings are being installed over any radiant heating system.

I. The radiant heating system should provide an even distribution of heat to the wood flooring surface. The wood floor surface temperature should vary no more than 3°F at any point within the installed wood floor.

J. In locations where the radiant heating tubing layout becomes bunched together (through hallways or where it emanates to or from the manifold), it will be necessary for the heating system installer to insulate the tubes in these areas of high-density to avoid creating high-density heat situations, which can impact the wood flooring performance.

K. Wood flooring performs best with subtle changes in temperature. The floor should not fluctuate by more than 5°F per day.
   1. For hydronic radiant heating systems, an outdoor reset control (zone reset controls) with high/low temperature settings (to minimize the boiler temperature), along with an in-floor sensor, should be installed with the system to minimize the effects of rapid changes in temperature. These sensors and thermostats allow the heating process to be gradual and based on small incremental increases in relation to the exterior temperature. "Set back" or programmable thermostats could vary room temperature greater than 5°F per day, and should not be used.
   2. For electric radiant heating systems, a thermostat along with an in-floor sensor must be installed with the electric floor heating system to minimize the effects of rapid changes in temperature. It is also recommended to use a thermostat that would limit floor temperature changes to 5°F per day.

L. Items such as area rugs, mattresses, exercise mats, pet beds, bean bags, or other highly insulating products that cover the floor will trap heat and increase the temperature of the floor it is covering, which can result in irreversible damage to any type of floor. When the floor is expected to be covered, the radiant heating design engineer, and the radiant heating installer should calculate and factor-in the R-value of the specific insulating item that will be covering the floor, and make adjustments to the heating output as necessary. The end-user should consider the effects of heat build-up and subsequent flooring damage.

M. All radiant heating systems should be fully operational, regardless of season, for a minimum of 5 days prior to delivery of wood flooring. Keeping the system on helps force out moisture and ensures the system is operational prior to flooring install.
   1. Water-heated (hydronic) radiant-heat systems should be pressure tested, all system controls should be fully operational, and functional operating results should be made available by the system installer.
   2. Electric underfloor systems should be tested for proper operation, and functional operating results documented and made available to the wood flooring installer by the heating system installer.

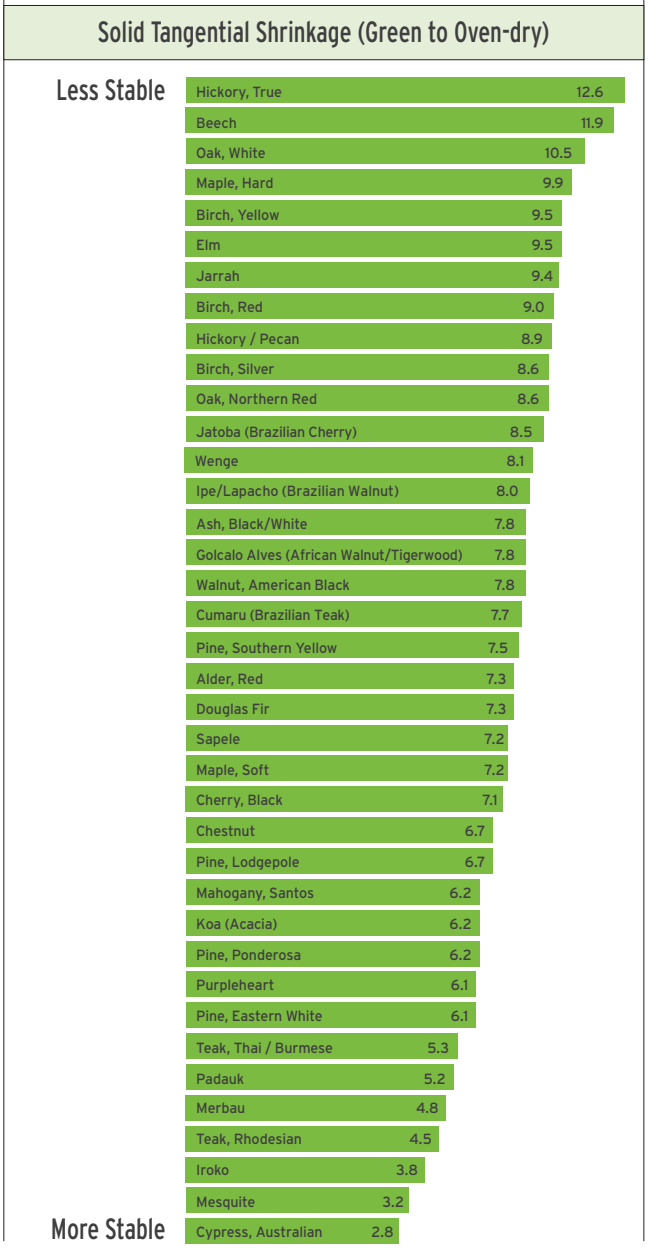
N. The end-user should be made aware of the importance of proper usage of the entire radiant heating system by the radiant heating system design engineer and the radiant heating

system installer as it directly relates to the floor covering installed over it. The wood floor installer should provide maintenance instructions related to the heating and relative humidity requirements of the wood floor to the end-user.

