Stable Foundations – Active Cooling of Thermosiphons

LEO Network
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 Thermosiphon Passive Cooling

Cold Air (Below Freezing)

Heat from ground is released into the air

CO₂ vapor condenses on thermosiphon wall

Liquid CO₂ flows down to bottom

CO₂ vapor rises

Heat from ground vaporizes CO₂

Liquid CO₂

Permafrost Soil

Heat from Building
Quinhagak Community Buildings Settling
• Mechanical room warmer than expected
• Exhaust vent warming thermosiphon condenser fins
• Summers significantly longer than design assumption

<table>
<thead>
<tr>
<th></th>
<th>Freezing Index</th>
<th>Thawing Index</th>
<th>Days of thaw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hartman/Johnson</td>
<td>3500 °F-days</td>
<td>2500 °F-days</td>
<td>170</td>
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<tr>
<td>1997</td>
<td>3460 °F-days</td>
<td>3410 °F-days</td>
<td>195</td>
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<td>1998</td>
<td>3470 °F-days</td>
<td>2700 °F-days</td>
<td>198</td>
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<tr>
<td>1999</td>
<td>4220 °F-days</td>
<td>2600 °F-days</td>
<td>164</td>
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<td>2000</td>
<td>4000 °F-days</td>
<td>2580 °F-days</td>
<td>201</td>
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<td>2001</td>
<td>2030 °F-days</td>
<td>2590 °F-days</td>
<td>168</td>
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<tr>
<td>2002</td>
<td>3750 °F-days</td>
<td>3300 °F-days</td>
<td>207</td>
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<tr>
<td>2003</td>
<td>2230 °F-days</td>
<td>3210 °F-days</td>
<td>212</td>
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<tr>
<td>2004</td>
<td>3350 °F-days</td>
<td>3630 °F-days</td>
<td>214</td>
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</tbody>
</table>
Active Cooling of Thermosiphons

Solar Panel

Refrigeration System

Cold Air Simulated by Refrigeration System

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Heat from Building
# Active Cooling Options

<table>
<thead>
<tr>
<th>Centralized chiller/heat exchangers</th>
<th>Individual refrigeration collars</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Off-the-shelf</td>
<td>• New – R&amp;D still needed</td>
</tr>
<tr>
<td>• Power to central chiller unit</td>
<td>• Power to each unit</td>
</tr>
<tr>
<td>• Modification of thermosiphon</td>
<td>• Modular - Can dismantle for easier transport</td>
</tr>
<tr>
<td>• Vulnerable refrigerant lines</td>
<td>• Keep refrigerant lines contained</td>
</tr>
<tr>
<td>• Require technician to service</td>
<td>• Can be serviced by local operators</td>
</tr>
<tr>
<td>• Larger, complex renewable system requirements</td>
<td>• Small enough to be powered by simple renewable systems</td>
</tr>
<tr>
<td>• $400,000-$500,000 installed (not including renewable energy system)</td>
<td>• $250,000 -$300,000 installed (10 units, not including renewable energy system)</td>
</tr>
</tbody>
</table>
Thermosiphon Refrigeration Collars (TRC)
Current Status

• First prototype installed at CCHRC in Fairbanks
• Logging ground and system temperature, pressure, power draw data
• Dialing in controls and operational setpoints
• Identifying vulnerabilities and opportunities for improvement
Next Steps

Phase 2: Finalize Design
• Apply lessons learned from version 1 to build an improved version.
• Optimize renewable integration.

Phase 3: Field Deployment
• Fabricate batch of 10 units
• Install refrigeration collars and solar array in rural Alaska
• Monitor and evaluate performance
Questions

• In which locations will operating the TRC with renewables alone be enough to maintain frozen ground and protect infrastructure?

• What is the extent of the need?
  • Locations where thermosiphons are present and
    • Settling foundations are observed
    • Changes in permafrost conditions are observed
  • Important to catch buildings BEFORE foundations begin to thaw
Thank you to Tashina Duttle, Will Fraser, John Warren, James Anderson, John Nelson, ARUC and DEHE leadership for helping make this project happen!

Thank you all for listening!