VRF Technology: Future of HVAC

Kartik Singla
Thursday June 22
Agenda

• VRV 101
• Energy Comparison
• Market Analysis
• Technology Growth
The VRF Solution

Refrigerant distribution system vs water
Multiple DX indoor units with electronic expansion valves
Variable inverter compressors in outdoor units
Optimized for part load efficiencies
The VRF Solution

Variable - System output depending on required load
Refrigerant - R-410A Direct Expansion System
Volume - Refrigerant flow regulated by EEV and variable speed compressor

*Trademarked VRV in 1982

Variable - System output depending on required load
Refrigerant - R-410A Direct Expansion System
Flow - Refrigerant flow regulated by EEV and variable speed compressor
Heat Pump Systems

All indoor units are in either heating or cooling

Automatic switchover within minutes, year round
Heat Pump Systems

No compressors in space
No water for HVAC
Heat Recovery Systems

Groups of indoor heads can heat or cool independently

Transfer of heat
Heat Recovery Systems

Heating & Cooling independence
No compressors in space
No water for HVAC
Water-Cooled VRV
The Water-Cooled VRV Solution

- Centralize all compressors into indoor VRV water-cooled condensing units
- Stack VRV condensing units in closets on each floor, feeding off central condenser water lines
- Distribute refrigerant in hallway ceilings from condensing units into each suite
- Use stacked VRV fan coils (similar to stacked heat pumps), or ceiling mounted horizontal fan coils
- LESS: compressors (1/10th), maintenance, in-suite noise, custom calls and complaints
- MORE: reliability, efficiency (helps meet SB-10, TGS Tier 1, Tier 2, LEED)
The Water-Cooled VRV Solution

Conventional water-source heat pumps
Water-Cooled VRV
Air-Cooled Example Layout #1

 Normally Heat Recovery

Up to 295ft.
Multiple condensing units on roof (one condensing unit per system, serving each floor)

Refrigerant risers for each suite stack (2/3-pipes per riser, ~1” per pipe)

Vertical fan coil in each suite

Air-Cooled Example Layout #2

Normally Heat Pump
VRV CU’s

Convert mechanical rooms into more leasable / sellable space

Air-Cooled VRV System

Boilers  Domestic F/P Pumps
HVAC Pumps
Tanks
Filtration
Cooling Towers
Heat Exchangers
Chillers
Boilers
Domestic F/P Pumps
Convert some mechanical room space into more leasable / sellable space

Water-Cooled VRV System

Cooling Towers

HVAC Pumps  Tanks  Filtration

Boilers  Domestic F/P Pumps

VRV Indoor Water-cooled condensing units in closets on each floor with one main water riser
Office - VAV

- HVAC Pumps
- Tanks
- Boilers
- Air Cooled Chiller
- Central VAV Air Handlers
- Filtration
- Domestic F/P Pumps
- Large ductwork
- Office - VAV
Office - VRV

- VRV Fan Coils
- Boilers
- Domestic, F/P Pumps
- VRV CU’s
- Increased ceiling heights
- Reduced mechanical rooms
Independent Energy Analysis

• Smith & Anderson [Footprint Division]
• Energy Modelling report
• VRF vs WSHP vs VAV vs VVT
• 25% Annual cost savings vs WSHP

![Annual Energy Cost Comparison](image)
Independent Energy Analysis

Annual Energy Comparison

- VVT
- VAV
- HP
- VRF 1
- VRF 2

- Lighting
- HP heating
- Heating gas
- Cooling
- Fans
- DHW
- Receptacle
- Pumps & Auxillary
- Heat Rejection
Independent Energy Analysis

- Nemetz & Associates
- Evaluation of a VRV system vs four pipe fan coil system for a downtown Toronto Condo
- 40.7% annual cost savings vs 4-Pipe fan coil

**TABLE – 2 SYSTEM ANNUAL ENERGY COST COMPARISON**

<table>
<thead>
<tr>
<th>Component</th>
<th>North Tower - 4 Pipe FC ($)</th>
<th>North Tower – VRV ($)</th>
<th>South Tower - 4 Pipe FC ($)</th>
<th>South Tower – VRV ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC Total</td>
<td>$67,348</td>
<td>$37,361</td>
<td>$160,480</td>
<td>$97,778</td>
</tr>
</tbody>
</table>

