

RESNET 2014

February 24-26, 2014

Beyond Mini-Splits

An Introduction to Variable Capacity Equipment for Whole-House HVAC Designs

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Kristof Irwin, *Positive Energy*



Agenda

Preview

Perspective

Part-Load

VRF



Disclaimer



The mention of any product, service or information does not constitute an endorsement, nor implied endorsement. None of these companies are supporting this seminar.

What is VRF?



- Established heating & cooling technology for commercial and residential applications.
- Provides for variable capacity operation.



VRF Multi-Split Technology



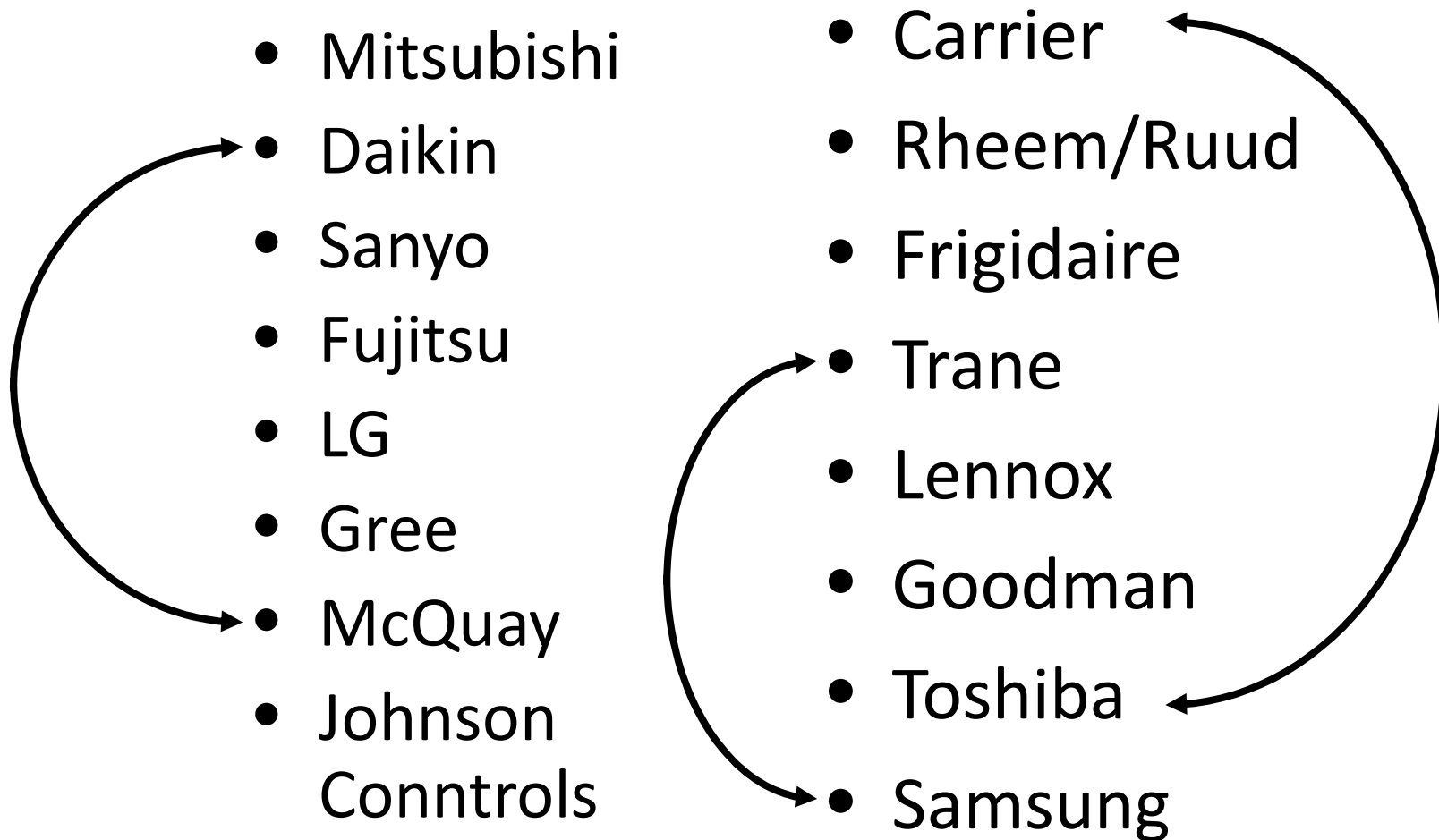
VRF Multi-Split Technology



VRF Multi-Split Technology



VRF Vendors & Industry Dynamism



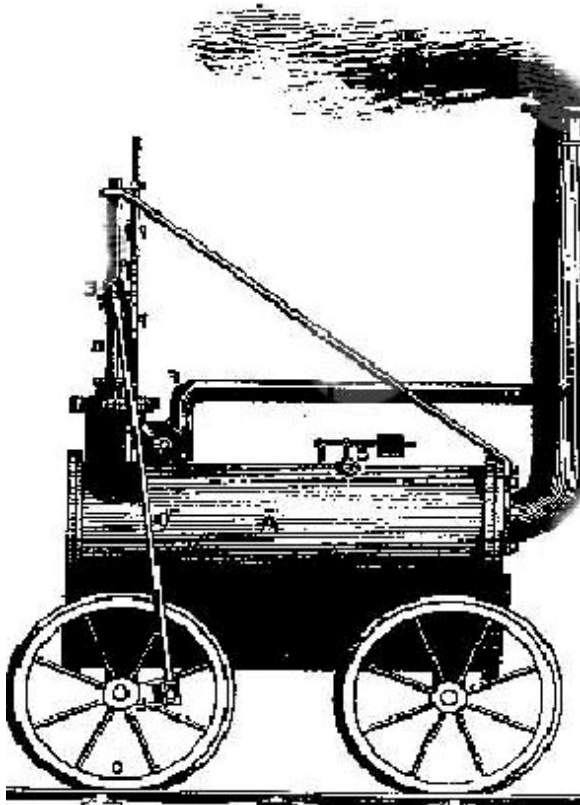
VRF Market Penetration



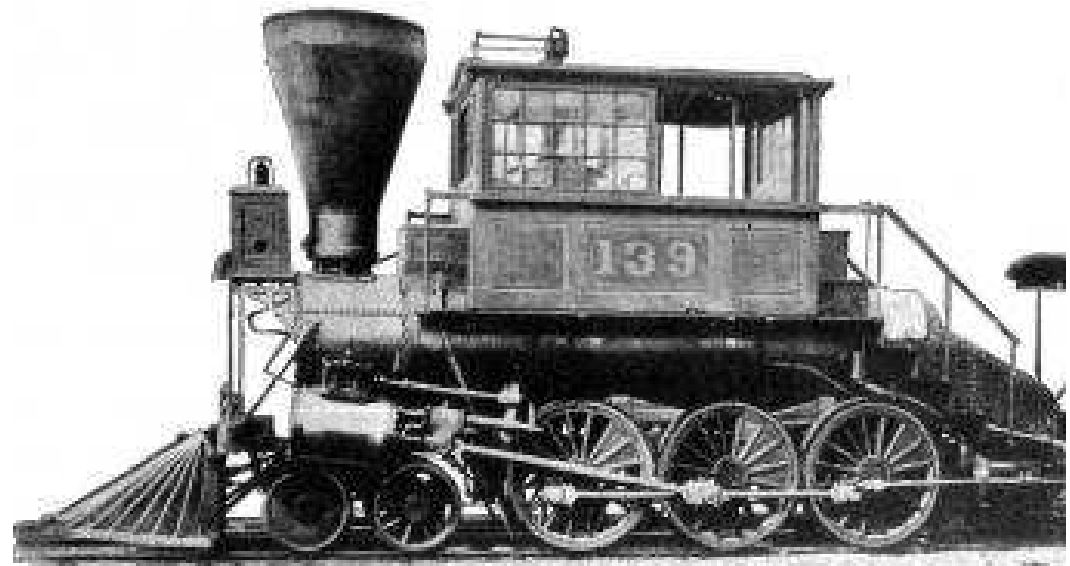
Perspective



50 Years



1803



1853

50 Years



1903



1953


50 Years



190 THE SATURDAY EVENING POST June 11, 1955

IN 1955
Vornado
AIR CONDITIONERS
HAVE THE
ONE BIG DIFFERENCE

.....



