Hands on Exercise
About the EnergyPlus zone model

- Single zone model, middle floor, large office building
- 82’ x 16’ (25m x 5m) in Boston
- 8am – 6pm occupancy
- AHSRAE 90.1 loads

Two cases: Core & Perimeter

- Core
  - Adiabatic interior walls
  - No infiltration or intrazone air

- South facing perimeter
  - Adiabatic walls except facade
  - No shading, 35% WWR, 0.25 SHGC
  - Infiltration: 0.115 cfm per ft² (0.57 l/s per m²) of exterior wall
About the EnergyPlus zone model

Tubing diameter: 5/8” (0.016 m)

Design loop length: 375’ (114m) – reduces pump power and waste (1500’ coils)
- Max recommended length: 500’
- Max: 400’ where CSA B214 standard applies

Commercial flooring: R-0.25 h ft² °F/Btu (R-0.044 K m²/W)

Insulation: R-5 h ft² °F/Btu (R-0.88 K m²/W)

Topping slab: 3” (0.076 m)

Structural slab: 8” (0.203 m)

9” spacing (0.229 m)
Other design info

- Radiant system is constant temperature, variable flow

- Ventilation system design:
  - Same ventilation rate as the all-air system:
    150 cfm (70 l/s)
  - Different supply and return temperatures:
    Supply: 65 °F (18.3 °C)
    Room: 78 °F (25.6 °C)
  - Design sensible load handled by ventilation system:
    1.5 Btu/hr ft² (5 W/m)

- Obtain capacities from the PEX manufacturer. Example excerpts from a manufacturer on the following pages.
Capacities (from manufacturer)

<table>
<thead>
<tr>
<th>Floor Covering R-Value (hr•°F/°F)</th>
<th>Depth of Tubing in Concrete (Inches)</th>
<th>Cooling Provided (Btu/hr/ft²)</th>
<th>16</th>
<th>14</th>
<th>11</th>
<th>9</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>64</td>
<td>66</td>
<td>68</td>
<td>70</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.75</td>
<td>6</td>
<td>58</td>
<td>61</td>
<td>63</td>
<td>66</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>9</td>
<td>54</td>
<td>59</td>
<td>61</td>
<td>63</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>12</td>
<td>50</td>
<td>54</td>
<td>56</td>
<td>58</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>12</td>
<td>54</td>
<td>59</td>
<td>61</td>
<td>64</td>
<td>67</td>
</tr>
<tr>
<td>0.75</td>
<td></td>
<td>6</td>
<td>58</td>
<td>61</td>
<td>63</td>
<td>66</td>
<td>69</td>
</tr>
<tr>
<td>0.25</td>
<td>1.5</td>
<td>9</td>
<td>54</td>
<td>59</td>
<td>61</td>
<td>63</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>12</td>
<td>50</td>
<td>54</td>
<td>56</td>
<td>58</td>
<td>61</td>
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<tr>
<td></td>
<td>6</td>
<td>12</td>
<td>54</td>
<td>59</td>
<td>61</td>
<td>64</td>
<td>67</td>
</tr>
<tr>
<td>0.5</td>
<td>0.75</td>
<td>6</td>
<td>52</td>
<td>56</td>
<td>60</td>
<td>63</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>9</td>
<td>56</td>
<td>60</td>
<td>63</td>
<td>66</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>12</td>
<td>52</td>
<td>56</td>
<td>60</td>
<td>63</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>12</td>
<td>56</td>
<td>60</td>
<td>63</td>
<td>67</td>
<td>70</td>
</tr>
</tbody>
</table>

Source: Excerpt from Viega ProRadiant Heating and Cooling Design Manual
**Tubing length estimator (from manufacturer)**

- Calculate the net heated area.
- Use charts to make an initial materials list for the net area to be heated.

### Concrete System Tubing Estimator

<table>
<thead>
<tr>
<th>Viegapex Barrier / FostaPex Tubing</th>
<th>Net. Heated Area</th>
<th>Multiplier</th>
<th>Estimated Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>6&quot; Spacing</td>
<td></td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>9&quot; Spacing</td>
<td></td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>12&quot; Spacing</td>
<td></td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Viegapex Barrier or FostaPex Tubing</td>
<td>1/2&quot;, 5/8&quot;, 3/4&quot;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Excerpt from Viega ProRadiant Heating and Cooling Design Manual
Maximum loop lengths (from manufacturer)

![Table 1-7 Maximum recommended circuit lengths in feet, assuming a temperature drop of \( \geq 20^\circ F \), 100% water, and air temperature of 68\(^o\)F](image)

<table>
<thead>
<tr>
<th>Tubing</th>
<th>( \leq 25 \text{ Btu/hr/ft}^2 )</th>
<th>( &gt;25 \text{ Btu/hr/ft}^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>%%</td>
<td>250</td>
<td>200</td>
</tr>
<tr>
<td>%%</td>
<td>300</td>
<td>250</td>
</tr>
<tr>
<td>%</td>
<td>400</td>
<td>350</td>
</tr>
<tr>
<td>%</td>
<td>500</td>
<td>450</td>
</tr>
<tr>
<td>%</td>
<td>800</td>
<td>750</td>
</tr>
</tbody>
</table>

*Table 1-7 Maximum recommended circuit lengths in feet, assuming a temperature drop of \( \geq 20^\circ F \), 100% water, and air temperature of 68\(^o\)F*

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Source: Excerpt from Viega ProRadiant Heating and Cooling Design Manual

![Table 1-8 Maximum length of continuous tubing from a supply-and-return manifold arrangement](image)

<table>
<thead>
<tr>
<th>Nominal Tube Size, in</th>
<th>Maximum Loop Length, m (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>%%</td>
<td>39 (125)</td>
</tr>
<tr>
<td>%%</td>
<td>61 (200)</td>
</tr>
<tr>
<td>%</td>
<td>76 (250)</td>
</tr>
<tr>
<td>%</td>
<td>91 (300)</td>
</tr>
<tr>
<td>%</td>
<td>122 (400)</td>
</tr>
<tr>
<td>%</td>
<td>152 (500)</td>
</tr>
<tr>
<td>1</td>
<td>229 (750)</td>
</tr>
</tbody>
</table>

*Table 1-8 Maximum length of continuous tubing from a supply-and-return manifold arrangement

**NOTE:** Data for this table were compiled by the B214 Technical Committee and are based on manufacturers’ recommendations and good engineering practice.

