This step-by-step design guide provides the tools necessary to design a heat loss replacement system using an nVent RAYCHEM RaySol self-regulating heating cable system or an nVent RAYCHEM Mineral Insulated heating cable system. For other applications or for design assistance, contact your nVent representative or call (800) 545-6258. Also, visit our website at nVentthermal.com.

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<td>Radiant Space Heating</td>
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INTRODUCTION

nVent offers RaySol and MI heating cable systems for large floor heating areas, like garages, loading docks, arcades, lobbies, foyers, gymnasiums, etc. RaySol heating cables and MI heating cables can be directly attached to the bottom of the concrete floor or be directly embedded in the concrete floor or in a thick mortar bed.

nVent also offers a full suite of best-in-class NUHEAT floor heating products for smaller floor heating areas, like kitchens, bathrooms, living spaces, shower benches, shower floors, granite counter tops, etc. For more information, refer to nVent.com/NUHEAT.

If your application conditions are different than described in this guide, or if you have any questions, contact your nVent representative or call (800) 545-6258.

How to Use this Guide

This design guide presents nVent recommendations for designing large floor heating systems. It provides design and performance data, electrical sizing information, control selection and heating-cable layout suggestions. Following these recommendations will result in a reliable, energy-efficient system.

Follow the design steps and use the appropriate design worksheets to document the project parameters that you will need for your project’s Bill of Materials.

OTHER REQUIRED DOCUMENTS

This guide is not intended to provide comprehensive installation instructions. For complete floor heating system installation instructions, please refer to the following additional required documents:

• RaySol Floor Heating and Freezer Frost Heave Prevention Installation and Operation Manual (H58138)
• Mineral Insulated Heating Cable Floor Heating and Freezer Frost Heave Prevention Installation and Operation Manual (H58137)
• Additional installation instructions are included with the connection kits, thermostats, controllers, and accessories

If you do not have these documents, you can obtain them from the nVent website at nVentthermal.com.

For products and applications not covered by this design guide, please contact your nVent representative or call (800) 545-6258.
Safety Guidelines

As with any electrical equipment, the safety and reliability of any system depends on the quality of the products selected and the manner in which they are installed and maintained. Incorrect design, handling, installation, or maintenance of any of the system components could damage the system and may result in inadequate performance, overheating, electric shock, or fire. To minimize these risks and to ensure that the system performs reliably, read and carefully follow the information, warnings, and instructions in this guide.

⚠️ This symbol identifies important instructions or information.

⚠️ This symbol identifies particularly important safety warnings that must be followed.

⚠️ WARNING: To minimize the danger of fire from sustained electrical arcing if the heating cable is damaged or improperly installed, and to comply with the requirements of nVent, agency certifications, and national electrical codes, ground-fault equipment protection must be used on each heating cable branch circuit. Arcing may not be stopped by conventional circuit protection.

Warranty

nVent’s standard limited warranty applies to nVent RAYCHEM Floor Heating Systems.

FOR RAYSOl AND MI HEATING CABLES

An extension of the limited warranty period to ten (10) years from the date of installation is available, except for the control and distribution systems, if a properly completed online warranty form is submitted within thirty (30) days from the date of installation. You can access the complete warranty on our website at nVentThermal.com/support/warranty/
SYSTEM OVERVIEW

There are three main floor heating applications:

- Heat loss replacement
- Comfort floor heating (includes concrete floor heating)
- Radiant space heating

nVent offers RaySol and MI heating cable systems for floor heating. Each product has specific design and installation considerations and this guide will address how to design the system that best suits your needs. RaySol and MI heating cables can be installed in multiple methods; however, the most common methods will be covered.

HEAT LOSS REPLACEMENT

RaySol and MI heating cables can be used to eliminate the chill felt from the heat lost through floors over non-heated areas such as garages, loading docks or arcades. The heating cables achieve this by replacing the heat normally lost through the floor insulation over a cold space.

For heat loss replacement, both RaySol and MI heating cables can be used and are attached to the bottom of the concrete floor.

COMFORT FLOOR HEATING

RaySol and MI heating cables can heat floors in places such as lobbies, foyers and gymnasiums. The heating cables are used to raise the floor temperature to 80°F (27°C) or warmer so it is comfortable to walk on the floor in bare feet.

For comfort floor heating, both RaySol and MI heating cables can be used and can be embedded in mortar or concrete.

RADIANT SPACE HEATING

RaySol and MI heating cable systems can be designed to provide primary space heating for rooms with concrete floors. RaySol heating cable systems must be custom designed through nVent. Contact your nVent representative or call (800) 545-6258 for design assistance.

For radiant space heating, both RaySol and MI heating cables can be used and are directly embedded in mortar or concrete.
Typical System

The following illustration shows a typical heat loss replacement system.

**Fig. 1 Typical heat loss replacement system**

The following illustration shows a typical heat loss replacement installation.

**Fig. 2 Typical heat loss replacement installation**
The following illustration shows a typical comfort floor heating system.

**Fig. 3 Typical comfort floor heating system**

The following illustration shows a typical comfort floor system installation.

**Fig. 4 Typical comfort floor heating system installation**

A radiant space heating system is similar to the illustration in Fig. 3. RaySol heating cable systems must be custom designed through nVent. Contact your nVent representative or call (800) 545-6258 for design assistance.
Table 1 summarizes which heating cable can be used for which application.

**TABLE 1  FLOOR HEATING APPLICATIONS AND RECOMMENDED HEATING CABLES**

<table>
<thead>
<tr>
<th>Application</th>
<th>RaySol</th>
<th>MI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat loss replacement</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Comfort floor heating</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Radiant space heating</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

### Self-Regulating Heating Cable Construction

RaySol self-regulating heating cables are comprised of two parallel nickel-coated bus wires in a cross-linked polymer core, a tinned copper braid, and a fluoropolymer outer jacket. These cables are cut to length, simplifying the application design and installation.

With self-regulating technology, the number of electrical paths between bus wires changes in response to temperature fluctuations. As the temperature surrounding the heater decreases, the conductive core contracts microscopically. This contraction decreases electrical resistance and creates numerous electrical paths between the bus wires. Current flows across these paths to warm the core.

As the temperature rises, the core expands microscopically. This expansion increases electrical resistance and the number of electrical paths decreases. The heating cable automatically reduces its output.
At low temperature, there are many conducting paths, resulting in high output and rapid heat-up. Heat is generated only when it is needed and precisely where it is needed.

At high temperature, there are few conducting paths and output is correspondingly lower, conserving energy during operation.

At moderate temperature, there are fewer conducting paths because the heating cable efficiently adjusts by decreasing output, eliminating any possibility of overheating.

The following graphs illustrate the response of self-regulating heating cables to changes in temperature. As the temperature rises, electrical resistance increases, and our heaters reduce their power output.

Fig. 6 Self-regulating heating cable technology

CODES AND APPROVALS

The RaySol system is UL Listed for heat loss replacement, comfort floor heating and radiant space heating applications.

The RaySol system is CSA Certified for comfort floor heating and radiant space heating applications. For heat loss replacement applications where the cable is attached to the bottom of the concrete floor, contact nVent for additional information.
MI Heating Cable Construction

MI heating cables used for floor heating applications are comprised of a single conductor surrounded by magnesium oxide insulation and a solid copper sheath. For embedded applications, such as comfort floor heating and radiant space heating, the heating cable also has an extruded Low Smoke Zero Halogen (LSZH) jacket.

**Heating cable construction**

- **Heating conductor**
- **Insulation (magnesium oxide)**
- **Copper sheath**
- **LSZH jacket** (for embedded cables only)

![Fig. 7 Typical MI heating cable construction](image)

The heating cables are supplied as complete factory-fabricated assemblies consisting of an MI heating cable that is joined to a section of MI non-heating cold lead and terminated with NPT connectors. Two configurations are available: Type SUA consisting of a looped cable joined to a single 7 ft (2.1 m) cold lead with one 1/2-in NPT connector; and Types SUB, HLR and FH consisting of a single run of cable with a 15 ft (4.6 m) cold lead and a 1/2-in NPT connector on each end.

![Fig. 8 Configurations for surface mount or directly embedded in concrete installations](image)

nVent offers all the components necessary for system installation. Details of these components and additional accessories can be found later in this design guide.

**CODES AND APPROVALS**

The MI system is c-CSA-us Certified for comfort floor heating and radiant space heating applications. For heat loss replacement applications where the cable is attached to the bottom of the concrete floor, contact nVent for additional information.
FLOOR HEATING APPLICATION DESIGN

This section guides you through the steps necessary to design the correct system for your application. The examples provided in each step are intended to incrementally illustrate the project parameter output for sample designs from start to finish. As you go through each step, use the appropriate design worksheets to document your project parameters, so that by the end of this section, you will have the information you need for your Bill of Materials.

For products and applications not covered by this design guide, please contact your nVent representative or call nVent directly at (800) 545-6258.

Design Step by Step

Your system design requires the following essential steps:

1. Determine the application
   - Heat loss replacement
   - Comfort floor heating
   - Radiant space heating

2. Select the heating cable system and installation method
   - Heat loss replacement
   - Comfort floor heating
   - Radiant space heating

3. Determine the floor configuration

4. Determine the heating cable spacing, layout, and length
   - RaySol heating cables
   - MI heating cables

5. Determine the electrical parameters

6. Select the connection kits and accessories

7. Select the control system

8. Select the power distribution

9. Complete the Bill of Materials

Depending on the heating cable system you select, use one of the following worksheets to help you document the project parameters you will need for your project’s Bill of Materials:

- Preliminary worksheet for determining your project’s application and product line on page 50.
- The “RaySol Heating Cable Floor Heating Design Worksheet” on page 51.
- The “MI Heating Cable Floor Heating Design Worksheet” on page 59.
Step 1 Determine the application

This step further defines the specific application and design assumptions. Once the application is verified, you will select the appropriate heating system in Step 2.

HEAT LOSS REPLACEMENT

A heat loss replacement system uses RaySol and MI heating cables for concrete floors built over garages, loading docks, arcades, or other cold spaces. The design goal is to prevent the floor over a cold space from cooling below room temperature. The heating cable system achieves this by replacing the heat normally lost through the floor insulation over a cold space.

A successful design must conform to the following requirements:

- The floor to be heated is indoors where the room temperature above the floor is approximately 70°F (21°C).
- RaySol and MI heating cables will be attached to the bottom of the concrete floor. If it is necessary to install RaySol or MI cables in conduit or to directly embed the MI cables in the concrete floor, contact your nVent representative or call (800) 545-6258 for design assistance.
- The bottom of the floor is insulated.

COMFORT FLOOR HEATING

A comfort floor heating system uses RaySol or MI heating cables for lobbies, foyers, schools, or gymnasiums. The design goal is to raise the floor temperature to 80°F (27°C) or above so it is comfortable to walk on the floor with bare feet. RaySol and LSZH jacketed copper sheathed MI heating cables are directly embedded in mortar or concrete.

A successful design must conform to the following requirements:

- For RaySol, the floor to be heated is indoors, and is located on grade or is located above an area where the ambient temperature is approximately 70°F (21°C) or the bottom of the floor is insulated.
- For MI, the floor to be heated is indoors, and is located on grade or is located above an area where the ambient temperature is approximately 70°F (21°C) or the bottom of the floor is insulated with minimum R-20 insulation when exposed to the outside ambient air temperature.
- RaySol and LSZH jacketed copper sheathed MI heating cables are embedded in a standard concrete floor or embedded in a mortar layer (at least 3/4 in (2 cm) thick) under ceramic tile or natural stone.
- RaySol or MI heating cables shall not be installed in shower floors, under tubs and spas, or under other permanent fixtures.

RADIANT SPACE HEATING

RaySol and MI heating cable systems can be designed to provide primary space heating for rooms with concrete floors. RaySol heating cable systems must be custom designed by nVent. Contact your nVent representative or call (800) 545-6258 for design assistance.

A successful design must conform to the following requirements:

- The Btu requirement and total heated area are provided by the customer.
- The bottom of the floor is insulated or located on grade.
- RaySol and LSZH jacketed copper sheathed MI heating cables are embedded in a concrete floor or embedded in mortar (at least 3/4 in (2 cm) thick), under ceramic tile or natural stone.
- RaySol or MI heating cables shall not be installed in shower floors, under tubs and spas, or under other permanent fixtures.
Floor Heating System
Design Steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Determine the application</td>
</tr>
<tr>
<td>2</td>
<td>Select the heating cable system and installation method</td>
</tr>
<tr>
<td>3</td>
<td>Determine the floor configuration</td>
</tr>
<tr>
<td>4</td>
<td>Determine the heating cable spacing, layout and length</td>
</tr>
<tr>
<td>5</td>
<td>Determine the electrical parameters</td>
</tr>
<tr>
<td>6</td>
<td>Select the connection kits and accessories</td>
</tr>
<tr>
<td>7</td>
<td>Select the control system</td>
</tr>
<tr>
<td>8</td>
<td>Select the power distribution</td>
</tr>
<tr>
<td>9</td>
<td>Complete the Bill of Materials</td>
</tr>
</tbody>
</table>

**Step 3 Select the heating cable system and installation method**

In this step you will determine the heating cable system and installation method to suit your specific needs. Table 2 indicates the various installation methods that will be discussed in this design guide for each heating cable technology as it pertains to each application.

### TABLE 2 INSTALLATION METHODS BY HEATING CABLE AND APPLICATION

<table>
<thead>
<tr>
<th>Installation method</th>
<th>Heat loss replacement</th>
<th>Comfort floor heating</th>
<th>Radiant space heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attach to bottom</td>
<td>X</td>
<td>X</td>
<td>--</td>
</tr>
<tr>
<td>Embed in concrete</td>
<td>--</td>
<td>--</td>
<td>X</td>
</tr>
<tr>
<td>Embed in mortar bed</td>
<td>--</td>
<td>--</td>
<td>X</td>
</tr>
</tbody>
</table>

**Step 4 Determine the floor configuration**

All floor heating applications require determining the area to be heated. For heat loss replacement and comfort floor heating you will also need the minimum ambient design temperature and the insulation R-value. For radiant space heating you will need to provide the Btu requirement.

In this design guide, two floor layouts will be used to illustrate all floor heating applications. The first example will be for heat loss replacement and the second example will be for comfort floor heating and radiant space heating.

