Utility Scale Geothermal ORC Systems using Large Screw Expanders

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Trends in HVAC / ORCs

- Positive displacement machines moving higher in capacity
- Key technology enabler: mass production of HVAC screw compressors

**HVAC Capacity**
- Large Screws to 500 Tons
  - 2000
  - Today

**ORC Capacity**
- ~50k W
  - 2012
- Large Screws to 1 MW
  - 2013
- Large Screws to 2.5 MW
  - 2014

Similar trend is now occurring in power generation.
## Compression Battleground Moves to Expanders

<table>
<thead>
<tr>
<th>Positive Displacement Machines</th>
<th>Dynamic Machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batch process</td>
<td>Continuous process</td>
</tr>
<tr>
<td>Sealed from inlet to outlet</td>
<td>Open from inlet to outlet</td>
</tr>
<tr>
<td>Leakage losses dominant</td>
<td>Friction/diffusion losses dominant</td>
</tr>
<tr>
<td>Tight machining tolerances</td>
<td>Modest machining tolerances</td>
</tr>
<tr>
<td>Fixed volumetric flow rate</td>
<td>Flow changes with pressure ratio</td>
</tr>
<tr>
<td>No pressure ratio limitation</td>
<td>Max pressure ratio limited by surge</td>
</tr>
<tr>
<td>Low speed operation feasible</td>
<td>Pressure ratio dictates (high) speed</td>
</tr>
<tr>
<td>Lower power density</td>
<td>Higher power density</td>
</tr>
<tr>
<td>Mostly on-off capacity control</td>
<td>Variable capacity control</td>
</tr>
</tbody>
</table>

1. Purdue Course on Centrifs - Brasz
Vapor Compression Cycle Similar to ORC

1 Pic from Chena Power
HFC-245fa Refrigerant

- Allows ORC to operate at VCC pressures
- Operating at HVAC pressures allows use of HVAC hardware

![Graph showing the comparison of pressures and temperatures for R134a and R245fa refrigerants.](image)
Geothermal Power in New Mexico

Lightning Dock
Resource temp - 310 deg F
Site Capable of supporting 50 MW
System Cycles

Each unit consist of 3 different cycles

- Water cycle (production, heat extraction, re-injection)
- Oil cycle (lubrication, separation, pressurization)
- ORC cycle (heating, expansion, condensation, pressurization)
Water Cycle

• Site Controller required to handle plant transients
• Issues – flashing/recondensing, water hammer, water chemistry
Oil Cycle

- Issues: oil superheat, recovery during transients
ORC Cycle

• Issues: pump cavitation, levels, transients, non-condensables
Manufacturing Description

- Fabricated and completed assemblies in 1 month
- Key enablers:
  - Available factory capacity
  - Similar to HVAC equipment (same flow lines)
Components and Shipped Assemblies

Screw Expander

Oil Skid
Components and Shipped Assemblies

Pre-heater Skid

Evaporator Skid
Installation Summary

• Construction: September – December 2013
• Final unit was commissioned on Dec. 24th 2013

Ongoing in November

Completed in December
Optimization: Non-Condensables

Before Purging

After Purging

Unit 1 Non-Condensables

Temperature [°F]

Pressure [psig]

L-Y Curve

unit 1 condensables
Optimization: Output

- Evaporator pressure is increased by raising the liquid level in the evaporator.
- Optimal levels found to be within the 580-600mm range.
Optimization: Output (continued)

- Pressure rise drives generation
  - Increased evaporator pressure directly correlates to increased power
Outlook and Expansion

- Plans to expand Lightning Dock to a 6MW plant by installing another 2.5MW screw expander and a 850kW bottom cycle unit
Future Trends in HVAC/ORCs - Prediction

- Migration of large screws developed for geothermal power back to HVAC
- Key technology enabler: mass production of ORC screw expanders

Large screws developed for geothermal will make their way back to HVAC

<table>
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<tr>
<th>HVAC Capacity</th>
<th>ORC Capacity</th>
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</thead>
<tbody>
<tr>
<td>Large Screws to 2000Tons</td>
<td>Large Screws to 2.5MW</td>
</tr>
<tr>
<td>3-5 years</td>
<td>2013</td>
</tr>
<tr>
<td></td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td>3-5 years</td>
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</tbody>
</table>

July 13, 2014
Installation - Foundation

- Earthwork was done to raise and level the plant.
- Cement supports and pads were poured for each unit.
Installation – Well Piping

• Simultaneously the well field piping and supports were installed for the production and injection wells.
Installation – Well Pumps

- Production well pump installation
- Well field interconnections for the units
Installation – Component Assembly

- Major component skids were put in place after the concrete pads were poured.
Installation - Piping

- Interconnecting piping between skids and piping from the well field were installed.
Installation - Electrical

- After completing the piping, the electrical cabling and instrumentation was done.