This step-by-step design guide provides the tools necessary to design a Raychem RaySol self-regulating heating cable system or a Raychem Mineral Insulated heating cable system for freezer frost heave prevention. For other applications or for design assistance, contact your Thermal Management representative or call (800) 545-6258. Also, visit our website at www.pentairthermal.com.

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Thermal Management offers two different heating cable technologies for freezer frost heave prevention: Raychem RaySol self-regulating heating cable system and Raychem MI heating cable system. Both RaySol and MI heating cables can be installed in conduit. Only MI heating cables can be embedded directly in the subfloor (concrete, sand, or compacted fill).

If your application conditions are different, or if you have any questions, contact your Thermal Management representative or call (800) 545-6258.

How to Use this Guide

This design guide presents Thermal Management’s recommendations for designing freezer frost heave prevention systems. It provides design and performance data, electrical sizing information, and heating cable layout suggestions. Following these recommendations will result in a reliable, energy-efficient system.

Follow the design steps in the respective “Design” sections and use the appropriate “RaySol and MI Heating Cable in Conduit Freezer Frost Heave Prevention Design Worksheet” on page 49 and “MI Cables Directly Embedded Freezer Frost Heave Prevention Design Worksheet” on page 54 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 freezer frost heave prevention system installation instructions, please refer to the following additional required documents:

- Raychem RaySol Floor Heating and Frost Heave Prevention Installation and Operation Manual [H58138]
- Raychem Mineral Insulated Heating Cable Floor Heating and 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 Thermal Management web site at www.pentairthermal.com.

For products and applications not covered by this design guide, please contact your Thermal Management 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 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 Thermal Management, 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

Thermal Management’s standard limited warranty applies to Raychem and Raychem Freezer Frost Heave Prevention Systems.

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 web site at www.pentairthermal.com.

### SYSTEM OVERVIEW

Subfreezing temperatures inside cold rooms, freezers, and ice arenas cause heat to be lost from the soil under the floor, even when it is well insulated. As the soil freezes, capillary action draws water into the frozen areas where the water forms a concentrated ice mass. As the ice mass grows, it heaves the freezer floor and columns, causing damage.

Thermal Management offers two different heating cable technologies for freezer frost heave prevention: Raychem RaySol self-regulating heating cable and Raychem MI heating cable system. Both RaySol and MI heating cables can be installed in conduit. Only MI heating cables can be embedded directly in the subfloor (sand, compacted fill or concrete). The electrical conduit carrying the heating cable or the directly embedded heating cable is installed in the subfloor under the freezer-floor insulation, as illustrated below. The subfloor layer may be a reinforced concrete slab, a concrete mud slab, a bed of compacted sand, or simply compacted fill.

![Fig. 1 Typical freezer frost heave installation](image-url)
The RaySol self-regulating heating cable provides a cut-to-length solution. The backbone of the system is the self-regulating heating cable available for 120 and 208–277 V applications. As Fig. 4 on page 6 indicates, the cable’s output is reduced automatically as the subfloor warms, so there is no possibility of failure due to overheating. Since there is no possibility of overheating, RaySol may be operated without thermostatic control. Elements of a RaySol system include the heating cable, termination, splice connections and accessories, controls, power distribution panels, and the tools necessary for a complete installation.

Raychem MI heating cable can be used for single-phase and three-phase applications up to 600 V and the cable can be installed in conduit or directly embedded in sand (recommended), concrete, or compacted fill. For directly embedded applications, long cable runs can be accommodated allowing frost heave prevention systems to be designed for large freezers and ice arenas using only a few circuits. Raychem MI heating cables are rugged factory-terminated cables (Fig. 6 and Fig. 7) that are engineered to suit your application, power and configuration requirements. Elements of an MI system include the heating cable, accessories, controls, power distribution panels, and the tools for a complete installation.

**Typical System**

A typical system includes the following:
- RaySol self-regulating heating cable or Raychem MI heating cable
- Connection kits [for RaySol only]
- Junction boxes
- Temperature control and power distribution systems
Fig. 2 Typical freezer frost heave system

The following table lists the heating cable, required connection kits, and accessories for a RaySol and MI heating cable systems.

**TABLE 1 HEATING CABLES AND CONNECTION KITS**

<table>
<thead>
<tr>
<th>Heating cable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RaySol-1</td>
<td>120 V</td>
</tr>
<tr>
<td>RaySol-2</td>
<td>208–277 V</td>
</tr>
<tr>
<td>HDPE jacketed copper sheath</td>
<td>≤600 V</td>
</tr>
<tr>
<td>MI heating cable</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connection kits for RaySol heating cables</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTC-XC</td>
<td>Power connection and end seal</td>
</tr>
<tr>
<td>RayClic-E</td>
<td>End seal</td>
</tr>
<tr>
<td>FTC-HST</td>
<td>Splice (as required – not for use inside conduit)</td>
</tr>
</tbody>
</table>
Raychem 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.

**Fig. 3 Typical RaySol heating cable construction**

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.
MI Heating Cable Construction

Raychem MI heating cables used for frost heave prevention applications are comprised of one or two conductors surrounded by magnesium oxide insulation and a solid copper sheath with an extruded high density polyethylene (HDPE) jacket or Alloy 825 stainless steel sheath for directly embedded or in conduit applications.

Heating conductor

Dual-conductor cable (32, 62 series)

Copper sheath or Alloy 825 sheath

HDPE jacket

Insulation (magnesium oxide)

Heating conductor

Single-conductor cable (61 series)

Copper sheath

HDPE jacket

Insulation (magnesium oxide)

Fig. 5 Typical MI heating cable construction

These 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. Three 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; Type SUB/FFHP 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; and Type FFHPC consisting of a single run of cable joined to a single 7 ft (2.1 m) cold lead with one 1/2-in NPT connector.

Types SUA and SUB/FFHP heating cables [Fig. 6] are used for directly embedded applications, and Type FFHPC heating cables [Fig. 7] are used for installation in conduit. Type FFHPC heating cables are supplied with a bare copper sheath cold lead and a 3/4-in NPT reversed gland connector and a pulling eye. The reversed gland connector provides a seal for the end of the conduit [see Fig. 13 on page 21].

Type SUA

Design A

Heated length

Cold lead length

Hot/cold joint

NPT threaded connector

Type SUB and FFHP

Design B

Cold lead length

Heated length

Cold lead length

Hot/cold joint

NPT threaded connector

Fig. 6 Configurations for directly embedded installations

Type FFHPC

Design D

Heated length

Cold lead length

Pulling eye

Hot/cold joint

Reversed gland

NPT threaded connector

Fig. 7 Configuration for installation in conduit

Thermal Management offers all the major components necessary for system installation. Details of these components and additional accessories can be found later in this section.
Installation of Raychem RaySol and Raychem MI heating cable systems is governed by national and local electrical codes. Thermal Management, the NEC, and the CEC all require the use of ground-fault protection of equipment to reduce the risk of fire caused by damage or improper installation.

RaySol system is UL Listed and CSA Certified for use in nonhazardous locations.

MI system is c-CSA-us Certified and FM Approved for use in nonhazardous locations. FM applies only to the bare copper and stainless steel cable for Freezer Frost Heave installation inside of conduits.

This section details the steps necessary to design 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 "RaySol and MI Heating Cable in Conduit Freezer Frost Heave Prevention Design Worksheet" on page 49 and "MI Cables Directly Embedded Freezer Frost Heave Prevention Design Worksheet" on page 54 to document your project parameters, so that by that end of this section, you will have the information you need for your Bill of Materials.

This section contains two major parts:
1. Design Step by Step RaySol and MI Heating Cables in Conduit (see page 9)
2. Design Step by Step MI Heating Cable Directly Embedded (see page 30)

When using this guide to design a system you need the following information:
- Size and layout of freezer or ice arena
- Freezer operating temperature
- Insulation R-value
- Supply voltage and phase
- Control recommendations (over-limit thermostat and monitoring)

The information and recommendations in this section are based on the following design assumptions:
- The information in this guide is based on the application of the RaySol and MI heating cables in the subfloor on grade only.
- Any size freezer or cold room operating below 32°F (0°C) may experience frost heaving.
- The heating cable is located in a sub-slab underneath the insulation. (see Fig. 1)
- The heating cable is in conduit embedded in concrete, sand, or soil (or directly embedded if using MI heating cables). If you are using a different medium, contact Thermal Management for an analysis.

For products and applications not covered by this design guide, please contact your Thermal Management representative or call (800) 545-6258.
Design Step by Step RaySol and MI Heating Cables in Conduit

This section guides you through the steps necessary to design your system using RaySol self-regulating or MI heating cables in conduit.

Your system design requires the following essential steps:

1. Determine the freezer configuration
2. Select the heating cable
   A. RaySol heating cable in conduit
   B. MI heating cable in conduit
3. Determine the heating cable conduit spacing and freezer load
4. Determine the heating cable layout and length
   A. RaySol heating cable in conduit
   B. MI heating cable in conduit
5. Determine the electrical parameters
   A. RaySol heating cable in conduit
   B. MI heating cable in conduit
6. Select the connection kits and accessories
7. Select the control system
8. Select the power distribution
9. Complete the Bill of Materials

The “RaySol and MI Heating Cable in Conduit Freezer Frost Heave Prevention Design Worksheet” on page 49 is included to help you document the project parameters that you will need for your project’s Bill of Materials.
Step 1  Determine the freezer configuration

GATHERING INFORMATION
The following information is required to complete the freezer frost heave prevention system design.

- Size and layout of freezer or ice arena
- Freezer operating temperature
- Insulation R-value
- Supply voltage (single-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 location and size of obstacles, such as floor drains, pipe penetrations, conduit runs (if required), columns, fixtures, and voltage supply location.

DETERMINE THE FREEZER OPERATING TEMPERATURE
Determine the temperature at which your freezer operates. If it operates at more than one temperature, or if the operating temperature may be changed in the future, base the spacing selection on the lowest anticipated operating temperature.

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 and MI heating cables in conduit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>80 ft x 40 ft = 3200 ft²</td>
</tr>
<tr>
<td></td>
<td>(24.4 m x 12.2 m = 297 m²)</td>
</tr>
<tr>
<td>Freezer operating temperature</td>
<td>-20°F (-29°C)</td>
</tr>
<tr>
<td>Insulation R-value</td>
<td>R-40 (40 ft²·°F·hr/Btu)</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>208 V, single-phase</td>
</tr>
</tbody>
</table>

**Step 2: Select the heating cable**

The heating cable you select will depend on your system:

A. RaySol heating cable in conduit
B. MI heating cable in conduit

**STEP 2A: FOR RAYSOl HEATING CABLE IN CONDUIT**

Select the heating cable based on the operating voltage determined in Step 1. For 120 volts, select RaySol-1; for 208/240/277 V, select RaySol-2.

**TABLE 2 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 in conduit**

Supply voltage: 208 V (from Step 1)

Catalog number: RaySol-2

**STEP 2B: FOR MI HEATING CABLE IN CONDUIT**

Select the heating cable from Table 3 based on the operating voltage from Step 1 and the freezer length. The freezer length must be equal to or within the minimum and maximum “Freezer length” shown in the shaded columns. For the example in Fig. 8, under 208 V, select the heating cable that corresponds to the Minimum (80 ft/24.4 m) and Maximum (84 ft/25.6 m) “Freezer length” in the shaded columns.