Regarding the annual operational cost, the VRV system present an operational energy cost savings of $92,689 per year or a 40.7% in energy savings, see table 2 above.
Independent Energy Analysis

- Provident Energy Management
- Building Permit Stage Energy Modeling Report
- Air-Cooled VRF vs 2-Pipe Fan Coil
- Condo. 9 Story. 106 Suites. 111,000 sq.ft. Toronto.
Independent Energy Analysis

• Provident Energy Management
• Building Permit Stage Energy Modeling Report
• Ontario Energy Efficiency Requirements
• Over 3 Story & Window to Wall ratio > 40%
• Permits > January 1 2014 : Part 12 of OBC & SB-10
• Building Efficiency (based on model) > ASHRAE 90.1-2010

<table>
<thead>
<tr>
<th>Goal</th>
<th>Requirement / Compliance method</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>TGS Tier 1</td>
<td>15% reduction over OBC SB-10 (15% better than ASHRAE 90.1-2010)</td>
<td>GJ</td>
</tr>
<tr>
<td></td>
<td>Summer &amp; Winter peak electricity better than OBC SB-10</td>
<td>kW</td>
</tr>
<tr>
<td>OBC SB-10</td>
<td>5% reduction over ASHRAE 90.1-2010</td>
<td>GJ / GHG emissions</td>
</tr>
<tr>
<td></td>
<td>Peak electricity better than OBC SB-10</td>
<td>kW</td>
</tr>
<tr>
<td></td>
<td>5% Carbon reduction over ASHRAE 90.1-2010</td>
<td>kG CO2e</td>
</tr>
<tr>
<td>LEED Gold</td>
<td>Minimum 38% reduction over MNECB (8 EAc1 points)</td>
<td>Cost</td>
</tr>
</tbody>
</table>
Independent Energy Analysis

- Provident Energy Management
- Building Permit Stage Energy Modeling Report
- Ontario Energy Efficiency Requirements
- Over 3 Story & Window to Wall ratio > 40%
- Permits > January 1 2014 : Part 12 of OBC & SB-10
- Building Efficiency (based on model) > ASHRAE 90.1-2010

### Table 3 - Project Performance Summary

<table>
<thead>
<tr>
<th>Metric</th>
<th>Air Source HP w/ VRV %improvement</th>
<th>Compliant?</th>
<th>2 Pipe Fan Coil %improvement</th>
<th>Compliant?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OBC</td>
<td>TGS</td>
<td>OBC</td>
<td>TGS</td>
</tr>
<tr>
<td>Energy Use</td>
<td>19.0 %</td>
<td>Yes</td>
<td>Yes</td>
<td>12.0 %</td>
</tr>
<tr>
<td>Peak kW</td>
<td>48.9 %</td>
<td>Yes</td>
<td>-</td>
<td>4.5 %</td>
</tr>
<tr>
<td>Carbon Emissions</td>
<td>22.8 %</td>
<td>Yes</td>
<td>-</td>
<td>15.8 %</td>
</tr>
<tr>
<td>Energy Cost</td>
<td>20.9 %</td>
<td>Yes</td>
<td>-</td>
<td>6.4 %</td>
</tr>
</tbody>
</table>
Independent Energy Analysis

- Provident Energy Management
- Building Permit Stage Energy Modeling Report
- Air-Cooled VRF vs 2-Pipe Fan Coil
How to compare VRV efficiency

AHRI Standard 1230

Testing and rating standard specially designed for VRF

This will allow manufacturer’s to show VRF efficiency levels for:

- Full Load
- Part Load
- Heat Recovery

https://www.ahridirectory.org/ahridirectory/pages/vrfhp/defaultSearch.aspx
What is IEER

- IEER - Integrated Energy Efficiency Ratio
  - New part load efficiency metric
  - Replaces IPLV in ASHRAE 90.1 2010 for Unitary Equipment above 65,000 Btu/h

- IEER vs. IPLV
  - IEER requires ratings at specific load conditions
  - Uses sliding temperature scale

<table>
<thead>
<tr>
<th>Stage</th>
<th>Ambient (F)</th>
<th>Actual % Load (Net Cap)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>95.0</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>81.5</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>68.0</td>
<td>50</td>
</tr>
<tr>
<td>1</td>
<td>65.0</td>
<td>25</td>
</tr>
</tbody>
</table>
System kW/Ton comparison

