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THE GREENCHILL PARTNERSHIP

Compressors and Compressor Technologies

August 2, 2012

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- Q&A session after presentation
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Today's speakers…

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Rajan Rajendran is the Vice President of Engineering Services and Sustainability at Emerson Climate Technologies in Sidney, Ohio, USA. He has worked at Emerson since 1990 in various capacities and is the spokesperson for Emerson Climate in technical communications with the media, customers, and industry organizations primarily in the United States.

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Mike Saunders is the Director of End User Technical Sales and Support at Emerson Climate Technologies, Inc. in Sidney, Ohio. He has over 18 years of experience in refrigeration product development and support. Mike's current roll is educating and supporting supermarkets on refrigeration trends and compressor technologies.

Mike holds a B.S. in Mechanical Engineering and a M.S. in Mechanical Engineering from the University of Idaho.

Compressor & Compressor Technologies

EMERSON™
Climate Technologies

Compressor Technologies Agenda

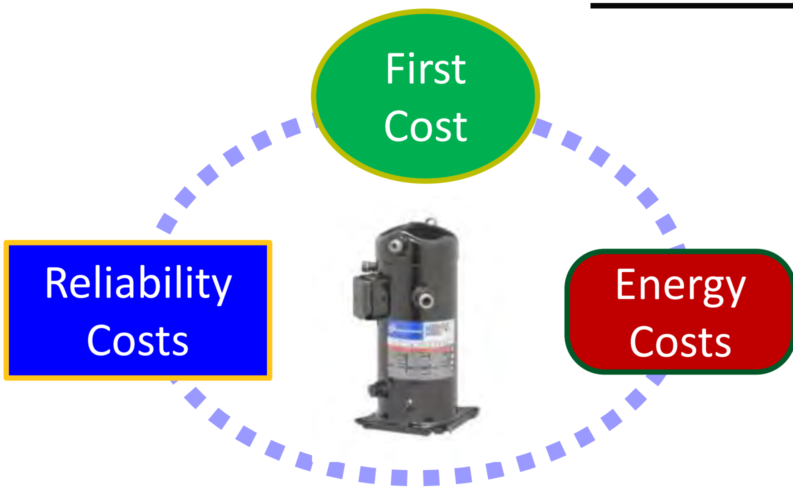
- **Compressor Introduction**
  - Typical Applications
  - Common Types
  - Compression Mechanisms
- **Compressor Features**
  - Efficiency
  - Modulation
  - Reliability

Typical Applications

Markets	 **Industrial**	 **Transport**	 **Food Retail**	 **Food Service**	 **A/C *Commercial***	 **A/C *Residential***
Compressors	 Screw Reciprocating	 Scroll Units	 Semi-Hermetic *(Rack)* Scroll *(Distributed)*	 Scroll Hermetic Units	 Scroll Hermetic Semi-Hermetic	 Scroll Hermetic
Refrigerants	NH_3 R134a R404A/507 R290	R134a R404A	R404A/507 R407A R134a CO_2	R404A/507 R407A R134a R290	R410A R407C	R410A

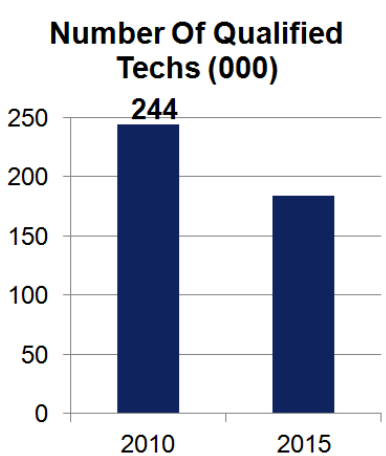
Key Industry Needs

Total Cost Of Ownership



- **Supermarket Refrigeration Accounts For 60-65% Of Total Energy Costs**
- **Reliability Costs - Varies**

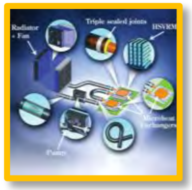
Maintenance Solutions (Reliability/Uptime)