Model D100A Custom 1 H.P.
A beautifully styled super cooling model with all the deluxe features including Fiberglas filter, automatic push buttons, a winter warmer, thermostat control and two speed control.

.....

Balanced Cooling

Vornado all new 1955 Air Conditioners have the one big difference that means more cooling comfort for you—that's **Balanced Cooling**.

Through latest engineering and design—Vornado Window Air Conditioners cool, dry and properly circulate the air in proper balance, and this important difference gives you **TRUE** air conditioning . . . at a price you can afford.







AIR CIRCULATORS
ROOM AIR CONDITIONERS
PACKAGED RESIDENTIAL AIR CONDITIONERS

PRODUCTS OF THE O. A. SUTTON CORPORATION
WICHITA, KANSAS

Specialists in the manufacture of comfort cooling appliances

DISTRIBUTED IN CANADA BY THE EAST WASHING MACHINE CO. LTD., TORONTO 16, CANADA

Vornado has a model to fit your needs—

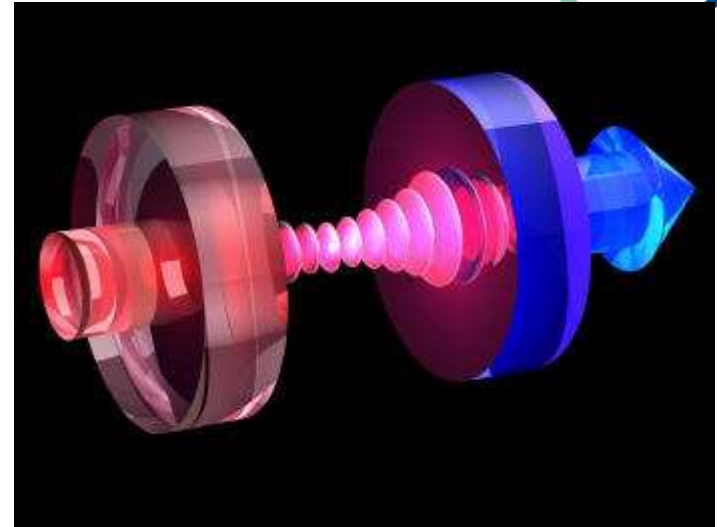
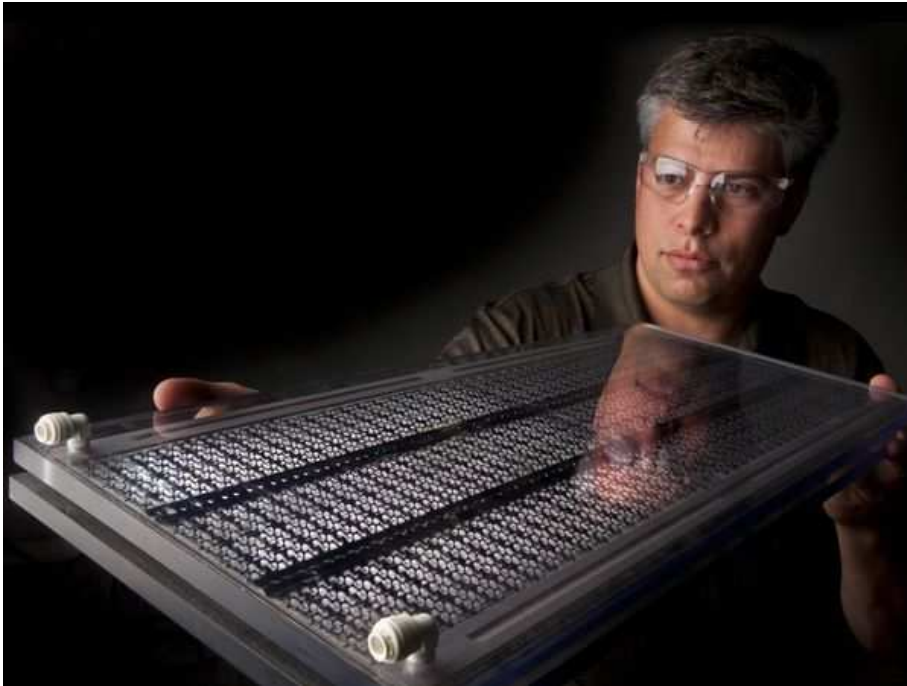
	1/2 H. P. Model D10A
	5/8 H. P. Models D71A—Custom D71A—Standard D873A—Balance Cycle
	1 H. P. Models D100A—Custom D100A—Standard
	1 1/2 H. P. Model D125A
	2 H. P. Model D20A
	3 H. P. Custom Window Model

