Scroll Compressor Technology

Optimizing Efficiency

Greg Swiercz

Engineering Manager – Emerson Climate Technologies Canada
Agenda

- Commercial Update
  - Market Outlook
- R-410A Update
- Design Comparison – Recip. vs. Scroll
- R410A model line
  - Fixed Capacity Scrolls
  - Tandems
  - Ultratech
  - Digital Scroll
- Efficiency Standards
R-410A Update
R-22 Phase-Out Timeline

- R-22 Banned From New U.S. System Installations In 2010
- In 2015, R-22 Production Drops To 10% Of 1996 Levels
- Production Of R-22 For Service Needs Ends 2020 In U.S.

% 1996 CAP

100% 65% 25% 10%

New Equipment Life: 15 Year Avg.
Commercial Conversion To R-410A

- “Green Buildings” Encourage Alternate Refrigerant Specifications
  - LEED Program Gaining Momentum
  - LEED Ordinances By State And City
- Governments/Institutions Adopting LEED
  - Environmental Stewardship
  - Product Life Cycle
- Major Retailers Specifying R-410A Systems
  - Wal-Mart Specified R-410A In Jan. 2004
  - Others Include Kroger, IKEA, Hobby Lobby, Bed Bath & Beyond
  - Total Cost Of Ownership Over Life Cycle
Commercial A/C Refrigerant Trends – North America Systems To 100 Tons

(% Of Sales)

R22

R410A

R407C/ R134a

R410A %

Commercial

1% 1% 4% 7% 11% 15% 25% 50% 95%

Residential

4% 5% 6% 9% 18% 22% 35% 56% 100%
Scroll Overview
Semi-Hermetic Compressors - Design & Construction

Discharge

Low Pressure Gas

Suction Reed

High Pressure Gas

Discharge Reed
How Semi-Hermetic Compressors Work

1. Start of cycle.
2. Low pressure refrigerant gas enters cylinder on piston down-stroke.
3. Pressure equalizes and suction reed closes.
How Semi-Hermetic Compressors Work

4. Piston up-stroke increases pressure and temperature of refrigerant in cylinder and causes discharge reed to open.

5. Pressure equalizes and discharge reed closes. Small volume of high pressure gas remains in valve plate port and clearance between piston and valve plate.

6. High pressure gas must re-expand to low pressure before suction reed can open. This “volumetric expansion loss” limits the compressor’s efficiency.
Scroll Compressors – Design & Construction

- IPR Valve
- Fixed Scroll
- Orbiting Scroll
- Press & Stake Main Bearing Housing
- Molded Plug
- Check Valve
- Floating Seal
- DU Drive And Main Bearings
- Lower Bearing

Copeland®

Emerson Climate Technologies
How The Copeland Scroll Works

Fixed Scroll

Orbiting Scroll
How a Compliant Scroll Works

Scrolls will compress gas only when operated in the correct direction of rotation.
All Sides Pump At Once

Med. Pressure Cell

Low Pressure Cell

High Pressure Cell

Center Discharge

Continuous Compression
“Compliant Scroll” – What Is It?

• “Compliance” Is The Ability Of Scrolls To Separate Under Abnormal Conditions
  • Scrolls Separate For Better Liquid Handling & Debris Tolerance

• Two Types Of Compliance
  • Radial & Axial Directions

• Patented Technology Found In No Other Scroll
  • Compliance Allows Scrolls To “Wear In” - No Tip Seals To Wear Out

• Full Compliance Improves Efficiency, Durability, Sound, And Reliability
Copeland Compliant Scrolls