If your freezer is longer than 104 ft (32 m), or the supply voltage is different than those listed, or the system will be powered from a three-phase supply, please contact your Thermal Management representative or call (800) 545-6258 for a custom design.

If it is not possible to install the conduit runs parallel to the freezer length (Side A), then select the heating cable based on the freezer width (Side B).
## TABLE 3 SELECTION TABLE FOR MI HEATING CABLES IN CONDUIT

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Freezer length</th>
<th>Heated length</th>
<th>Power output</th>
<th>Heating cable current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td><strong>120 V</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFHPC1</td>
<td>15</td>
<td>19</td>
<td>4.6</td>
<td>5.8</td>
</tr>
<tr>
<td>FFHPC2</td>
<td>20</td>
<td>24</td>
<td>6.1</td>
<td>7.3</td>
</tr>
<tr>
<td>FFHPC3</td>
<td>25</td>
<td>29</td>
<td>7.6</td>
<td>8.8</td>
</tr>
<tr>
<td>FFHPC4</td>
<td>30</td>
<td>34</td>
<td>9.1</td>
<td>10.4</td>
</tr>
<tr>
<td>FFHPC5</td>
<td>35</td>
<td>39</td>
<td>10.7</td>
<td>11.9</td>
</tr>
<tr>
<td>FFHPC6</td>
<td>40</td>
<td>44</td>
<td>12.2</td>
<td>13.4</td>
</tr>
<tr>
<td>FFHPC7</td>
<td>45</td>
<td>49</td>
<td>13.7</td>
<td>14.9</td>
</tr>
<tr>
<td>FFHPC8</td>
<td>50</td>
<td>54</td>
<td>15.2</td>
<td>16.5</td>
</tr>
<tr>
<td>FFHPC9</td>
<td>55</td>
<td>59</td>
<td>16.8</td>
<td>18.0</td>
</tr>
<tr>
<td>FFHPC10</td>
<td>60</td>
<td>64</td>
<td>18.3</td>
<td>19.5</td>
</tr>
<tr>
<td>FFHPC11</td>
<td>65</td>
<td>69</td>
<td>19.8</td>
<td>21.0</td>
</tr>
<tr>
<td>FFHPC12</td>
<td>70</td>
<td>74</td>
<td>21.3</td>
<td>22.6</td>
</tr>
<tr>
<td>FFHPC13</td>
<td>75</td>
<td>79</td>
<td>22.9</td>
<td>24.1</td>
</tr>
<tr>
<td>FFHPC14</td>
<td>80</td>
<td>84</td>
<td>24.4</td>
<td>25.6</td>
</tr>
<tr>
<td>FFHPC15</td>
<td>85</td>
<td>89</td>
<td>25.9</td>
<td>27.1</td>
</tr>
<tr>
<td>FFHPC16</td>
<td>90</td>
<td>94</td>
<td>27.4</td>
<td>28.7</td>
</tr>
<tr>
<td>FFHPC17</td>
<td>95</td>
<td>99</td>
<td>29.0</td>
<td>30.2</td>
</tr>
<tr>
<td>FFHPC18</td>
<td>100</td>
<td>104</td>
<td>30.5</td>
<td>31.7</td>
</tr>
<tr>
<td><strong>208 V</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFHPC19</td>
<td>25</td>
<td>29</td>
<td>7.6</td>
<td>8.8</td>
</tr>
<tr>
<td>FFHPC20</td>
<td>30</td>
<td>34</td>
<td>9.1</td>
<td>10.4</td>
</tr>
<tr>
<td>FFHPC21</td>
<td>35</td>
<td>39</td>
<td>10.7</td>
<td>11.9</td>
</tr>
<tr>
<td>FFHPC22</td>
<td>40</td>
<td>44</td>
<td>12.2</td>
<td>13.4</td>
</tr>
<tr>
<td>FFHPC23</td>
<td>45</td>
<td>49</td>
<td>13.7</td>
<td>14.9</td>
</tr>
<tr>
<td>FFHPC24</td>
<td>50</td>
<td>54</td>
<td>15.2</td>
<td>16.5</td>
</tr>
<tr>
<td>FFHPC25</td>
<td>55</td>
<td>59</td>
<td>16.8</td>
<td>18.0</td>
</tr>
<tr>
<td>FFHPC26</td>
<td>60</td>
<td>64</td>
<td>18.3</td>
<td>19.5</td>
</tr>
<tr>
<td>FFHPC27</td>
<td>65</td>
<td>69</td>
<td>19.8</td>
<td>21.0</td>
</tr>
<tr>
<td>FFHPC28</td>
<td>70</td>
<td>74</td>
<td>21.3</td>
<td>22.6</td>
</tr>
<tr>
<td>FFHPC29</td>
<td>75</td>
<td>79</td>
<td>22.9</td>
<td>24.1</td>
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<tr>
<td>FFHPC30</td>
<td>80</td>
<td>84</td>
<td>24.4</td>
<td>25.6</td>
</tr>
<tr>
<td>FFHPC31</td>
<td>85</td>
<td>89</td>
<td>25.9</td>
<td>27.1</td>
</tr>
<tr>
<td>FFHPC32</td>
<td>90</td>
<td>94</td>
<td>27.4</td>
<td>28.7</td>
</tr>
<tr>
<td>FFHPC33</td>
<td>95</td>
<td>99</td>
<td>29.0</td>
<td>30.2</td>
</tr>
<tr>
<td>FFHPC34</td>
<td>100</td>
<td>104</td>
<td>30.5</td>
<td>31.7</td>
</tr>
</tbody>
</table>

1 Single-phase current shown
Tolerance on cable length is –0% to +1%.
All heating cables supplied with 3/4-in NPT reversed gland and pulling eye.
Type FFHPC cables supplied with 7 ft [2.1 m] long cold lead.
### Table 3: Selection Table for MI Heating Cables in Conduit

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Freezer length</th>
<th>Heated length</th>
<th>Power output</th>
<th>Heating cable current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFHPC35</td>
<td>30 34</td>
<td>30 9.1</td>
<td>10.4</td>
<td>230 0.8</td>
</tr>
<tr>
<td>FFHPC36</td>
<td>35 39</td>
<td>35 10.7</td>
<td>11.9</td>
<td>240 0.9</td>
</tr>
<tr>
<td>FFHPC37</td>
<td>40 44</td>
<td>40 12.2</td>
<td>13.4</td>
<td>255 0.9</td>
</tr>
<tr>
<td>FFHPC38</td>
<td>45 49</td>
<td>45 13.7</td>
<td>14.9</td>
<td>285 1.0</td>
</tr>
<tr>
<td>FFHPC39</td>
<td>50 54</td>
<td>50 15.2</td>
<td>16.5</td>
<td>380 1.4</td>
</tr>
<tr>
<td>FFHPC40</td>
<td>55 59</td>
<td>55 16.8</td>
<td>18.0</td>
<td>350 1.3</td>
</tr>
<tr>
<td>FFHPC41</td>
<td>60 64</td>
<td>60 18.3</td>
<td>19.5</td>
<td>465 1.7</td>
</tr>
<tr>
<td>FFHPC42</td>
<td>65 69</td>
<td>65 19.8</td>
<td>21.0</td>
<td>430 1.6</td>
</tr>
<tr>
<td>FFHPC43</td>
<td>70 74</td>
<td>70 21.3</td>
<td>22.6</td>
<td>400 1.4</td>
</tr>
<tr>
<td>FFHPC44</td>
<td>75 79</td>
<td>75 22.9</td>
<td>24.1</td>
<td>500 1.8</td>
</tr>
<tr>
<td>FFHPC45</td>
<td>80 84</td>
<td>80 24.4</td>
<td>25.6</td>
<td>480 1.7</td>
</tr>
<tr>
<td>FFHPC46</td>
<td>85 89</td>
<td>85 25.9</td>
<td>27.1</td>
<td>530 1.9</td>
</tr>
<tr>
<td>FFHPC47</td>
<td>90 94</td>
<td>90 27.4</td>
<td>28.7</td>
<td>500 1.8</td>
</tr>
<tr>
<td>FFHPC48</td>
<td>95 99</td>
<td>95 29.0</td>
<td>30.2</td>
<td>700 2.5</td>
</tr>
<tr>
<td>FFHPC49</td>
<td>100 104</td>
<td>100 30.5</td>
<td>31.7</td>
<td>670 2.4</td>
</tr>
</tbody>
</table>

- **Footnotes**:
  - Single-phase current shown.
  - Tolerance on cable length is –0% to +1%.
  - All heating cables supplied with 3/4-in NPT reversed gland and pulling eye.
  - Type FFHPC cables supplied with 7 ft (2.1 m) long cold lead.

### Example: MI heating cables in conduit

- Supply voltage: 208 V
- Freezer (Side A) length: 80 ft (24.4 m) [from Step 1]
- Catalog number: FFHPC30
- Power output: 475 W
Step 3 Determine the heating cable conduit spacing and freezer load

FOR RAYSOl AND MI CABLE SYSTEMS

In this step you will determine the conduit spacing, and freezer loads for the RaySol or MI heating cable systems. Use the freezer operating temperature and the floor insulation R-value to select the correct spacing shown in Table 4. If your calculated R-value or freezer operating temperature does not match the values in the table, use the values that give the closer spacing.

Within each cell in Table 4, there are two numbers: conduit spacing and freezer load. Freezer load is the additional cooling load imposed on the cooling system by the freezer frost heave prevention heating cable. It is the heat transferred through the insulation into the freezer, expressed in W/ft² (W/m²) of floor area.