1955

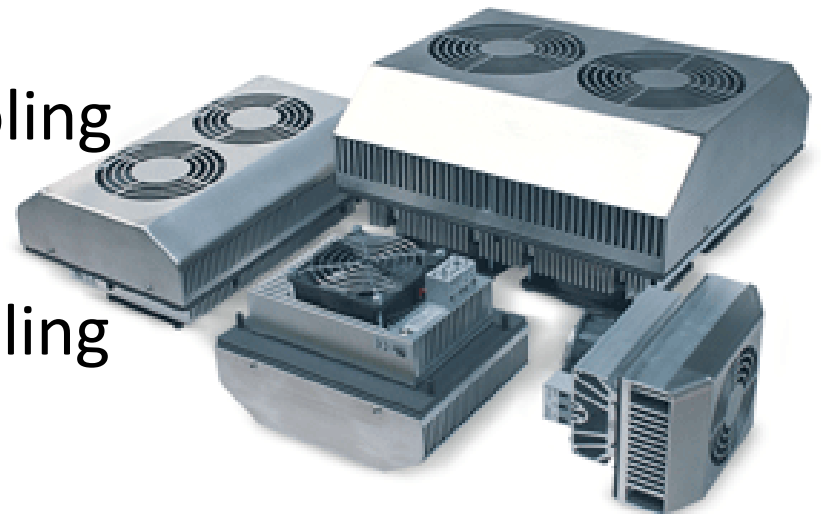


2055

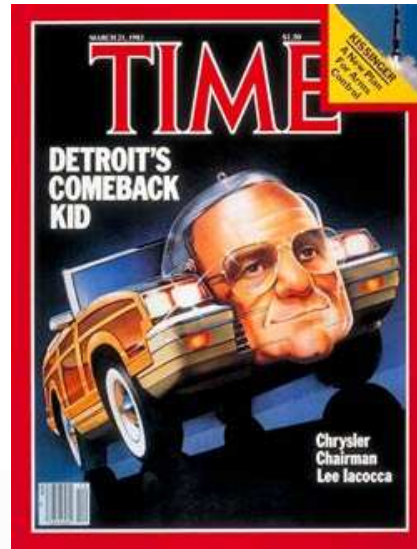
HVAC Looking Forward...



- Desiccant based evaporative cooling
(Especially Liquid Desiccants)
- Thermo-electric heating and cooling
- Quantum Effect devices



Changing Performance



Enhanced functionality. Superior performance.