**VRV vs. W/C Centrifugal**

- VRV
- AHU
- CHW
- PUMP

**VRV vs. A/C Screw Chiller**

- System kW/Ton comparison
- System Load %
System kW/Ton

VRV vs. VFD W/C Centrifugal

VRV vs. VFD A/C Screw Chiller

System Load %
1973 - Global oil crises
1979 - New energy efficiency laws passes in Japan
1980 - Chiller design engineers challenged with making a higher efficiency chiller
1982 - The worlds first VRV System is launched by Daikin in Japan
1983 - 1987 - Daikin introduces VRV to European and Middle Eastern markets
2001 - VRV is introduced to North America
VRF’s delay in move to North America

Low utility rates
Existing AC market / solutions
Force air / Chilled water AC
Strong N/A brands & products

High utility rates
Single Split replacement
Retrofit / AC addition
New AC markets
After Daikin - McQuay in 2006
All 4 major North America brands have partnered with an Asian VRF manufacturer
ALL IN THE PAST 24 MONTHS
The shift is happening
VRV growth and projected growth in North America

- VRF Units p.a.
- 25% p.a. growth through 2018
- Fastest growing segment of North American HVAC market
North America

**THEN**

- Life cycle commitment to one manufacturer
- No secondary market
- Limited to single source reps / distributors

**NOW**

- Multiple sources of distribution
- 10 year parts warranty (Daikin)

**ASHRAE 15 / CSA B52 Refrigerant charge limitations**

- Limited to 13 lbs / 1,000 cu.ft. until:
  - 2007 (US - ASHRAE)
  - 2009 (CANADA - CSA B52)
- Eliminated major VRF verticals
  - Mid/High-rise residential & hospitality
  - Office
- Limit increased to 26 lbs / 1,000 cu.ft until:
  - 2010 (US - ASHRAE ADD-L)
  - 2013 (CANADA - CSA B52 < 1,000m)

**VRF product performance & certification**

- Non-existent
- No ASHRAE reference
- AHRI industry standard (Standard 1230)
- VRF section in 2012 ASHRAE Handbook
AHRI Standard 1230

North America

Contracting Community

**THEN**

- Very few trained installers
- Very few trained for service & maintenance
- High equipment cost
- High install cost (lack of training)
- Resulted in long paybacks

**NOW**

- Many (many) trained contractors
- Multiple contractors for service & maintenance
- Competitive equipment cost
- Competition on install costs
- In-line or up-front savings vs traditional

**Up-front Capital costs**

**Price of utilities & paybacks**

**THEN**

- Avg. US electricity: ~7 cents
- Price of oil: $25
- Avg. Ontario electricity: ~4.3 cents

**NOW**

- Avg. US electricity: ~10 cents
- Price of oil: $45
- Avg. Ontario electricity: ~11 cents
Heating Capability of Air-Cooled Heat Pump

**THEN**
- No Data at design temperatures
- No easy integration with auxiliary heating
- No market confidence

**NOW**
- Tested data down to -13°F
- Direct integration with auxiliary heating
- Market confidence via operational data

*2014/15 Winter - Polar Vortex tests*
Vaunting VRF: An Energy Slashing System Is on the Rise

Get familiar with an HVAC technology that is dominant overseas

By Christopher Curtland

Variable refrigerant flow (VRF) HVAC systems may soon become a very important import in the U.S. It has about 24% of the global commercial air conditioning market and over 35% market share in China, India, the European Union, and Eastern Europe. But as of 2012 in the U.S., VRF represents only 3%, according to a GSA report citing manufacturer LG.
Existing projects (large) Northern US / Canada

- 400,000 sq.ft (42F)
- 500,000 sq.ft.
- 175,000 sq.ft.
- 110,000 sq.ft (22F)
- 265,000 sq.ft.
- 300,000 sq.ft.
- 150,000 sq.ft.
- 310,000 sq.ft.
Existing projects (large) Northern US / Canada

- 800 Tons
- 964 Tons
- 350 Tons
- 220 Tons
- 530 Tons
- 600 Tons
- 620 Tons
- 300 Tons
- 530 Tons
- 600 Tons
- 964 Tons
- 620 Tons
Questions?

Kartik Singla
kartik.singla@dxseng.com