Sustainability

Refrigerant Containment

Low GWP Refs. & Natural Alternatives



System Architecture

Energy Efficiency

Compressor Types

Hermetic

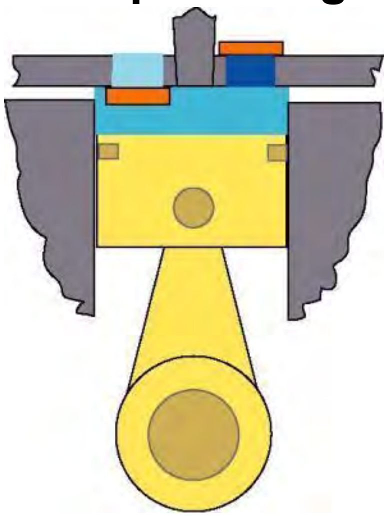
Semi-Hermetic

Open-Drive

Compression Mechanisms

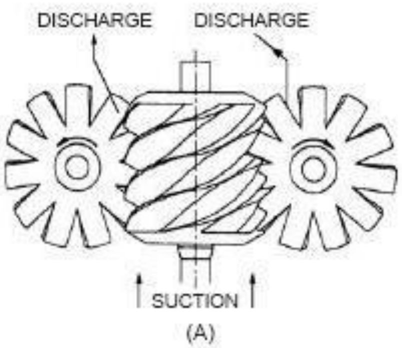
Scroll

Reciprocating

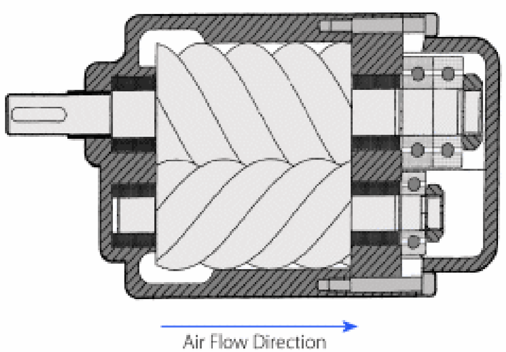


Screw

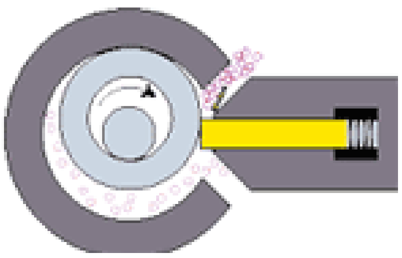
Single



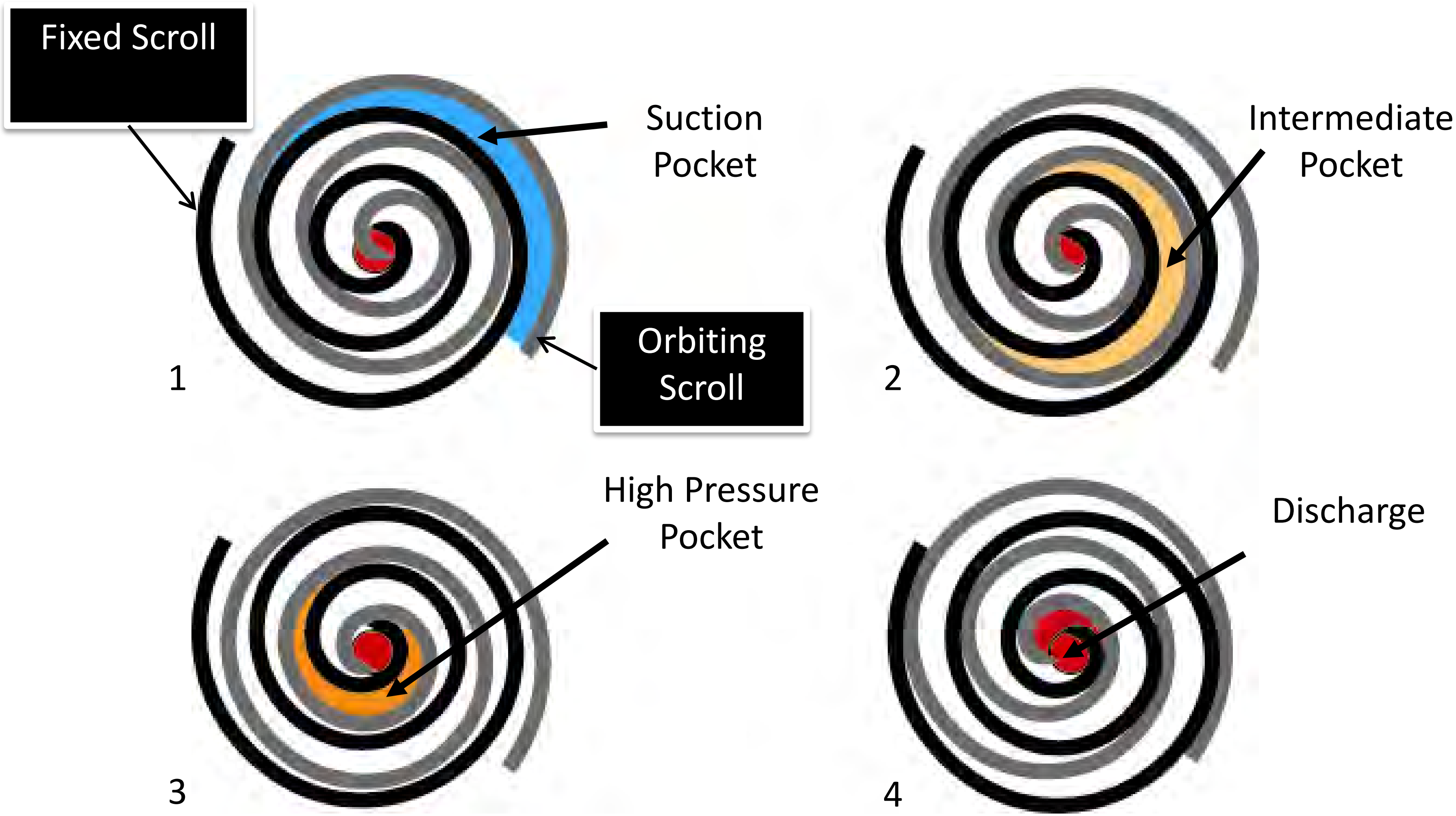
Dual



Rotary Vane

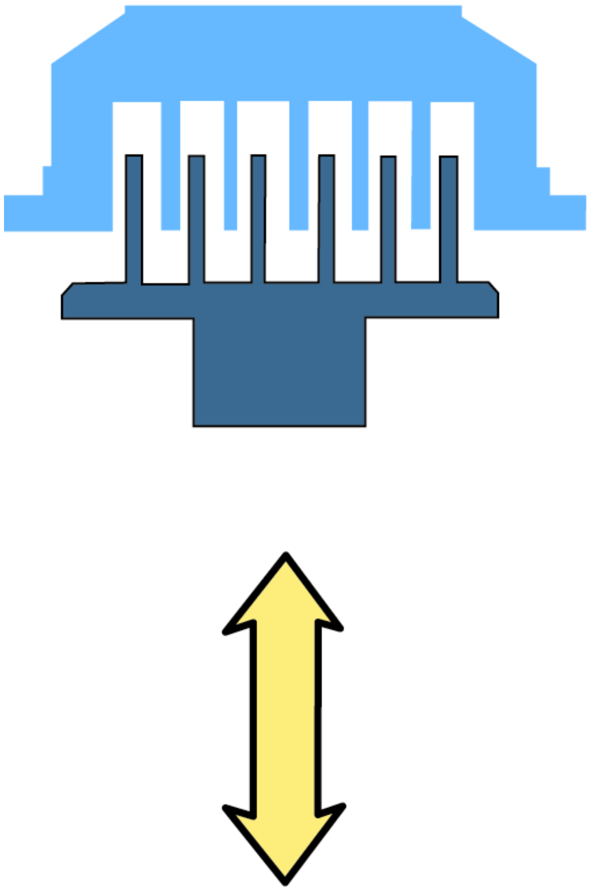


How The Scroll Compressor Works

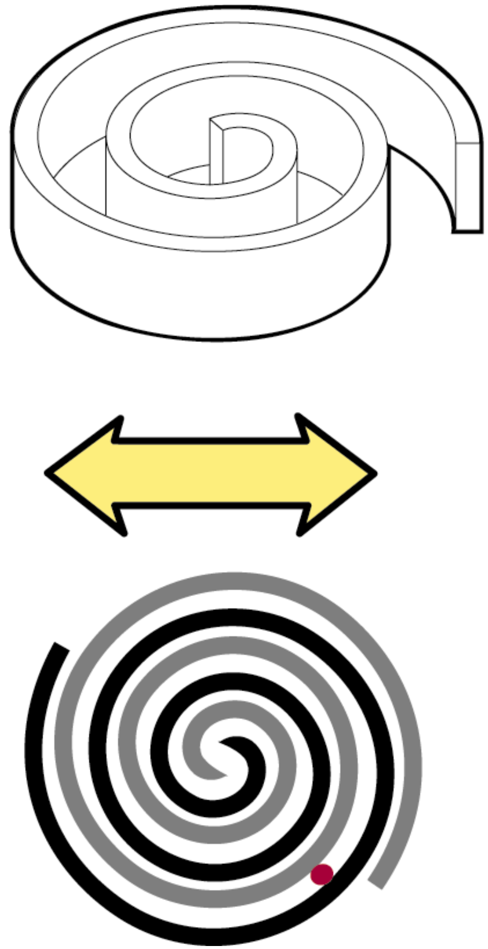