Axial Compliance

Axial compliance is the key to Digital Modulation

Radial Compliance
Floating Seal

**Air Conditioning**
- Loaded: <11:1
- Refrigeration: <26:1

**Unloaded**
- Loaded: >11:1
- Refrigeration: >26:1
Floating Seal
R410A Scroll Compressor Availability

Single Stage Compressors
## Copeland Scroll Air Conditioning Product Offering

<table>
<thead>
<tr>
<th>Family:</th>
<th>Quantum&lt;sup&gt;1,2,3&lt;/sup&gt;</th>
<th>Quest&lt;sup&gt;1,2,3&lt;/sup&gt;</th>
<th>5G</th>
<th>Summit&lt;sup&gt;2,3&lt;/sup&gt;</th>
<th>LCS&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame:</td>
<td>63</td>
<td>70</td>
<td>53 &amp; 63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cap. (HP):</td>
<td>2-4</td>
<td>4-6.5</td>
<td>1.5-5</td>
<td>7-12→15</td>
<td>20-30</td>
</tr>
<tr>
<td>Mfg. Location:</td>
<td>Missouri Louisiana Ohio</td>
<td>Missouri Louisiana Ohio</td>
<td>Missouri Louisiana Thailand</td>
<td>Ohio Thailand Belgium</td>
<td>Ohio Belgium</td>
</tr>
<tr>
<td></td>
<td>Louisiana Ohio</td>
<td>Louisiana Thailand N. Ireland</td>
<td>China</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thailand</td>
<td>N. Ireland</td>
<td>China</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>China</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N. Ireland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Available With UltraTech, Two Stage Modulation
2. Available With Digital, Continuous Modulation
3. Available In Tandem Options

“Specter” now only produced in Europe for service
Copeland Has Introduced New Generation Scroll Product for R410A

- Developed New Scroll Technology That Increases Capacity Within A Given Diameter
  - New Scroll Designs – Optimized
  - Smaller Diameter Motors
  - Higher Efficiency
- Light Commercial Applications Will Also Use New Scrolls
  - Rooftop, Splits
  - Other Derivative Applications
  - 13 SEER Residential Standard a driving force
**ZPK5 Scroll**
**Improved R410A Performance**

- **Range:** 1.5 – 5.0 Tons
- **Refrigerant:** R-410A
- **Application:** ZPK5 13+ SEER
  Single Phase And Three Phase
  Full Envelope
  50/60 Hz
- **Efficiency:** 10.0-10.6 EER (3 Phase)
  1-5% Higher Efficiency
- **Sound:** 66 dBA
  (2-4 dBA Quieter Than ZPK3)
- **Production:** In Production
# R-410A Summit & LCS Availability

## HP Model

<table>
<thead>
<tr>
<th>HP</th>
<th>Model</th>
<th>7.5</th>
<th>9</th>
<th>10</th>
<th>12</th>
<th>13</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>26</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5</td>
<td>ZP90</td>
<td>ZPT180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>ZP103</td>
<td>ZPT206</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>ZP120</td>
<td>ZPU223</td>
<td>ZPT240</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>ZP137</td>
<td>ZPU240</td>
<td>ZPU257</td>
<td>ZPT274</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>ZP154</td>
<td>ZPU227</td>
<td>ZPU274</td>
<td>ZPT308</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>ZP182</td>
<td>ZPU272</td>
<td>ZPU285</td>
<td>ZPU302</td>
<td>ZPU319</td>
<td>ZPU336</td>
<td>ZPT364</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>ZP235</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>ZP285</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZPT570</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>ZP295</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZPU449</td>
<td>ZPU477</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>ZP385</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZPU680</td>
</tr>
</tbody>
</table>

## Trio

Drawings Only

<table>
<thead>
<tr>
<th>Trio</th>
<th>ZPY360</th>
<th>ZPY411</th>
<th>ZPY462</th>
<th>ZPY546</th>
<th>ZPY705</th>
<th>ZPY855</th>
<th>ZPY885</th>
<th>ZPY116M</th>
</tr>
</thead>
</table>

- **Final Released Tandem/Trio**
- **SEPTEMBER 2007 Final Release**
- **NOVEMBER 2007 Final Release**
- **JANUARY 2008 Final Release**
- **Phase-Out In March 2008**
- **No Tandem Development Will Happen**
- **No USA Production Release Planned At This Time - Only Drawings**
LCS Update
ZP295KCE – 26HP Design

- ZP295 Is R410A Derivative Of ZR310
  - Alternative To ZP285
  - In Production Since 2005
- Increased Cooling Capacity
  - +16K Btu/hr (+ 5.8%)
- Reduction In Efficiency
  - -0.1 EER Rated Difference In OPI (-0.9%)
  - ZP285 Gains Driven By Large Suction
- Benefits Of ZP295
  - Sidney Production Begins October 2007
  - ZP285 Phase-Out Effective March 31, 2008
# 25-26HP Technical Comparison (R-410A)