### Table 4: RaySol and MI Conduit Spacing and Freezer Load

<table>
<thead>
<tr>
<th>Freezer operating temperature</th>
<th>Conduit spacing in [cm]</th>
<th>R-10 (W/ft² [W/m²])</th>
<th>R-20 (W/ft² [W/m²])</th>
<th>R-30 (W/ft² [W/m²])</th>
<th>R-40 (W/ft² [W/m²])</th>
</tr>
</thead>
<tbody>
<tr>
<td>30°F [-1°C]</td>
<td>96 (244)</td>
<td>96 (244)</td>
<td>96 (244)</td>
<td>96 (244)</td>
<td></td>
</tr>
<tr>
<td>Freezer load</td>
<td>0.7 (8)</td>
<td>0.4 (4)</td>
<td>0.3 (3)</td>
<td>0.2 (2)</td>
<td></td>
</tr>
<tr>
<td>20°F [-7°C]</td>
<td>81 (206)</td>
<td>96 (244)</td>
<td>96 (244)</td>
<td>96 (244)</td>
<td></td>
</tr>
<tr>
<td>Freezer load</td>
<td>0.8 (9)</td>
<td>0.5 (5)</td>
<td>0.3 (3)</td>
<td>0.3 (3)</td>
<td></td>
</tr>
<tr>
<td>10°F [-12°C]</td>
<td>63 (160)</td>
<td>96 (244)</td>
<td>96 (244)</td>
<td>96 (244)</td>
<td></td>
</tr>
<tr>
<td>Freezer load</td>
<td>1.0 (11)</td>
<td>0.6 (6)</td>
<td>0.4 (4)</td>
<td>0.3 (3)</td>
<td></td>
</tr>
<tr>
<td>0°F [-18°C]</td>
<td>51 (130)</td>
<td>84 (213)</td>
<td>96 (244)</td>
<td>96 (244)</td>
<td></td>
</tr>
<tr>
<td>Freezer load</td>
<td>1.2 (13)</td>
<td>0.8 (9)</td>
<td>0.5 (5)</td>
<td>0.4 (4)</td>
<td></td>
</tr>
<tr>
<td>-10°F [-23°C]</td>
<td>42 (107)</td>
<td>72 (183)</td>
<td>96 (244)</td>
<td>96 (244)</td>
<td></td>
</tr>
<tr>
<td>Freezer load</td>
<td>1.5 (16)</td>
<td>0.8 (9)</td>
<td>0.6 (6)</td>
<td>0.5 (5)</td>
<td></td>
</tr>
<tr>
<td>-20°F [-29°C]</td>
<td>36 (91)</td>
<td>63 (160)</td>
<td>87 (221)</td>
<td>96 (244)</td>
<td></td>
</tr>
<tr>
<td>Freezer load</td>
<td>1.8 (19)</td>
<td>1.0 (11)</td>
<td>0.6 (6)</td>
<td>0.5 (5)</td>
<td></td>
</tr>
<tr>
<td>-30°F [-34°C]</td>
<td>33 (84)</td>
<td>57 (145)</td>
<td>78 (198)</td>
<td>93 (236)</td>
<td></td>
</tr>
<tr>
<td>Freezer load</td>
<td>2.0 (22)</td>
<td>1.1 (12)</td>
<td>0.8 (9)</td>
<td>0.6 (6)</td>
<td></td>
</tr>
<tr>
<td>-40°F [-40°C]</td>
<td>30 (76)</td>
<td>51 (130)</td>
<td>69 (175)</td>
<td>84 (213)</td>
<td></td>
</tr>
<tr>
<td>Freezer load</td>
<td>2.3 (25)</td>
<td>1.2 (13)</td>
<td>0.8 (9)</td>
<td>0.7 (8)</td>
<td></td>
</tr>
</tbody>
</table>

Example: RaySol and MI heating cables in conduit

- Freezer operating temperature: -20°F [-29°C] (from Step 1)
- Insulation R-value: R-40 (40 ft²·°F·hr/Btu) (from Step 1)
- Conduit spacing: 96 in (244 cm)
- Freezer load: 0.5 W/ft² (5 W/m²)
**Step 4A** Determine the heating cable layout and length

**STEP 4A FOR RAYSOL HEATING CABLE IN CONDUIT**

**Estimate number of conduit runs**

To calculate the number of conduit runs and heating cable length from your scaled drawing, refer to Fig. 9 and Fig. 10.

Define Side “A” as the side that is parallel to the conduit runs. Side “A” cannot be greater than the maximum circuit length for RaySol (Table 5).

Define Side “B” as the side that is perpendicular to the conduit runs. Refer to Fig. 9 and Fig. 10 for examples of Side A and Side B.

Two basic types of heating cable layouts are used:

1. The hairpin layout (Fig. 9) is used both in smaller freezers where it results in material and labor savings over the straight run layout (Fig. 10), and in other freezers where only one wall of the freezer is accessible for mounting junction boxes.

2. The straight run layout (Fig. 10) is used when the freezer dimension exceeds one-half the maximum heating cable circuit length (insufficient heating cable allowed for a run down and back).

Calculate the number of estimated conduit runs as follows:

\[
\text{Estimated number of conduit runs} = \frac{\text{Side B (ft)} \times 12}{\text{Conduit spacing (in)}} + \frac{\text{Side B (m)} \times 100}{\text{Conduit spacing (cm)}}
\]
Round the estimated number of conduit runs to the next larger whole number. For example, if the result is 7.4, then 8 conduit runs are required. It may be necessary to recalculate the conduit spacing following this step.

**Example: RaySol heating cables in conduit**

<table>
<thead>
<tr>
<th>Side B length</th>
<th>40 ft [12.2 m] (from Step 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduit spacing</td>
<td>96 in [244 cm] (from Step 3)</td>
</tr>
<tr>
<td>Number of conduit runs</td>
<td></td>
</tr>
<tr>
<td>Side B x 12 / spacing (in)</td>
<td>40 ft x 12 / 96 in = 5</td>
</tr>
<tr>
<td>Side B x 100 / spacing [cm]</td>
<td>12.2 m x 100 / 244 cm = 5</td>
</tr>
</tbody>
</table>

**Estimate the heating cable length required for conduit runs**

Multiply the conduit length (Side A) by the number of conduit runs to determine the length of heating cable required for the freezer area.

\[
\text{Heating cable length} = \text{Conduit length (Side A)} \times \text{number of conduit runs}
\]

**Example: RaySol heating cables in conduit (continued)**

| Heating cable length required | 80 ft [24.4 m] x 5 = 400 ft [122 m] |

**Determine the maximum circuit length for the heating cable length and layout**

For the appropriate supply voltage, use Table 5 to select the maximum circuit length which is closest to, but greater than the length calculated. Select the smallest appropriate circuit breaker size.

**TABLE 5  RAYSOLO MAXIMUM CIRCUIT LENGTHS IN FEET (METERS)**

<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>180</td>
<td>54.9</td>
<td>305</td>
<td>93.0</td>
</tr>
<tr>
<td>20</td>
<td>240</td>
<td>73.2</td>
<td>410</td>
<td>125.0</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>

If the heating cable length required is greater than the maximum circuit length, multiple circuits must be used.

When Side A x 2 is less than or equal to the maximum circuit length, then the conduit run can be looped into the hairpin layout (Fig. 9). In a hairpin configuration, when you have an odd number of conduit runs, one run will be a straight run as shown in Fig. 11.
**Example: RaySol heating cables in conduit (continued)**

Heating cable length required: 400 ft (122 m)
Supply voltage: 208 V (from Step 1)
Maximum circuit length: 410 ft (125 m) (from Table 5)
Number of circuits: 1
Power supply: One 20 A circuit breaker
Run in two hairpin loops and one straight run (see Fig. 11)

**Ground-Fault Protection**

A 30-mA ground-fault protection device (GFPD) must be used to provide protection from arcing or fire, and to comply with warranty requirements, agency certifications, and national electrical codes. If the heating cable is improperly installed, or physically damaged, sustained arcing or fire could result. If arcing does occur, the fault current may be too low to trip conventional circuit breakers.
**Determine 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 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 heating cable length you already calculated, and then add heating cable allowances, as follows:

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

**TABLE 6 RAYSOl ADDITIONAL HEATING CABLE ALLOWANCE**

<table>
<thead>
<tr>
<th>Heating cable</th>
<th>Description</th>
<th>Hairpin layout</th>
<th>Straight run layout</th>
</tr>
</thead>
<tbody>
<tr>
<td>End allowances</td>
<td>From end of conduit to junction box</td>
<td>8 ft per hairpin conduit</td>
<td>8 ft per straight run conduit</td>
</tr>
<tr>
<td>Connection kit allowances</td>
<td>Required to assemble the connection kit</td>
<td>4 ft per kit</td>
<td>4 ft per kit</td>
</tr>
</tbody>
</table>

The end allowance is the length of heating cable installed in protective conduit between the heated floor and the power connection junction box. The connection kit allowance (usually 2 ft per end) is the length of heating cable inside the power connection junction box.

**Example: RaySol heating cables in conduit (continued)**

Heating cable length required 400 ft (122 m)

End allowance

- 2 hairpin runs = 16 ft (4.9 m)
- 1 straight run = 8 ft (2.4 m)

Connection kit allowance

- 2 hairpin runs (2 FTC-XC kits) = 8 ft (2.4 m)
- 1 straight run (1 FTC-XC kit) = 4 ft (1.2 m)

Total heating cable allowance

16 ft (4.9 m) + 8 ft (2.4 m) + 4 ft (1.2 m) = 36 ft (11 m)

Total heating cable length required 400 ft (122 m) + 36 ft (11 m)

- 436 ft (133 m) of RaySol-2

**Locate the junction boxes for a RaySol heating cable system**

The heating cable connects to the branch circuit wiring in a junction box using a Raychem FTC-XC power connection and end seal kit. The heating cable is routed from the subfloor to a junction box located above grade through protective conduit. In most freezer frost heave prevention applications, separate junction boxes are used for the power connection and end seal.
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.
- Do not design more than one run of heating cable per conduit.
- Arrange the conduit so it uniformly covers the area to be heated.
- Maintain the design conduit spacing within 4 in (10 cm).
- Do not extend the heating cable beyond the room or area in which it originates.
- Do not cross expansion or other subfloor joints.
- Do not route the conduit 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 circuit length allowed on a branch circuit breaker as given in Table 5.
- The maximum length of heating cable that can be pulled through conduit is 500 feet (150 m). The maximum total degree of conduit turn is 360 degrees.
- 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.

Record 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.
STEP 4b FOR MI HEATING CABLE IN CONDUIT

Estimate number of conduit runs

MI cables in conduit can only be installed using the straight run layout shown in Fig. 12.

![Diagram of conduit layout]

**Fig. 12 Layout for straight run example**

To calculate the number of conduit runs from your scaled drawing, refer to Fig. 12, and calculate as follows:

\[
\text{Estimated number of conduit runs} = \frac{\text{Side B (ft) \times 12}}{\text{Conduit spacing (in)}} \times \frac{\text{Side B (m) \times 100}}{\text{Conduit spacing (cm)}}
\]

Round the estimated number of conduit runs to the next larger whole number. For example, if the result is 7.4, then 8 conduit runs are required. It may be necessary to recalculate the conduit spacing following this step.

**Note:** If the heating cable was selected using the freezer width (Side B) in Step 2, use Side A in the above formula.
**Example: MI heating cables in conduit**

Side B length: 40 ft (12.2 m) (from Step 1)

Conduit spacing: 96 in (244 cm) (from Step 3)

Number of conduit runs:

- Side B x 12 / spacing (in) = 40 ft x 12 / 96 in = 5
- Side B x 100 / spacing (cm) = 12.2 m x 100 / 244 cm = 5

**Determine the number of MI heating cables**

Number of heating cables required = Number of conduit runs

**Example: MI heating cables in conduit (continued)**

- Heating cable: FFHPC30 (from Step 2)
- Number of conduit runs: 5
- Number of heating cables required: 5

**Locate the junction boxes for an MI heating cable system**

Raychem MI heating cables are factory terminated with 7 ft (2.1 m) long non-heating cold leads, making it possible to connect two or three heating cables to a single junction box. A Raychem D1297TERM4 may be used where two heating cables are connected in parallel. A junction box is only required for the power connection end.

**Lay out the MI heating cable runs, circuits, and junction boxes**

After determining the number of heating cables required, the number of circuits, and the junction box locations, do a trial layout. In making the trial layout, follow these recommendations:

- The conduits must be laid out in straight runs as shown in Fig. 12.
- Where cable lengths exceed 50 ft (15.2 m), the conduit must be accessible from both ends to allow long runs of cable to be pulled into the conduit.
- If it is necessary to stub-up the ends of the conduit, use a minimum 12 in (30 cm) radius as shown in Fig. 13.
- Arrange the conduits so that they uniformly cover the area to be heated.
- Maintain the design conduit spacing within 4 in (10 cm).
- Do not cross expansion or other subfloor joints.
- Do not route the conduit closer than 4 in (10 cm) to the edge of the subfloor, drains, anchors, or other material in the concrete.