### HEAT LOSS REPLACEMENT

**GATHERING INFORMATION**

When using this guide to design a system, you need the following information:

- Size and layout of exposed floor
- Minimum ambient design temperature
- Insulation R-value
- Supply voltage and phase
- Control requirements
PREPARE SCALE DRAWING

Draw to scale the floor area to be heated. Carefully note the limits of the area to be heated. Show all concrete joints on the drawing and note the voltage supply location, and location and size of obstacles, such as floor drains, pipe penetrations, conduit runs, columns and fixtures.

For heat loss replacement, the entire floor is considered the area to be heated.

Heated area = Total area

![Fig. 9 Floor layout for heat loss replacement example](image)

DETERMINE MINIMUM AMBIENT DESIGN TEMPERATURE

Determine the lowest temperature that is expected below the floor insulation.

RECORD INSULATION R-VALUE

The insulation R-value is the thermal resistance of the floor’s insulation. Normally, the R-value will be printed on the insulation material. If that is not the case, you can calculate it by dividing the insulation thickness in inches by the insulation thermal conductivity.

Example: RaySol heating cables for heat loss replacement

- Heated area: $80 \text{ ft} \times 40 \text{ ft} = 3200 \text{ ft}^2$ (see Fig. 9)
  \[ (24.4 \text{ m} \times 12.2 \text{ m} = 297.4 \text{ m}^2) \]
- Minimum ambient design temperature: $-10^\circ \text{F} (-23^\circ \text{C})$
- Insulation R-value: $R-20$ ($20 \text{ ft}^2 \cdot \text{°F} \cdot \text{hr}/\text{Btu}$)
- Supply voltage and phase: $208 \text{ V}, \text{ single-phase}$
- Control requirements: Electronic thermostat, monitoring requested

Example: MI heating cables for heat loss replacement

- Heated area: $80 \text{ ft} \times 40 \text{ ft} = 3200 \text{ ft}^2$ (see Fig. 9)
  \[ (24.4 \text{ m} \times 12.2 \text{ m} = 297.4 \text{ m}^2) \]
- Minimum ambient design temperature: $-10^\circ \text{F} (-23^\circ \text{C})$
- Insulation R-value: $R-20$ ($20 \text{ ft}^2 \cdot \text{°F} \cdot \text{hr}/\text{Btu}$)
- Supply voltage and phase: $208 \text{ V}, \text{ three-phase}$
- Control requirements: Electronic thermostat, monitoring requested

Advance to Step 4, page 16.
**COMFORT FLOOR HEATING**

**GATHERING INFORMATION**
When using this guide to design a system you need the following information:

- Size and layout of floor
- Minimum ambient design temperature
- Insulation R-value
- Supply voltage and phase
- Control requirements

For comfort floor heating, it is also important to note the locations of shower floors, tubs, spas, toilets, and other permanent fixtures and subtract these areas from the total area.

Heated area = Total area – Permanent fixture space

**DETERMINE MINIMUM AMBIENT DESIGN TEMPERATURE**
Determine the lowest temperature that is expected below the floor insulation.

**RECORD INSULATION R-VALUE**
The insulation R-value is the thermal resistance of the floor’s insulation. Normally, the R-value will be printed on the insulation material. If that is not the case, you can calculate it by dividing the insulation thickness in inches by the insulation thermal conductivity.

**Example: Comfort floor heating (RaySol and MI heating cables)**

Heated area: 
(34 ft x 20 ft) – (22 ft² + 11 ft²) = 647 ft²
(see Fig. 10)
(10.4 m x 6.1 m) – (2 m² + 1 m²) = 60.4 m²

Minimum ambient design temperature: 10°F (−12°C)
Insulation R-value: R-30 (30 ft²°F·hr/Btu)
Supply voltage and phase: 208 V, single-phase
Control requirements: Electronic thermostat

Advance to Step 4, page 16.
RADIANT SPACE HEATING

GATHERING INFORMATION
When using this guide to design a system, you need the following information:

- Size and layout of floor
- The Btu requirement (heat loss) calculated by the engineer or architect
- Supply voltage and phase
- Control requirements

For radiant space heating, the heat loss, or Btu required, is based on the total area of the room. However, the heating cable must not be installed under the area occupied by columns, fixtures, shower floors, tubs and spas, toilets and other permanent fixtures. To determine the area in which the heating cable will be installed, subtract the area occupied by these permanent fixtures from the total area.

Heated area = Total area – Permanent fixture space

Example: MI heating cables for radiant space heating

- Floor area: \((34\, \text{ft} \times 20\, \text{ft}) - (22\, \text{ft}^2 + 11\, \text{ft}^2) = 647\, \text{ft}^2\) (see Fig. 11)
  \((10.4\, \text{m} \times 6.1\, \text{m}) - (2\, \text{m}^2 + 1\, \text{m}^2) = 60.4\, \text{m}^2\)
- Btu requirement: 34,800 Btu / hr (supplied by engineer)
- Supply voltage and phase: 208 V, single-phase
- Control requirements: Electronic thermostat

Advance to Step 4, page 16.
Step 4 Determine the heating cable spacing, layout and length

In this step you will select the heating cable and determine the spacing, layout and length. This section is organized by heating cable type with specific design criteria for each application and installation method.

- For RaySol self-regulating heating cable design
  - For heat loss replacement, see below.
  - For comfort floor heating, see page 20.

- For MI heating cable design
  - For heat loss replacement, see page 25.
  - For comfort floor heating, see page 30.
  - For radiant space heating, see page 34.

**RAYSOL SELF-REGULATING HEATING CABLE SYSTEM DESIGN**

**HEAT LOSS REPLACEMENT**

Design a RaySol heating cable system for heat loss replacement as follows:

1. **Select the appropriate RaySol heating cable**

Select the heating cable based on the operating voltage. For 120 V, select RaySol-1; for 208–277 V, select RaySol-2.

**TABLE 3 RAYSOL HEATING CABLE**

<table>
<thead>
<tr>
<th>Supply voltage</th>
<th>Catalog number</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 V</td>
<td>RaySol-1</td>
</tr>
<tr>
<td>208–277 V</td>
<td>RaySol-2</td>
</tr>
</tbody>
</table>

**Example: RaySol heating cables for heat loss replacement**

- Supply voltage: 208 V (from Step 3)
- Catalog number: RaySol-2
2. Determine the RaySol heating cable spacing

Use the minimum ambient design temperature and the floor insulation R-value (from Step 3) to select the correct spacing shown in Table 4 for heat loss replacement. If the calculated R-value or minimum design temperature does not match the values in the table, use the values that give the closer spacing.

### TABLE 4  RAYSOL HEATING CABLE SPACING FOR HEAT LOSS REPLACEMENT

<table>
<thead>
<tr>
<th>Minimum ambient design temperature</th>
<th>Floor insulation R-value (ft²·°F·hr/Btu)</th>
<th>R-10</th>
<th>R-20</th>
<th>R-30</th>
<th>R-40</th>
</tr>
</thead>
<tbody>
<tr>
<td>50°F (10°C)</td>
<td></td>
<td>30 in (73 cm)</td>
<td>36 in (91 cm)</td>
<td>36 in (91 cm)</td>
<td>36 in (91 cm)</td>
</tr>
<tr>
<td>30°F (–1°C)</td>
<td></td>
<td>24 in (61 cm)</td>
<td>30 in (76 cm)</td>
<td>36 in (91 cm)</td>
<td>36 in (91 cm)</td>
</tr>
<tr>
<td>10°F (–12°C)</td>
<td></td>
<td>21 in (53 cm)</td>
<td>30 in (76 cm)</td>
<td>30 in (76 cm)</td>
<td>36 in (91 cm)</td>
</tr>
<tr>
<td>–10°F (–23°C)</td>
<td></td>
<td>18 in (46 cm)</td>
<td>24 in (61 cm)</td>
<td>30 in (76 cm)</td>
<td>36 in (91 cm)</td>
</tr>
<tr>
<td>–30°F (–34°C)</td>
<td></td>
<td>15 in (38 cm)</td>
<td>24 in (61 cm)</td>
<td>30 in (76 cm)</td>
<td>36 in (91 cm)</td>
</tr>
</tbody>
</table>

If the space below the floor is maintained at 50–70°F (10–21°C), insulate the floor to R-10 minimum and select a heating cable spacing from the 50°F (10°C) row in Table 4.

**Example: RaySol heating cables for heat loss replacement**

Minimum ambient design temperature  –10°F (–23°C) (from Step 3)
Insulation R-value  R-20 (from Step 3)
Heating cable spacing  24 in (61 cm)

3. Determine the RaySol heating cable layout and length

**Estimate the heating cable length** The length of heating cable and the number of heating cable circuits can be estimated before a detailed layout is done if the heating cable spacing, total heated area, and the available branch circuit breaker rating are known. Fig. 12 shows typical layouts when the heating cable is directly attached to the bottom of the floor.

![Fig. 12 Typical heating cable layouts for heat loss replacement](image-url)
Estimate the heating cable length required:

Estimated heating cable length (ft) = \( \frac{\text{Heated area (ft}^2\) \times 12}{\text{Spacing (in)}} \)

Estimated heating cable length (m) = \( \frac{\text{Heated area (m}^2\) \times 100}{\text{Spacing (cm)}} \)

---

**Example: RaySol heating cable length for heat loss replacement**

Heated area \( 3200\ ft^2 \) (297.4 m²) (from Step 3, Fig. 9)

Estimated heating cable length \( 3200\ ft^2 \times 12 / 24\ in = 1600\ ft \)
\( 297.4\ m^2 \times 100 \div 61\ cm = 487.5\ m \)

4. **Determine the maximum circuit length for the heating cable length**

For the appropriate supply voltage, use Table 5 to select the maximum circuit length which is closest to, but greater than the length calculated. If the estimated heating cable length required is greater than the maximum circuit length, multiple circuits must be used.

**TABLE 5** MAXIMUM RAYSOL CIRCUIT LENGTH IN FEET (METERS) WHEN ATTACHING HEATING CABLE TO THE BOTTOM OF THE FLOOR (40°F (4°C) START-UP)*

<table>
<thead>
<tr>
<th>Supply voltage</th>
<th>120 V</th>
<th>208 V</th>
<th>240 V</th>
<th>277 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit breaker size (A)</td>
<td>ft</td>
<td>m</td>
<td>ft</td>
<td>m</td>
</tr>
<tr>
<td>15</td>
<td>120</td>
<td>36.6</td>
<td>205</td>
<td>62.5</td>
</tr>
<tr>
<td>20</td>
<td>160</td>
<td>48.8</td>
<td>275</td>
<td>83.8</td>
</tr>
<tr>
<td>30</td>
<td>240</td>
<td>73.2</td>
<td>410</td>
<td>125.0</td>
</tr>
<tr>
<td>40</td>
<td>240</td>
<td>73.2</td>
<td>410</td>
<td>125.0</td>
</tr>
</tbody>
</table>

*For start-up temperatures less than 40°F (4°C), contact your nVent representative.

Calculate the estimated number of circuits as follows:

Number of circuits = \( \frac{\text{Estimated heating cable length (ft/m)}}{\text{Maximum circuit length (ft/m)}} \)

Round the number of circuits to the next larger whole number.
Example: RaySol heating cable length for heat loss replacement

Estimated heating cable length: 1600 ft (487.5 m) (from earlier in this step)
Supply voltage: 208 V (from Step 3)
Maximum circuit length: 410 ft (125 m) (from Table 5)
Number of circuits: 1600 ft / 410 ft = 4 circuits (rounded)
Power supply: Four 30 A circuit breakers (from Table 5)

5. Determine the additional heating cable allowance

Additional heating cable is required to make power connections and to route the circuits to junction boxes. This extra heating cable need not be considered when determining the maximum heating cable length for circuit breaker sizing. In order to estimate the total heating cable length, you will need to take the estimated heating cable length you already calculated, and then add heating cable allowances, as follows:

Estimated total heating cable length = Estimated heating cable length + End allowances + Connection kit allowances

### TABLE 6 RAYSOL ADDITIONAL HEATING CABLE ALLOWANCE

<table>
<thead>
<tr>
<th>Heating cable allowance</th>
<th>Description</th>
<th>Length of cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>End allowances</td>
<td>From end of protective conduit to junction box</td>
<td>4 ft (1.2 m) per end</td>
</tr>
<tr>
<td>Connection kit allowances</td>
<td>Required to assemble the connection kit (one per circuit)</td>
<td>4 ft (1.2 m) per kit</td>
</tr>
</tbody>
</table>

Example: RaySol heating cable for heat loss replacement

Estimated heating cable length: 1600 ft (487 m) (from earlier in this step)
End allowance: 4 circuits x 4 ft per end x 2 ends = 32 ft (10 m) (from Table 6)
Connection kit allowances: 4 connection kits x 4 ft per kit = 16 ft (5 m) (from Table 6)
Total heating cable allowances: 32 ft (10 m) + 16 ft (5 m) = 48 ft (15 m)
Estimated total heating cable length: 1600 ft (487 m) + 48 ft (15 m) = 1648 ft (502 m)

6. Locate the junction boxes for the RaySol heating cable system

The heating cable connects to the branch circuit wiring in a junction box with the RaySol FTC-P power connection and end seal kit.

The junction boxes may be distributed around the area to be heated, or collected at a single location. In many applications, the heating cable can be laid out so that all power connections and end seals can be grouped in a common area without using extra heating cable. If this can be done, select the common junction box location to minimize the electrical conduit and wire needed to reach the branch circuit breakers. Refer to Fig. 12 on page 17 for examples of typical layouts of cable attached to the bottom of concrete floors.

7. Lay out the heating cable runs, circuits, and junction boxes

After determining the estimated total heating cable length, the number of circuits, and the junction box location, do a trial layout. In making the trial layout, follow these recommendations:

- Start and end each circuit in a junction box. The power connection and end seal may be located in the same box or in different boxes.
- Arrange the heating cable run so it uniformly covers the area to be heated.
- Maintain the design heating cable spacing within 1 in (2.5 cm).
- Do not route the heating cable closer than 4 in (10 cm) to the edge of the subfloor, drains, anchors, or other material in the concrete.
• Do not exceed the maximum length of heating cable allowed on a branch circuit breaker as given in Table 5.

• When the combined lengths of two or more circuit runs are less than the maximum circuit length allowed, these runs can be combined in parallel on one circuit breaker.

8. Record the circuit information
Reconfigure the trial circuit layout until the design meets all of the previous recommendations. Assign each circuit to a circuit breaker in a specific panel board and record each circuit length.
Advance to Step 5, page 37.