<table>
<thead>
<tr>
<th>Model</th>
<th>Refrigerant</th>
<th>Cooling Capacity - Kbtu/hr</th>
<th>Efficiency - EER (COP)</th>
<th>Dimensions - mm</th>
<th>Weight - lbs. (kg)</th>
<th>Suction - Brazed</th>
<th>Suction - Rotalock/Flange</th>
<th>Discharge - Brazed</th>
<th>Discharge - Rotalock/Flange</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZP235KCE</td>
<td>R-410A</td>
<td>235</td>
<td>11.1 (3.25)</td>
<td>427 x 376 x 737</td>
<td>324 (147)</td>
<td>1-5/8&quot; ID</td>
<td>2-1/4&quot; x 12UN</td>
<td>1-3/8&quot; ID</td>
<td>1-3/4&quot; x 12 UN</td>
</tr>
<tr>
<td>ZP285KCE</td>
<td>R-410A</td>
<td>278</td>
<td>11.4 (3.34)</td>
<td>447 x 427 x 734</td>
<td>417 (189)</td>
<td>2-1/8&quot; ID</td>
<td>2-1/4&quot; x 12UN</td>
<td>1-3/8&quot; ID</td>
<td>1-3/4&quot; x 12 UN</td>
</tr>
<tr>
<td>ZP295KCE</td>
<td>R-410A</td>
<td>294</td>
<td>11.3 (3.31)</td>
<td>447 x 390 x 734</td>
<td>353 (160)</td>
<td>1-5/8&quot; ID</td>
<td>2-1/4&quot; x 12UN</td>
<td>1-3/8&quot; ID</td>
<td>1-3/4&quot; x 12 UN</td>
</tr>
<tr>
<td>ZP385KCE</td>
<td>R-410A</td>
<td>385</td>
<td>11.1 (3.25)</td>
<td>447 x 427 x 734</td>
<td>390 (177)</td>
<td>1-5/8&quot; ID</td>
<td>2-1/4&quot; x 12UN</td>
<td>1-3/8&quot; ID</td>
<td>1-3/4&quot; x 12 UN</td>
</tr>
</tbody>
</table>
Widest selection available in the industry

Nominal Tonnage from 1.3 – 32 “tons”

40 “ton” soon to be released

Continual development ongoing to increase compressor efficiency
Modulation

- Manifolding
- UltraTech Scroll
- Digital Scroll
Modulation Methods Overview

- Manifolding Compressors
  - Stepped Capacity
  - Uneven & Even Configurations

- Copeland Scroll UltraTech
  - Two-Step Scroll Capacity

- Copeland Scroll Digital
  - Infinitely Variable Scroll Capacity
Tandems And Trios

- Tandem Even And Uneven For Optimal Modulation
- High Reliability
  - Symmetric Suction Design
  - Gas And Oil Equalization Lines To Ensure Equal Oil Distribution At Any Operating Conditions
- No Lead Compressor
- Compact Size And Ease Of Assembly
# Tandem Performance & Reliability Testing

<table>
<thead>
<tr>
<th>Test/Item</th>
<th>Purpose / Method</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Of Tubing Manifolds</td>
<td>Best Practices &amp; CFD</td>
<td>2-3 weeks</td>
</tr>
<tr>
<td>Calorimeter Testing</td>
<td>Oil Balancing Confirmation</td>
<td></td>
</tr>
<tr>
<td>2-3 weeks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strain Gauging</td>
<td>Avoid Tubing Fatigue &amp; Resonance</td>
<td></td>
</tr>
<tr>
<td>2-3 weeks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life Testing</td>
<td>Confirm Reliability Under Accelerated Field</td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Start/Stop Tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>60 days</td>
</tr>
<tr>
<td>- Continuous Run</td>
<td>Long Term Oil Starvation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>21 days</td>
</tr>
<tr>
<td>- HCR &amp; Floodback</td>
<td></td>
<td>84 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>6+ months</td>
</tr>
</tbody>
</table>
R410A Tandem Compressor Availability

- Even and uneven tandems available
- Even Tandems
  - ZPT100 – ZPT770 (8-64 TONS)
- 100/50% capacity steps per unit
  (100/75/50/25% if 2 tandems are used on separate circuits.)
- Uneven Tandems
- ZPU274 – ZPU680 (23-56 TONS)
  - 56/44% capacity split approx (depends on compressor match)
Single Compressor Modulation Platforms

- Fixed Scroll Platforms
- UltraTech
  - Residential A/C SEER-Based Systems
- Digital
  - Refrigeration Transport
  - Asia Multi-Evaps
  - Commercial A/C
## UltraTech Scroll And Digital Scroll Serve Different Markets