Compliant Scrolls

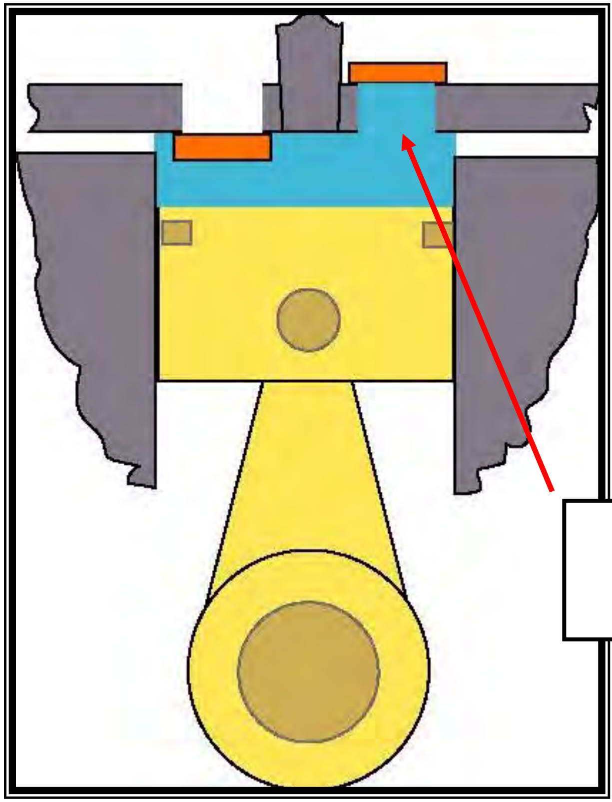
Axial Compliance

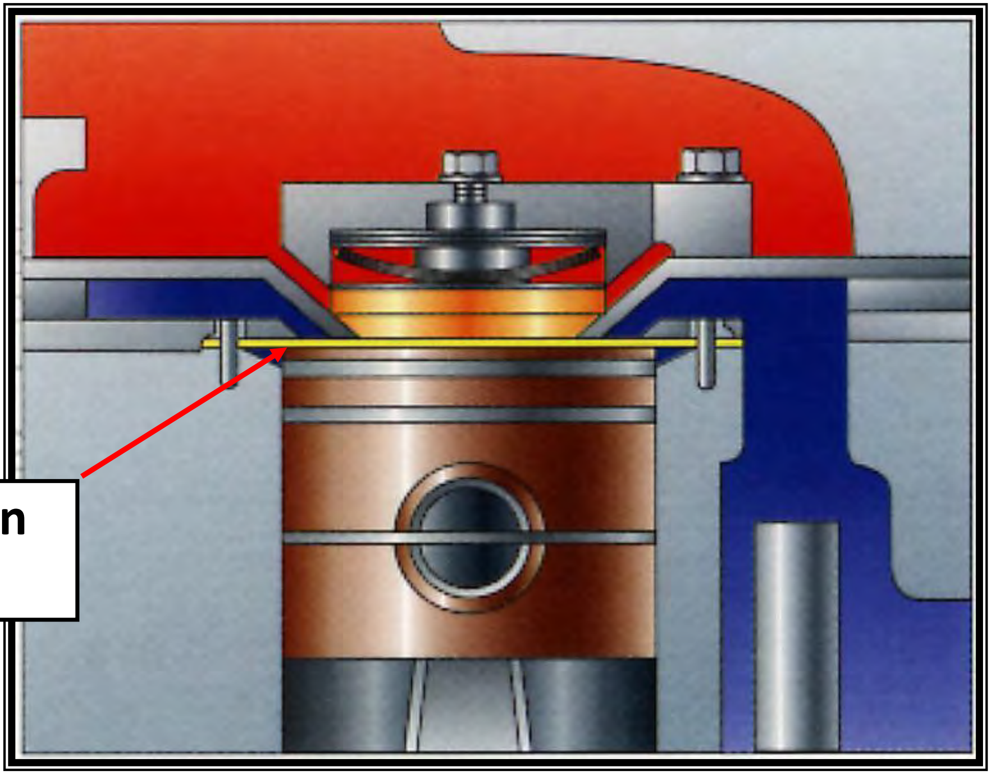


Radial Compliance



Semi-Hermetic Reed vs. Discus Technology

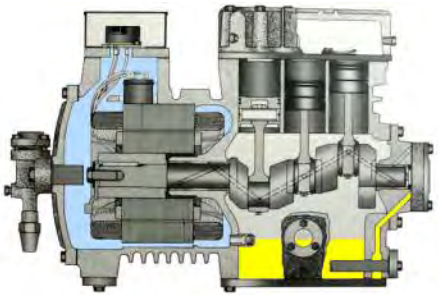




Re-Expansion Volume

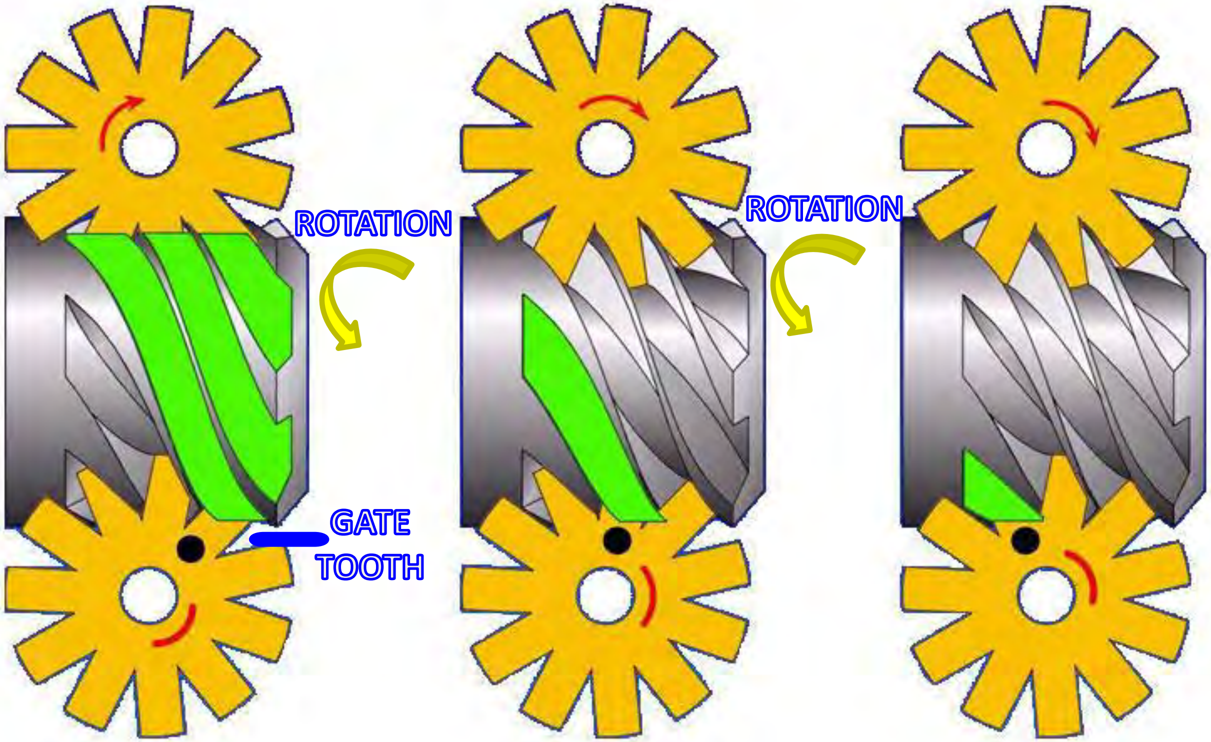
Reed Compressor

Discus Compressor

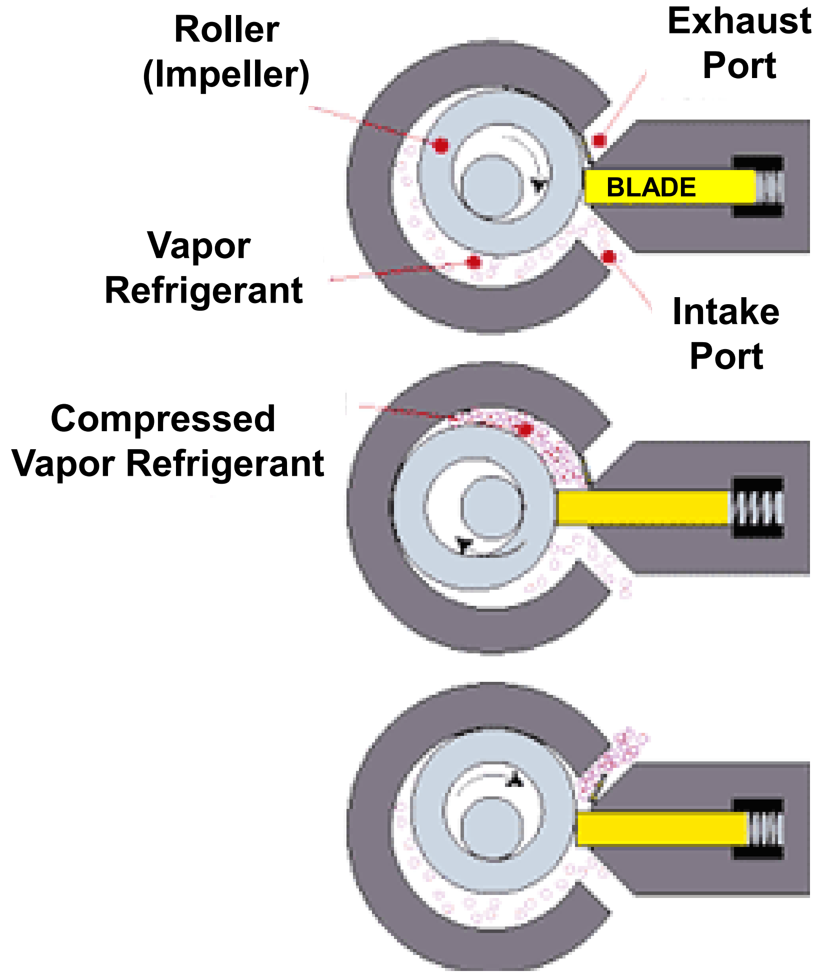


- The Geometry Of A Reed Compressor Does Not Allow All The Discharge Gas To Exit When The Piston Is At Top Dead Center, Leading To Re-Expansion Volume
- Re-Expansion In The Discus Design Is Virtually Zero, Providing Higher Efficiency