PART III
Wood Flooring Selection over Radiant Heat

A. Most wood flooring can be installed over radiant heat, providing all of the necessary conditions are met.
   1. Successful wood floor installations occur when the radiant heat system design engineer, the radiant heating system installer, the wood flooring installer, and the end-user all communicate and fully understand what is required for the entire flooring system being installed.
   2. This communication should include which type of wood flooring to use, what installation method to use, understanding how this heat source may impact the wood flooring, what precautions to take before-, during- and after-installation, and consistent communication between all parties when any changes take place to any part of the system.

B. The types of wood flooring best suited for under-floor radiant heat systems should be accounted for to ensure long-term performance. The flooring categories directly affecting the dimensional stability of the wood flooring often include:
   1. **Flooring cut:** Wood is a hygroscopic and an anisotropic material, meaning it takes-on and throws-off moisture, and it shrinks and swells differently in each direction, dependent on changes in moisture. How the wood changes dimension is largely influenced by the species characteristics and the way in which the wood is cut from the tree. The way in which it is cut from the tree for solid or sawn flooring is classified as plainsawn, quartersawn, riftsawn, livesawn, or end-grain. Quartersawn and riftsawn wood flooring is more dimensionally stable in width than plainsawn or end-grain wood flooring.
   2. **Flooring width:** Wood changes dimension proportional to the width of the plank. Narrow boards expand and contract less than wider width boards of the same species and cut.
   3. **Flooring type:** Engineered wood flooring is, in general, more dimensionally stable than solid wood flooring. However, not all engineered wood flooring is recommended or appropriate for use over radiant heating systems. Engineered flooring with less-stable wear layer species such as hickory, beech, and maple are not normally best-suited over radiant heat, unless otherwise suggested by the flooring manufacturer. The cut of the wear layer lamina (peeled, sliced, or sawn) can also affect how the floor performs over radiant heat. Follow the flooring manufacturer recommendations as to whether or not each specific product is intended to be used over radiant heat.
   4. Wood flooring manufactured and expected to perform at MC levels higher than 9% or in conditions above 50% RH, should not be used with radiant heating systems unless otherwise recommended by the flooring manufacturer.
   5. **Species**: Both in solid and engineered flooring options, certain species are known for their inherent dimensional stability such as American chestnut, black cherry, black walnut, and others. Less-stable species such as hickory, beech, and maple are less-suitable for use over radiant heat.



C. A supplemental humidity control system is often necessary, and should be specified into any radiant heat wood flooring project, in order to properly support ambient airspace conditions between 30% - 50% RH, or as otherwise required by the wood flooring manufacturer. Supplemental humidification should be present and operational prior to delivery, during and post-installation of the wood flooring.

D. Wood flooring selection should be aligned with the conditions in which it is expected to perform. With the heating source placed directly below the installed wood flooring, the moisture content will forcibly be reduced during the heating season if supplemental humidification is not added.

E. In-floor, or under-floor temperature and humidity data-logging devices are recommended to be installed by the radiant system installer or the flooring contractor, to monitor the conditions in the space after the floor has been placed into service. Placement of these sensors should be determined with the assistance of the radiant heating system installer in order to gain the most-accurate floor temperature readings.

F. The end-user should have a clear understanding of the flooring product, maintenance requirements, humidification systems, data loggers, and the radiant heating system features, limitations, and abilities, to ensure adequate conditions are maintained year-round.

PART IV
Installation Methods over Radiant Heat

Radiant heating systems may be installed within, above, or below any substrate. Substrates may include concrete, wood, screeds/sleepers or a combination of any of these. The type of flooring specified, the flooring manufacturer requirements, and the subflooring system will dictate the flooring installation method.