COMFORT FLOOR HEATING
Design a RaySol heating cable system for comfort floor heating as follows:

1. Select the appropriate RaySol heating cable
Select the heating cable based on the operating voltage (see Table on page 16). For 120 V, select RaySol-1; for 208–277 V, select RaySol-2.

Example: RaySol heating cables for comfort floor heating
Supply voltage 208 V (from Step 3)
Catalog number RaySol-2

2. Determine the RaySol heating cable spacing
Use the minimum ambient design temperature and the floor insulation R-value (from Step 3) to select the correct spacing shown in Table 7 for comfort floor heating. If the calculated R-value or minimum design temperature does not match the values in the table, use the values that give the closer spacing.

<table>
<thead>
<tr>
<th>Minimum ambient design temperature</th>
<th>R-10</th>
<th>R-20</th>
<th>R-30</th>
<th>R-40</th>
</tr>
</thead>
<tbody>
<tr>
<td>50°F (10°C)</td>
<td>8 in (20 cm)</td>
<td>9 in (23 cm)</td>
<td>9 in (23 cm)</td>
<td>9 in (23 cm)</td>
</tr>
<tr>
<td>30°F (–1°C)</td>
<td>7 in (18 cm)</td>
<td>8 in (20 cm)</td>
<td>8 in (20 cm)</td>
<td>8 in (20 cm)</td>
</tr>
<tr>
<td>10°F (–12°C)</td>
<td>7 in (18 cm)</td>
<td>7 in (18 cm)</td>
<td>8 in (20 cm)</td>
<td>8 in (20 cm)</td>
</tr>
<tr>
<td>–10°F (–23°C)</td>
<td>6 in (15 cm)</td>
<td>7 in (18 cm)</td>
<td>7 in (18 cm)</td>
<td>8 in (20 cm)</td>
</tr>
<tr>
<td>–30°F (–34°C)</td>
<td>6 in (15 cm)</td>
<td>7 in (18 cm)</td>
<td>7 in (18 cm)</td>
<td>7 in (18 cm)</td>
</tr>
</tbody>
</table>

For on-grade installations use heating cable on 9 in (23 cm) centers.

If the space below the floor is maintained at more than 50°F (10°C), insulate the floor to R-10 minimum and select heating cable spacing from the 50°F (10°C) row in Table 7.

Example: RaySol heating cables for comfort floor heating
Minimum ambient design temperature 10°F (–23°C) (from Step 3)
Insulation R-value R-30 (from Step 3)
Heating cable spacing 8 in (20 cm)
3. Determine the RaySol heating cable layout and length

**Estimate the heating cable length** The length of heating cable and the number of heating cable circuits can be estimated before a detailed layout is done if the heating cable spacing, total heated area, and the available branch circuit breaker rating are known.

Estimate the heating cable length required:

Estimated heating cable length (ft) = $\frac{\text{Heated area (ft}^2\text{)} \times 12}{\text{Spacing (in)}}$

Estimated heating cable length (m) = $\frac{\text{Heated area (m}^2\text{)} \times 100}{\text{Spacing (cm)}}$

Fig. 14 RaySol heating cable layout for comfort floor heating

**Example: RaySol heating cable length for comfort floor heating**

Heated area: $647 \text{ ft}^2$ (60.4 m$^2$) (from Step 3)

Estimated heating cable length: $647 \text{ ft}^2 \times 12 / 8 \text{ in} = 971 \text{ ft}$

60.4 m$^2 \times 100 / 20 \text{ cm} = 302 \text{ m}$

4. Determine the maximum circuit length for the heating cable length and layout

For the appropriate supply voltage, use Table 8 to select the maximum circuit length which is closest to, but greater than the length calculated. If the estimated heating cable length required is greater than the maximum circuit length, multiple circuits must be used.

**TABLE 8 MAXIMUM RAYSOL CIRCUIT LENGTH IN FEET (METERS) WHEN EMBEDDED IN CONCRETE OR MORTAR (40°F (4°C) START-UP)***

<table>
<thead>
<tr>
<th>Circuit breaker size (A)</th>
<th>120 V ft</th>
<th>120 V m</th>
<th>208 V ft</th>
<th>208 V m</th>
<th>240 V ft</th>
<th>240 V m</th>
<th>277 V ft</th>
<th>277 V m</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>80</td>
<td>24.4</td>
<td>135</td>
<td>41.1</td>
<td>140</td>
<td>42.7</td>
<td>145</td>
<td>44.2</td>
</tr>
<tr>
<td>20</td>
<td>105</td>
<td>32.0</td>
<td>185</td>
<td>56.4</td>
<td>185</td>
<td>56.4</td>
<td>195</td>
<td>59.4</td>
</tr>
<tr>
<td>30</td>
<td>160</td>
<td>48.8</td>
<td>275</td>
<td>83.8</td>
<td>280</td>
<td>85.3</td>
<td>290</td>
<td>88.4</td>
</tr>
<tr>
<td>40</td>
<td>170</td>
<td>51.8</td>
<td>280</td>
<td>85.3</td>
<td>320</td>
<td>97.5</td>
<td>360</td>
<td>109.7</td>
</tr>
</tbody>
</table>

* For start-up temperatures less than 40°F, contact your nVent representative.

**Note:** If RaySol is installed in a bathroom, a 5 mA GFCI breaker must be used. In this case, the circuit breaker size cannot exceed 30 A.
Calculate the estimated number of circuits as follows:

\[
\text{Number of circuits} = \frac{\text{Estimated heating cable length (ft/m)}}{\text{Maximum circuit length (ft/m)}}
\]

Round the number of circuits to the next larger whole number.

**Example: RaySol heating cable length for comfort floor heating**

Estimate heating cable length = 971 ft (302 m) (from earlier in this step)
Supply voltage = 208 V (Step 3)
Maximum circuit length = 275 ft (83.8 m) (from Table 8)
Number of circuits = \(\frac{971 \text{ ft}}{275 \text{ ft}} = 4 \) circuits (rounded)

Power supply

- **Four 30 A circuit breakers** (from Table 8)

5. **Determine the additional heating cable allowances**

Additional heating cable is required to make power connections and to route the circuits to junction boxes. This extra heating cable shall not be considered when determining the maximum heating cable length for circuit breaker sizing. In order to estimate the total heating cable length, you will need to take the estimated heating cable length you already calculated, and then add heating cable allowances, as follows:

\[
\text{Estimated total heating cable length} = \text{Estimated heating cable length} + \text{End allowances} + \text{Connection kit allowances}
\]

Refer to Table 6 on page 19 to calculate the additional RaySol heating cable allowances.

**Example: RaySol heating cable for comfort floor heating**

Estimated heating cable length = 971 ft (302 m) (from earlier in this step)
End allowance = 4 circuits x 4 ft per end x 2 ends = 32 ft (10 m) (from Table 6)
Connection kit allowances = 4 connection kits x 4 ft per end = 16 ft (5 m) (from Table 6)
Total heating cable allowances = 32 ft (10 m) + 16 ft (5 m) = 48 ft (15 m)
Estimated total heating cable length = 971 ft (302 m) + 48 ft (15 m) = 1019 ft (317 m)
6. **Locate the junction boxes for RaySol heating cable system**

The heating cable connects to the branch circuit wiring in a junction box with the RaySol FTC-XC power connection and end seal kit.

The junction boxes may be distributed around the area to be heated, or collected at a single location. In many applications the heating cable can be laid out so that all power connections and end seals can be grouped in a common area without using extra heating cable. If this can be done, select the common junction box location to minimize the electrical conduit and wire needed to reach the branch circuit breakers. Typical heating cable layout for comfort floor heating is similar to the examples shown in Fig. 13 on page 18 for heat loss replacement.

Fig. 15 illustrates the proper method to route the RaySol heating cable from the mortar bed up to the junction box using protective conduit.

![Fig. 15 Typical RaySol comfort floor heating installation](image-url)
7. Lay out heating cable runs, circuits, and junction boxes
After determining the approximate total length of heating cable, the number of circuits, and the junction box location, do a trial layout. In making the trial layout, follow these recommendations:

• Start and end each circuit in a junction box. The power connection and end seal may be located in the same box or in different boxes.
• Arrange the heating cable run so it uniformly covers the area to be heated.
• Maintain the design heating cable spacing within 1 in (2.5 cm).
• Do not extend the heating cable beyond the room or area in which it originates.
• Do not install cables under shower floors, tubs and spas, toilets and other permanent fixtures.
• Do not cross expansion, crack control, or other subfloor joints.
• Do not route the heating cable closer than 4 in (10 cm) to the edge of the subfloor, drains, anchors, or other material in the concrete.
• Do not exceed the maximum length of heating cable allowed on a branch circuit breaker as given in Table 8.
• When the combined lengths of two or more circuit runs are less than the maximum circuit length allowed, these runs can be combined in parallel on one circuit breaker.

8. Record the circuit information
Reconfigure the trial circuit layout until the design meets all of the previous recommendations. Assign each circuit to a circuit breaker in a specific panel board and record each circuit length.

Advance to Step 5, page 37.
MI HEATING CABLE SYSTEM DESIGN

A single heating cable may be sufficient for small floor areas. For large floor areas, it may be necessary to divide the area into two or more equal subsections (Fig. 17 on page 30). For a three-phase voltage supply, divide the total area into three equal subsections (Fig. 16 on page 27) or a multiple of three equal subsections when more than one circuit is necessary. If expansion joints will be used in the floor, divide the area so that the heating cables will not cross any expansion joints.

Designing the floor heating system using a three-phase voltage supply has the added advantages of fewer circuits, reduced distribution costs, and a balanced heating system load and is recommended for large areas.

Three-phase voltage supplies include 208/120 V, 480/277 V, and 600/347 V. The heating cables may be connected in delta or wye configuration as shown in Fig. 20 on page 46 and Fig. 21 on page 47. If the heating cables are connected in the delta configuration, select the cables based on the phase-to-phase voltage (example: select 208 V cables for a 208 V supply). If the heating cables are connected in the wye configuration, select the cables based on the phase-to-neutral voltage (example: select 120 V cables for a 208 V supply).

HEAT LOSS REPLACEMENT

SELECT THE HEATING CABLE

Table 9 lists the heat loss for minimum design temperature and insulation R-value determined in Step 3. Select your design power from this table. If your calculated R-value or minimum design temperature does not match the values in the table, use the values that give the higher design power.

<table>
<thead>
<tr>
<th>Minimum design temperature</th>
<th>Floor insulation R-value (ft²·°F·hr/Btu)</th>
<th>Design power - W/ft² (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R-10</td>
<td>R-20</td>
</tr>
<tr>
<td>30°F (−1°C)</td>
<td>2.2</td>
<td>(23.7)</td>
</tr>
<tr>
<td>20°F (−7°C)</td>
<td>2.5</td>
<td>(26.9)</td>
</tr>
<tr>
<td>10°F (−12°C)</td>
<td>2.8</td>
<td>(30.1)</td>
</tr>
<tr>
<td>0°F (−18°C)</td>
<td>3.0</td>
<td>(32.3)</td>
</tr>
<tr>
<td>−10°F (−23°C)</td>
<td>3.3</td>
<td>(35.5)</td>
</tr>
<tr>
<td>−20°F (−29°C)</td>
<td>3.6</td>
<td>(38.7)</td>
</tr>
<tr>
<td>−30°F (−34°C)</td>
<td>3.9</td>
<td>(42.0)</td>
</tr>
<tr>
<td>−40°F (−40°C)</td>
<td>4.1</td>
<td>(44.1)</td>
</tr>
</tbody>
</table>

The heating cables shown in Table 10 have been optimized for heat loss replacement applications. They are manufactured with a bare copper sheath and are designed to be attached to the bottom of the concrete floor. Do not use these heating cables for embedded applications. If assistance is required to select heating cables for embedded heat loss replacement applications, irregular shaped areas, or applications outside the scope of this design guide, contact your nVent representative or call (800) 545-6258 for design assistance.
Single-phase supply
Small floor areas require only one heating cable. Large floor areas may require two or more heating cables.

• Divide large floor areas into equal subsection areas, if possible (Fig. 17 on page 30).
• Calculate the power required for the total area (small floor areas) or for each subsection area (large floor areas) by multiplying the design power (from Table 9) by the total area or subsection area.

\[
\text{Power required} = \text{Design power} \times \text{Total area (or Subsection area)}
\]

Simply select the heating cable from Table 10 on page 28 based on the total area or subsection area. Under the appropriate voltage, make sure that the total area or subsection area falls within the minimum and maximum range of the "Area coverage" columns and verify that the "Cable wattage" shown directly across from the "Area coverage" is equal to or higher than the calculated "Power required" for the total area or subsection area.

In cases where the floor area has been divided into equal subsections, select the appropriate number of heating cables.

Note: Several heating cables in Table 10 may satisfy the requirements. Selecting one cable over another will simply result in a higher or lower watt density or different cable spacing. It may be desirable to select the lowest wattage cable that satisfies the area coverage to reduce the breaker size, or a longer cable to reduce cable spacing. Reduced cable spacing will provide a more uniform floor temperature.

Three-phase supply
Since a balanced three-phase system requires three cables, each cable will occupy 1/3 of the floor area when installed.

• Divide the total heated floor area into three equal subsections (Fig. 16) or a multiple of three equal subsections when more than one circuit is necessary.
• Calculate the power required for each subsection by multiplying the design power (from Table 9) by the subsection area.

\[
\text{Power required} = \text{Design power} \times \text{Subsection area}
\]

Simply select the heating cable from Table 10 on page 28 based on the subsection area. Under the appropriate voltage, make sure that the subsection area falls within the minimum and maximum range of the "Area coverage" column and verify that the "Cable wattage" shown directly across from the "Area coverage" is equal to or higher than the calculated "Power required" for the subsection area.

Select the appropriate number of heating cables equal to the number of subsection areas (multiples of three cables required).