![Diagram of conduit layout](image)
Step 5 Determine the electrical parameters

**5A FOR RAYSOL HEATING CABLE IN CONDUIT**

**Determine number of circuits**

For RaySol, the circuit breaker sizing was determined in Step 4 using Table 5. Record the number and ratings of the circuit breakers to be used on the worksheet.

A 30-mA ground-fault protection device (GFPD) must be used to provide protection from arcing or fire, and to comply with warranty requirements, agency certifications, and national electrical codes. If the heating cable is improperly installed, or physically damaged, sustained arcing or fire could result. If arcing does occur, the fault current may be too low to trip conventional 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 Thermal Management, 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:

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

Calculate the Total Transformer Load as follows:

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

**Example: RaySol heating cables in conduit**

- Circuit breaker size: One 20 A circuit (from Step 4)
- Supply voltage: 208 V (from Step 1)
- Circuit breaker load: \((20 \times 0.8 \times 208) / 1000 = 3.3 \text{ kW}\)
- Total transformer load: **3.3 kW**
5B FOR MI HEATING CABLE IN CONDUIT

For MI heating cable, the power output and current draw is shown in Table 3. Heating cables may be individually connected to circuit breakers, but to reduce the number of circuits, cables may be connected in parallel. When connecting heating cables in parallel, total the individual heating cable currents to 80% of the circuit breaker rating.

**Determine number of circuits**

Refer to Table 3 to determine the Amps for the selected heating cable. Next, calculate the total Amps to determine the circuit breaker requirements, as follows:

\[ \text{Total Amps} = \text{Amps per cable} \times \text{Number of heating cables required} \]

From the Total Amps, determine the most appropriate circuit breaker size and number of circuit breakers.

A 30-mA ground-fault protection device (GFPD) must be used to provide protection from arcing or fire, and to comply with warranty requirements, agency certifications, and national electrical codes. If the heating cable is improperly installed, or physically damaged, sustained arcing or fire could result. If arcing does occur, the fault current may be too low to trip conventional 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 Thermal Management, 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:

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

**Example: MI heating cables in conduit**

- **Amps/cable:** 2.3 A (from Table 3)
- **Total Amps:** 2.3 A x 5 = 11.5 A [5 cables wired in parallel on one circuit]
- **Circuit breaker size:** 15 A circuit breaker, 80% loading 12 A
- **Number of circuit breakers:** 1

- **Cable power output:** 475 W (from Step 2)
- **Number of cables:** 5 (from Step 4)
- **Total Transformer load:** \( \frac{(475 \text{ W} \times 5)}{1000} = 2.4 \text{ kW} \)

Record the number and ratings of the circuit breakers to be used and total transformer load on the worksheet.
1. Determine the freezer configuration
2. Select the heating cable
3. Determine heating cable conduit spacing and freezer load
4. Determine the heating cable 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

For RaySol systems, determine the number of junction boxes, power connections, end seals and splice kits required.

- Hairpin and straight layouts have one junction box per conduit end (see Fig. 9 and Fig. 10).

For MI systems, determine the number of junction boxes required.

- Straight run layout has one junction box per conduit run (see Fig. 12 for MI cable).

**SELECT JUNCTION BOX**

For RaySol and MI cable, use a 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. Metal junction boxes, such as the Raychem D1297TERM4, are recommended for MI cable.

### TABLE 7 CONNECTION KITS AND ACCESSORIES

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Description</th>
<th>Standard packaging</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTC-XC</td>
<td>Power connection and end seal. (Junction box not included)</td>
<td>1</td>
<td>1 per conduit run</td>
</tr>
<tr>
<td>FTC-HST</td>
<td>Low-profile splice/tee</td>
<td>2</td>
<td>As required (for use inside intermediate pull box or cable tray)</td>
</tr>
<tr>
<td>RayClic-E</td>
<td>Extra end seal</td>
<td>1</td>
<td>Replacement end seal</td>
</tr>
<tr>
<td>D1297TERM4</td>
<td>A cast aluminum junction box (NEMA 3) for installation in nonhazardous and CID2 locations. Three 1/2-in 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. (for MI only) Enclosure dimensions: 6 in x 6 in x 4 in (150 mm x 150 mm x 100 mm).</td>
<td>1</td>
<td>For MI systems only</td>
</tr>
</tbody>
</table>
### Example: RaySol heating cables in conduit

- **Power connection and end seal kit**: FTC-XC
- **Quantity**: 3
- **Junction box**: Contractor supplied
- **Quantity**: 6

### Example: MI heating cables in conduit

- **Junction box**: D1297TERM
- **Quantity**: 5

---

**Step 7: Select the control system**

The following control systems are suitable for both RaySol and MI heating cable frost heave protection systems. For MI cable, a temperature controller must be used to maintain the subfloor temperature at 40°F (5°C). For RaySol or MI heating cable installations where temperature control and temperature monitoring is desired, a Thermal Management Raychem C910-485 or Raychem ACS-30 controller is recommended.

### TABLE 8 TEMPERATURE CONTROL OPTIONS

<table>
<thead>
<tr>
<th>Features</th>
<th>Raychem ECW-GF</th>
<th>Raychem C910-485</th>
<th>Raychem 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>RTD ¹</td>
<td>See data sheet</td>
</tr>
<tr>
<td>Sensor length</td>
<td>25 ft</td>
<td>Varies</td>
<td>&quot;</td>
</tr>
<tr>
<td>Set point range</td>
<td>32°F to 200°F</td>
<td>-0°F to 200°F</td>
<td>&quot;</td>
</tr>
<tr>
<td>Enclosure</td>
<td>NEMA 4X</td>
<td>NEMA 4X</td>
<td>&quot;</td>
</tr>
<tr>
<td>Deadband</td>
<td>2°F to 10°F</td>
<td>1°F to 10°F</td>
<td>&quot;</td>
</tr>
<tr>
<td>Enclosure limits</td>
<td>-40°F to 140°F</td>
<td>-40°F to 140°F</td>
<td>&quot;</td>
</tr>
<tr>
<td>Switch rating</td>
<td>30 A</td>
<td>30 A</td>
<td>&quot;</td>
</tr>
<tr>
<td>Switch type</td>
<td>DPST</td>
<td>DPST</td>
<td>&quot;</td>
</tr>
<tr>
<td>Electrical rating</td>
<td>100–277 V</td>
<td>100–277 V</td>
<td>&quot;</td>
</tr>
<tr>
<td>Approvals</td>
<td>c-UL-us</td>
<td>c-CSA-us</td>
<td>&quot;</td>
</tr>
<tr>
<td>Ground-fault protection</td>
<td>30 mA fixed</td>
<td>20 mA to 100 mA</td>
<td>&quot;</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>&quot;</td>
</tr>
<tr>
<td>Dry contact relay</td>
<td>2 A at 48 Vdc</td>
<td>48 Vac/dc, 500 mA max.</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

¹ Ordered separately

² The C910-485 is available to provide RS-485 communication capability. Connect to the BMS using Raychem ProtoNode multi-protocol gateways.

---

**Freezer Frost Heave Prevention System Design Steps (in Conduit)**

1. Determine the freezer configuration
2. Select the heating cable
3. Determine heating cable conduit spacing and freezer load
4. Determine the heating cable 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
### Table 9: Control Systems

<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) 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 Raychem C910-485 is a compact, full featured, microprocessor-based, single-point commercial heating cable controller. The C910-485 provides control and monitoring of electrical heating cable circuits for commercial heating applications, with built-in ground-fault protection. The C910-485 can be set to monitor and alarm for high and low temperature, high and low current, ground-fault level, and voltage. Communications modules are available for remote control and configuration.</td>
</tr>
<tr>
<td>ACS-UIT2, ACS-PCM2-5</td>
<td>The Raychem 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 Raychem 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 electro-mechanical relays rated at 30 A up to 277 V.</td>
</tr>
<tr>
<td>Protonode-RER</td>
<td>The Raychem ProtoNode is an external, high performance multi-protocol gateway for customers needing protocol translation between Building Management Systems (BMS) and the Raychem ACS-30 or C910-485 controllers. The ProtoNode-RER is for BACnet® or Metasys® N2 systems.</td>
</tr>
<tr>
<td>RTD-200, RTD10CS, RTD50CS</td>
<td>Stainless steel jacketed three-wire RTD (Resistance Temperature Detector) used with Raychem C910-485 and ACS-30 controllers. RTD-200: 3-in (76 mm) temperature sensor with a 6-ft (1.8 m) lead wire and 1/2-in NPT bushing RTD10CS: temperature sensor with a 10-ft (3 m) flexible armor, 18-in (457 mm) lead wire and 1/2-inch NPT bushing RTD50CS: temperature sensor with a 50-ft (3 m) flexible armor, 18-in (457 mm) lead wire and 1/2-inch NPT bushing</td>
</tr>
</tbody>
</table>

**Example: RaySol and MI heating cables in conduit**

<table>
<thead>
<tr>
<th>Electronic thermostat</th>
<th>Raychem C910-485</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
<td>1</td>
</tr>
</tbody>
</table>
**Step 8** Select the power distribution

**FOR RAYSOL AND MI HEATING CABLE IN CONDUIT**

Power to the heating cables can be provided in several ways:
- Directly to the power connection kits (RaySol only)
- Directly through the temperature controller
- Through external contactors or through HTPG power distribution panels

**Single circuit control**

Heating cable circuits that do not exceed the current rating of the selected controller can be switched directly (Fig. 14). When the total electrical load exceeds the rating of the controller, an external contactor is required.

RaySol systems without temperature control can be connected directly to the power connection kits from the ground-fault circuit breakers in subpanels.

**Group control**

If the controller will activate multiple circuits (group control) then an external contactor must be used (Fig. 14).

---

**Fig. 14 Single circuit and group control**
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 freeze protection and 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. 15 HTPG power distribution panel

Three-phase, 4 wire supply (Wye)

Fig. 16 HTPG power schematic
### TABLE 10 POWER DISTRIBUTION

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heat-tracing power distribution panel with ground-fault and monitoring for group control.</td>
</tr>
</tbody>
</table>

#### Power Distribution and Control Panels

#### 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.
Design Step by Step MI Heating Cables Directly Embedded

Embedding cables directly in sand (recommended), concrete, or compacted fill subfloors has the advantage of simpler installation and reduced costs. The number of electrical circuits can be minimized considerably compared to a similar installation using conduit. If embedded in a concrete subfloor below the insulation, the cable must not cross any joints in the subfloor.

Follow these steps to design your system:

1. Determine the freezer configuration
2. Determine heat loss and freezer load
3. Select the heating cable, layout and length
4. Determine the heating cable spacing
5. Determine the electrical parameters
6. Select the accessories
7. Select the control system
8. Select the power distribution
9. Complete the Bill of Materials

The "MI Cables Directly Embedded Freezer Frost Heave Prevention Design Worksheet" on page 54 is included to help you document the project parameters that you will need for your project’s Bill of Materials.
Step 1 Determine the freezer configuration

GATHERING INFORMATION
The following information is required to complete the freezer frost heave prevention system design.
- Size and layout of freezer or ice arena
- Freezer operating 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 location and size of obstacles, such as floor drains, pipe penetrations, columns, fixtures, and voltage supply location.