A. Nail-Down over Wood Panel Subfloor
   1. Refer to the Nail-Down Installation chapter for details on proper installation methods, unless otherwise directed by the flooring manufacturer.
   2. Subfloor surface temperature should not exceed 80ºF at the time of installation.
   3. A class II vapor retarder should be placed over a wood subfloor and below the wood flooring when being installed over an unconditioned space (refer to the Underlayments: Moisture Control chapter). Do not use asphalt- or bitumen-type vapor retarders over radiant heat systems.
   4. Where a wood panel subfloor has been installed over a concrete slab, install a Class 1 impermeable vapor retarder over the slab, and under the wood panel subfloor in all on- and below-grade applications, and when calcium chloride readings are greater than 3 pounds, relative humidity readings are greater than 80%, or calcium carbide readings are greater than 2.5%.
   5. Fastener length should be taken into account to avoid penetration of the vapor retarder.
   6. Avoid penetration of the heating tubes/elements with wood flooring fasteners. Length and placement of fasteners must be assessed and addressed prior to and during the install.
   7. When the required fastener schedule cannot be followed due to the type of radiant heating system being used, an alternative installation method may be necessary. This may include any of the following:
      a. Nail-assisted glue-down (the use of an elastomeric adhesive in conjunction with the mechanical fasteners is recommended any time fastener length, fastener schedule, or any portion of the installation would benefit from additional hold-power).
      b. Full spread glue-down.
      c. Floating installation methods.

B. Direct Nail to Screeds/Sleepers
   1. Refer to the Screeds/Sleepers chapter for proper nail-down installation methods over screeds/sleepers, unless otherwise directed by the flooring manufacturer.
   2. The subfloor surface temperature should never exceed 80ºF at the time of installation.
   3. A vapor retarder should be installed below the screeds/sleepers. Do not use asphalt- or bitumen-type vapor retarders over radiant heat systems.

4. Hydronic tubing and electric elements typically are installed into the channels between the screeds/sleepers, and then embedded in a gypsum or lightweight concrete mix, which is poured even with the top of the screed/sleeper. This should present a flat surface that minimizes any air space between the subfloor and the flooring. The heating tubes/elements should be submerged enough below the surface of the screeds/sleepers that the wood flooring does not come into direct contact with the heating tubes/elements.
5. When nailing down a wood floor, consider the screed/sleeper placement in comparison to the angle of the fastener to avoid penetrating into any radiant heating tubes or elements.
6. When the required fastener schedule cannot be followed due to the placement of the screeds/sleepers, an alternative installation method may be necessary. This may include any of the following:
    a. Nail-assisted glue-down (the use of an elastomeric adhesive in conjunction with the mechanical fasteners is recommended any time fastener length, fastener schedule, or any portion of the installation would benefit from additional hold-power).
    b. Full spread glue-down.
    c. Floating installation methods.

C. Glue-Down
1. Refer to the Glue-Down Installation chapter for details on proper installation methods, unless otherwise directed by the flooring manufacturer.
2. The heat will need to be reduced or even turned off during installation of the flooring to avoid premature drying and skinning-over of the adhesive. Check with the adhesive manufacturer for minimum/maximum subfloor temperature limitations during the installation.
3. The subfloor surface temperature should never exceed 80°F at the time of installation.
4. Do not fill the channels containing radiant tubing with adhesive.
5. Install a Class 1 impermeable vapor retarder over the slab in all on- and below-grade applications, and when calcium chloride readings are greater than 3 pounds, relative humidity readings are greater than 80%, or calcium carbide readings are greater than 2.5%. Use an adhesive and moisture control system suitable for the flooring being installed and for the radiant heating system it is being installed over. Do not use asphalt- or bitumen-type vapor retarders over radiant heat systems.
6. Note: When using the in-situ relative humidity tests (ASTM F2170), be extremely cautious when drilling into the slab where hydronic tubing or electric heating elements have been embedded, so as to not damage or puncture the heating system. Use of infrared cameras or heat-detecting devices may assist in identifying a safe location for testing.

D. Floating Engineered
1. Refer to the Floating Installation chapter for details on proper installation methods, unless otherwise directed by the flooring manufacturer.
2. Subfloor surface temperature should never exceed 80°F at the time of installation.
3. The insulating properties (R-values) of flooring underlayment pads vary, and may compromise the radiant heat efficiency. The pad R-value should be taken into account during the design and specification of the heating system. Do not use asphalt- or bitumen-type vapor retarders over radiant heat systems.
4. For edge-glued floors, ensure the glue recommended by the flooring manufacturer is approved for use with radiant heat.

E. Direct-Nail through Low-Voltage Radiant Systems
1. Refer to the radiant heating manufacturer installation instructions prior to nailing through any electric radiant heating system.
2. Refer to the flooring manufacturer for proper installation methods over these types of heating systems.