<table>
<thead>
<tr>
<th>Target</th>
<th>UltraTech Ducted Systems</th>
<th>Digital Non-Ducted Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Evaps</td>
<td>One</td>
<td>Multiple</td>
</tr>
<tr>
<td>Ratings</td>
<td>SEER Based</td>
<td>EER/IPLV Based</td>
</tr>
<tr>
<td>Capacity Range</td>
<td>67% Or 100%</td>
<td>10% To 100%</td>
</tr>
<tr>
<td>Full Load Efficiency</td>
<td>95%</td>
<td>100%</td>
</tr>
<tr>
<td>67% Load Efficiency</td>
<td>94%</td>
<td>87%</td>
</tr>
<tr>
<td>SEER Rating</td>
<td>Best</td>
<td>Good</td>
</tr>
<tr>
<td>IPLV Rating</td>
<td>Good</td>
<td>Best</td>
</tr>
</tbody>
</table>
Capacity Modulation Product Plan

- UltraTech Scroll (Two Step) is the right technology for U.S. Residential A/C Applications
  - Part Load Efficiency is Excellent
  - 33% Unloading Adequate – Preferred for Residential

- Digital Scroll (Continuous) is the right technology for applications requiring large or varied steps of unloading
  - Commercial A/C systems requiring steps <15 tons
  - Specialty applications requiring tight temperature control
  - Commercial systems with wide varying loads
  - Multi-Evaporator / Single Condenser systems
**Copeland Scroll UltraTech**

- High Efficiency
  - 17.5 EER @ 45/100 (R-410A)
- Premium Comfort
  - 67% Part Load Capacity
- Quiet Operation (Sound And Vibration)
- Easy To Apply/Control
  - No Power Lead Switching
  - No Shutdown To Change Capacity
  - Control Via Solenoid
- Copeland Scroll Reliability
UltraTech Design Overview

Two Step Gas Bypass

- Bypass Ports Closed: 100% Capacity
- Bypass Ports Open: 67% Capacity
UltraTech Design Overview

- Fixed Scroll Sub-Assembly
- Modulation Ring and By Pass Seals
- Bypass Ports
- Solenoid Coil Assembly
- Locating & Hold Down Pins
Copeland Scroll UltraTech
“An Even Better Copeland Scroll”

Improves Temp And Humidity Control 53%

OEMs Can Reach Higher Efficiencies

Florida 2-Step vs. Single Speed Field Data

Readings from 3/29/02 - 4/9/02

It’s So Simple!

“UltraTech Is Fabulous! It’s Extremely Quiet. I’m Very, Very Pleased” – California Contractor
Copeland Scroll Digital Technology

- Continuous Modulation From 10-100% Capacity
  - Modulate Without Inverters
- Nearly 200K Pcs Sold Worldwide Since 2001
- Digital Scroll Applications Include:
  - Rooftop A/C
  - Precision Cooling
  - Air Driers
  - Asia Multi-Evap
  - Specialty A/C Equipment
- R-22 Models Available From 4-10 HP
- 5-10 HP R-410A Models Launched In ‘07
## 8-10HP Digital Design

### Comparison To Current Design

<table>
<thead>
<tr>
<th>Current Design (4-7HP)</th>
<th>New Design (8-10HP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Piston Lifts Fixed Scroll Up To Unload</td>
<td>• Tubing Routes Gas To Manifold In Shell</td>
</tr>
<tr>
<td>• External Tubing</td>
<td>• External Cartridge Valve Controls Gas Flow</td>
</tr>
</tbody>
</table>

![Piston Modulation](image1.png)

![Intermediate Cavity Modulation](image2.png)
Digital Modulation – How It Works

- Full Capacity
- Zero Capacity

20% Output
- Full Capacity
- Zero Capacity
- 4 Sec
- 16 Sec

50% Output
- Full Capacity
- Zero Capacity
- 10 Sec
Copeland Scroll Digital Controller

- Simple Controller That Enables OEM’s To Use Digital Scrolls
- Relieves OEM From Developing Special Controllers
  - Faster Time To Market
- Copeland Controller Functions
  - Controls
    - Compressor Contactor
    - Capacity Modulation Solenoid
    - Vapor Injection Solenoid
  - Protection
    - Excessive Discharge Temperature
    - Low Flow Conditions
    - Operation Under Fault Conditions
  - Diagnostics
    - 8 Codes Indicating Faults
- Module Is Installed In System Cabinet
Copeland Scroll Digital Technology

How It Works (40% Capacity Example)