Fig. 17 Typical freezer example – single-phase

DETERMINE FREEZER OPERATING TEMPERATURE
Determine the temperature at which your freezer operates. If it operates at more than one temperature, or if the operating temperature may be changed in the future, base the design on the lowest anticipated operating temperature.

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: MI heating cables directly embedded – Single-phase

Area \(40 \text{ ft} \times 20 \text{ ft} = 800 \text{ ft}^2\)
\((12.2 \text{ m} \times 6.1 \text{ m} = 74 \text{ m}^2)\)

Freezer operating temperature \(-30^\circ\text{F} (-34^\circ\text{C})\)

Insulation R-value R-20 (20 \text{ ft}^2\cdot^\circ\text{F} \cdot \text{hr}/\text{Btu})

Supply voltage 208 V, single-phase

Example: MI heating cables directly embedded – Three-phase

Area \(80 \text{ ft} \times 80 \text{ ft} = 6400 \text{ ft}^2\)
\((24.4 \text{ m} \times 24.4 \text{ m} = 595 \text{ m}^2)\)

Freezer operating temperature \(-20^\circ\text{F} (-29^\circ\text{C})\)

Insulation R-value R-20 (20 \text{ ft}^2\cdot^\circ\text{F} \cdot \text{hr}/\text{Btu})

Supply voltage 208 V, three-phase

### Step 2 Determine heat loss and freezer load

In Table 11, we have calculated the heat loss for directly embedded MI heating cable systems based on the freezer temperatures and the floor insulation R-values; from this table, you will select your design power and freezer load. If your calculated R-value or freezer operating temperature does not match the values in the table, use the values that give the higher design power.

Within each cell, there are two numbers; design power and freezer load. Freezer load is the additional cooling load imposed on the cooling system by the freezer frost heave prevention heating cable. It is the heat transferred through the insulation into the freezer, expressed in W/ft\(^2\) (W/m\(^2\)) of floor area.
### Table 11 MI Heating Cable: Design Power Requirement and Freezer Load Based on 40°F (5°C) Control

<table>
<thead>
<tr>
<th>Freezer operating temperature</th>
<th></th>
<th>R-10</th>
<th>R-20</th>
<th>R-30</th>
<th>R-40</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Floor insulation R-value (ft²·°F·hr/Btu)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R-10</td>
<td>R-20</td>
<td>R-30</td>
<td>R-40</td>
<td></td>
</tr>
<tr>
<td>30°F (–1°C)</td>
<td>Design power W/ft² [W/m²]</td>
<td>0.5</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Freezer load W/ft² [W/m²]</td>
<td>0.2</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>20°F (–7°C)</td>
<td>Design power W/ft² [W/m²]</td>
<td>0.6</td>
<td>0.8</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>Freezer load W/ft² [W/m²]</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>10°F (–12°C)</td>
<td>Design power W/ft² [W/m²]</td>
<td>0.9</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Freezer load W/ft² [W/m²]</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>0°F (–18°C)</td>
<td>Design power W/ft² [W/m²]</td>
<td>1.1</td>
<td>1.3</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Freezer load W/ft² [W/m²]</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>–10°F (–23°C)</td>
<td>Design power W/ft² [W/m²]</td>
<td>1.4</td>
<td>1.5</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Freezer load W/ft² [W/m²]</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>–20°F (–29°C)</td>
<td>Design power W/ft² [W/m²]</td>
<td>1.6</td>
<td>1.8</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Freezer load W/ft² [W/m²]</td>
<td>0.9</td>
<td>1.0</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>–30°F (–34°C)</td>
<td>Design power W/ft² [W/m²]</td>
<td>1.7</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Freezer load W/ft² [W/m²]</td>
<td>1.1</td>
<td>1.1</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>–40°F (–40°C)</td>
<td>Design power W/ft² [W/m²]</td>
<td>2.0</td>
<td>2.3</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>Freezer load W/ft² [W/m²]</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**Example: MI heating cables directly embedded – Single-phase**

- Freezer operating temperature: –30°F (–34°C) (from Step 1)
- Insulation R-value: R-20 (20 ft²·°F·hr/Btu) (from Step 1)
- Design power: 1.1 W/ft² [11.8 W/m²]
- Freezer load: 1.1 W/ft² [11.8 W/m²]

**Example: MI heating cables directly embedded – Three-phase**

- Freezer operating temperature: –20°F (–29°C) (from Step 1)
- Insulation R-value: R-20 (20 ft²·°F·hr/Btu) (from Step 1)
- Design power: 0.9 W/ft² [9.7 W/m²]
- Freezer load: 1.0 W/ft² [10.8 W/m²]
Step 3: Select the heating cable, layout and length

To select the correct MI heating cable for the heated area, you must determine the wattage required for the area or subsection area.

For small freezers, one heating cable may be sufficient. For large freezers, it may be necessary to divide the freezer into two or more equal subsection areas. To balance the load in a three-phase circuit, three cables will be required, or a multiple of three cables when more than one three-phase circuit is required. If the heating cables are to be embedded in a concrete subfloor, divide the area so that the heating cables will not cross any joints in the subfloor.

The heating cables shown in Table 12 are general purpose cables and may be used for a variety of applications depending on the supply voltage; the heating cables in Table 13 have been optimized for frost heave prevention applications. If assistance is required to select heating cables for irregular shaped areas or applications outside the scope of this design guide, contact your Thermal Management representative for assistance in designing a custom heating cable.

SINGLE-PHASE SUPPLY

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

- Divide large freezer areas into equal subsection areas, if possible.
- Calculate the power required for the total area (small freezers) or for each subsection area (large freezers) by multiplying the design power (from Table 11) 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 12 or Table 13 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 (see example following).

**Note:** If two or more cables in the Tables meet the requirements, use the cable with the lower wattage.
In cases where the freezer area has been divided into equal subsections, select the appropriate number of heating cables. Where heating cables are directly embedded in concrete subfloors, calculate the wattage required for each area bounded by joints in the subfloor and select an appropriate cable for each area.

**Example: M1 heating cables directly embedded – Single-phase**

- **Area**: 800 ft² (74 m²) [See Fig. 18]
- **Design power**: 1.1 W/ft² (11.8 W/m²) [from Step 2]
- **Power required**: Design power x Area = 1.1 W/ft² x 800 ft² = 880 W (11.8 W/m² x 74 m² = 880 W)
- **Supply voltage**: 208 V, single-phase [from Step 1]
- **Catalog number**: SUB19
- **Cable wattage**: 885 W
- **Heated length**: 245 ft (74.7 m)
- **Quantity**: 1
THREE-PHASE SUPPLY

Designing the frost heave prevention 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 freezers.

Three-phase voltages include 208/120 V, 480/277 V, and 600/347 V. When selecting heating cables for three-phase voltages, cable layout will be easier if the heating cables are wye connected (Fig. 19); therefore select the cables based on the phase-to-neutral voltage (e.g., select 277 V cables for a 480 V supply).

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

- Calculate the “Power required” by multiplying the design power from Table 11 by the total freezer area.
- Divide the total freezer area by three to determine the “Area coverage for each cable.”
- Calculate the “Wattage for each cable” by dividing the “Power required” by three.

\[
\text{Wattage for each cable} = \frac{\text{Design power} \times \text{Total freezer area}}{3}
\]

Simply select the heating cable from Table 12 on page 38 or Table 13 on page 39 based on the area coverage for each cable. Under the appropriate voltage, make sure that the area coverage for each cable 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 “Wattage for each cable” (see example following). Three of the same cables are required for balanced three-phase systems.

⚠ Note: If two or more cables in the Tables meet the requirements, use the cable with the lower wattage.

⚠ Note: For very large freezers, it may be necessary to divide the freezer into subsections and use two or more three-phase circuits.
Example: MI heating cables directly embedded – Three-phase

- **Area**: 6400 ft² [595 m²] (see Fig. 19)
- **Design power**: 0.9 W/ft² [9.7 W/m²] (from Step 2)
- **Power required**: 
  
  \[
  \text{(Design Power x Area)} = \\
  (0.9 \text{ W/ft}^2 \times 6400 \text{ ft}^2) = 5760 \text{ W} \\
  (9.7 \text{ W/m}^2 \times 595 \text{ m}^2) = 5760 \text{ W}
  \]
- **Area coverage for each cable**: 
  
  \[
  \frac{\text{Area}}{3} = \frac{6400 \text{ ft}^2}{3} = 2133 \text{ ft}^2 \\
  \frac{595 \text{ m}^2}{3} = 198.3 \text{ m}^2
  \]
- **Wattage for each cable**: 
  