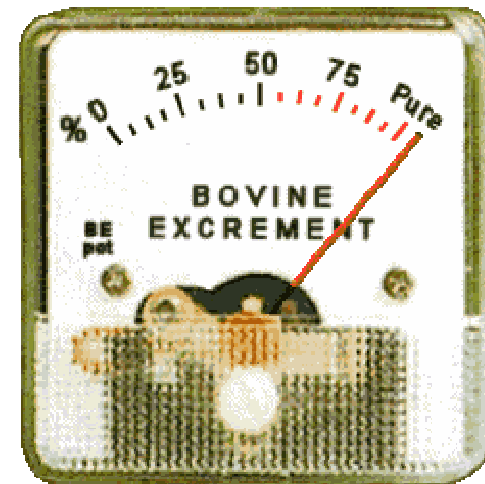


Not for free

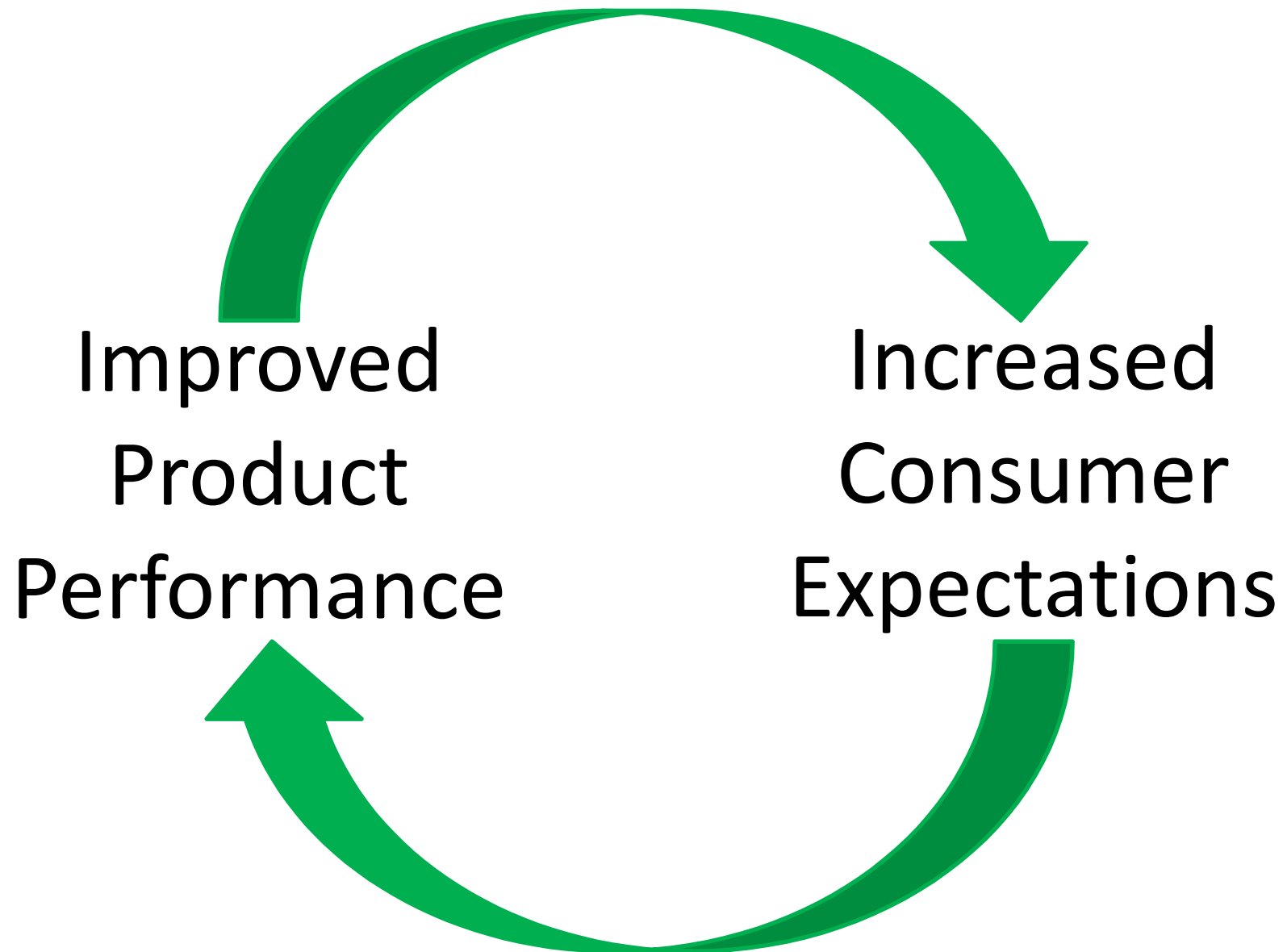
- Highly engineered systems
- Specialized materials
- Complex assemblies
- Precise tolerances