Note: Several heating cables in Table 10 may satisfy the requirements. Selecting one cable over another will simply result in a higher or lower watt density or different cable spacing. It may be desirable to select the lowest wattage cable that satisfies the area coverage to reduce the breaker size, or a longer cable to reduce cable spacing. Reduced cable spacing will provide a more uniform floor temperature.
Example: MI heating cables for heat loss replacement

Heated area 3200 ft² (297.4 m²) (from Step 3)
Supply voltage and phase 208 V, three-phase (from Step 3)
Minimum ambient design temperature −10°F (−23°C) (from Step 3)
Insulation R-value R-20 (20 ft²·°F·hr/Btu) (from Step 3)
Design power 2.2 W/ft² (23.7 W/m²) (from Table 9)
Subsection area 3200 ft² / 3 = 1067 ft² (see Fig. 16)
                          297.4 m² / 3 = 99.1 m²
Power required (for each subsection) (Design power x Subsection area) =
                          2.2 W/ft² x 1067 ft² = 2347 W
                          23.7 W/m² x 99.1 m² = 2347 W
Heating cable catalog number HLR24 (from Table 10)
Cable wattage 5150 W (from Table 10)
Cable voltage 208 V (for cables connected in Delta configuration)
Heating cable length 420 ft (128.0 m) (from Table 10)
Number of cables 3 (one cable required for each subsection)
### TABLE 10  SELECTION TABLE FOR HEAT LOSS REPLACEMENT

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Area coverage</th>
<th>Cable wattage (W)</th>
<th>Heated length (ft) (m)</th>
<th>Heating cable current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>120 V and 208 V, three-phase Wye</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLR1</td>
<td>56 88 5 8</td>
<td>330</td>
<td>70 21.3</td>
<td>2.8</td>
</tr>
<tr>
<td>HLR2</td>
<td>89 132 8 12</td>
<td>540</td>
<td>44 13.4</td>
<td>4.5</td>
</tr>
<tr>
<td>HLR3</td>
<td>112 165 10 15</td>
<td>670</td>
<td>55 16.8</td>
<td>5.6</td>
</tr>
<tr>
<td>HLR4</td>
<td>127 189 12 18</td>
<td>760</td>
<td>63 19.2</td>
<td>6.3</td>
</tr>
<tr>
<td>HLR5</td>
<td>156 231 14 21</td>
<td>935</td>
<td>77 23.5</td>
<td>7.8</td>
</tr>
<tr>
<td>HLR6</td>
<td>180 267 17 25</td>
<td>1080</td>
<td>89 27.1</td>
<td>9.0</td>
</tr>
<tr>
<td>HLR7</td>
<td>216 318 20 30</td>
<td>1295</td>
<td>106 32.3</td>
<td>10.8</td>
</tr>
<tr>
<td>HLR8</td>
<td>246 366 23 34</td>
<td>1475</td>
<td>122 37.2</td>
<td>12.3</td>
</tr>
<tr>
<td>HLR9</td>
<td>286 420 27 39</td>
<td>1715</td>
<td>140 42.7</td>
<td>14.3</td>
</tr>
<tr>
<td>HLR10</td>
<td>349 516 32 48</td>
<td>2100</td>
<td>172 52.4</td>
<td>17.5</td>
</tr>
<tr>
<td>HLR11</td>
<td>404 594 38 55</td>
<td>2425</td>
<td>198 60.4</td>
<td>20.2</td>
</tr>
<tr>
<td>HLR12</td>
<td>492 732 46 68</td>
<td>2950</td>
<td>244 74.4</td>
<td>24.6</td>
</tr>
<tr>
<td>HLR13</td>
<td>654 966 61 90</td>
<td>3925</td>
<td>322 98.2</td>
<td>32.7</td>
</tr>
<tr>
<td><strong>208 V</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLR14</td>
<td>156 228 14 21</td>
<td>935</td>
<td>76 23.2</td>
<td>4.5</td>
</tr>
<tr>
<td>HLR15</td>
<td>195 285 18 26</td>
<td>1170</td>
<td>95 29.0</td>
<td>5.6</td>
</tr>
<tr>
<td>HLR16</td>
<td>221 327 20 30</td>
<td>1325</td>
<td>109 33.2</td>
<td>6.4</td>
</tr>
<tr>
<td>HLR17</td>
<td>271 399 25 37</td>
<td>1625</td>
<td>133 40.5</td>
<td>7.8</td>
</tr>
<tr>
<td>HLR18</td>
<td>312 462 29 43</td>
<td>1875</td>
<td>154 47.0</td>
<td>9.0</td>
</tr>
<tr>
<td>HLR19</td>
<td>373 552 35 51</td>
<td>2240</td>
<td>184 56.1</td>
<td>10.8</td>
</tr>
<tr>
<td>HLR20</td>
<td>427 633 40 59</td>
<td>2565</td>
<td>211 64.3</td>
<td>12.3</td>
</tr>
<tr>
<td>HLR21</td>
<td>495 729 46 68</td>
<td>2970</td>
<td>243 74.1</td>
<td>14.3</td>
</tr>
<tr>
<td>HLR22</td>
<td>609 888 57 83</td>
<td>3655</td>
<td>296 90.2</td>
<td>17.6</td>
</tr>
<tr>
<td>HLR23</td>
<td>697 1035 65 96</td>
<td>4180</td>
<td>345 105.2</td>
<td>20.1</td>
</tr>
<tr>
<td>HLR24</td>
<td>858 1260 80 117</td>
<td>5150</td>
<td>420 128.0</td>
<td>24.8</td>
</tr>
<tr>
<td>HLR25</td>
<td>1129 1680 105 156</td>
<td>6780</td>
<td>560 170.7</td>
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<td>153 46.6</td>
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<td>2170</td>
<td>177 54.0</td>
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<td>431 636 40 59</td>
<td>2590</td>
<td>212 64.6</td>
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<tr>
<td>HLR32</td>
<td>494 729 46 68</td>
<td>2965</td>
<td>243 74.1</td>
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<td>571 840 53 78</td>
<td>3430</td>
<td>280 85.4</td>
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<td>4175</td>
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<td>810 1185 75 110</td>
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<td>1316 1920 122 178</td>
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<td>258 381 24 35</td>
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<td>145 44.2</td>
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**TABLE 10  SELECTION TABLE FOR HEAT LOSS REPLACEMENT**

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Area coverage</th>
<th>Cable wattage (W)</th>
<th>Heated length (ft)</th>
<th>Heating cable current (A)</th>
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<tbody>
<tr>
<td>HLR43</td>
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<td>3425</td>
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<td>656 975 61 91</td>
<td>3935</td>
<td>325 99.1</td>
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<td>807 1188 75 110</td>
<td>4845</td>
<td>396 120.7</td>
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<tr>
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<td>5560</td>
<td>460 140.2</td>
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</tr>
<tr>
<td>HLR48</td>
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<td>6850</td>
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<tr>
<td>HLR49</td>
<td>1516 2220 141 206</td>
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347 V and 600 V, three-phase wye

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<th>Heating cable current (A)</th>
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<td>2205</td>
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<td>519 774 48 72</td>
<td>3110</td>
<td>258 78.7</td>
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</tr>
<tr>
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<td>3750</td>
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<td>717 1050 67 98</td>
<td>4300</td>
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<tr>
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<td>4955</td>
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<td>575 175.3</td>
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<tr>
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480 V

<table>
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<th>Heating cable current (A)</th>
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<td>2160</td>
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<td>2685</td>
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<td>3070</td>
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</tr>
<tr>
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<td>627 918 58 85</td>
<td>3770</td>
<td>306 93.3</td>
<td>7.9</td>
</tr>
<tr>
<td>HLR65</td>
<td>721 1065 67 99</td>
<td>4330</td>
<td>355 108.2</td>
<td>9.0</td>
</tr>
<tr>
<td>HLR66</td>
<td>863 1272 80 118</td>
<td>5175</td>
<td>424 129.3</td>
<td>10.8</td>
</tr>
<tr>
<td>HLR67</td>
<td>990 1455 92 135</td>
<td>5940</td>
<td>485 147.9</td>
<td>12.4</td>
</tr>
<tr>
<td>HLR68</td>
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<td>6860</td>
<td>560 170.7</td>
<td>14.3</td>
</tr>
<tr>
<td>HLR69</td>
<td>1391 2070 129 192</td>
<td>8350</td>
<td>690 210.4</td>
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</table>

600 V

<table>
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<th>Heating cable current (A)</th>
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</thead>
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<td>2685</td>
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</tr>
<tr>
<td>HLR71</td>
<td>559 825 52 77</td>
<td>3360</td>
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<tr>
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<td>3835</td>
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</tr>
<tr>
<td>HLR73</td>
<td>781 1152 73 107</td>
<td>4690</td>
<td>384 117.1</td>
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</tr>
<tr>
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<td>903 1329 84 124</td>
<td>5420</td>
<td>443 135.1</td>
<td>9.0</td>
</tr>
<tr>
<td>HLR75</td>
<td>1078 1590 100 148</td>
<td>6470</td>
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<td>10.8</td>
</tr>
<tr>
<td>HLR76</td>
<td>1240 1815 115 169</td>
<td>7440</td>
<td>605 184.5</td>
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</tr>
<tr>
<td>HLR77</td>
<td>1429 2100 133 195</td>
<td>8570</td>
<td>700 213.4</td>
<td>14.3</td>
</tr>
</tbody>
</table>

**Note:** Type HLR cables supplied with 15 ft (4.6 m) long cold lead
Heating cable length tolerance is ±0% to +3%.

Advance to "Determine the heating cable spacing" on page 35.
COMFORT FLOOR HEATING

The heating cables shown in Table 12 have been optimized for comfort floor heating applications. If assistance is required to select heating cables for irregular shaped areas, or applications outside the scope of this design guide, contact your nVent representative or call (800) 545-6258 for design assistance.

Single-phase supply

Small floor areas require only one heating cable. Large floor areas may require two or more heating cables.

• Divide large floor areas into equal subsection areas, if possible (Fig. 17).

Simply select the heating cable from Table 11 or Table 12 based on the total area or subsection area. Under the appropriate voltage, make sure that the total area or subsection area falls within the minimum and maximum range of the “Area coverage” column.

In cases where the heated floor area has been divided into equal subsections, select the appropriate number of heating cables.

Note: Several heating cables in Table 11 may satisfy the requirements. Selecting one cable over another will simply result in a higher or lower watt density or different cable spacing. It may be desirable to select the lowest wattage cable that satisfies the area coverage to reduce the breaker size, or a longer cable to reduce cable spacing. Reduced cable spacing will provide a more uniform floor temperature.

Fig. 17 Typical heating cable layout for comfort floor heating

Note: In Fig. 17, the subsections are equal heated areas.

Example: MI heating cables for comfort floor heating

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>Heated area</td>
<td>647 ft² (60.4 m²) (from Step 3)</td>
</tr>
<tr>
<td>Supply voltage and phase</td>
<td>208 V, single-phase (from Step 3)</td>
</tr>
<tr>
<td>Subsection area</td>
<td>647 ft² / 2 = 324 ft² (see Fig. 17)</td>
</tr>
<tr>
<td></td>
<td>60.4 m² / 2 = 30.2 m²</td>
</tr>
<tr>
<td>Heating cable catalog number</td>
<td>FH21 (from Table 12)</td>
</tr>
<tr>
<td>Cable wattage</td>
<td>3390 W (from Table 12)</td>
</tr>
<tr>
<td>Cable voltage</td>
<td>208 V (from Table 12)</td>
</tr>
<tr>
<td>Heating cable length</td>
<td>425 ft (129.6 m) (from Table 12)</td>
</tr>
<tr>
<td>Number of cables</td>
<td>2 (one cable required for each subsection)</td>
</tr>
</tbody>
</table>
Three-phase supply

Since a balanced three-phase system requires three cables, each cable will occupy 1/3 of the heated floor area when installed.

- Divide the total heated floor area into three equal subsections or a multiple of three equal subsections when more than one circuit is necessary.

Simply select the heating cable from Table 11 or Table 12 based on the subsection area. Under the appropriate voltage, make sure that the subsection area falls within the minimum and maximum range of the “Area coverage” column.

Select the appropriate number of heating cables equal to the number of subsection areas (multiples of three cables required).

Note: Several heating cables in Table 11 may satisfy the requirements. Selecting one cable over another will simply result in a higher or lower watt density or different cable spacing. It may be desirable to select the lowest wattage cable that satisfies the area coverage to reduce the breaker size, or a longer cable to reduce cable spacing. Reduced cable spacing will provide a more uniform floor temperature.

### TABLE 11 SELECTION TABLE FOR COMFORT FLOOR HEATING

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>120 V and 208 V, three-phase wye</th>
<th>208 V</th>
<th>240 V</th>
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<td>Max (ft²)</td>
<td>Min (m²)</td>
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<td>64</td>
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<td>SUA4</td>
<td>45</td>
<td>51</td>
<td>4.2</td>
</tr>
<tr>
<td>SUA7</td>
<td>63</td>
<td>71</td>
<td>5.9</td>
</tr>
<tr>
<td>SUA8</td>
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<td>6.0</td>
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<td>87</td>
<td>100</td>
<td>8.0</td>
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<tr>
<td>SUB2</td>
<td>83</td>
<td>125</td>
<td>7.7</td>
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<td>SUB3</td>
<td>107</td>
<td>160</td>
<td>10.0</td>
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<tr>
<td>SUB4</td>
<td>125</td>
<td>187</td>
<td>11.6</td>
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<tr>
<td>SUB5</td>
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<td>14.3</td>
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<tr>
<td>SUB6</td>
<td>160</td>
<td>240</td>
<td>14.9</td>
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TABLE 11  SELECTION TABLE FOR COMFORT FLOOR HEATING

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<th>Area coverage</th>
<th>Cable wattage (W)</th>
<th>Heated length (ft)</th>
<th>Heating cable current (A)</th>
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<tr>
<td></td>
<td>Min (ft²)</td>
<td>Max (ft²)</td>
<td>Min (m²)</td>
<td>Max (m²)</td>
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<td>12.1</td>
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<td>255</td>
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<td>233</td>
<td>15</td>
<td>21.6</td>
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</table>

Note: Type SUA cables supplied with 7 ft (2.1 m) foot long cold lead: type SUB cables supplied with 15 ft (4.6 m) long cold lead. Heating cable length tolerance is –0% to +3%.