  \[
  \frac{\text{Power required}}{3} = \frac{5760 \text{ W}}{3} = 1920 \text{ W}
  \]
- **Supply voltage**: 208 V, three-phase (from Step 1) (select 120 volt cable for wye connection)
- **Catalog number**: SUB8
- **Cable wattage**: 2300 W
- **Cable voltage**: 120 V
- **Heated length**: 550 ft [167.6 m]
- **Quantity**: 3
<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Area coverage</th>
<th>Cable wattage</th>
<th>Heated length</th>
<th>Heating cable current</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min (ft²)</td>
<td>Max (ft²)</td>
<td>Min (m²)</td>
<td>Max (m²)</td>
</tr>
<tr>
<td><strong>120 V and 208 V, three-phase wye</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUA3</td>
<td>205</td>
<td>700</td>
<td>19.1</td>
<td>65.1</td>
</tr>
<tr>
<td>SUA4</td>
<td>220</td>
<td>340</td>
<td>20.4</td>
<td>31.6</td>
</tr>
<tr>
<td>SUA7</td>
<td>300</td>
<td>480</td>
<td>27.9</td>
<td>44.6</td>
</tr>
<tr>
<td>SUA8</td>
<td>310</td>
<td>885</td>
<td>28.8</td>
<td>82.2</td>
</tr>
<tr>
<td>SUB1</td>
<td>420</td>
<td>660</td>
<td>39.0</td>
<td>61.3</td>
</tr>
<tr>
<td>SUB2</td>
<td>400</td>
<td>1200</td>
<td>37.2</td>
<td>111.5</td>
</tr>
<tr>
<td>SUB3</td>
<td>520</td>
<td>1400</td>
<td>48.3</td>
<td>130.1</td>
</tr>
<tr>
<td>SUB4</td>
<td>600</td>
<td>1600</td>
<td>55.8</td>
<td>148.7</td>
</tr>
<tr>
<td>SUB5</td>
<td>750</td>
<td>1300</td>
<td>69.7</td>
<td>120.8</td>
</tr>
<tr>
<td>SUB6</td>
<td>780</td>
<td>1875</td>
<td>72.5</td>
<td>174.3</td>
</tr>
<tr>
<td>SUB7</td>
<td>940</td>
<td>1550</td>
<td>87.4</td>
<td>144.1</td>
</tr>
<tr>
<td>SUB8</td>
<td>930</td>
<td>2750</td>
<td>86.4</td>
<td>255.6</td>
</tr>
<tr>
<td>SUB9</td>
<td>1250</td>
<td>3150</td>
<td>116.2</td>
<td>292.8</td>
</tr>
<tr>
<td>SUB10</td>
<td>1700</td>
<td>3585</td>
<td>158.0</td>
<td>333.2</td>
</tr>
<tr>
<td><strong>208 V</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUA1</td>
<td>260</td>
<td>540</td>
<td>24.2</td>
<td>50.2</td>
</tr>
<tr>
<td>SUA6</td>
<td>650</td>
<td>1320</td>
<td>60.4</td>
<td>122.7</td>
</tr>
<tr>
<td>SUB19</td>
<td>350</td>
<td>1225</td>
<td>32.5</td>
<td>113.8</td>
</tr>
<tr>
<td>SUB20</td>
<td>480</td>
<td>1700</td>
<td>44.6</td>
<td>158.0</td>
</tr>
<tr>
<td>SUB21</td>
<td>650</td>
<td>2200</td>
<td>60.4</td>
<td>204.5</td>
</tr>
<tr>
<td>SUB22</td>
<td>820</td>
<td>2625</td>
<td>76.2</td>
<td>244.0</td>
</tr>
<tr>
<td><strong>240 V</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUB19</td>
<td>350</td>
<td>1225</td>
<td>32.5</td>
<td>113.8</td>
</tr>
<tr>
<td>SUB20</td>
<td>480</td>
<td>1700</td>
<td>44.6</td>
<td>158.0</td>
</tr>
<tr>
<td>SUB21</td>
<td>650</td>
<td>2200</td>
<td>60.4</td>
<td>204.5</td>
</tr>
<tr>
<td>SUB22</td>
<td>820</td>
<td>2625</td>
<td>76.2</td>
<td>244.0</td>
</tr>
<tr>
<td><strong>277 V and 480 V, three-phase wye</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUB19</td>
<td>400</td>
<td>1225</td>
<td>37.2</td>
<td>113.8</td>
</tr>
<tr>
<td>SUB20</td>
<td>550</td>
<td>1700</td>
<td>51.1</td>
<td>158.0</td>
</tr>
<tr>
<td>SUB21</td>
<td>720</td>
<td>2200</td>
<td>66.9</td>
<td>204.5</td>
</tr>
<tr>
<td>SUB22</td>
<td>940</td>
<td>2625</td>
<td>87.4</td>
<td>244.0</td>
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<tr>
<td><strong>347 V and 600 V, three-phase wye</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SUB11</td>
<td>540</td>
<td>1125</td>
<td>50.2</td>
<td>104.6</td>
</tr>
<tr>
<td>SUB12</td>
<td>770</td>
<td>1550</td>
<td>71.6</td>
<td>144.1</td>
</tr>
<tr>
<td>SUB13</td>
<td>1060</td>
<td>2140</td>
<td>98.5</td>
<td>199.9</td>
</tr>
<tr>
<td>SUB14</td>
<td>1440</td>
<td>2740</td>
<td>133.8</td>
<td>254.6</td>
</tr>
</tbody>
</table>

1 Tolerance on heating cable length is –0% to +3%
2 Single-phase current shown

Note: Type SUA cables supplied with 7 ft (2.1 m) long cold lead; type SUB cables supplied with 15 ft (4.6 m) long cold leads.
### TABLE 13 SELECTION TABLE FOR MI HEATING CABLES FOR DIRECTLY EMBEDDED CABLES

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Area coverage</th>
<th>Cable wattage (W)</th>
<th>Heated length 1</th>
<th>Heating cable current</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min (ft²)</td>
<td>Max (ft²)</td>
<td>Min (m²)</td>
<td>Max (m²)</td>
<td>(ft)</td>
</tr>
<tr>
<td>120 V and 208 V, three-phase Wye</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>FFHP1</td>
<td>163</td>
<td>290</td>
<td>15.1</td>
<td>27.0</td>
<td>405</td>
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<td>FFHP2</td>
<td>205</td>
<td>360</td>
<td>19.1</td>
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<td>30.5</td>
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<td>36.4</td>
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<td>980</td>
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<td>68.1</td>
<td>121.7</td>
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</tr>
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<td>148.7</td>
<td>2250</td>
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<tr>
<td>FFHP12</td>
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<td>2130</td>
<td>110.2</td>
<td>198.0</td>
<td>2965</td>
</tr>
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<td>2640</td>
<td>136.6</td>
<td>245.4</td>
<td>3675</td>
</tr>
<tr>
<td>FFHP14</td>
<td>1862</td>
<td>3320</td>
<td>173.0</td>
<td>308.6</td>
<td>4650</td>
</tr>
<tr>
<td>208 V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFHP15</td>
<td>281</td>
<td>505</td>
<td>26.1</td>
<td>46.9</td>
<td>700</td>
</tr>
<tr>
<td>FFHP16</td>
<td>352</td>
<td>630</td>
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<tr>
<td>FFHP17</td>
<td>401</td>
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<td>37.2</td>
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<td>FFHP18</td>
<td>492</td>
<td>880</td>
<td>45.7</td>
<td>81.8</td>
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<tr>
<td>FFHP19</td>
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<td>52.8</td>
<td>94.3</td>
<td>1420</td>
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<tr>
<td>FFHP20</td>
<td>678</td>
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<td>63.0</td>
<td>112.9</td>
<td>1700</td>
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<tr>
<td>FFHP21</td>
<td>778</td>
<td>1390</td>
<td>72.3</td>
<td>129.2</td>
<td>1945</td>
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<tr>
<td>FFHP22</td>
<td>901</td>
<td>1600</td>
<td>83.8</td>
<td>148.7</td>
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<tr>
<td>FFHP23</td>
<td>1098</td>
<td>1970</td>
<td>102.1</td>
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<tr>
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<tr>
<td>FFHP25</td>
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<td>2785</td>
<td>144.4</td>
<td>258.8</td>
<td>3885</td>
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<td>240 V</td>
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<td></td>
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<tr>
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<tr>
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<td>725</td>
<td>37.9</td>
<td>67.4</td>
<td>1020</td>
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<td>830</td>
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<td>61.0</td>
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<td>1640</td>
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<tr>
<td>FFHP31</td>
<td>786</td>
<td>1395</td>
<td>73.1</td>
<td>129.6</td>
<td>1965</td>
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<td>1600</td>
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<td>96.5</td>
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<td>118.4</td>
<td>210.0</td>
<td>3185</td>
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<td>2610</td>
<td>136.7</td>
<td>242.6</td>
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<tr>
<td>FFHP36</td>
<td>1800</td>
<td>3200</td>
<td>167.3</td>
<td>297.4</td>
<td>4500</td>
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</tbody>
</table>

1 Tolerance on heating cable length is –0% to +3%.
2 Single-phase current shown

**Note:** Type FFHP cables supplied with 15 ft (4.6 m) long cold leads.
### TABLE 13 SELECTION TABLE FOR MI HEATING CABLES FOR DIRECTLY EMBEDDED CABLES

<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>
</tr>
<tr>
<td><strong>277 V and 480 V, three-phase wye</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>FFHP37</td>
<td>375</td>
<td>670</td>
<td>34.9</td>
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<td>FFHP38</td>
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<td>60.9</td>
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<td>70.4</td>
<td>125.5</td>
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<td>FFHP42</td>
<td>908</td>
<td>1610</td>
<td>84.4</td>
<td>149.6</td>
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<td>FFHP43</td>
<td>1037</td>
<td>1850</td>
<td>96.4</td>
<td>171.9</td>
</tr>
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<td>FFHP44</td>
<td>1201</td>
<td>2130</td>
<td>111.6</td>
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<td>244.0</td>
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<td>3015</td>
<td>157.7</td>
<td>280.2</td>
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<td>3700</td>
<td>192.7</td>
<td>343.9</td>
</tr>
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<td><strong>347 V and 600 V, three-phase wye</strong></td>
<td></td>
<td></td>
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<td></td>
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<td>FFHP48</td>
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<td>840</td>
<td>43.7</td>
<td>78.1</td>
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<td>62.4</td>
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<td>76.1</td>
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<td>2025</td>
<td>105.3</td>
<td>188.2</td>
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<td>120.3</td>
<td>216.1</td>
</tr>
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<td>2675</td>
<td>139.4</td>
<td>248.6</td>
</tr>
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<td>FFHP56</td>
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<td>3275</td>
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<td>FFHP57</td>
<td>2126</td>
<td>3775</td>
<td>197.6</td>
<td>350.8</td>
</tr>
</tbody>
</table>

1 Tolerance on heating cable length is –0% to +3%.

2 Single-phase current shown.

**Note:** Type FFHP cables supplied with 15 ft (4.6 m) long cold leads.
### Step 4: Determine the heating cable spacing

To determine the spacing between runs of heating cables, use the formula below:

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

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

**Note:** If a large area has been divided into subsections or if a three-phase voltage supply is used, the “Area” in the above equations will be the subsection area or area coverage for each cable and the “Heated length” will be the length of the selected cable.

**Example: MI heating cables directly embedded – Single-phase**

- **Area:** 800 ft\(^2\) (74 m\(^2\)) (from Step 3)
- **Catalog number:** SUB19 (from Step 3)
- **Heated length:** 245 ft (74.7 m) (from Step 3)
- **Cable spacing:**
  \[
  \frac{800 \text{ ft}^2 \times 12}{245 \text{ ft}} = 39.2 \text{ in}
  \]
  rounded to 39 in

  \[
  \frac{74 \text{ m}^2 \times 100}{74.7 \text{ m}} = 99.1 \text{ cm}
  \]
  rounded to 99 cm

**Example: MI heating cables directly embedded – Three-phase**

- **Area coverage for each cable:** 2133 ft\(^2\) (198.3 m\(^2\)) (from Step 3)
- **Catalog number:** SUB8 (from Step 3)
- **Heated length:** 550 ft (167.6 m) (from Step 3)
- **Cable spacing:**
  \[
  \frac{2133 \text{ ft}^2 \times 12}{550 \text{ ft}} = 46.5 \text{ in}
  \]
  rounded to 47 in

  \[
  \frac{198.3 \text{ m}^2 \times 100}{167.6 \text{ m}} = 118.3 \text{ cm}
  \]
  rounded to 118 cm

### Step 5: Determine the electrical parameters

**DETERMINE NUMBER OF CIRCUITS**

For single-phase circuits, when connecting individual heating cables to circuit breakers, the cable current draw must not exceed 80% of the circuit breaker rating. To reduce the number of circuits, multiple heating cables may be connected in parallel. When multiple cables are connected in parallel, the total of the individual heating cable currents must not exceed 80% of the circuit breaker rating. The single-phase heating cable current is shown in Table 12 and Table 13.

For three-phase circuits used in frost heave protection systems, the three heating cables are generally connected in the wye configuration shown in Fig. 21 on page 46. For a wye connected three-phase circuit, the current draw is the same as the single-phase heating cable current and must not exceed 80% of the 3-pole circuit breaker rating.

A 30-mA ground-fault protection device (GFPD) must be used to provide protection from arcing or fire, and to comply with warranty requirements, agency certifications, and national electrical codes. If the heating cable is improperly installed, or physically damaged, sustained arcing or fire could result. If arcing does occur, the fault current may be too low to trip conventional 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 Thermal Management, 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.