Single Screw Compression Cycle



Rotary Vane Compressor



Information Sources: Samsung.com & Pilot Light Newsletter, FSCC Summer 2000

Compressor Efficiency & Technology

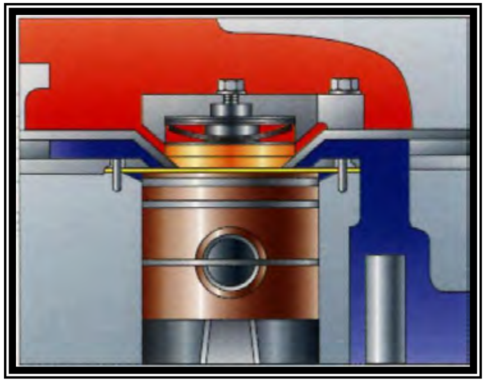
- **Compressor Rating Conditions**
  - LT: -25F/105F/65RG/0SC
  - MT: 20F/120F/65RG/0SC
- **AEER**
- **Peak Loads**
- **Factors Affecting Efficiency**
  - Evaporating Temperature
  - Condensing Temperature
  - Return Gas or Superheat Temperature

Table 1. Standard Rating Conditions for Compressors and Compressor Units for Commercial Refrigeration Applications (Based on 95°F [35°C] Ambient Temperature)

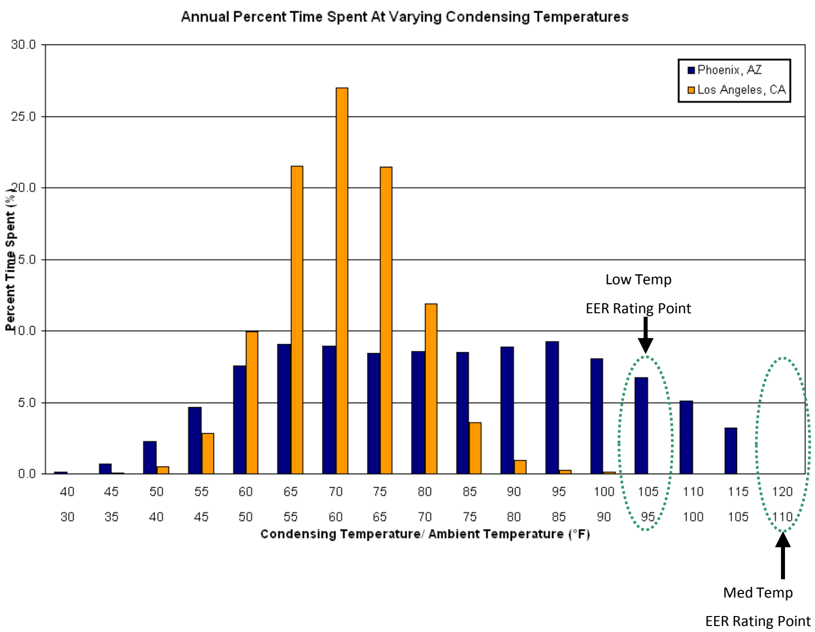
Suction Dew Point Temperature		Compressor Type	Discharge Dew Point Temperature		Return Gas Temperature		Subcooling	
°F	°C		°F	°C	°F	°C	°F	°C
45	7.2	All	130	54.4	65	18	15	8.3
20	-6.7	All*	120	48.9	40/65*	4.4/18*	0	0
-10	-23	Hermetic	120	48.9	40	4.4	0	0
-25	-32	All*	105	40.6	40/65*	4.4/18*	0	0
-40	-40	All*	105	40.6	40/65*	4.4/18*	0	0

Note: If airflow across the compressor is used to determine ratings, it shall be specified by the compressor manufacturer.
* 1) For hermetic type compressors, 40°F [4.4°C] return gas temperature shall be used.
2) For external drive and accessible hermetic type compressors, 65°F [18°C] return gas temperature shall be used.

AHRI 540



What Is AEER Using Bin Analysis?



$$\text{Total\_Energy\_Cost}\ {}^{\$}\!/_{\text{yr}} = \frac{\text{Load}\ {}^{\text{Btu}}\!/_{\text{hr}}}{\text{AEER}\ {}^{\text{Btu}}\!/_{\text{W-hr}}} * 8.76 * \text{Energy\_Cost}\ {}^{\$}\!/_{\text{kWh}}$$

- **Annual EER (AEER) is the EER weighted averaged by the condensing temperature for the whole year**
  - AEER = 1 sum (%time EER)
- **If the cost of energy consumed is required, that can be calculated as well**
- **Weather data used is data from U.S. National Weather Service**
- **AEER is useful for comparison purposes**

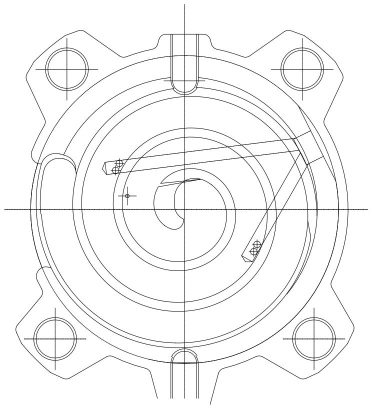
AEER is a better efficiency metric

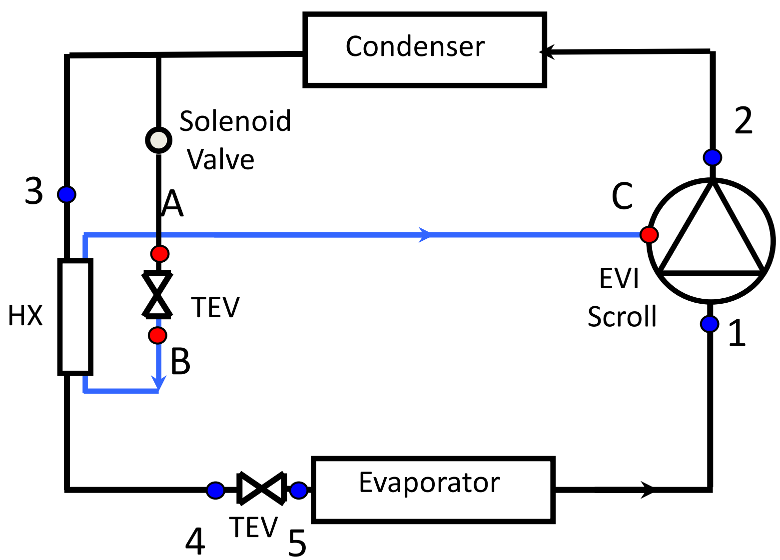
Methods To Improve Efficiency

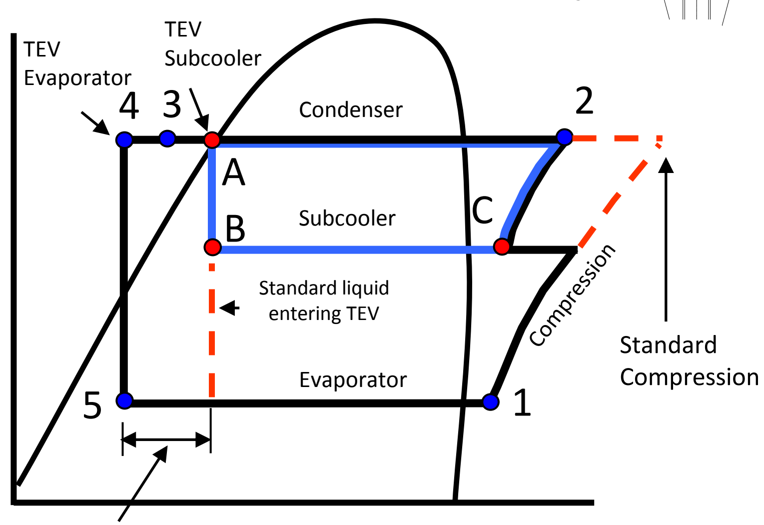
- Enhanced Vapor Injection (EVI)
- Variable Capacity
- Floating Head
- System Architecture (Close Coupled Systems)
- Refrigerant
- etc