**CSA B214 Clause 14.3.2**

The maximum length of continuous tubing from a supply-and-return manifold arrangement shall not exceed the lengths specified by the manufacturer or, in the absence of manufacturer’s specifications, the lengths specified in Table 1. Actual loop lengths shall be determined by spacing, number of loops and pressure drop requirements, as specified in the system design.
PEX pipe pressure drop (from manufacturer)

Source: Excerpt from Viega ProRadiant Heating and Cooling Design Manual
All-air system load calcs for the core and perimeter zones

**Core zone**

**Perimeter zone**
Design worksheet (part 1)

<table>
<thead>
<tr>
<th></th>
<th>Core 9”</th>
<th>Core 12”</th>
<th>Perim 6”</th>
<th>Perim 9”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design sensible cooling load</strong> [Btu/hr ft²]</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cooling load removed by ventilation</strong> [Btu/hr ft²]</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Design radiant system cooling load</strong> [Btu/hr ft²]</td>
<td>8.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Mean chilled water temp (MCWT) [°F]**  
See first page of tables supplied by manufacturer, R-0.25 h ft² °F/Btu carpet, 3” covering | 62      |          |          |          |
| **Supply water temp** [°F]  
Assume design delta temp of 5 °F | 59.5    |          |          |          |
| **Design radiant system load** [Btu/hr]  
= Floor area x Design radiant system cooling load  
Zone area = 1346 ft² | 11441   |          |          |          |
| **Design water flow rate** [gpm]  
= Design radiant system load / 500 x Design delta T | 4.6     |          |          |          |
### Design worksheet (part 2)

<table>
<thead>
<tr>
<th></th>
<th>Core 9”</th>
<th>Core 12”</th>
<th>Perim 6”</th>
<th>Perim 9”</th>
</tr>
</thead>
</table>
| **Total PEX tubing length [ft]**  
  = Floor area x Floor area multiplier  
  Floor area multiplier: 6” = 2.2, 9” = 1.5, 12” = 1.1  
  See second page of tables supplied by manufacturer | 2019     |          |          |          |
| **Number of loops [-]**  
  = Total PEX tubing length / Design max loop length  
  Selected design max: 375ft (minimizes waste on 1500 ft coil). See third page of tables supplied by manufacturer for recommended limits. |          |          | 6        |          |
| **Circuit length [ft]**  
  = Total PEX tubing length / Number of loops |          |          |          |          |
| **Flow per loop [gpm]**  
  = Design water flow rate / Number of loops |          |          |          |          |
| **Pressure drop per foot of pipe [ft/ft]**  
  See fourth page of tables supplied by manufacturer with 5/8in diameter tubing |          |          | 0.011    |          |
| **Pressure drop [ft]** |          |          |          | 3.7      |
Now it’s your turn

Group A: Design **core** zone for 12” spacing

Group B: Design **perimeter** zone for 9” spacing

Group C: Design **perimeter** zone for 6” spacing
Comfort and peak cooling load assessment (Perimeter zone)
Perimeter all-air system

Max temp during occupied hours:

- **Air:**
  - 74 °F (23.3 °C)
- **Operative:**
  - 76.4 °F (24.7 °C)
- **Mean radiant:**
  - 78.8 °F (26 °C)
CBE Thermal Comfort Tool

Select method: PMV method

Air temperature: 74.0 °F
Mean radiant temperature: 78.8 °F
Air speed: 20 tpm
Humidity: 50%
Metabolic rate: 1.1 met
Clothing level: 0.5 clo

Use operative temperature
Typical summer indoor

ASHRAE-55
EN-15251
Compare
Ranges
Upload

Complies with ASHRAE Standard 55-2017

PMV: -0.26
PPD: 6%
Sensation: Neutral
SET: 75.9°F

Psychrometric chart (air temperature):

Dry-bulb Temperature [°F]
Humidity Ratio [lb_h/lb_d]

50 60 70 80 90 95
0 5 10 15 20 25 30

t_r 50.0 °F
rh 74.4 %
W_b 6.7 lb_h/klb_m
w_e 46.0 °F
t_o 42.1 °F
h 6.1 btm/ft²

Perimeter (6”) zone assessment worksheet

<table>
<thead>
<tr>
<th></th>
<th>All-air</th>
<th>Radiant: On if air temp &gt;75F</th>
<th>Radiant: On at night</th>
<th>Radiant: Constant on</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temp</td>
<td>74 °F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operative temp</td>
<td>76.8 °F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean radiant temp</td>
<td>78.6 °F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor surface temp</td>
<td>78.6 °F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meets comfort criteria?</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak hydronic cooling load</td>
<td>12.5 Btu/hr.ft²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>As percent of all-air?</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Perim radiant system: On if air > 75 °F

6” spacing
56.5 °F water
Perim radiant system: On during night hours

6” spacing
56.5 °F water
Perim radiant system: On constantly

6” spacing
56.5 °F water