SELECT BRANCH CIRCUIT BREAKER SIZE
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 3-pole breaker and a ground fault sensor.

DETERMINE TRANSFORMER LOAD
The total transformer load is the sum of the wattages of the selected heating cables. Calculate the Total Transformer Load as follows:

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

Example: MI heating cables directly embedded – Single-phase
- Amps: 4.3 A (from Table 12)
- Circuit breaker size: 15 A breaker, 80% loading 12 A
- Number of circuit breakers: 1
- Cable power output: 885 W (from Step 3)
- Number of cables: 1 (from Step 3)
- Transformer load: \( \frac{885 \text{ W}}{1000} = 0.9 \text{ kW} \)

Example: MI heating cables directly embedded – Three-phase
- Amps/cable: 19.2 A (from Table 12)
- Circuit breaker size: 25 A, 3-pole breaker, 80% loading 20 A
- Number of circuit breakers: 1 (3 cables wye connected – see Fig. 21)
- Cable power output: 2300 W (from Step 3)
- Number of cables: 3 (from Step 3)
- Total Transformer load: \( \frac{2300 \text{ W} \times 3}{1000} = 6.9 \text{ kW} \)

Record the number and ratings of the circuit breakers to be used and total transformer load on the worksheet.
**Step 6 Select the accessories**

For your embedded system, determine the number of junction boxes required.

**SELECT JUNCTION BOX**

Select a UL Listed and/or CSA Certified junction box that is suitable for the location, such as the Raychem 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.

After determining the number of heating cables required, the number of circuits, and the junction box locations, do a trial layout. In making the trial layout, follow these recommendations:

- Install the heating cables in a sand layer beneath the insulation.
- Maintain the design spacing within 4 in (10 cm).
- When directly embedded in the concrete floor, do not cross expansion joints in the floor.
- Do not route the cables closer than 4 in (10 cm) to the edge of the subfloor, drains, anchors, or other material.

**TABLE 14 ACCESSORIES**

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Description</th>
<th>Standard packaging</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1297TERM4</td>
<td>A cast aluminum junction box (Type 3) for installation in nonhazardous and CID2 locations. Three 1/2-in 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. (for MI only) Enclosure dimensions: 6 in x 6 in x 4 in (150 mm x 150 mm x 100 mm).</td>
<td>1</td>
<td>For MI cable only</td>
</tr>
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</table>

**Example: MI heating cables directly embedded – Single-phase**

<table>
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<tr>
<th>Junction box</th>
<th>D1297TERM4</th>
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</thead>
<tbody>
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</tbody>
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**Example: MI heating cables directly embedded – Three-phase**

<table>
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</thead>
<tbody>
<tr>
<td>Quantity required</td>
<td>2</td>
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**Freezer Frost Heave Prevention System**

**Design Steps (Embedded)**

1. Determine the freezer configuration
2. Determine heat loss and freezer load
3. Select the heating cable, layout and length
4. Determine the heating cable spacing
5. Determine the electrical parameters
6. Select the accessories
7. Select the control system
8. Select the power distribution
9. Complete the Bill of Materials

**TABLE 15 CONTROL SYSTEMS**

<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 Raychem C910-485 is a compact, full featured, microprocessor-based, single-point commercial heating cable controller. The C910-485 provides control and monitoring of electrical heating cable circuits for commercial heating applications, with built-in ground-fault protection. The C910-485 can be set to monitor and alarm for high and low temperature, high and low current, ground-fault level, and voltage. Communications modules are available for remote control and configuration.</td>
</tr>
</tbody>
</table>

**Step 7 Select the control system**

For MI cable, a temperature controller must be used to maintain the subfloor temperature at 40°F (4°C). For installations where temperature control and temperature monitoring is desired, a Thermal Management Raychem C910-485 or Raychem ACS-30 controller is recommended. For additional information on temperature controller options, refer to Table 8 on page 25.
### TABLE 15 CONTROL SYSTEMS

<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS-UIT2</td>
<td>The Raychem 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 Raychem 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></td>
</tr>
<tr>
<td>ProtoNode-RER</td>
<td>The Raychem ProtoNode is an external, high performance multi-protocol gateway for customers needing protocol translation between Building Management Systems (BMS) and the Raychem ACS-30 or C910-485 controllers. The 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 Raychem 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 (3 m) flexible armor, 18-in (457 mm) lead wire and 1/2-inch NPT bushing</td>
</tr>
</tbody>
</table>

**Example: MI heating cables directly embedded – Single-phase**

| Single circuit, electronic controller | Raychem C910-485 |
| Quantity                               | 1               |

**Example: MI heating cables directly embedded – Three-phase**

| Single circuit, monitoring requested   | Raychem ACS-30* |
| Quantity                              | 1               |

*Use ACS-30 General part number (P000001232) for custom three-phase panels. Please contact your Thermal Management representative for a custom ACS-PCM2-5 panel quotation.

---

**Step 4: Select the power distribution**

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

1. Directly through the temperature controller
2. Through external contactors activated by a temperature controller
3. Through an HTPG power distribution panel

**SINGLE CIRCUIT CONTROL**

Heating cable circuits that do not exceed the current rating of the selected controller can be switched directly (Fig. 20). When the total electrical load exceeds the rating of the controller or if a single-pole temperature controller is used to control a three-phase circuit (Fig. 21), an external contactor is required.

**GROUP CONTROL**

If the temperature controller will activate multiple single-phase or three-phase circuits [group control], then an external contactor must be used. In Fig. 20, three single-phase circuits are activated by a temperature controller through an external contactor.
**Single circuit control**

- Heating cable
- Temperature controller
- 1-pole GFEP breaker
- Heating cable sheath, braid or ground

**Group control**

- Temperature controller
- 1-pole GFEP breaker
- 3-phase 4-wire supply (WYE)
- Contactor
- 3-pole main breaker
- Heating cable sheath, braid or ground

**Fig. 20** Single circuit and group control

**Fig. 21** Typical three-phase wye connected cables with temperature controller and contactor

*Note:* Heating cable voltage is the same as the phase-to-neutral voltage \( \frac{V_{A-N}}{\sqrt{3}} \)

*Note:* For Wye connected heating cables, the current in the supply feeder, contactor, and breakers is equal to the 'Single Phase Heating Cable Current.'
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 freeze protection and 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](image)

![Fig. 23 Typical HTPG power schematic](image)
<table>
<thead>
<tr>
<th>Catalog number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTPG</td>
<td>Heat-tracing power distribution panel with ground-fault and monitoring for group control.</td>
</tr>
</tbody>
</table>

**Design Steps (Embedded)**

1. Determine the freezer configuration
2. Determine heat loss and freezer load
3. Select the heating cable, layout and length
4. Determine the heating cable spacing
5. Determine the electrical parameters
6. Select the accessories
7. Select the control system
8. Select the power distribution system
9. Complete the Bill of Materials

**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 to complete your Bill of Materials.
# RAYSOL AND MI HEATING CABLE IN CONDUIT FREEZER FROST HEAVE PREVENTION DESIGN WORKSHEET

## Step 1 Determine the freezer configuration (RaySol and MI heating cable systems)

<table>
<thead>
<tr>
<th>Determine freezer area (from scale drawing)</th>
<th>Determine freezer operating temperature</th>
<th>Record insulation R-value</th>
<th>Supply voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side A (length) [ft/m] x Side B (width) [ft/m] = Freezer area (ft²/m²)</td>
<td>°F/°C</td>
<td>ft²·°F·hr/Btu</td>
<td>Volts</td>
</tr>
</tbody>
</table>

**Example: RaySol and MI heating cables**

<table>
<thead>
<tr>
<th>Side A (length)</th>
<th>Side B (width)</th>
<th>Freezer area (ft²)</th>
<th>Operating Temperature</th>
<th>R-value</th>
<th>Supply Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 ft</td>
<td>40 ft</td>
<td>3200 ft²</td>
<td>-20°F</td>
<td>R-40</td>
<td>208 Volts</td>
</tr>
</tbody>
</table>

## Step 2 Select the heating cable

### RaySol heating cable

- **Supply voltage**
  - 120 V
  - 208 V
  - 240 V
  - 277 V

- **Catalog number:**

### MI heating cable

- **Supply voltage**
  - 120 V
  - 208 V
  - 277 V

- **Catalog number:**

**Example: RaySol heating cable**

- **Supply voltage:** 208 V
- **Catalog number:** RaySol-2

**Example: MI heating cable**

- **Supply voltage:** 208 V
- **Catalog number:** FFHPC30

**Power output:** 475 W

## Step 3 Determine the heating cable conduit spacing and freezer load (RaySol and MI heating cable systems)

Based on the insulation R-value and freezer operating temperature you recorded in Step 1, use Table 4 to select the following:

- **Conduit spacing [in/cm]**
- **Freezer load [W/ft²] [W/m²]**

**Example: For RaySol and MI heating cables**

- **Conduit spacing:** 96 in
- **Freezer load:** 0.5 W/ft²

---

**Pipe Freeze Protection**
- Flow Maintenance
- Fire Sprinkler System
- Freeze Protection
- Roof and Gutter
- De-Icing - RIM
- Roof and Gutter
- De-Icing - IceStop
- Surface Snow Melting – MI
- Surface Snow Melting – ElectroMelt
- Freezer Frost Heave Prevention
- Heat Loss Replacement

**HWAT Technical Data Sheets**
### Step 2. Determine the heating cable layout and length

#### RaySol heating cable in conduit

1. **Estimate the number of conduit runs**

   **Imperial**
   \[
   \left( \frac{\text{Side B (ft)}}{12} \right) \times \frac{1}{\text{Conduit spacing (in)}} = \text{Estimated number of conduit runs}
   \]

   **Metric**
   \[
   \left( \frac{\text{Side B (m)}}{100} \right) \times \frac{1}{\text{Conduit spacing (cm)}} = \text{Estimated number of conduit runs}
   \]

   If necessary, round to the next whole number

#### Example: RaySol heating cable

\[
\left( \frac{40 \text{ ft}}{12} \right) \times \frac{1}{96 \text{ in}} = 5 \text{ Estimated number of conduit runs}
\]

2. **Estimate the heating cable length required for conduit runs**

   \[
   \text{Side A (ft/m)} \times \frac{\text{Number of conduit runs}}{\text{Heating cable length required (ft/m)}} = \text{Heating cable length required (ft/m)}
   \]

#### Example: RaySol heating cable

\[
80 \text{ ft} \times \frac{5}{400 \text{ ft}} = \text{Heating cable length required (ft/m)}
\]

3. **Determine the maximum circuit length** [see Table 5]

   \[
   \text{Heating cable length required (ft/m)} \times \text{Supply voltage (V)} = \text{Maximum circuit length (ft/m)}
   \]

#### Example: RaySol heating cable

\[
400 \text{ ft} \times 208 \text{ V} = 410 \text{ ft}
\]

#### Example: MI heating cable

\[
5 \text{ Number of conduit runs} = 5 \text{ Number of heating cables required}
\]

4. **Determine layout**

   **Is Side A x 2 ≤ the maximum circuit length?**
   - Yes – Conduit can be looped in hairpin configuration
   - Odd number of conduit runs – One conduit run will be straight
   - Even number of conduit runs – All conduit run are looped in hairpin configuration
   - No – Use a straight run layout