Compressor Efficiency & Technology

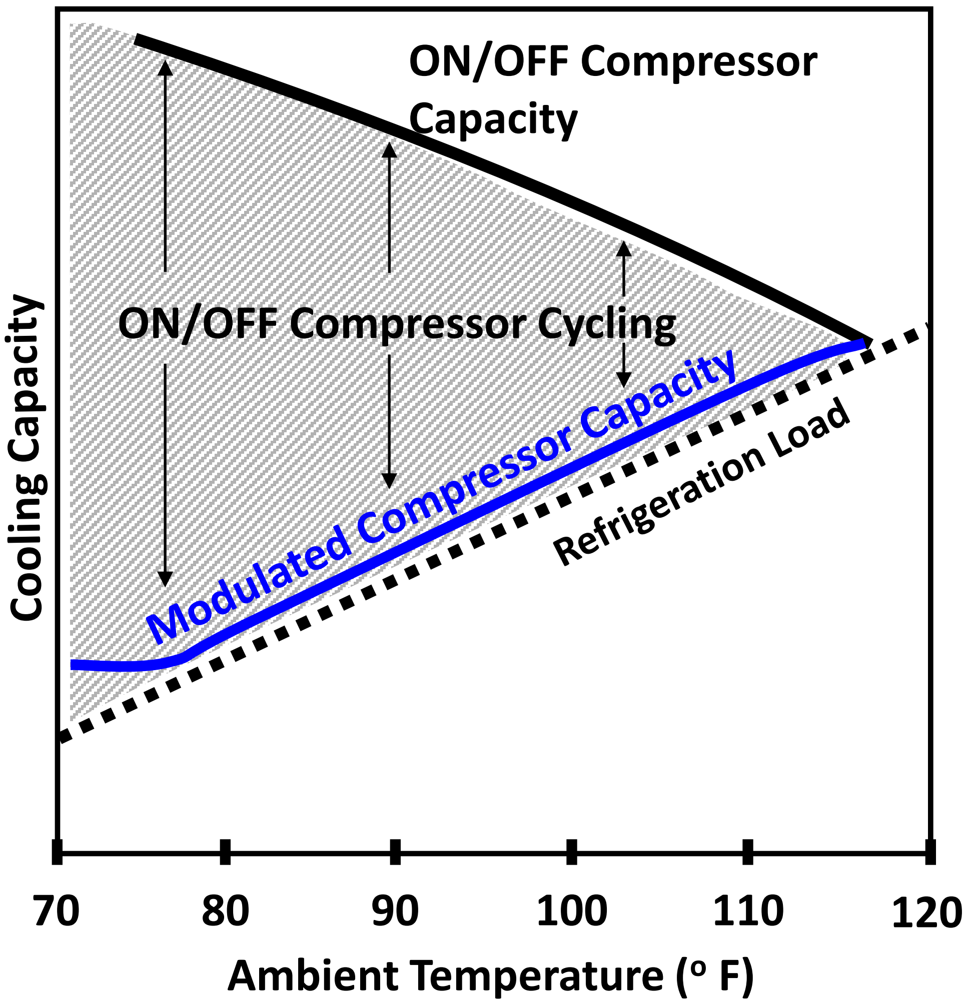
- **Economized Vapor Injection For Scroll Compressors**
  - Similar To A 2 Stage Cycle, But Accomplished With A Single Scroll Compressor
    - 40% Capacity Gain At LT ARI Condition
    - 20% Efficiency Gain At LT ARI Condition







Capacity Modulation Improves Efficiency & Reliability

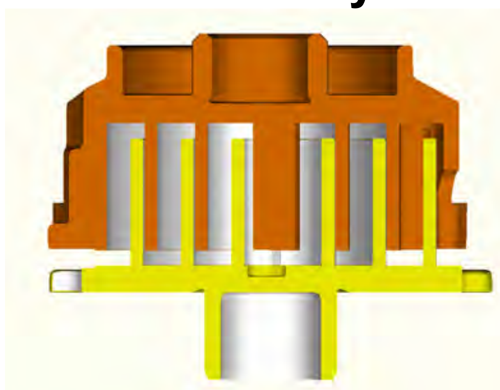


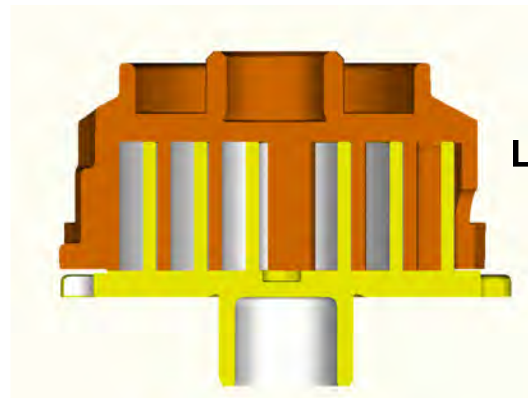
- **Modulation Allows Capacity To Precisely Match The Load**
- **Simple & Effective Modulation Results In Important Benefits**
  - Suction Pressure Stability
  - Tight Temperature Control
  - Energy Efficiency
  - Reduced Compressor Cycles
- **Modulation Methods**
  - Blocked Suction
  - Variable Speed
  - Pulse Width Modulation (Digital)

Scroll Digital Capacity Modulation

- **Takes Advantage Of Scroll Axial Compliance**
- **When Scrolls Are Separated Axially (0.5 – 1.0 mm), Little To No Gas Flow**
- **When Scrolls Are In Contact, 100% Gas Flow**
- **Modulate 10 – 100% By Pulsing**

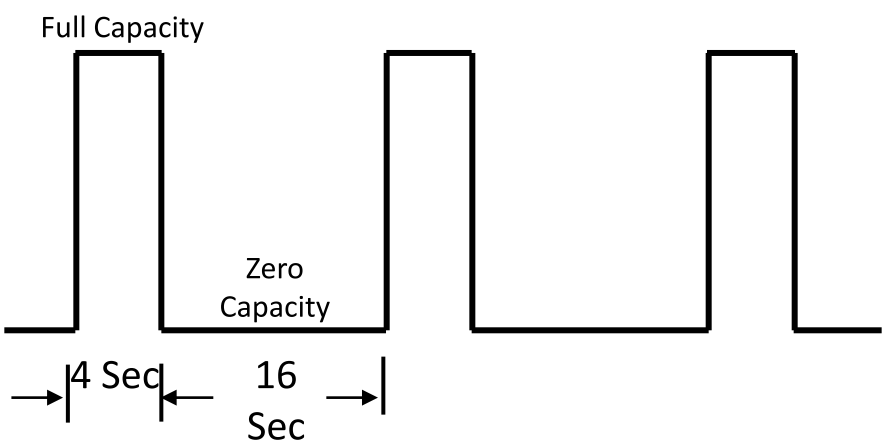
Unloaded Scrolls Separated Zero Capacity