- Copeland Scroll Digital Controller Checks For Cooling Demand
- Controller Then Sends Capacity Requirements To Compressor
  - Run Loaded For 8 Seconds
  - Run Unloaded For 12 Seconds
- Over 20 Second Cycle, Average Compressor Output Is 40% of full capacity
- At End Of 20 Second Cycle, Controller Checks For Demand & Adjusts Loaded/Unloaded Time Accordingly
Input Signal From OEM Controller

- Digital Controller Receives 1.4-5.0 V Input Signal From System Controller
- 1.4-5.0 VDC Corresponds To 10-100% Compressor Capacity
Copeland Digital Scroll Controller
Optional Pressure Signal Filtering

- Digital Controller Can Provide Suction Pressure Feedback
  - 5 VDC Suction Pressure Transducer Required
  - Algorithm “Filters” Suction Pressure Swings
Who Benefits From Copeland Scroll Digital Technology?

- Applications That See Large Daily Temperature Swings
  - Schools
  - Restaurants
  - Natatoriums

- Applications With Tight Temperature/Humidity Control Requirements
  - Hospitals
  - Museums
  - Telecom
Copeland Scroll Digital Application Benefits

- Match Varying Load
  - Hot Gas Bypass Replacement

- Precise Temp Control (±0.5°F)

- Simple Modulation Scheme Compared To Inverter Drive
  - Less Complex Controls
  - No EMI Issues
  - No Oil Return Issues

Modulation Features Benefits

- Lower Operating Cost
- Improved Comfort
- Improved Humidity Control
- Higher Reliability
- Lower Maintenance Cost
- Lower Installed Cost
Copeland Scroll Digital™ Power Savings

- **Energy Savings**
  - Hot Gas By-Pass

Copeland Scroll Digital reduces power consumption linearly as it modulates capacity.
Modulation Overview – Micro View

- Proper Matching Of Compressor Suction Pressure to Set Point Could Lead To Reduced Energy – Only Empirical Information To Date

**Chart 2: Compressor Cycling Suction Pressure Load Matching**

**Without Good Load Matching**
- Higher Energy Cost Due To Pressure Fluctuations

**Chart 3: Variable Speed Suction Pressure Load Matching**

**With Good Load Matching**
- Expected Energy Savings
  - 2-3% for LT
  - 3-7% for MT

*Blue – Set-point; Red - Actual*
Digital Scroll Offers Superior Part-Load Efficiency Versus Hot Gas By-Pass

<table>
<thead>
<tr>
<th>% Full Capacity</th>
<th>Hot Gas By-Pass EER</th>
<th>Digital Scroll EER</th>
<th>IPLV Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>2.9</td>
<td>6.3</td>
<td>12%</td>
</tr>
<tr>
<td>50%</td>
<td>5.7</td>
<td>8.2</td>
<td>45%</td>
</tr>
<tr>
<td>75%</td>
<td>8.6</td>
<td>10.0</td>
<td>42%</td>
</tr>
<tr>
<td>100%</td>
<td>11.5</td>
<td>11.3</td>
<td>1%</td>
</tr>
<tr>
<td>Integrated Part Load Value</td>
<td>6.7</td>
<td>8.8</td>
<td>100%</td>
</tr>
</tbody>
</table>

Part-Load Efficiency (IPLV)

- Hot Gas By-Pass
- Digital Scroll

30% Part-Load Efficiency Improvement With Copeland Scroll Digital!
Digital Modulation Over Larger Capacities

18 HP System Example

- Digital Can Be Used In Parallel With Fixed Capacity Scrolls To Get Even Wider Range Of Capacities
- Power Savings Still Follow The Same Line
- Leverages The Cost And Capability Of One Digital Over Larger Systems

1. Ramp Digital From .6 To 6 HP
2. Ramp Digital From 6.6 To 12 HP
1. Turn On 1 6 HP Scroll
2. Ramp Digital From 12.6 To 18 HP
1. Turn On 2nd 6 HP Scroll
# Digital Scroll Benefits Multi-Circuit Applications

## Capacity Range (4 Circuit System)

<table>
<thead>
<tr>
<th>Load Demand (HP)</th>
<th>Capacity ZPD83 Digital (HP)</th>
<th>Capacity ZP83 Fixed (HP)</th>
<th>Capacity ZP83 Fixed (HP)</th>
<th>Capacity ZP83 Fixed (HP)</th>
<th>System Output (HP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load = 0</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>0</td>
</tr>
<tr>
<td>Load &lt; 7.5</td>
<td>0.75 – 7.5</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>0.75 – 7.5</td>
</tr>
<tr>
<td>8.25 &lt; Load &lt; 15</td>
<td>0.75 – 7.5</td>
<td>7</td>
<td>OFF</td>
<td>OFF</td>
<td>8.25 – 15</td>
</tr>
<tr>
<td>15.75 &lt; Load &lt; 22.5</td>
<td>0.75 – 7.5</td>
<td>7</td>
<td>7</td>
<td>OFF</td>
<td>15.75 – 22.5</td>
</tr>
<tr>
<td>22.5 &lt; Load &lt; 30</td>
<td>0.75 – 7.5</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>22.5 – 30</td>
</tr>
</tbody>
</table>