#### Example: RaySol heating cable

<table>
<thead>
<tr>
<th>Heating cable length required (ft)</th>
<th>Supply voltage (V)</th>
<th>Maximum circuit length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 ft</td>
<td>208 V</td>
<td>410 ft</td>
</tr>
</tbody>
</table>

#### Example: MI heating cable

<table>
<thead>
<tr>
<th>Number of circuits</th>
<th>Power supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>One 20 A circuit breaker</td>
</tr>
</tbody>
</table>
Step 4 Determine the heating cable layout and length

5. Determine end allowances and kit connection kit allowances (see Table 6) and total heating cable length required.

Determine end allowances

\[
\begin{align*}
\text{Number of straight run conduits} & \times 8 \text{ ft} = \\
\text{Number of hairpin conduits} & \times 8 \text{ ft} = \\
\end{align*}
\]

Heating cable length for end allowances

Example: RaySol heating cable

\[
\begin{align*}
2 & \times 8 \text{ ft} = 16 \text{ ft} \\
1 & \times 8 \text{ ft} = 8 \text{ ft} \\
\end{align*}
\]

Heating cable length for end allowances 24 ft

Determine connection kit allowances

\[
\begin{align*}
\text{Number of FTC-XC kits for hairpin conduits} & \times 4 \text{ ft} = \\
\text{Number of FTC-XC kits for straight run conduits} & \times 4 \text{ ft} = \\
\end{align*}
\]

Heating cable length for connection kit allowances

Example: RaySol heating cable

\[
\begin{align*}
2 & \times 4 \text{ ft} = 8 \text{ ft} \\
1 & \times 4 \text{ ft} = 4 \text{ ft} \\
\end{align*}
\]

Heating cable length for connection kit allowances 12 ft

Determine total heating cable length required for conduit runs and allowances

\[
\begin{align*}
\text{Heating cable length for conduit runs (ft/m)} + & \text{Heating cable length for end allowances (ft/m)} + & \text{Heating cable length for connection kit allowances (ft/m)} = & \text{Total heating cable length required (ft/m)} \\
\end{align*}
\]

Example: RaySol heating cable

\[
\begin{align*}
400 \text{ ft} + & 24 \text{ ft} + & 12 \text{ ft} = & 436 \text{ ft} \\
\text{Heating cable length for conduit runs (ft)} + & \text{Heating cable length for end allowances (ft)} + & \text{Heating cable length for connection kit allowances (ft)} = & \text{Total heating cable length required (ft)} \\
\end{align*}
\]
### Step 5 Determine the electrical parameters

**RaySol heating cable in conduit**

<table>
<thead>
<tr>
<th>Determine number of circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit breaker rating (A):</td>
</tr>
<tr>
<td>Number of circuits:</td>
</tr>
</tbody>
</table>

**MI heating cable in conduit**

<table>
<thead>
<tr>
<th>Determine circuit breaker rating and number of circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit breaker rating (A):</td>
</tr>
<tr>
<td>Number of circuits:</td>
</tr>
</tbody>
</table>

#### Calculate circuit breaker load

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

#### Example: RaySol heating cable

\[
\frac{20 \text{ A} \times 0.8 \times 208 \text{ V}}{1000} = 3.3 \text{ kW}
\]

#### Example: MI heating cable

\[
\frac{11.5 \text{ A} \times 1.25}{\text{Total current (A)}} = 14.4 \text{ A}
\]

#### Calculate total transformer load

\[
\text{Total transformer load (kW)} = \sum_{i=1}^{n} \frac{\text{Cable}_i (W)}{1000}
\]

#### Example: RaySol heating cable

\[
\frac{475 \text{ W}}{1000} = 2.4 \text{ kW}
\]

#### Example: MI heating cable

\[
\frac{475 \text{ W} + 475 \text{ W} + 475 \text{ W} + 475 \text{ W} + 475 \text{ W}}{1000} = 2.4 \text{ kW}
\]

### Step 6 Select the connection kits and accessories

<table>
<thead>
<tr>
<th>Connection kits and accessories</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTC-XC</td>
<td>Power connection and end seal</td>
<td></td>
</tr>
<tr>
<td>FTC-HST</td>
<td>Low-profile splice/tee</td>
<td></td>
</tr>
<tr>
<td>RayClic-E</td>
<td>Extra end seal</td>
<td></td>
</tr>
<tr>
<td>D1297TERM4</td>
<td>Cast aluminum junction box (for MI cable only)</td>
<td></td>
</tr>
</tbody>
</table>

**Example:**
- **FTC-XC**
- **D1297TERM4**

*Use next largest available circuit breaker or break into smaller circuits.*
### Step 7 Select the control system

<table>
<thead>
<tr>
<th>Thermostats, controllers, and accessories</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECW-GF</td>
<td>Electronic thermostat with 25-ft sensor</td>
<td></td>
</tr>
<tr>
<td>ECW-GF-DP</td>
<td>Remote display panel for ECW-GF</td>
<td></td>
</tr>
<tr>
<td>MI-GROUND-KIT</td>
<td>Grounding kit for nonmetallic enclosures</td>
<td></td>
</tr>
<tr>
<td>C910-485</td>
<td>Microprocessor-based single-point heat-trace controller</td>
<td></td>
</tr>
<tr>
<td>ACS-UIT2</td>
<td>ACS-30 user interface terminal</td>
<td></td>
</tr>
<tr>
<td>ACS-PCM2-5</td>
<td>ACS-30 power control panel</td>
<td></td>
</tr>
<tr>
<td>ProtoNode-RER</td>
<td>Multi-protocol gateway</td>
<td></td>
</tr>
<tr>
<td>RTD10CS</td>
<td>Resistance temperature device for Raychem C910-485 &amp; ACS-30</td>
<td></td>
</tr>
<tr>
<td>RTD-200</td>
<td>Resistance temperature device for Raychem C910-485 &amp; ACS-30</td>
<td></td>
</tr>
<tr>
<td>RTD50CS</td>
<td>Resistance temperature device for Raychem C910-485 &amp; ACS-30</td>
<td></td>
</tr>
</tbody>
</table>

**Example:**

- Raychem C910-485
  - Microprocessor-based single-point heat-trace controller
  - Quantity: 1

### Step 8 Select the power distribution

<table>
<thead>
<tr>
<th>Power distribution</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTPG</td>
<td>Heat-tracing power distribution panel for group control</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.
FREEZER FROST HEAVE PREVENTION – RAYSOL AND MI HEATING CABLE SYSTEM

MI CABLES DIRECTLY EMBEDDED FREEZER FROST HEAVE PREVENTION DESIGN WORKSHEET

Step 1 Determine the freezer configuration

<table>
<thead>
<tr>
<th>Determine freezer area (from scale drawing)</th>
<th>Determine freezer operating temperature</th>
<th>Record insulation R-value</th>
<th>Supply voltage</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side A (length) (ft/m) x Side B (width) (ft/m) = Freezer area (ft²/m²)</td>
<td>°F/°C</td>
<td>ft²·°F·hr/Btu</td>
<td>Volts</td>
<td>Phase</td>
</tr>
</tbody>
</table>

Example:

40 ft x 20 ft = 800 ft²

-30°F

R-20 (20 ft²·°F·hr/Btu)

208 V

Single phase

Step 2 Determine the heat loss and freezer load

Based on the insulation R-value and freezer operating temperature you recorded in Step 1, use Table 11 to select the following:

Design power ___________W/ft² (W/m²) Freezer load ___________W/ft² (W/m²)

Example:

1.1 W/ft²

Design power

Freezer load

Step 3 Select the heating cable, layout and length

Use Table 12 and Table 13 to select your heating cable and determine your cable wattage.

Heating cable voltage

- 120 V
- 208 V
- 240 V
- 277 V
- 347 V

Design power (W/ft²) / (W/m²) x Area (ft²/m²) = Power required (W) Catalog number Cable wattage (W) Heated length (ft) Quantity

Example:

208 V

1.1 W/ft² x 800 ft² = 880 W

SUB19 885 W 245 ft 1

1
Step 4 Determine the heating cable spacing

Imperial

<table>
<thead>
<tr>
<th>Area (ft²)</th>
<th>Heated length (ft)</th>
<th>Cable spacing (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 /</td>
<td></td>
</tr>
</tbody>
</table>

Metric

<table>
<thead>
<tr>
<th>Area (m²)</th>
<th>Heated length (m)</th>
<th>Cable spacing (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 /</td>
<td></td>
</tr>
</tbody>
</table>

If necessary, round to whole number.

Example:

<table>
<thead>
<tr>
<th>800 ft²</th>
<th>245 ft</th>
<th>39.2 in rounded to 39 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ft²)</td>
<td>Heated length (ft)</td>
<td>Cable spacing (in)</td>
</tr>
</tbody>
</table>

Step 5 Determine the electrical parameters

Determine circuit breaker rating and number of circuits

Circuit breaker rating (A): _____________________________
Number of circuits: _____________________________

Calculate circuit breaker rating and number of circuits

\[
\text{Total current (A)} \times 1.25 = \text{Minimum circuit breaker rating (A)*} = \text{Circuit breaker rating (A)} = \text{Number of circuits (A)}
\]

*Use next largest available circuit breaker or break into smaller circuits

Example

<table>
<thead>
<tr>
<th>4.3 A</th>
<th>5.4 A</th>
<th>15 A</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total current (A)</td>
<td>Minimum circuit breaker rating (A)*</td>
<td>Circuit breaker rating (A)</td>
<td>Number of circuits</td>
</tr>
</tbody>
</table>

Calculate total transformer load

\[
\text{Cable}_1 (W) + \text{Cable}_2 (W) + \text{Cable}_3 (W) \ldots + \text{Cable}_n (W) / 1000 = \text{Total transformer load (kW)}
\]

Example

<table>
<thead>
<tr>
<th>885 W</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable</td>
<td>/ 1000</td>
</tr>
</tbody>
</table>

Step 6 Select the accessories

Accessory | Description
---|---
D1297TERM4 | Cast aluminum junction box

Example:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D1297TERM4</td>
<td>Cast aluminum junction box</td>
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</tbody>
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Example:
**Step 7 Select the control system**

<table>
<thead>
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<th>Thermostats, controllers, and accessories</th>
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<td>ACS-30 power control panel</td>
<td></td>
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<tr>
<td>ProtoNode-RER</td>
<td>Multi-protocol gateway</td>
<td></td>
</tr>
<tr>
<td>RTD10CS</td>
<td>Resistance temperature device for Raychem C910-485 &amp; ACS-30</td>
<td></td>
</tr>
<tr>
<td>RTD-200</td>
<td>Resistance temperature device for Raychem C910-485 &amp; ACS-30</td>
<td></td>
</tr>
<tr>
<td>RTD50CS</td>
<td>Resistance temperature device for Raychem C910-485 &amp; ACS-30</td>
<td></td>
</tr>
</tbody>
</table>

**Example:**

- Raychem C910-485: Microprocessor-based single-point heat-trace controller 1

**Step 8 Select the power distribution**

<table>
<thead>
<tr>
<th>Power distribution</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTPG</td>
<td>Heat-tracing power distribution panel for group control</td>
<td></td>
</tr>
</tbody>
</table>

**Step 9 Complete the Bill of Materials**

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