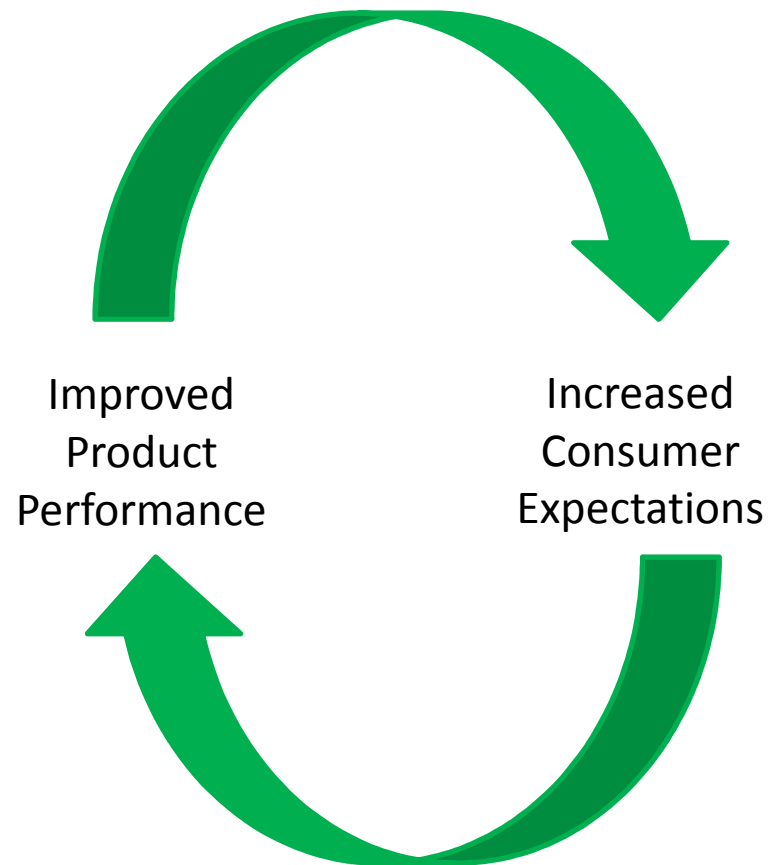
Changing Client Dynamics



Feedback Loop



The New Normal



High Performance

- Comfort
- Health
- Safety
- Durability
- Energy Efficiency

Control Layers & Equipment Loads

One Functional System



What do we want this system to do?

What should it deliver?

- Comfort
- Durability
- Health
- Safety
- Energy Efficiency



+



Control Strategy



Control flows across a boundary:



- Heat
- Air
- Moisture

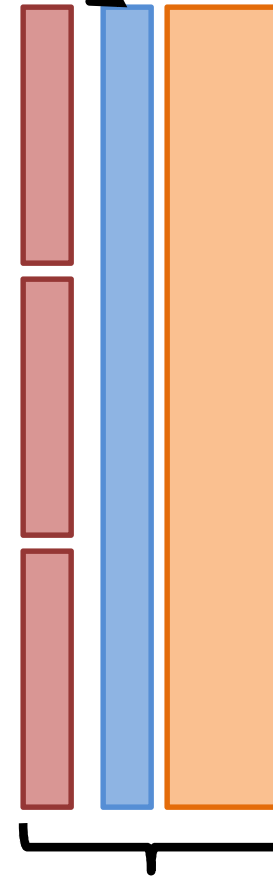


Control Layers



Priority Order:

1. Bulk Water
(Rain & Ground, Liquid)
1. Air
2. Water Vapor
3. Thermal



Building Envelope
Assembly (Boundary)

Control Layer Failure

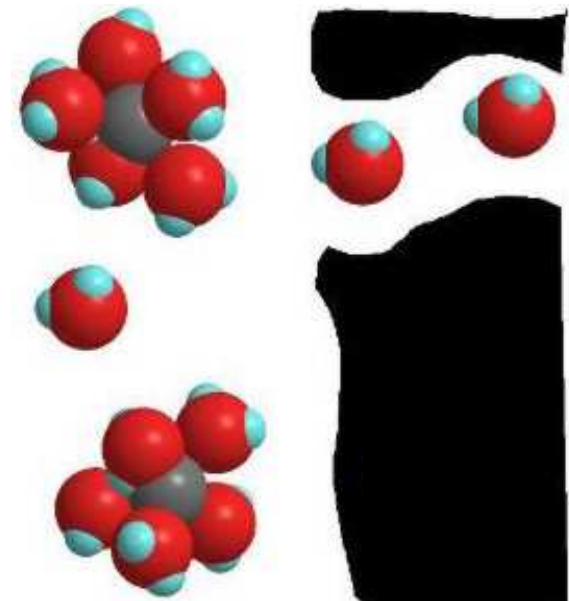


Keep Outside Out & Inside In. Control Exchange.

