The What, When and Why of Variable Refrigerant Flow

Marcia L. Karr, P.E.
Variable Refrigerant Flow (VRF)

- Overview
  - How VRF works
  - How VRF is different
- Benefits
- Challenges
- Case studies
  - Lewis County PUD
  - Pacific University Burlingham Hall
  - Little Deschutes Lodge
## Evolution of VRF

<table>
<thead>
<tr>
<th>Region</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>25+</td>
</tr>
<tr>
<td>Europe</td>
<td>20+</td>
</tr>
<tr>
<td>Latin America</td>
<td>15+</td>
</tr>
<tr>
<td>Bermuda</td>
<td>15+</td>
</tr>
<tr>
<td>USA</td>
<td>10+</td>
</tr>
</tbody>
</table>
Technological Advances

VRF IS TO HEAT PUMPS

AS

FUEL INJECTION IS TO CARBURETORS
What is VRF?

- Heat pump (changeover)
  - All heating or all cooling to zones at a time
- Heat recovery
  - Heating and cooling simultaneously to multiple zones
  - Requires more controls and equipment, and costs more
VRF Efficiency Features

- Variable speed compressor
- Variable speed fan on outdoor unit
- Variable speed indoor unit fans
- Linear (variable) expansion valve
- Piping system in place of ductwork
- Refrigerant used directly for heat transfer
- Ventilation – usually a dedicated outside air system
How is VRF Different?

- Adjust cooling and heating by adjusting refrigerant flow and variable speed compressor
- Serves multiple zones from one outdoor unit
- Indoor units can be in different modes
  - Called heat recovery
- Backup heat is not usually necessary in the NW (or even in Montana!)
Variable Refrigerant Flow
VRF with Heat Recovery
VRF Benefits

• Overall more energy efficient
• Improved temperature (comfort) control
• Very good low-temperature heating performance
• Quiet
• Design flexibility
• Lighter-weight equipment, smaller footprint
• Compressor operates at actual load, not peak

continued
VRF Benefits

- Heat recovery among zones
- Great submetering capability
- Allows above-ceiling height to be reduced, saving construction costs
- Smaller power distribution system, saving electrical installation costs
- Conducive to retrofits
- Longer compressor life – soft start, variable speeds
VRF Challenges

• Higher first cost (not always)
• Refrigerant safety issues (easily solvable)
• Allows for dedicated outside air system
• Lack of expertise and experience (getting better)
• No air-side economizer (some jurisdictions)
Equipment Component Options

Outdoor Units + Branch Circuit Controller + Indoor Units + Control System
Domestic Hot Water and Boiler Unit

**Hot/chilled water unit**
- Heats water to 113°F
- Cools water to 50°F

**Booster unit**
- Heats water to 160°F
Zonal Temperature Control

- VRF
- Conventional HVAC

Graph showing room temperature over time for VRF and conventional HVAC systems.
Controls Network

- BMS integration controls, LonWorks® or BACnet®
- PC-based control via web browsers or software
- Centralized control
- Individual zone control
Water-Source Heat Recovery System

Water-source units

Heat recovery

BC controller

Indoor units

Water circuit

Heat recovery
VRF Summary

- VRF can reduce HVAC energy consumption up to 40 percent over the current code minimum efficiency,
  - Depends on location and application
- Ground source system is more efficient in extreme climates
- Fan energy savings:
  - Ductless capability
  - VRF operates at ~300 cfm/ton vs ~400 cfm/ton for traditional HVAC

continued
• High part-load efficiency per AHRI 1230 (IEER)
• Internal/external heat recovery
• Current energy model software underestimates energy savings
Case Study #1

Lewis County PUD (Rice Group, Inc.)
Chehalis, Washington

Two-story, 23,700 square foot office building
Built in the 1940s
VRF installed to:

• Increase zoning for better comfort
• Allow building to remain occupied during construction
• Allow phased installation
• Reduce carbon footprint
• Keep hard ceilings intact
• Provide simple control system
• Existing supply/return duct for dedicated outdoor air system (DOAS) with a heat recovery unit
Lewis County PUD

Design considerations

• Condensate drainage
• Submetering capability

Comments

• Occupants very happy with increased comfort and control
• Very quiet system
• Control system simple and easy to operate
Case Study #2

Pacific University, Burlingham Hall
Forest Grove, Oregon

49-unit dorm, 59,000 square feet
Pacific University, Burlingham Hall

Benefits

• Uses 33.5 percent fewer kilowatt-hours than modeled in the baseline
• Uses 28.9 percent fewer kWh than expected
• Electricity costs are $11,600/year less than forecasted
• Works well with historical campus architecture
• Structural and architectural advantages
• No additional backup heat required
Case Study #3

Little Deschutes Lodge
La Pine, Oregon

Little Deschutes Lodge

26-unit complex
## Annual Energy Use (kBtu/sf/yr) and Percent Savings Compared to Air-Source Heat Pump

<table>
<thead>
<tr>
<th>City</th>
<th>Air-Source Heat Pump (HP)(^1)</th>
<th>Ground-Source HP(^2)</th>
<th>VRF (air-source)</th>
<th>Ground-Source VRF HP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kBtu</td>
<td>kBtu</td>
<td>kBtu</td>
<td>kBtu</td>
</tr>
<tr>
<td>Billings</td>
<td>65.3</td>
<td>46.0</td>
<td>46.2</td>
<td>42.5</td>
</tr>
<tr>
<td>Phoenix</td>
<td>65.9</td>
<td>51.8</td>
<td>45.5</td>
<td>40.9</td>
</tr>
<tr>
<td>Denver</td>
<td>59.5</td>
<td>44.3</td>
<td>41.5</td>
<td>40.4</td>
</tr>
<tr>
<td>Kansas City</td>
<td>73.5</td>
<td>49.3</td>
<td>46.2</td>
<td>43.5</td>
</tr>
<tr>
<td>Seattle</td>
<td>54.9</td>
<td>43.9</td>
<td>34.7</td>
<td>34.6</td>
</tr>
<tr>
<td>Portland</td>
<td>56.5</td>
<td>44.6</td>
<td>36.0</td>
<td>35.3</td>
</tr>
</tbody>
</table>

\(^1\) EER = 10.0, Seasonal Energy Efficiency Ratio (SEER) = 13.0, Heating Season Performance Factor (HSPF) = 5.0
Air-source heat pumps are commonly used in assisted living facilities, hotels, etc.

\(^2\) EER = 15.7, Coefficient of Performance (COP) = 3.3
Little Deschutes Lodge

- 26-unit complex, on-site laundry, community room, reading room, two computer centers, kitchens
- Gas and electric = $37/month per occupant
- EUI = 29 KBtu/sf (national average = 70 KBtu/sf)
- 28 horizontal trenches, 150 feet long
- 600 feet of 1-inch pipe per trench
- Four 8-ton VRF water-source heat pump
- Cost-effective for HUD affordable housing owners
Benefits

- Extreme temperatures – winter and summer
- Ground source more beneficial than air source
- HUD – rental fees constrained
  - Utility cost more cost-effective with VRF