TABLE 12  SELECTION TABLE FOR COMFORT FLOOR HEATING

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Area coverage</th>
<th>Cable wattage (W)</th>
<th>Heated length (ft)</th>
<th>Heating cable current (A)</th>
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<tbody>
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<td>Min (ft²)</td>
<td>Max (ft²)</td>
<td>Min (m²)</td>
<td>Max (m²)</td>
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<tr>
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<td>42</td>
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<td>208 V</td>
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<td>390</td>
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### TABLE 12  SELECTION TABLE FOR COMFORT FLOOR HEATING

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Area coverage</th>
<th>Heated length</th>
<th>Heating cable current</th>
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<td></td>
<td>Min (ft²)</td>
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<td>102</td>
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<td>FH26</td>
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<td>FH27</td>
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<td>FH28</td>
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<td>FH33</td>
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<tr>
<td><strong>277 V and 480 V, three-phase wye</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>FH34</td>
<td>80</td>
<td>97</td>
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<td>FH44</td>
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<td>518</td>
<td>40.5</td>
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<td><strong>347 V and 600 V, three-phase wye</strong></td>
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<td></td>
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<tr>
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<td>100</td>
<td>120</td>
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<td>FH46</td>
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<td>11.2</td>
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<td>151</td>
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<td>35.4</td>
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<td><strong>480 V</strong></td>
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TABLE 12  SELECTION TABLE FOR COMFORT FLOOR HEATING

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Area coverage</th>
<th>Cable wattage (W)</th>
<th>Heated length (ft)</th>
<th>Heating cable current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min (ft²)</td>
<td>Max (ft²)</td>
<td>Min (m²)</td>
<td>Max (m²)</td>
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<td>210</td>
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<td>19.5</td>
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<td>FH64</td>
<td>211</td>
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<td>19.6</td>
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<td>FH65</td>
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<td>295</td>
<td>23.8</td>
<td>27.4</td>
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<td>FH66</td>
<td>296</td>
<td>360</td>
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<td>FH67</td>
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<td>FH68</td>
<td>421</td>
<td>488</td>
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<td>45.3</td>
</tr>
</tbody>
</table>

Note: Type FH cables supplied with 15 ft (4.6 m) long cold lead. Tolerance on heating cable length is −0% to +3%.

Advance to "Determine the heating cable spacing" on page 35.

RADIANT SPACE HEATING

For radiant space heating, the total heat loss in Btu/hr or wattage is supplied by the customer. Heating cables can be selected for single phase or three-phase voltage supplies as shown for comfort floor heating, but based on the heat loss, in watts required, for each area. Use Table 11 or Table 12 to select a heating cable from the "Cable wattage" column that is equal to or the next highest wattage than the wattage specified.

![Fig. 18 Typical heating cable layout for radiant space heating](image)

Note: In Fig. 18, the subsections are equal heated areas.
Example: MI heating cables for radiant space heating

Heated area: 647 ft² (60.4 m²) (from Step 3)
Supply voltage and phase: 208 V, single phase (from Step 3)
Subsection area: 647 ft² / 3 = 215 ft²
   60.4 m² / 3 = 20.1 m²
Btu requirement: 34,800 Btu/hr (from Step 3)
Power required: 34,800 Btu/hr / 3.412 = 10200 W
Power per subsection: 10200 W / 3 = 3400 W
Heating cable catalog number: FH21 (from Table 12)
Cable wattage: 3390 W
Cable voltage: 208 V (from Table 12)
Heating cable length: 425 ft (129.6 m) (from Table 12)
Number of cables: 3 (one heating cable per subsection)

Note: Divide Btu/hr by 3.412 to convert to watts.

Advance to “Determine the heating cable spacing” following.

DETERMINE THE HEATING CABLE SPACING

In this section you will determine the heating cable spacing for heat loss replacement, comfort floor heating and radiant space heating.

For heat loss replacement, the heated area in the equation following is the total floor area. For comfort floor heating and radiant space heating, the heated area does not include the space occupied by tubs and spas, toilets, cabinets, and other permanent fixtures. This heated floor area was determined in Step 3.

\[
\text{Cable spacing (in) = } \frac{\text{Heated area (ft}^2\text{)} \times 12 \text{ in}}{\text{Heating cable length (ft)}}
\]

\[
\text{Cable spacing (cm) = } \frac{\text{Heated area (m}^2\text{)} \times 100 \text{ cm}}{\text{Heating cable length (m)}}
\]

Round to the nearest 1/2 in or nearest 1 cm to obtain cable spacing.

Note: If a large area has been divided into subsections or if a three-phase voltage supply is used, the heated area in the above equations will be the subsection area and the heating cable length will be the length of the cable selected for the subsection.

Example: MI heating cables for heat loss replacement

Subsection area: 1067 ft² (99.1 m²)
Heating cable catalog number: HLR24 (from Table 10)
Heating cable length: 420 ft (128.0 m) (from Table 10)
Cable spacing: (1067 ft² x 12 in) / 420 ft = 30.5 in
   Rounded to 31 in
   (99.1 m² x 100 cm) / 128.0 m = 77.4 cm
   Rounded to 77 cm
Example: MI heating cables for comfort floor heating
Subsection area 324 ft² (30.2 m²)
Heating cable catalog number FH21 (from Table 12)
Heating cable length 425 ft (129.6 m) (from Table 12)
Cable spacing 
\[
\frac{(324 \text{ ft}^2 \times 12 \text{ in})}{425 \text{ ft}} = 9.1 \text{ in}
\]
**Rounded to 9 in**
\[
\frac{(30.2 \text{ m}^2 \times 100 \text{ cm})}{129.6 \text{ m}} = 23.3 \text{ cm}
\]
**Rounded to 23 cm**

Example: MI heating cables for radiant space heating
Subsection area 216 ft² (20.1 m²)
Heating cable catalog number FH21 (from Table 12)
Heating cable length 425 ft (129.6 m) (from Table 12)
Cable spacing 
\[
\frac{(216 \text{ ft}^2 \times 12 \text{ in})}{425 \text{ ft}} = 6.1 \text{ in}
\]
**Rounded to 6 in**
\[
\frac{(20.1 \text{ m}^2 \times 100 \text{ cm})}{129.6 \text{ m}} = 15.5 \text{ cm}
\]
**Rounded to 15 cm**

Advance to Step 5, page 37.
Floor Heating System 
Design Steps 
1. Determine the application 
2. Select the heating cable system and installation method 
3. Determine the floor configuration 
4. Determine the heating-cable spacing, layout and length 
5. Determine the electrical parameters 
6. Select the connection kits and accessories 
7. Select the control system 
8. Select the power distribution 
9. Complete the Bill of Materials

**Step 5 Determine the electrical parameters**

In this step you will determine the electrical parameters. This section is organized by heating cable type.

For RaySol self-regulating heating cables, see below.

For MI heating cables, see page 38.

**RAYSOl SELF-REGULATING HEATING CABLE**

**DETERMINE NUMBER OF CIRCUITS**

Record the number of circuits (from Step 4) to be used on the worksheet.

**SELECT BRANCH CIRCUIT BREAKING RATING**

For RaySol, the circuit breaker rating was determined in Step 4 using Table 5 or Table 8.

Use ground-fault protection devices (GFPDs) for all RaySol heating cable applications.

⚠️ **WARNING**: To minimize the danger of fire from sustained electrical arcing if the heating cable is damaged or improperly installed, and to comply with the requirements of nVent, agency certifications, and national electrical codes, ground-fault equipment protection must be used on each heating cable branch circuit. Arcing may not be stopped by conventional circuit protection.

**DETERMINE TRANSFORMER LOAD**

The total transformer load is the sum of the loads on all the circuit breakers in the system.

Calculate the Circuit Breaker Load (CBL) as:

\[
CBL (kW) = \frac{\text{Circuit breaker rating (A) x 0.8 x Supply voltage}}{1000}
\]

Calculate the Total Transformer Load as follows:

\[
\text{Total Transformer Load (kW)} = CBL_1 + CBL_2 + CBL_3... + CBL_N
\]

**Example: RaySol heating cables for heat loss replacement**

- Heating cable catalog number: RaySol-2 (from Step 4)
- Number of circuits: 4 (from Step 4)
- Circuit breaker rating: 30 A breaker (from Step 4)
- Circuit breaker load: \((30 \text{ A} \times 0.8 \times 208 \text{ V}) / 1000 = 5\text{ kW}\)
- Total transformer load: \(5\text{ kW} \times 4 = 20\text{ kW}\)

**Example: RaySol heating cables for comfort floor heating**

- Heating cable catalog number: RaySol-2 (from Step 4)
- Number of circuits: 4 (from Step 4)
- Circuit breaker rating: 30 A breaker (from Step 4)
- Circuit breaker load: \((30 \text{ A} \times 0.8 \times 208 \text{ V}) / 1000 = 5\text{ kW}\)
- Total transformer load: \(5\text{ kW} \times 4 = 20\text{ kW}\)

Advance to Step 6, page 40.
MI HEATING CABLE

DETERMINE NUMBER OF CIRCUITS
For single-phase circuits, individual heating cables are normally connected to separate circuit breakers. Multiple heating cables may be connected in parallel to reduce the number of circuits with permission from the Authority Having Jurisdiction. The single-phase heating cable current is shown in Table 10, Table 11, and Table 12.

For three-phase circuits used in floor heating systems, the three heating cables are generally connected in the delta configuration shown in Fig. 20 on page 46. Heating cables may also be connected using the wye configuration shown in Fig. 21 on page 47, but this configuration is less common. For both delta and wye configurations, each set of three equal cables form a single circuit.

SELECT BRANCH CIRCUIT BREAKING RATING
The power output and heating cable current draw for the floor heating cables are shown in Table 10, Table 11, and Table 12.

For single-phase circuits, the load current must not exceed 80% of the circuit breaker rating.
Load current = Heating cable current (for a single circuit)
Circuit breaker rating = Load current / 0.8

For a Delta connected three-phase circuit, shown in Fig. 20 on page 46, the load current can be determined by multiplying the heating cable current times 1.732 and it must not exceed 80% of the 3-pole circuit breaker rating.
Load current = Heating cable current x 1.732 (for a single Delta connected circuit)
Circuit breaker rating = Load current / 0.8

For a Wye connected three-phase circuit, shown in Fig. 21 on page 47, the load current is the same as the heating cable current and it must not exceed 80% of the 3-pole circuit breaker rating.
Load current = Heating cable current (for a single Wye connected circuit)
Circuit breaker rating = Load current / 0.8

Record the number and ratings of the circuit breakers to be used. Use ground-fault protection devices (GFPDs) for all applications. For three-phase circuits, ground fault may be accomplished using a shunt trip three-pole breaker and ground fault sensor.

Circuit breaker rating (amps) ________ Number of circuit breakers ________

⚠️ WARNING: To minimize the danger of fire from sustained electrical arcing if the heating cable is damaged or improperly installed, and to comply with the requirements of nVent, agency certifications, and national electrical codes, ground-fault equipment protection must be used on each heating cable branch circuit. Arcing may not be stopped by conventional circuit protection.
DETERMINE TRANSFORMER LOAD

The total transformer load is the sum of the loads in the system. Calculate the Total Transformer Load as follows:

For cables of equal wattage:

\[
\text{Transformer load (kW)} = \frac{\text{Cable (W) \times Number of cables}}{1000}
\]

When cable wattages are not equal:

\[
\text{Transformer load (kW)} = \frac{\text{Cable}_1 \text{ (W)} + \text{Cable}_2 \text{ (W)} + \text{Cable}_3 \text{ (W)} + \ldots + \text{Cable}_N \text{ (W)}}{1000}
\]

**Example: MI heating cables for heat loss replacement**

Heating cable catalog number: HLR24 (from Step 4)
Heating cable current: 24.8 A (from Table 10)
Load current: 24.8 \times 1.732 = 43 A
Circuit breaker rating: 60 A breaker, 80% loading 48 A
Number of circuit breakers: 1 (3-pole breaker)
Cable wattage: 5150 W (from Step 4)
Number of cables: 3 (from Step 4)
Total transformer load: \((5150 \text{ W} \times 3) / 1000 = 15.5 \text{ kW}\)

**Example: MI heating cables for comfort floor heating**

Heating cable catalog number: FH21 (from Step 4)
Heating cable current: 16.3 A (from Table 12)
Load current: 16.3 A
Circuit breaker rating: 25 A breaker, 80% loading 20 A
Number of circuit breakers: 2
Cable wattage: 3390 W (from Step 4)
Number of cables: 2 (from Step 4)
Total transformer load: \((3390 \text{ W} \times 2) / 1000 = 6.8 \text{ kW}\)

**Example: MI heating cables for radiant space heating**

Heating cable catalog number: FH21 (from Step 4)
Heating cable current: 16.3 A (from Table 12)
Load current: 16.3 A
Circuit breaker rating: 25 A breaker, 80% loading 20 A
Number of circuit breakers: 3
Cable wattage: 3390 W (from Step 4)
Number of cables: 3 (from Step 4)
Total transformer load: \((3390 \text{ W} \times 3) / 1000 = 10.2 \text{ kW}\)

**Advance to Step 6, page 40.**
Step 6 Select the connection kits and accessories

In this step you will determine the number of junction boxes, power connections, end seals and splice kits required. This section is separated by heating cable type.

For RaySol self-regulating heating cables, see below.

For MI heating cables, see page 38.

**RAYSOl SELF-REGULATING HEATING CABLE**

**SELECT NUMBER OF POWER CONNECTION KITS**

For heat loss replacement, one FTC-P power connection kit and two junction boxes are required per circuit. For comfort floor heating, one FTC-XC power connection kit and two junction boxes are required per circuit.

**SELECT JUNCTION BOX**

Select a contractor-supplied UL Listed and/or CSA Certified junction box that is suitable for the location. Use a box with minimum internal volume of 16 cubic inches if the box is metallic and 19 cubic inches if the box is not metallic.

*Note:* The junction box must be accessible according to national electrical codes.

**TABLE 13 CONNECTION KITS AND ACCESSORIES**

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Description</th>
<th>Standard packaging</th>
<th>Usage</th>
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</thead>
<tbody>
<tr>
<td>RaySol Connection Kits</td>
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<tr>
<td>FTC-P</td>
<td>Power connection and end seal. (Junction box not included)</td>
<td>1</td>
<td>1 per cable run (for heat loss replacement)</td>
</tr>
<tr>
<td>FTC-XC</td>
<td>Power connection and end seal. (Junction box not included)</td>
<td>1</td>
<td>1 per cable run (for comfort floor heating and radiant space heating)</td>
</tr>
</tbody>
</table>

- **FTC-HST** | Low-profile splice/tee | 2 | As required (for embedded applications, splice must be accessible) |
- **RayClic-E** | Extra end seal | 1 | Replacement end seal |

**Example: RaySol heating cables for heat loss replacement**

- Junction box: Contractor supplied
- Quantity: 8
- Connection kit: FTC-P
- Quantity: 4

**Example: RaySol heating cables for comfort floor heating**

- Junction box: Contractor supplied
- Quantity: 8
- Connection kit: FTC-XC
- Quantity: 4

Advance to Step 7, page 42.
MI HEATING CABLES
A typical floor heating system consists of several accessories. All of the accessories work together to provide a safe and reliable floor heating system that is easy to install and maintain.