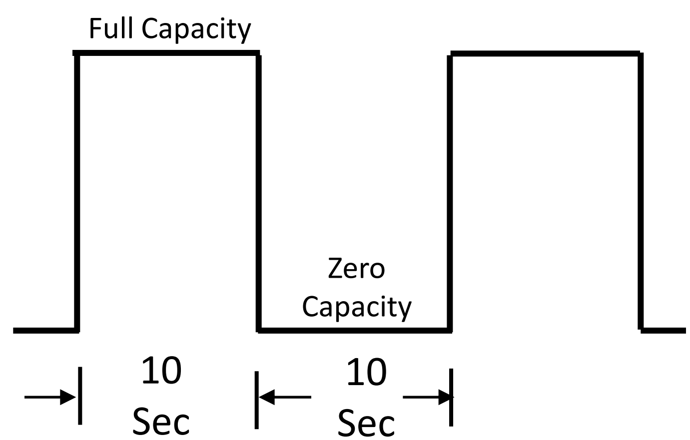


Loaded Scrolls Together Full Capacity

20% Output



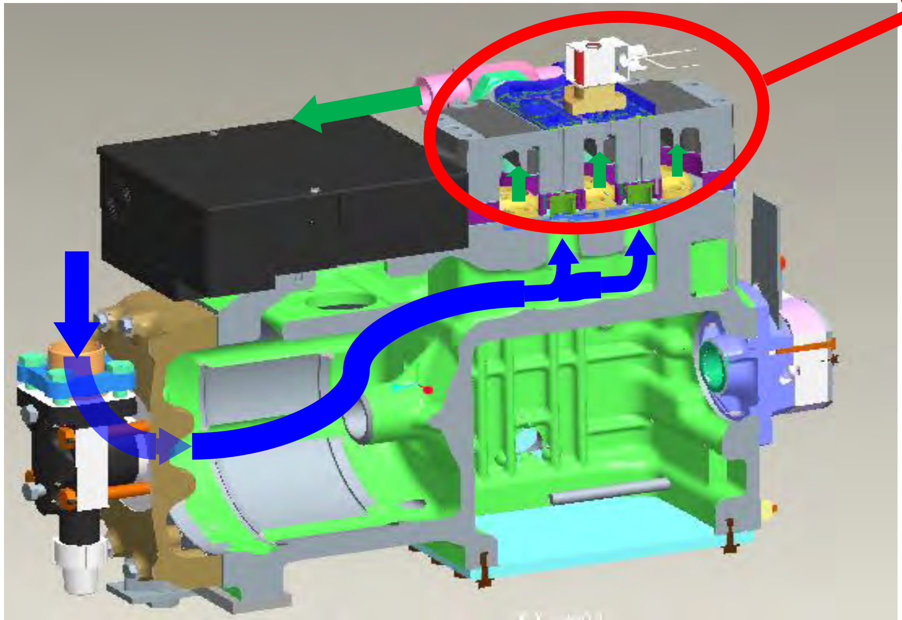
50% Output



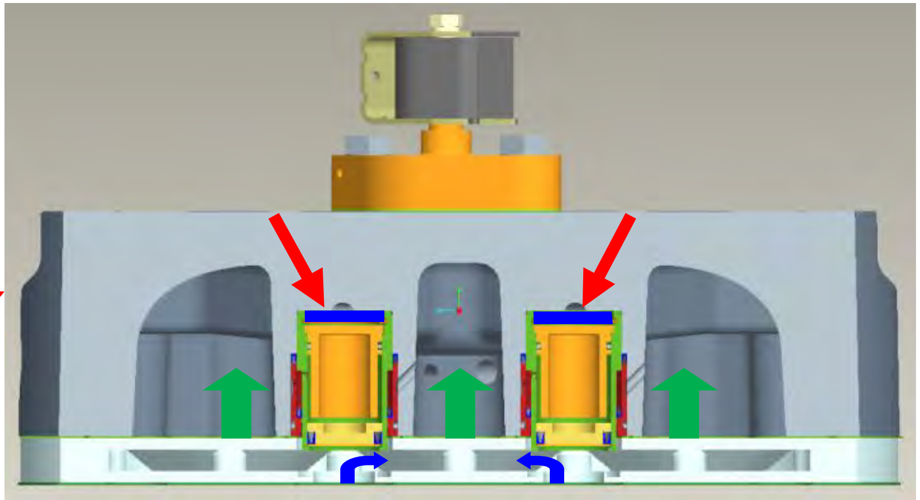
Discus Digital
Refrigerant Gas Flow

Loaded

1. Enters Compressor
2. Passes Through Body
3. Into Valve Plate
4. Compressed by Pistons
5. Exits Compressor



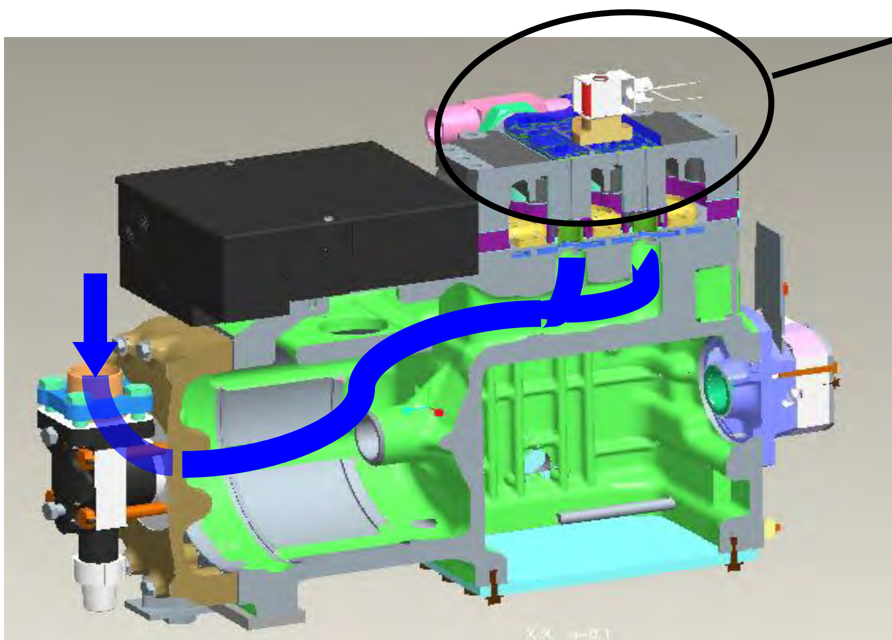
Valve assembly routes suction gas above unloader pistons



Unloader pistons allow suction gas flow into valve plate

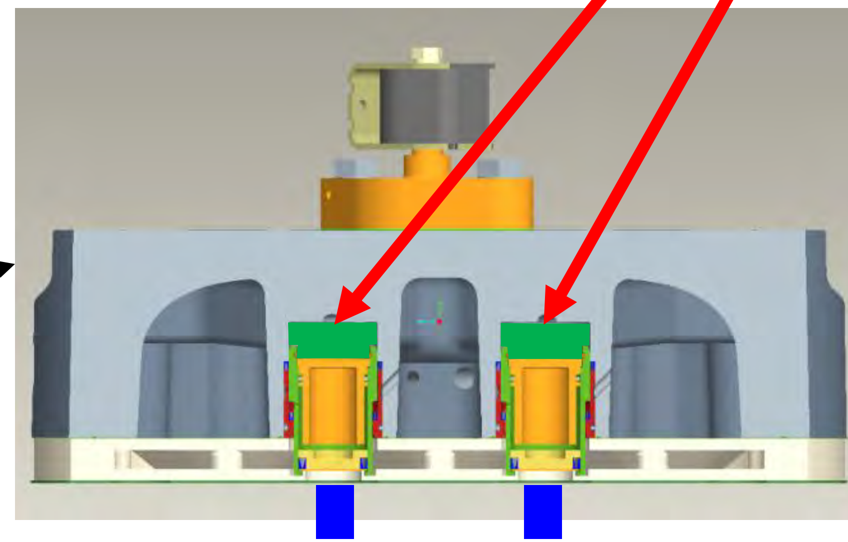
Discus Digital
Refrigerant Gas Flow

1. Enters Compressor
2. Passes Through Body
3. 4 Unloader Pistons Block Gas Before Entering Valve Plate



Unloaded

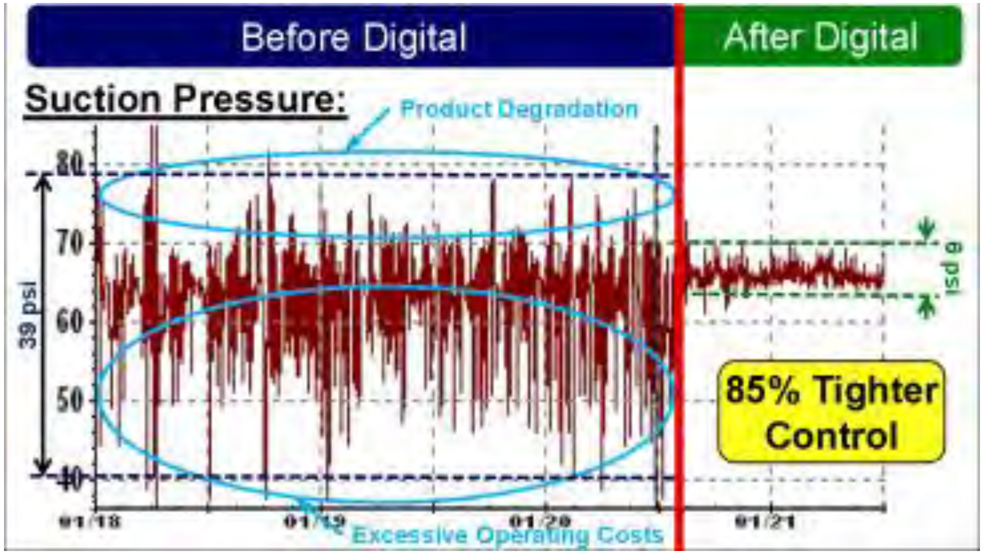
Valve assembly routes discharge gas above unloader pistons