## 4 Circuit 30 HP System

- **ZPD83 Digital**
- **ZP83 Fixed**

Leverage Cost & Capability Of 1 Digital Scroll Across Entire System
Copeland Scroll Digital – Product Offering

R-22 / R-407C – Current
- Digital Quantum – 36K (TF5), 42K (TFD) – Thailand
- Digital Quest – 49K, 61K, 72K, 81K (TFD)
- Digital Quest Tandems – 11M, 12M, 13M, 14M, 16M (TFD)
- Digital Summit – 94K, 125K

R-410A – Current
- Digital Quest – 61K (TFD), 72K (TFD), 83K (TFD) – Thailand

R-410A – In Development
- Digital Quantum – 42K5, 51K5 – Thailand
- Digital Quest – 61K (TF5), 72K (TF5), 83K (TF5) – Thailand
- Digital Summit – ZPD120
# Copeland Scroll Digital – Product Offering

<table>
<thead>
<tr>
<th>HP</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>12</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-22/R407C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantum/Quest</td>
<td>7 Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quest Tandems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-410A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantum/Quest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summit Tandems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stretch Quest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **R-22/R407C**
  - Quantum/Quest: 7 Models
  - Quest Tandems: 5 Models
  - Summit: 2 Models

- **R-410A**
  - Quantum/Quest
  - Summit
  - Summit Tandems
  - Stretch Quest
  - LCS
Efficiency Standards
Regulatory Changes Converging In 2010

2010 Phase-Out Of R-22 In OEM Production

- Massive OEM System Redesign Required
- Commercial R-410A Adoption Rates Lagging Residential
  - Limited By OEM System Availability, Longer Design Cycles And End User Awareness

Energy Efficiency Standards

- 2010 Federal Standards Increase Minimum Efficiency 10%
- Higher State/Regional Efficiency Standards May Emerge
- Higher Efficiency Tiers Will Provide Differentiation
**Commercial A/C Efficiency Standards**

  - Averaging 10% Above Current ASHRAE 90.1 Minimums
  - Effective January 2010; Coincides With R-22 Phase-Out

- **Consortium for Energy Efficiency Proposing Tiers Above EPACT**

<table>
<thead>
<tr>
<th>System Size</th>
<th>ASHRAE 90.1</th>
<th>Tier 1</th>
<th>Proposed Tier 2</th>
<th>Proposed Tier 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 – 10T</td>
<td>10.0 EER</td>
<td>11.0-11.2 EER +10-12%</td>
<td>11.5 EER +15% 11.9 IPLV</td>
<td>12.0 EER +20% 12.4 IPLV</td>
</tr>
<tr>
<td>10 – 20T</td>
<td>9.7 EER</td>
<td>10.6-11.0 EER +9-13%</td>
<td>11.5 EER +19% 11.9 IPLV</td>
<td>12.0 EER +24% 12.4 IPLV</td>
</tr>
<tr>
<td>20 – 60T</td>
<td>9.2 EER</td>
<td>9.5-10.0 EER</td>
<td>10.5 EER</td>
<td>10.8 EER</td>
</tr>
</tbody>
</table>
## IEER Emerging As Part-Load Efficiency Standard

<table>
<thead>
<tr>
<th>Load</th>
<th>IPLV Ambient</th>
<th>Weighting</th>
<th>IEER Ambient</th>
<th>Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>80°F</td>
<td>1%</td>
<td>95°F</td>
<td>2%</td>
</tr>
<tr>
<td>75%</td>
<td>80°F</td>
<td>42%</td>
<td>82°F</td>
<td>62%</td>
</tr>
<tr>
<td>50%</td>
<td>80°F</td>
<td>45%</td>
<td>68°F</td>
<td>24%</td>
</tr>
<tr>
<td>25%</td>
<td>80°F</td>
<td>12%</td>
<td>65°F</td>
<td>12%</td>
</tr>
</tbody>
</table>
Discussion & Questions

Thank You!