SELECT JUNCTION BOX
Select a UL Listed and/or CSA Certified junction box that is suitable for the location, such as the D1297TERM4. Use a box with minimum internal volume of 16 cubic inches if the box is metallic and 19 cubic inches if the box is not metallic. Metal junction boxes are recommended.

Note: The junction box must be accessible according to the national electrical codes.

SELECT PREPUNCHED STRAPPING
For heat loss replacement applications, use stainless steel prepunched strapping attached to the bottom of the concrete floor to secure the heating cables at the proper spacing. For floor heating applications where the heating cable is embedded in concrete or mortar floors, use galvanized steel prepunched strapping to maintain the heating cables at the proper spacing.

Number of rolls required = Total area (ft²) x 0.005 (Total area (m²) x 0.05)

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Description</th>
<th>Standard packaging</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPACERGALV</td>
<td>HARD-SPACER-GALV-25MM-25M galvanized steel prepunched strapping. <strong>Note:</strong> Use when cable is embedded in concrete or mortar.</td>
<td>82 ft (25 m) rolls</td>
<td>No. rolls = 0.005 x area (ft²) No. rolls = 0.05 x area (m²)</td>
</tr>
<tr>
<td>107826-000</td>
<td>HARD-SPACER-SS-25MM-25M stainless steel prepunched strapping. <strong>Note:</strong> Use with all heat loss replacement applications.</td>
<td>82 ft (25 m) rolls</td>
<td>No. rolls = 0.005 x area (ft²) No. rolls = 0.05 x area (m²)</td>
</tr>
<tr>
<td>D1297TERM4</td>
<td>A cast aluminum junction box (NEMA 3) for installation in nonhazardous and CID2 locations. Three 1/2” NPT entries on bottom, provided with plugs. Includes 4-pole terminal block (CSA - 600 V, 65 A, 18 - 6 AWG; UL - 300 V, 65 A, 18 - 6 AWG). External mounting feet. CSA approved for Class I, Div. 2, Groups A, B, C, and D. Enclosure dimensions: 6 in x 6 in x 4 in (150 mm x 150 mm x 100 mm).</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Example: MI heating cables for heat loss replacement
- Junction box: Contractor supplied
- Quantity: 1 (7 entries)
- Prepunched strapping: 107826-000
- Quantity: 16

Example: MI heating cables for comfort floor heating
- Junction box: D1297TERM4
- Quantity: 2
- Prepunched strapping: SPACERGALV
- Quantity: 4

Example: MI heating cables for radiant space heating
- Junction box: D1297TERM4
- Quantity: 3
- Prepunched strapping: SPACERGALV
- Quantity: 4

For comfort floor heating and radiant space heating applications in slab floors, prepunched strapping may not be required if it is possible to attach the heating cable to the reinforcement.

Advance to Step 7, page 42.
Step 7 Select the control system

There are two types of controls that may be used with floor heating systems: floor temperature sensing control and ambient temperature control with overlimit sensor.

Floor temperature sensing control must be used for heat loss replacement and comfort floor heating applications, while an ambient temperature control with an overlimit sensor must be used for radiant space heating applications.

For RaySol and MI heating cables, the recommended control for heat loss replacement and comfort floor heating is nVent RAYCHEM ECW-GF. For RaySol or MI heating cable installations where temperature control and temperature monitoring is desired, an nVent RAYCHEM C910-485 or ACS-30 controller is recommended.

### TABLE 15 TEMPERATURE CONTROL OPTIONS

<table>
<thead>
<tr>
<th>Features</th>
<th>ECW-GF</th>
<th>C910-485 ¹</th>
<th>ACS-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of heating cable circuits</td>
<td>Single</td>
<td>Single</td>
<td>Multiple</td>
</tr>
<tr>
<td>Sensor</td>
<td>Thermistor</td>
<td>RTD¹</td>
<td>See data sheet</td>
</tr>
<tr>
<td>Sensor length</td>
<td>25 ft</td>
<td>Varies</td>
<td>—</td>
</tr>
<tr>
<td>Set point range</td>
<td>32°F to 200°F (0°C to 93°C)</td>
<td>–0°F to 200°F (–18°C to 93°C)</td>
<td>—</td>
</tr>
<tr>
<td>Enclosure</td>
<td>NEMA 4X</td>
<td>NEMA 4X</td>
<td>—</td>
</tr>
<tr>
<td>Deadband</td>
<td>2°F to 10°F (2°C to 6°C)</td>
<td>1°F to 10°F (1°C to 6°C)</td>
<td>—</td>
</tr>
<tr>
<td>Enclosure limits</td>
<td>–40°F to 140°F (–40°C to 60°C)</td>
<td>–40°F to 140°F (–40°C to 60°C)</td>
<td>—</td>
</tr>
<tr>
<td>Switch rating</td>
<td>30 A</td>
<td>30 A</td>
<td>—</td>
</tr>
<tr>
<td>Switch type</td>
<td>DPST</td>
<td>DPST</td>
<td>—</td>
</tr>
<tr>
<td>Electrical rating</td>
<td>100–277 V</td>
<td>100–277 V</td>
<td>—</td>
</tr>
<tr>
<td>Approvals</td>
<td>c-UL-us</td>
<td>c-CSA-us</td>
<td>—</td>
</tr>
<tr>
<td>Ground-fault protection</td>
<td>30 mA fixed</td>
<td>20 mA to 100 mA (adjustable)</td>
<td>—</td>
</tr>
<tr>
<td>Alarm outputs</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>AC relay</td>
<td>2 A at 277 Vac</td>
<td>100–277 V, 0.75 A max.</td>
<td>—</td>
</tr>
<tr>
<td>Dry contact relay</td>
<td>2 A at 48 Vdc</td>
<td>48 Vac/dc, 500 mA max.</td>
<td>—</td>
</tr>
</tbody>
</table>

¹ Ordered separately
² The C910-485 is available to provide RS-485 communication capability. Connect to the BMS using ProtoNode multi-protocol gateways.
<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electronic thermostats and accessories</strong></td>
<td></td>
</tr>
<tr>
<td>ECW-GF</td>
<td>Electronic ambient sensing controller with 30-mA ground-fault protection. The controller can be programmed to maintain temperatures up to 200°F (93°C) at voltages from 100 to 277 V and can switch current up to 30 Amperes. The ECW-GF is complete with a 25-ft (7.6-m) temperature sensor and is housed in a Type 4X rated enclosure. The controller features an AC/DC dry alarm contact relay. An optional ground-fault display panel (ECW-GF-DP) can be added to provide ground-fault or alarm indication in applications where the controller is mounted in inaccessible locations.</td>
</tr>
<tr>
<td>ECW-GF-DP</td>
<td>An optional remote display panel (ECW-GF-DP) that can be added to provide ground-fault or alarm indication in applications where the controller is mounted in inaccessible locations.</td>
</tr>
<tr>
<td>MI-GROUND-KIT</td>
<td>Grounding kit for nonmetallic enclosures (for MI only)</td>
</tr>
<tr>
<td><strong>Electronic controllers and sensors</strong></td>
<td></td>
</tr>
<tr>
<td>C910-485</td>
<td>The C910-485 is a compact, full-featured microprocessor-based single-point heat-trace controller. The C910-485 provides control and monitoring of electrical heat-tracing circuits for both freeze protection and temperature maintenance, and can be set to monitor and alarm for high and low temperature, high and low current, ground-fault level, and voltage. The C910-485 controller is available with an electromechanical relay (EMR) for use in ordinary areas. The C910-485 comes with an RS-485 communication module.</td>
</tr>
<tr>
<td>ACS-UIT2</td>
<td>The ACS-30 Advanced Commercial Control System is a multipoint electronic control and monitoring system for heat-tracing used in various commercial applications such as pipe freeze protection, roof and gutter de-icing, surface snow melting, hot water temperature maintenance and floor heating. The ACS-30 system can control up to 260 circuits with multiple networked ACS-PCM2-5 panels, with a single ACS-UIT2 user interface terminal. The ACS-PCM2-5 panel can directly control up to 5 individual heat-tracing circuits using electromechanical relays rated at 30 A up to 277 V.</td>
</tr>
<tr>
<td>ACS-PCM2-5</td>
<td>The ACS-30 Advanced Commercial Control System is a multipoint electronic control and monitoring system for heat-tracing used in various commercial applications such as pipe freeze protection, roof and gutter de-icing, surface snow melting, hot water temperature maintenance and floor heating. The ACS-30 system can control up to 260 circuits with multiple networked ACS-PCM2-5 panels, with a single ACS-UIT2 user interface terminal. The ACS-PCM2-5 panel can directly control up to 5 individual heat-tracing circuits using electromechanical relays rated at 30 A up to 277 V.</td>
</tr>
<tr>
<td>ProtoNode-RER</td>
<td>The ProtoNode is an external, high performance multi-protocol gateway for customers needing protocol translation between Building Management Systems (BMS) and the ACS-30 or C910-485 controllers. ProtoNode-RER is for BACnet® or Metasys® N2 systems.</td>
</tr>
<tr>
<td>RTD-200</td>
<td>Stainless steel jacketed three-wire RTD (Resistance Temperature Detector) used with C910-485 and ACS-30 controllers.</td>
</tr>
<tr>
<td>RTD10CS</td>
<td>RTD-200: 3-in (76 mm) temperature sensor with a 6-ft (1.8 m) lead wire and 1/2-in NPT bushing</td>
</tr>
<tr>
<td>RTD50CS</td>
<td>RTD10CS: temperature sensor with a 10-ft (3 m) flexible armor, 18-in (457 mm) lead wire and 1/2-inch NPT bushing</td>
</tr>
<tr>
<td></td>
<td>RTD50CS: temperature sensor with a 50-ft (15.2 m) flexible armor, 18-in (457 mm) lead wire and 1/2-in NPT bushing</td>
</tr>
</tbody>
</table>
Example: RaySol heating cables for heat loss replacement
Multiple circuits, monitoring requested ACS-30
Quantity 1

Example: MI heating cables for heat loss replacement
Single circuit, monitoring requested ACS-30*
Quantity 1
* Use ACS-30 General part number (P000001232) for custom three-phase panels. Please contact your nVent representative for a custom ACS-PCM2-5 panel quotation.

Example: RaySol and MI heating cables for comfort floor heating
Multiple circuits, electronic thermostat requested ECW-GF
Quantity 1

Example: MI heating cables for radiant space heating
Multiple circuits, electronic thermostat requested ECW-GF
Quantity 1

1 Ambient control to be supplied by the contractor
Step 8 Select the power distribution

Power to the heating cables can be provided in several ways:

- Directly through the temperature controller
- Through external contactors activated by a temperature controller
- Through an HTPG power distribution panel

SINGLE CIRCUIT CONTROL

RaySol and MI heating cable circuits that do not exceed the current rating of the selected control can be switched directly (Fig 19). When the total electrical load exceeds the rating of the controller, an external contactor is required.

The three-phase Delta and Wye configurations shown in Fig. 20 and Fig. 21 are common wiring configurations for MI heating cables used to heat large areas. DO NOT use these wiring configurations for RaySol heating systems. A single pole temperature controller may be used to control a three-phase circuit through a contactor.

GROUP CONTROL

For group control, a single temperature controller may be used to control two or more single-phase or three-phase circuits. Multiple single-phase RaySol or MI heating cable circuits may be controlled by a single temperature controller, through a contactor, as shown in Fig. 19. Multiple three-phase MI heating cable circuits may be controlled in the same manner.
Fig. 19 Single circuit and group control

Fig. 20 Typical single circuit control for three-phase delta connected cables
Fig. 21 Typical single circuit control for three-phase wye connected cables

Large systems with many circuits should use an HTPG power distribution panel. The HTPG is a dedicated power-distribution, control, ground-fault protection, monitoring, and alarm panel for broad temperature-maintenance heat-tracing applications. This enclosure contains an assembled circuit-breaker panelboard. Panels are equipped with ground-fault circuit breakers with or without alarm contacts. The group control package allows the system to operate automatically in conjunction with a temperature control system.
Fig. 22 HTPG power distribution panel

Fig. 23 HTPG power schematic
TABLE 17  POWER DISTRIBUTION

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Power Distribution and Control Panels</td>
</tr>
<tr>
<td></td>
<td>HTPG</td>
</tr>
</tbody>
</table>

Step 9 Complete the Bill of Materials

If you used the Design Worksheet to document all your design parameters, you should have all the details necessary complete your Bill of Materials.

Floor Heating System Design Steps

1. Determine the application
2. Select the heating cable system and installation method
3. Determine the floor configuration
4. Determine the heating cable spacing, layout and length
5. Determine the electrical parameters
6. Select the connection kits and accessories
7. Select the control system
8. Select the power distribution
9. Complete the Bill of Materials
FLOOR HEATING PRE-DESIGN WORKSHEET

Step 1 Determine the application (see page 11)
Select the application that best describes your needs
- Heat loss replacement
- Comfort floor heating
- Radiant space heating
  If you have selected the radiant space heating application, use the MI Heating Cable Floor Heating Design Worksheet on page 59.

Step 2 Determine the installation method
Select the installation you plan to use.