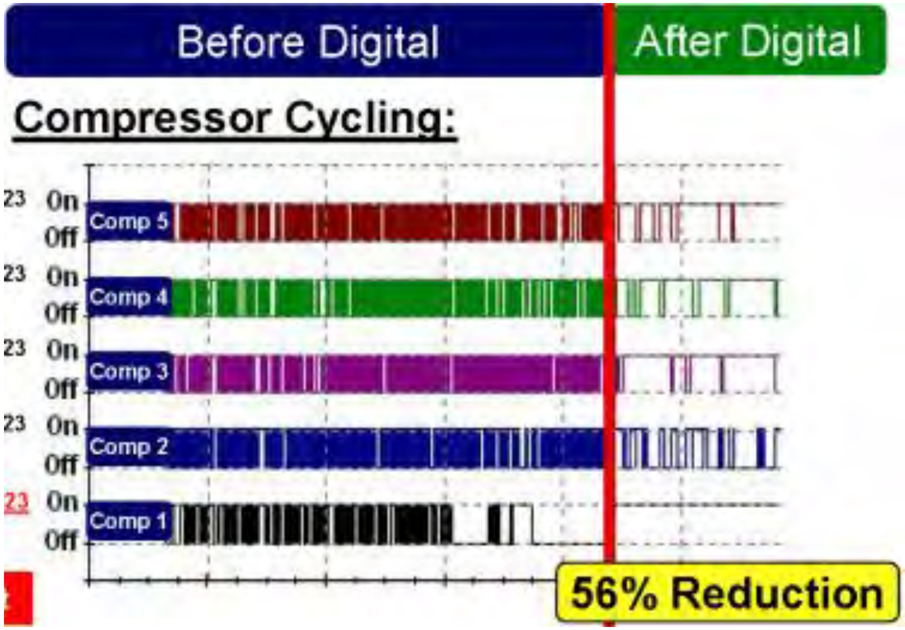


Unloader pistons block suction gas flow into valve plate

Capacity Modulation

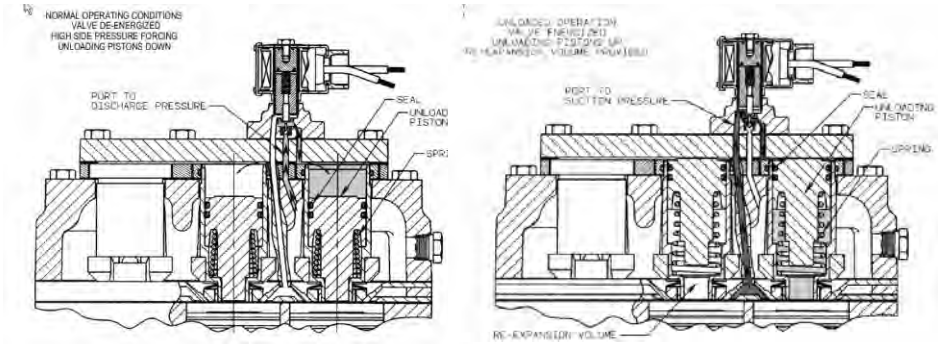
- **Copeland Digital Results**





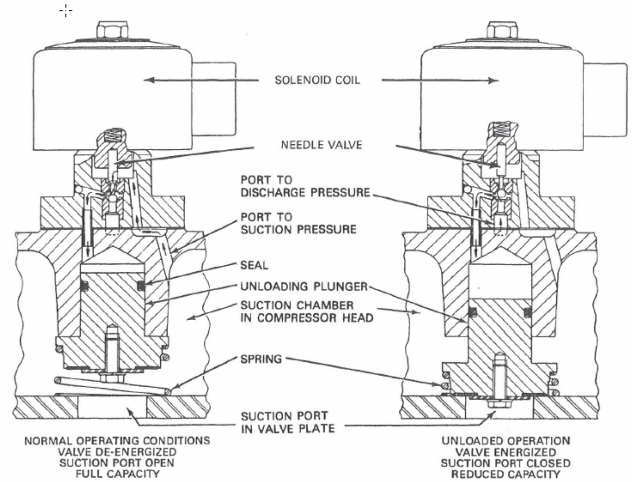
Other Capacity Modulation Options

Unloaders



- Unloaders & Blocked Suction
  - Discrete Capacity Steps
- Variable Speed
  - Continuous Capacity Control
  - Requires External Inverter Drive