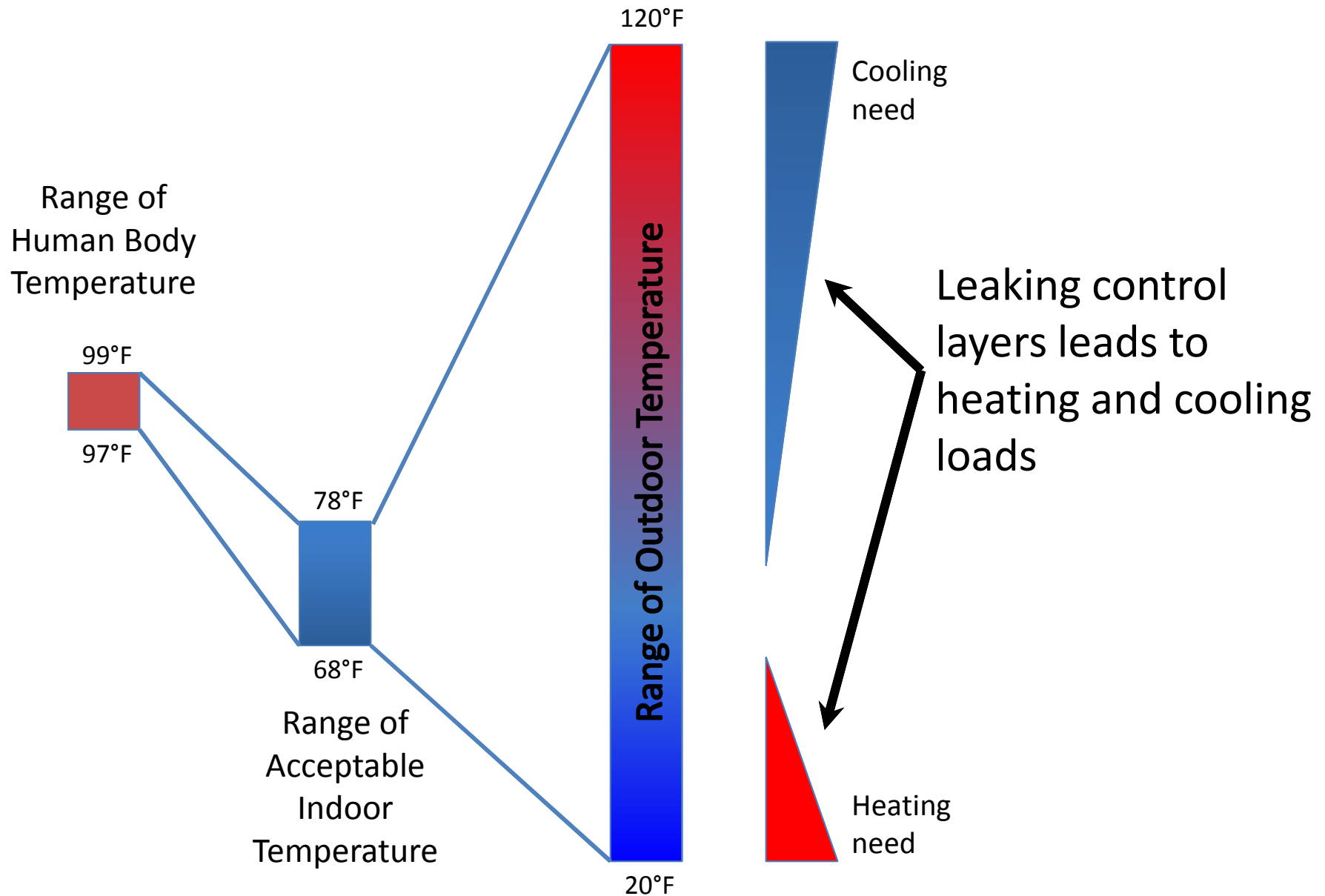
Control layer failure - All 3 Required