Heat loss replacement
- Attach to the bottom of the floor
  - RaySol
  - MI

Comfort floor heating
- Embed in concrete
  - RaySol
  - MI
- Embed in mortar bed
  - RaySol
  - MI

Radiant space heating
- Embed in concrete
  - RaySol*
  - MI
- Embed in mortar bed
  - RaySol*
  - MI

*Please contact nVent for design assistance.
# RaySol Heating Cable Floor Heating Design Worksheet

## Heat Loss Replacement

**Step 3** Determine the floor configuration (Steps 1 and 2 were completed in the pre-design worksheet)

<table>
<thead>
<tr>
<th>Heat loss replacement (see Fig. 9 on page 13)</th>
<th>Minimum ambient design temperature °F/°C</th>
<th>Insulation R-value ft²·°F·hr/Btu</th>
<th>Supply voltage and phase</th>
<th>Control requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side A (length) (ft/m) ( \times ) Side B (width) (ft/m) = Heated area (ft²/m²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Example: RaySol heating cables for heat loss replacement**

<table>
<thead>
<tr>
<th>Side A (length) (ft/m)</th>
<th>Side B (width) (ft/m)</th>
<th>Heated area (ft²/m²)</th>
<th>Minimum ambient temperature °F/°C</th>
<th>Insulation R-value</th>
<th>Supply voltage and phase</th>
<th>Control requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 ft</td>
<td>40 ft</td>
<td>3200 ft²</td>
<td>–10°F</td>
<td>R-20</td>
<td>208 V</td>
<td>Single phase</td>
</tr>
</tbody>
</table>

**Step 4** Determine the heating cable spacing, layout and length

### 4.1 Select the appropriate RaySol heating cable (see Table 3 on page 16)

Supply voltage: \( \text{(from Step 3)} \)
Catalog number: \( \text{(from Table 3)} \)

**Example: RaySol heating cables for heat loss replacement**

Supply voltage: 208 V (from Step 3)
Catalog number: RaySol-2 (from Table 3)

### 4.2 Determine the RaySol heating cable spacing (see Table 4 on page 17)

Minimum ambient temperature: \( \text{________°F/°C (from Step 3)} \)
Insulation R-value: \( \text{________ (from Step 3)} \)
Heating cable spacing: \( \text{________in/cm (from Table 4)} \)

**Example: RaySol heating cables for heat loss replacement**

Minimum ambient temperature: –10°F (from Step 3)
Insulation R-value: R-20 (from Step 3)
Heating cable spacing: 24 in (from Table 4)

### 4.3 Determine the RaySol heating cable layout and length

**Imperial**

\[
\frac{\text{Heated area (ft²)}}{12} \times \frac{1}{\text{Heating cable spacing (in)}} = \text{Estimated heating cable length (ft)}
\]

**Metric**

\[
\frac{\text{Heated area (m²)}}{100} \times \frac{1}{\text{Heating cable spacing (cm)}} = \text{Estimated heating cable length (m)}
\]

**Example: RaySol heating cables for heat loss replacement**

Estimate the heating cable length

\[
\frac{3200 \text{ ft}²}{12} \times \frac{24 \text{ in}}{\text{Heating cable spacing (in)}} = 1600 \text{ ft}
\]
Step 4 Determine the heating cable spacing, layout and length

4.4 Determine the maximum circuit length for the heating cable length (see Table 5 on page 18)

\[
\frac{\text{Estimated heating cable length (ft/m)}}{\text{Maximum circuit length (ft/m)}} = \text{Number of circuits}
\]

Round the number of circuits to the next larger whole number

**Example: RaySol heating cables for heat loss replacement**

\[
\frac{1600 \text{ ft}}{410 \text{ ft}} = 4 \text{ (rounded)}
\]

Power supply: Four 30 A circuit breakers
Step 4 Determine the heating cable spacing, layout and length

4.5 Determine the additional heating cable allowance (see Table 6 on page 19)

End allowance

\[ \text{End allowance (ft/m)} = \left( \frac{\text{Number of circuits}}{\text{ft/m per end (from Table 6)}} \times \text{Number of ends} \right) \]

Connection kit allowance

\[ \text{Connection kit allowance (ft/m)} = \left( \frac{\text{Number of kits}}{\text{ft/m per connection kit (from Table 6)}} \right) \]

Total heating cable allowance

\[ \text{Total heating cable allowance (ft/m)} = \left( \frac{\text{End allowance (ft/m)}}{\text{Connection kit allowance (ft/m)}} \right) \]

Estimated total heating cable length

\[ \text{Estimated total heating cable length (ft/m)} = \left( \frac{\text{Estimated heating cable length (ft/m)}}{\text{Total heating cable allowance (ft/m)}} \right) \]

**Example: RaySol heating cables for heat loss replacement**

**End allowance**

\[ \text{End allowance} = \left( 4 \times 4 \times 2 \right) \text{ft} = 32 \text{ ft} \]

**Connection kit allowance**

\[ \text{Connection kit allowance} = 4 \times 4 \text{ ft} = 16 \text{ ft} \]

**Total heating cable allowance**

\[ \text{Total heating cable allowance} = 32 \text{ ft} + 16 \text{ ft} = 48 \text{ ft} \]

**Estimated total heating cable length**

\[ \text{Estimated total heating cable length} = 1600 \text{ ft} + 48 \text{ ft} = 1648 \text{ ft} \]

4.6 Locate the junction boxes for the RaySol heating cable (see Fig. 12 on page 17 for examples of a typical system)

4.7 Lay out the heating cable runs, circuits, and junction boxes

4.8 Record the circuit information

Advance Step 5 on page 57.
Comfort Floor Heating

**Step 3 Determine the floor configuration** (Steps 1 and 2 were completed in the pre-design worksheet)

<table>
<thead>
<tr>
<th>Comfort floor heating (see Fig. 10 on page 14)</th>
<th>Minimum ambient design temperature</th>
<th>Insulation R-value</th>
<th>Supply voltage and phase</th>
<th>Control requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area (ft²/m²)</td>
<td>Heat area (ft²/m²)</td>
<td>°F/°C</td>
<td>ft²·°F·hr/Btu</td>
<td>Volts</td>
</tr>
</tbody>
</table>

**Example: Raysol heating cables for comfort floor heating**

<table>
<thead>
<tr>
<th>Side A (see Figure 10)</th>
<th>Side B (see Figure 10)</th>
<th>Total area</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 ft</td>
<td>20 ft</td>
<td>680 ft²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total area</th>
<th>Permanent fixture space (see Figure 10)</th>
<th>Heated area</th>
</tr>
</thead>
<tbody>
<tr>
<td>680 ft²</td>
<td>(22 ft² counter + 11 ft² columns)</td>
<td>647 ft²</td>
</tr>
</tbody>
</table>

Minimum ambient design temperature: 10°F
Insulation R-value: R-30
Supply voltage and phase: 208 V, single phase
Control requirements: Electronic thermostat

**Step 4 Determine the heating cable spacing, layout and length**

**4.1 Select the appropriate RaySol heating cable** (see Table 3 on page 16)

Supply voltage: ________________ (from Step 3)
Catalog number: ________________ (from Table 3)

**Example: RaySol heating cables for comfort floor heating**

Supply voltage: 208 V (from Step 3)
Catalog number: RaySol-2 (from Table 3)

**4.2 Determine the RaySol heating cable spacing** (see Table 7 on page 20)

Minimum ambient design temperature: __________ °F/°C (from Step 3)
Insulation R-value: __________ (from Step 3)
Heating cable spacing: __________ in/cm (from Table 7)

**Example: RaySol heating cables for comfort floor heating**

Minimum ambient design temperature: 10°F (from Step 3)
Insulation R-value: R-30 (from Step 3)
Heating cable spacing: 8 in (from Table 7)
**Step 4** Determine the heating cable spacing, layout and length

### 4.3 Determine the RaySol heating cable layout and length (see Fig. 14 on page 21)

**Imperial**

\[
\frac{\text{Heated area (ft}^2\text{)}}{\text{Heating cable spacing (in)}} \times \frac{12}{\text{Estimated heating cable length (ft)}}
\]

**Metric**

\[
\frac{\text{Heated area (m}^2\text{)}}{\text{Heating cable spacing (cm)}} \times \frac{100}{\text{Estimated heating cable length (m)}}
\]

**Example: RaySol heating cables for comfort floor heating**

Estimate the heating cable length

\[
\frac{647 \text{ ft}^2}{8 \text{ in}} \times \frac{12}{\text{Estimated heating cable length (ft)}} = 971 \text{ ft}
\]

### 4.4 Determine the maximum circuit length for the heating cable length and layout (see Table 8 on page 21)

\[
\frac{\text{Estimated heating cable length (ft/m)}}{\text{Maximum circuit length (ft/m)}} = \text{Number of circuits}
\]

Round the number of circuits to the next larger whole number

**Example: RaySol heating cables for comfort floor heating**

\[
\frac{971 \text{ ft}}{275 \text{ ft}} = 4 \text{ (rounded)}
\]

Power supply: **Four 30 A circuit breakers** (from Table 8)
Step 4.5 Determine the additional heating cable allowance (see Table 6 on page 19)

### End allowance

\[
\text{End allowance (ft/m)} = \text{number of circuits (from Step 4.4)} \times \text{ft/m per end (from Table 6)} \times \text{number of ends}
\]

### Connection kit allowance

\[
\text{Connection kit allowance (ft/m)} = \text{number of kits} \times \text{ft/m per connection kit (from Table 6)}
\]

### Total heating cable allowance

\[
\text{Total heating cable allowance (ft/m)} = \text{end allowance (ft/m)} + \text{connection kit allowance (ft/m)}
\]

### Estimated total heating cable length

\[
\text{Estimated total heating cable length (ft/m)} = \text{estimated heating cable length (ft/m)} + \text{total heating cable allowance (ft/m)}
\]

**Example: RaySol heating cables for comfort floor heating**

### End allowance

\[
\text{End allowance} = 4 \times 4 \times 2 = 32 \text{ ft}
\]

### Connection kit allowance

\[
\text{Connection kit allowance} = 4 \times 4 = 16 \text{ ft}
\]

### Total heating cable allowance

\[
\text{Total heating cable allowance} = 32 \text{ ft} + 16 \text{ ft} = 48 \text{ ft}
\]

### Estimated total heating cable length

\[
\text{Estimated total heating cable length} = 971 \text{ ft} + 48 \text{ ft} = 1019 \text{ ft}
\]

4.6 Locate the junction boxes for the RaySol heating cable (see Fig. 12 on page 17 for examples of a typical system)

4.7 Lay out the heating cable runs, circuits, and junction boxes

4.8 Record the circuit information
**Step 5 Determine the electrical parameters**

**Determine transformer load**

Calculate the circuit breaker load (CBL)

\[
\left( \frac{\text{Circuit breaker rating} \times 0.8 \times \text{Supply voltage}}{1000} \right) = \text{Circuit breaker load (kW)}
\]

If the CBL is equal on all circuits, calculate the transformer load as:

\[
\frac{\text{Circuit breaker load (kW)}}{\text{Number of breakers}} = \text{Total transformer load (kW)}
\]

If the CBL is NOT equal on all circuits, calculate the transformer load as:

\[
\text{CBL}_1 + \text{CBL}_2 + \text{CBL}_3 + \ldots + \text{CBL}_n = \text{Total transformer load (kW)}
\]

**Example: RaySol cables for heat loss replacement and comfort floor heating**

Determine transformer load:

\[
(30 \text{ A} \times 0.8 \times 208 \text{ V}) / 1000 = \text{Rounded to 5 kW}\]

\[
5 \text{ kW} \times 4 = 20 \text{ kW}
\]

**Step 6 Select the connection kits and accessories**

RaySol connection kits | Quantity
--- | ---
- FTC-P | 
- FTC-XC | 
- FTC-HST | 
- RayClic-E | 

**Example: RaySol heating cables for heat loss replacement**

✓ FTC-P (1 per cable run) 4

**Example: RaySol heating cables for comfort floor heating**

✓ FTC-XC (1 per cable run) 4

**Step 7 Select the control system** (see Table 16 on page 43)

Control system | Quantity
--- | ---
- ECW-GF | 
- ECW-GF-DP | 
- MI-GROUND-KIT | 
- C910-485 | 
- ACS-UIT2 | 
- ACS-PCM2-5 | 
- ProtoNode-RER | 
- RTD10CS | 
- RTD-200 | 
- RTD50 | 

**Example: RaySol heating cables for heat loss replacement**

✓ ACS-30 1
Example: RaySol heating cables for comfort floor heating
✓ ECW-GF

Step 1: Select the power distribution (see Table 17 on page 49)

<table>
<thead>
<tr>
<th>Power Distribution and Control Panels</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTPG</td>
<td></td>
</tr>
</tbody>
</table>

Step 2: Complete the Bill of Materials

Use the information recorded in this worksheet to complete the Bill of Materials.
MI HEATING CABLE FLOOR HEATING DESIGN WORKSHEET

Heat Loss Replacement

**Step 3** Determine the floor configuration (Steps 1 and 2 were completed in the pre-design worksheet)

<table>
<thead>
<tr>
<th>Heat loss replacement (see Fig. 9 on page 13)</th>
<th>Minimum ambient design temperature</th>
<th>Insulation R-value</th>
<th>Supply voltage and phase</th>
<th>Control requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side A (length) (ft/m) x Side B (width) (ft/m) = Heated area (ft²/m²)</td>
<td>_____°F/°C</td>
<td>_____ ft²·F·hr/Btu</td>
<td>_____ Volts</td>
<td>_____ Phase</td>
</tr>
</tbody>
</table>

**Example: MI heating cables for heat loss replacement**

<table>
<thead>
<tr>
<th>Side A (length) (ft/m) x Side B (width) (ft/m) = Heated area (ft²/m²)</th>
<th>80 ft</th>
<th>40 ft</th>
<th>3200 ft²</th>
<th>–10°F</th>
<th>R-20 (20 ft²·°F·hr/Btu)</th>
<th>208 V Three-phase</th>
<th>Electronic thermostat, monitoring requested</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 ft x 40 ft = 3200 ft²</td>
<td>20°F</td>
<td>20°F</td>
<td>1067 ft²</td>
<td>208 V</td>
<td>208 V</td>
<td>208 V</td>
<td>208 V</td>
</tr>
</tbody>
</table>

**Step 4** Determine the heating cable spacing, layout and length

Select heating cable (For design power, see Table 9 on page 25; for heating cable selection, see Table 10 on page 28.)