Blocked Suction



Variable Speed

EMS

Inverter

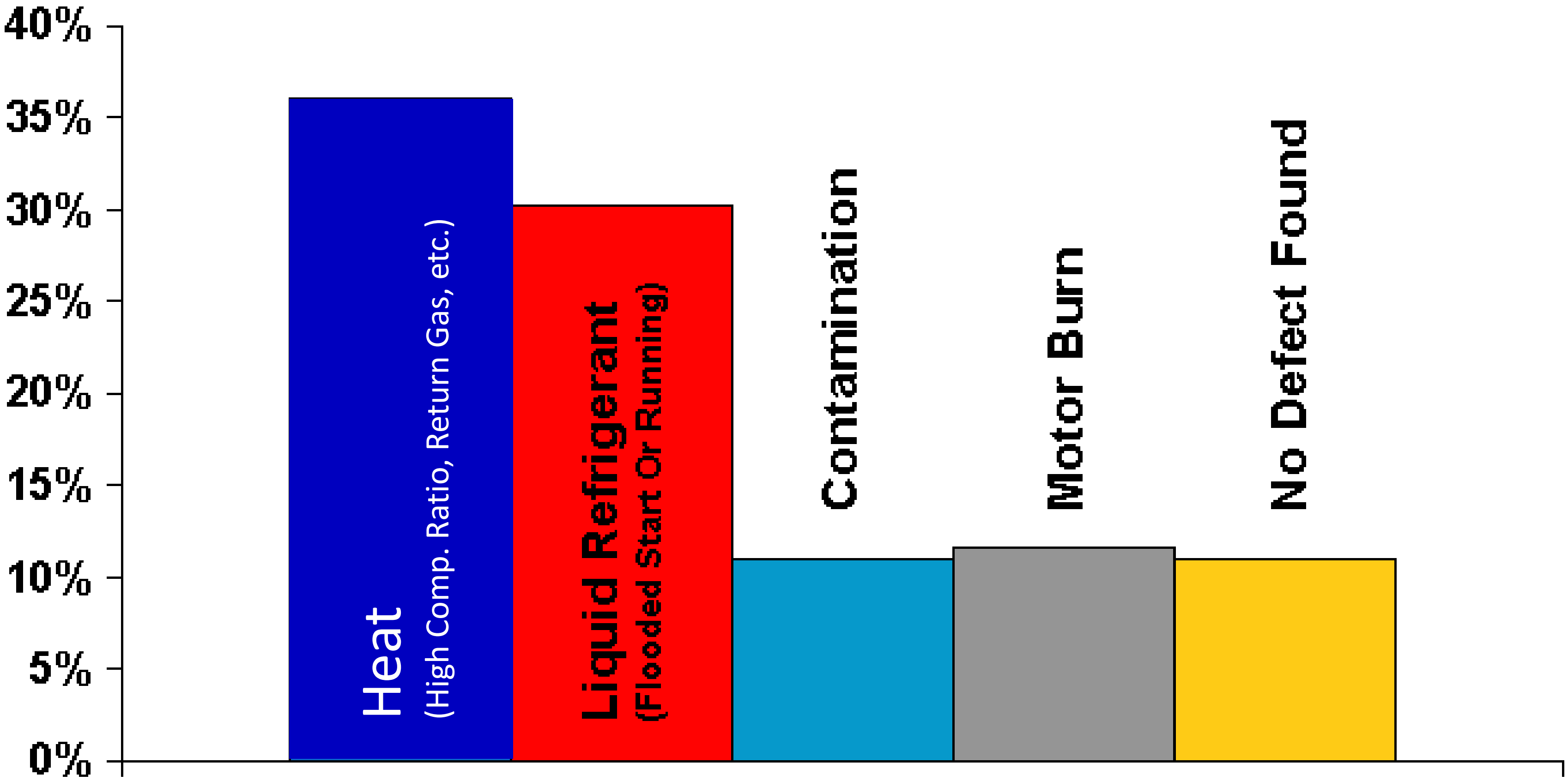
Compressor

Industry Pain Points Are Evident

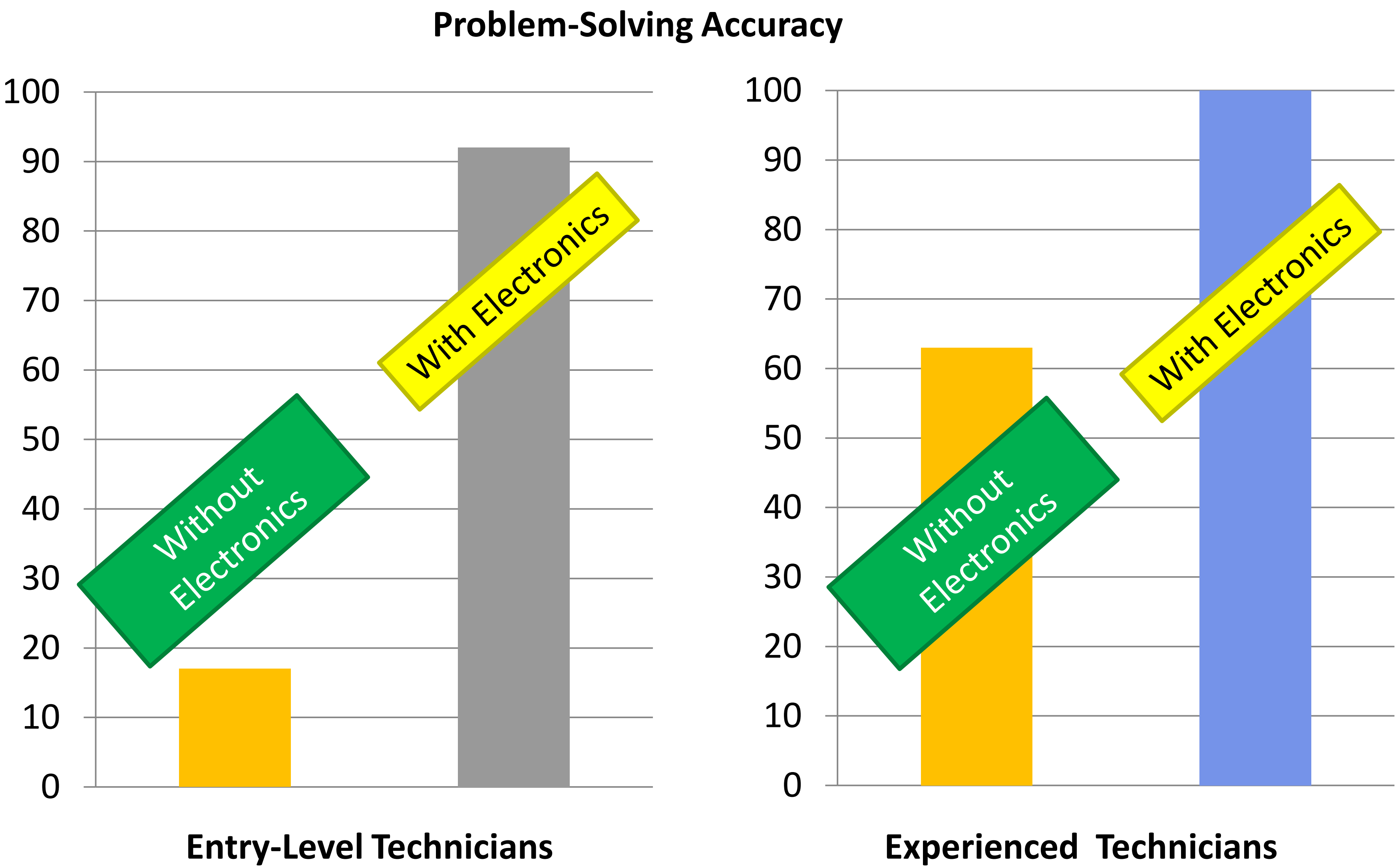
- Reliable performance in the HVACR markets is key
- Need for equipment that can diagnose and protect itself
- Critical pain points: maintenance cost, system downtime, call-backs
- Value Proposition:
  - "Compressor electronics enhances compressor and system performance by sensing, monitoring and interpreting electrical and mechanical information within the compressor to provide advanced capabilities, such as system diagnostics, protection, verification and communication."

Compressor Reliability

- **Common Compressor Failure Modes**



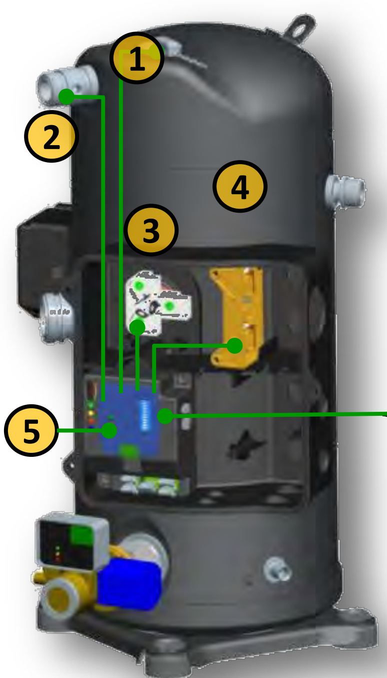
Electronics Have Proven To Increase Accuracy, Even For Experienced Technicians

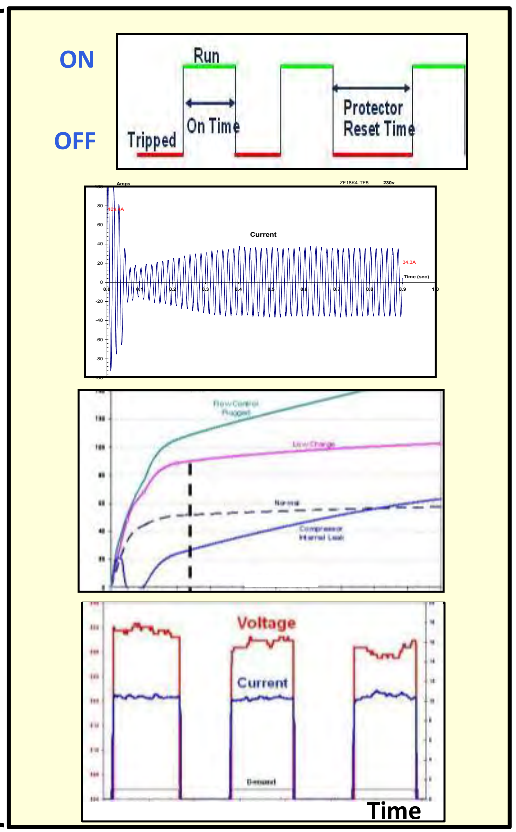


Compressor Reliability & Technology

- **Compressor Electronics Identify & React To System Problems**

Compressor Sensors	+	Algorithms	=>	Compressors That Predict & Diagnose System Health





Benefits:

- Lower Maintenance Costs
- Less System Downtime
- Faster Troubleshooting
- More Accurate Diagnosis
- Reduced Contractor Callbacks
- Service Root Cause vs. Replace Compressors. “open the system”

Questions?

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