**Determine the design power**

Heated area: _________ (from Step 3)
Supply voltage and phase: _________ (from Step 3)
Minimum ambient design temperature: _________ (from Step 3)
Insulation R-value: _________ (from Step 3)
Design power: _________ (from Table 9 on page 25)
Subsection area: _________ (from Step 4)

**Determine the power requirement:**

Single-phase supply

Design power (W/ft²) (W/m²) x Total area or subsection area (ft²/m²) = Power required (W)

Three-phase supply

Design power (W/ft²) (W/m²) x Subsection area (ft²/m²) = Power required (for each subsection) (W)

**Select the heating cable**

Heating cable catalog number: _________ (from Table 10 on page 28)
Cable wattage: _________ (from Table 10 on page 28)
Cable voltage: _________ (from Table 10 on page 28)
Heating cable length: _________ (from Table 10 on page 28)
Number of cables: _________
Example: MI heating cables for heat loss replacement

**Determine the design power**

- Heated area: 3200 ft² (from Step 3)
- Supply voltage and phase: 208 V, three-phase (from Step 3)
- Minimum ambient design temperature: −10°F (from Step 3)
- Insulation R-value: R-20 (from Step 3)
- Design power: 2.2 W/ft² (from Table 9 on page 25)
- Subsection area: 1067 ft² (from Step 4)

**Determine the power requirement:**

Three-phase supply (see Fig. 16 on page 27)

\[
\frac{2.2 \text{ W/ft}^2 \times 1067 \text{ ft}^2}{\text{Design power/ft}^2} = 2347 \text{ W}
\]

- Heating cable catalog number: HLR24 (from Table 10 on page 28)
- Cable wattage: 5150 W (from Table 10 on page 28)
- Cable voltage: 208 V (from Table 10 on page 28)
- Heating cable length: 420 ft (from Table 10 on page 28)
- Number of cables: 3 (one cable required for each subsection)

**Determine the heating cable spacing**

**Imperial**

\[
\frac{\text{Area (ft}^2\text{)} \times 12 \text{ in}}{\text{Heating cable length (ft)}} = \text{Cable spacing (in)}
\]

**Metric**

\[
\frac{\text{Area (m}^2\text{)} \times 100 \text{ cm}}{\text{Heating cable length (m)}} = \text{Cable spacing (cm)}
\]

Example: MI heating cables for heat loss replacement

- Subsection area: 1067 ft² (from Step 4)
- Heating cable catalog number: HLR24 (from Step 4)
- Heating cable length: 420 ft (from Table 10)

\[
\frac{1067 \text{ ft}^2 \times 12 \text{ in}}{420 \text{ ft}} = 31 \text{ in (rounded)}
\]

Advance Step 5 on on page 65.
## Comfort Floor Heating

### Step 3 Determine the floor configuration  
(Steps 1 and 2 were completed in the pre-design worksheet)

<table>
<thead>
<tr>
<th>Comfort floor heating (see Fig. 10 on page 14)</th>
<th>Minimum ambient design temperature</th>
<th>Insulation R-value</th>
<th>Supply voltage and phase</th>
<th>Control requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area (ft²/m²)</td>
<td>Permanent fixture space (ft²/m²)</td>
<td>Heated area (ft²/m²)</td>
<td>°F/°C</td>
<td>ft²·°F·hr/Btu</td>
</tr>
</tbody>
</table>

### Example: Raysol heating cables for comfort floor heating

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>34 ft</td>
<td>20 ft</td>
</tr>
<tr>
<td>Side A (see Figure 10)</td>
<td>Side B (see Figure 10)</td>
</tr>
<tr>
<td>680 ft²</td>
<td>(22 ft² counter + 11 ft² columns)</td>
</tr>
</tbody>
</table>

Total area: 680 ft²

Minimum ambient design temperature: 10°F

Insulation R-value: R-30

Supply voltage and phase: 208 V, single phase

Control requirements: Electronic thermostat

### Step 4 Determine the heating cable spacing, layout, and length

#### Select the heating cable  
(see Table 11 on page 31 and Table 12 on page 32)

Heat area: ___________ (from Step 3)

Supply voltage and phase: ___________ (from Step 3)

Subsection area:

<table>
<thead>
<tr>
<th>Heated area (ft²/m²) / Number of subsections</th>
<th>Subsection area (ft²/m²)</th>
</tr>
</thead>
</table>

Heating cable catalog number: ___________ (from Table 11 on page 31 or Table 12 on page 32)

Cable wattage: ___________ (from Table 11 on page 31 or Table 12 on page 32)

Cable voltage: ___________ (from Table 11 on page 31 or Table 12 on page 32)

Heating cable length: ___________ (from Table 11 on page 31 or Table 12 on page 32)

Number of cables: ___________

### Example: MI heating cables for comfort floor heating

**Note:** In this example, the subsections are equal heated areas.

Supply voltage and phase: 208 V, single phase (from Step 3)

Subsection area: (see Fig. 17 on page 30)

<table>
<thead>
<tr>
<th>Heated area (ft²/m²) / Number of subsections</th>
<th>Subsection area (ft²/m²)</th>
</tr>
</thead>
</table>

Heating cable catalog number: FH21 (from Table 12 on page 32)

Cable wattage: 3390 W (from Table 12 on page 32)

Cable voltage: 208 V (from Table 12 on page 32)

Heating cable length: 425 ft (from Table 12 on page 32)

Number of cables: 2 (one cable required for each subsection)
Determine the heating cable spacing, layout, and length

**Imperial**

\[
\frac{\text{Area (ft}^2\text{)}}{\text{Heating cable length (ft)}} \times 12 \text{ in} = \text{Cable spacing (in)}
\]

**Metric**

\[
\frac{\text{Area (m}^2\text{)}}{\text{Heating cable length (m)}} \times 100 \text{ cm} = \text{Cable spacing (cm)}
\]

Round to the nearest 1/2 in or 1 cm.

**Example: MI heating cables for comfort floor heating**

Subsection area: \(324 \text{ ft}^2\) (from Step 4)
Heating cable catalog number: FH21 (from Step 4)
Heating cable length: 425 ft (from Table 12)

\[
\text{Area} \times 12 \text{ in} = \frac{324 \text{ ft}^2}{425 \text{ ft}} = 9 \text{ in (rounded)}
\]

Advance Step 5 on page 64.

**Radiant Space Heating**

**Determine the floor configuration** (Steps 1 and 2 were completed in the pre-design worksheet)

<table>
<thead>
<tr>
<th>Radiant space heating (see Fig. 11 on page 15)</th>
<th>Btu requirement (supplied by engineer)</th>
<th>Supply voltage and phase</th>
<th>Control requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area (\text{(ft}^2/\text{m}^2)) - Permanent fixture space (\text{(ft}^2/\text{m}^2)) = Heated area (\text{(ft}^2/\text{m}^2))</td>
<td>Btu/hr</td>
<td>Volts</td>
<td>Phase</td>
</tr>
</tbody>
</table>

**Example: MI heating cables for radiant space heating**

Side A (see Figure 11) \(34 \text{ ft}\) x \(20 \text{ ft}\) = \(680 \text{ ft}^2\)

\[
\text{Total area} = \frac{680 \text{ ft}^2}{22 \text{ ft}^2 \text{ counter} + 11 \text{ ft}^2 \text{ columns}} = 647 \text{ ft}^2
\]

\[
\text{Heated area} = \frac{647 \text{ ft}^2}{22 \text{ ft}^2 \text{ counter} + 11 \text{ ft}^2 \text{ columns}} = 647 \text{ ft}^2
\]

Btu requirement: \(34,800 \text{ Btu/hr}\) (supplied by engineer)
Supply voltage and phase: \(208 \text{ V, single phase}\)
Control requirements: \(\text{Electronic thermostat}\)
Step 4 Determine the heating cable spacing, layout, and length

Select the heating cable

Heated area: ________________ (from Step 3)
Supply voltage and phase: ________________ (from Step 3)

Subsection area:

\[
\frac{\text{Heated area} \text{(ft}^2/\text{m}^2) \text{ / Number of subsections}}{\text{Subsection area} \text{(ft}^2/\text{m}^2)}
\]

Btu requirement: ________________ (from Step 3)
Power required:

\[
\frac{\text{Btu/hr}}{3.412} = \text{Power requirement (W)}
\]

Power per subsection:
Heating cable catalog number: ________________ (from Table 11 on page 31 or Table 12 on page 32)
Cable wattage: ________________ (from Table 11 on page 31 or Table 12 on page 32)
Cable voltage: ________________ (from Table 11 on page 31 or Table 12 on page 32)
Heating cable length: ________________ (from Table 11 on page 31 or Table 12 on page 32)
Number of cables: ________________

Example: MI heating cables for radiant space heating

Note: In this example, the subsections are equal heated areas.

Heated area: 647 ft\(^2\)
Supply voltage and phase: 208 V, single-phase (from Step 3)
Subsection area: (see Fig. 18 on page 34)

\[
\frac{647 \text{ ft}^2}{3} = 216 \text{ ft}^2
\]

Btu requirement: 34,800 Btu/hr (from Step 3)
Power required: 34,800 Btu/hr / 3.412 = 10200 W
Power per subsection: 10200 W / 3 = 3400 W
Heating cable catalog number: FH21 (from Table 12 on page 32)
Cable wattage: 3390 W (from Table 12 on page 32)
Cable voltage: 208 V (from Table 12 on page 32)
Heating cable length: 425 ft (from Table 12 on page 32)
Number of cables: 3 (one cable required for each subsection)
**Step 4 Determine the heating cable spacing, layout, and length**

**Determine the heating cable spacing**

**Imperial**

\[
\text{Cable spacing (in)} = \frac{\text{Area (ft}^2\text{)} \times 12 \text{ in}}{\text{Heating cable length (ft)}}
\]

**Metric**

\[
\text{Cable spacing (cm)} = \frac{\text{Area (m}^2\text{)} \times 100 \text{ cm}}{\text{Heating cable length (m)}}
\]

**Example: MI heating cables for radiant space heating**

Subsection area: 216 ft² (from Step 4)
Catalog number: FH21 (from Step 4)
Heating cable length: 425 ft (from Table 12)

\[
\begin{align*}
\text{Cable spacing (in)} &= \frac{216 \text{ ft}^2 \times 12 \text{ in}}{425 \text{ ft}} \\
&= 6 \text{ in (rounded)}
\end{align*}
\]

**Step 5 Determine the electrical parameters**

**Determine the number of circuits**

Single-phase circuits (see Fig. 19 on page 46)
Three-phase circuits (see Fig. 20 on page 46 and Fig. 21 on page 47)

**Select the branch circuit breaker rating**

**Single-phase circuit**

\[
\text{Load Current (A)} = \frac{\text{Heating cable current (A)}}{0.8}
\]

**Delta-connected three-phase circuit**

\[
\text{Load current (A)} = \frac{\text{Heating cable current (A)}}{1.732}
\]

**Wye-connected three-phase circuit**

\[
\text{Load current (A)} = \frac{\text{Heating cable current (A)}}{0.8}
\]
Step 2 Determine the electrical parameters

Determine the transformer load

For cables of equal wattage

\[
\left( \frac{\text{Cable (W)}}{\text{Number of cables}} \right) \times \frac{1000}{1000} = \text{Transformer load (kW)}
\]

When cable wattages are not equal

\[
\left( \frac{\text{Cable}_1 (W) + \text{Cable}_2 (W) + \ldots + \text{Cable}_N (W)}{\text{Number of cables}} \right) \times \frac{1000}{1000} = \text{Total transformer load (kW)}
\]

Example: MI heating cables for heat loss replacement

Heating cable catalog number: HLR24 (from Step 4)
Heating cable current: 24.8 A (from Table 10 on page 28)
Load current:
Delta-connected three-phase circuit

\[
\frac{24.8}{1.732} = 43 \text{ A (rounded)}
\]

Circuit breaker size: 60 A breaker, 80% loading 48 A
Number of circuit breakers: 1 (3-pole breaker)
Cable power output: 5150 W (from Step 4)
Number of cables: 3 (from Step 4)
Transformer load:

\[
\left( \frac{5150}{\text{Number of cables}} \right) \times \frac{1000}{1000} = 15.5 \text{ kW (rounded)}
\]

Example: MI heating cables for comfort floor heating

Heating cable catalog number: FH21 (from Step 4)
Heating cable current: 16.3 A (from Table 12 on page 32)
Load current: 16.3 A
Circuit breaker size: 25 A breaker, 80% loading 20 A
Number of circuit breakers: 2
Cable power output: 3390 W (from Step 4)
Number of cables: 2 (from Step 4)
Transformer load:

\[
\left( \frac{3390}{\text{Number of cables}} \right) \times \frac{2}{1000} = 6.8 \text{ kW (rounded)}
\]

Example: MI heating cables for radiant space heating

Heating cable catalog number: FH21 (from Step 4)
Heating cable current: 16.3 A (from Table 12 on page 32)
Load current: 16.3 A
Circuit breaker size: 25 A breaker, 80% loading 20 A
Number of circuit breakers: 3
Cable power output: 3390 W (from Step 4)
Number of cables: 3 (from Step 4)
Transformer load:

\[
\left( \frac{3390}{\text{Number of cables}} \right) \times \frac{3}{1000} = 10.2 \text{ kW (rounded)}
\]
### Step 6 Select the connection kits and accessories

<table>
<thead>
<tr>
<th>MI accessories</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1297TERM4</td>
<td></td>
</tr>
<tr>
<td>SPACERGALV</td>
<td></td>
</tr>
<tr>
<td>107826-000</td>
<td></td>
</tr>
</tbody>
</table>

- **Cast aluminum junction box**
- **Galvanized steel prepunched strapping**
- **Stainless steel prepunched strapping (use for Heat Loss Replacement applications)**

**Example: MI heating cables for heat loss replacement**
- Junction Box (supplied by contractor)
- 107826-000 - 16

**Example: MI heating cables for comfort floor heating**
- D1297TERM4 - 2
- SPACERGALV - 4

**Example: MI heating cables for radiant space heating**
- D1297TERM4 - 3
- SPACERGALV - 4

### Step 7 Select the control system (see Table 16 on page 43)

<table>
<thead>
<tr>
<th>Control system</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECW-GF</td>
<td></td>
</tr>
<tr>
<td>ECW-GF-DP</td>
<td></td>
</tr>
<tr>
<td>C910-485</td>
<td></td>
</tr>
<tr>
<td>ACS-UIT2</td>
<td></td>
</tr>
<tr>
<td>ACS-PCM2-5</td>
<td></td>
</tr>
<tr>
<td>ProtoNode-RER</td>
<td></td>
</tr>
<tr>
<td>RTD10CS</td>
<td></td>
</tr>
<tr>
<td>RTD-200</td>
<td></td>
</tr>
<tr>
<td>RTD50</td>
<td></td>
</tr>
</tbody>
</table>

- **ACS-30** - 1
- **ECW-GF** - 1

### Step 8 Select the power distribution (see Table 17 on page 49)

<table>
<thead>
<tr>
<th>Power Distribution and Control Panels</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTPG</td>
<td></td>
</tr>
</tbody>
</table>

### Step 9 Complete the Bill of Materials

Use the information recorded in this worksheet to complete the Bill of Materials.