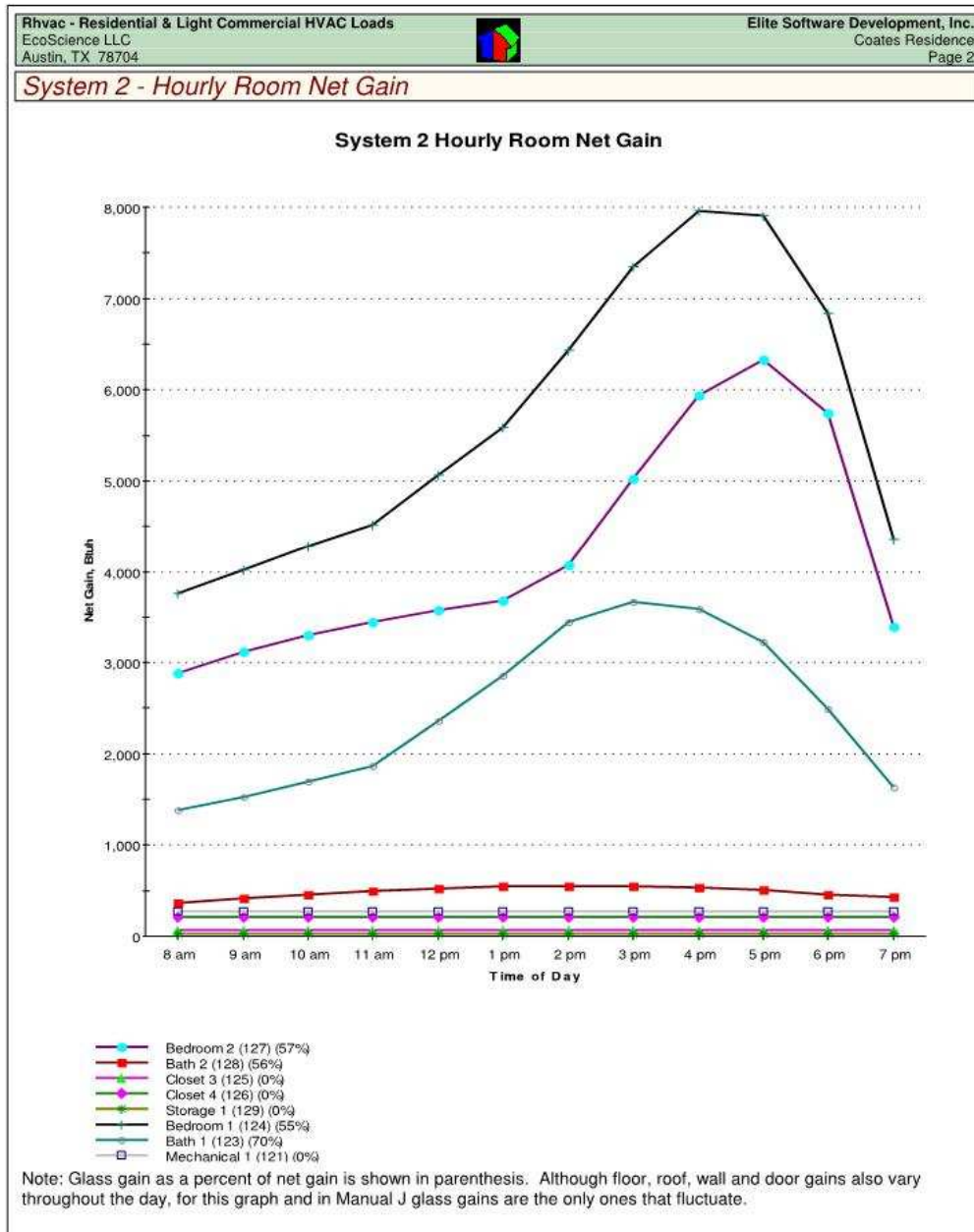
1. Something to leak
2. Opening
3. Driving force



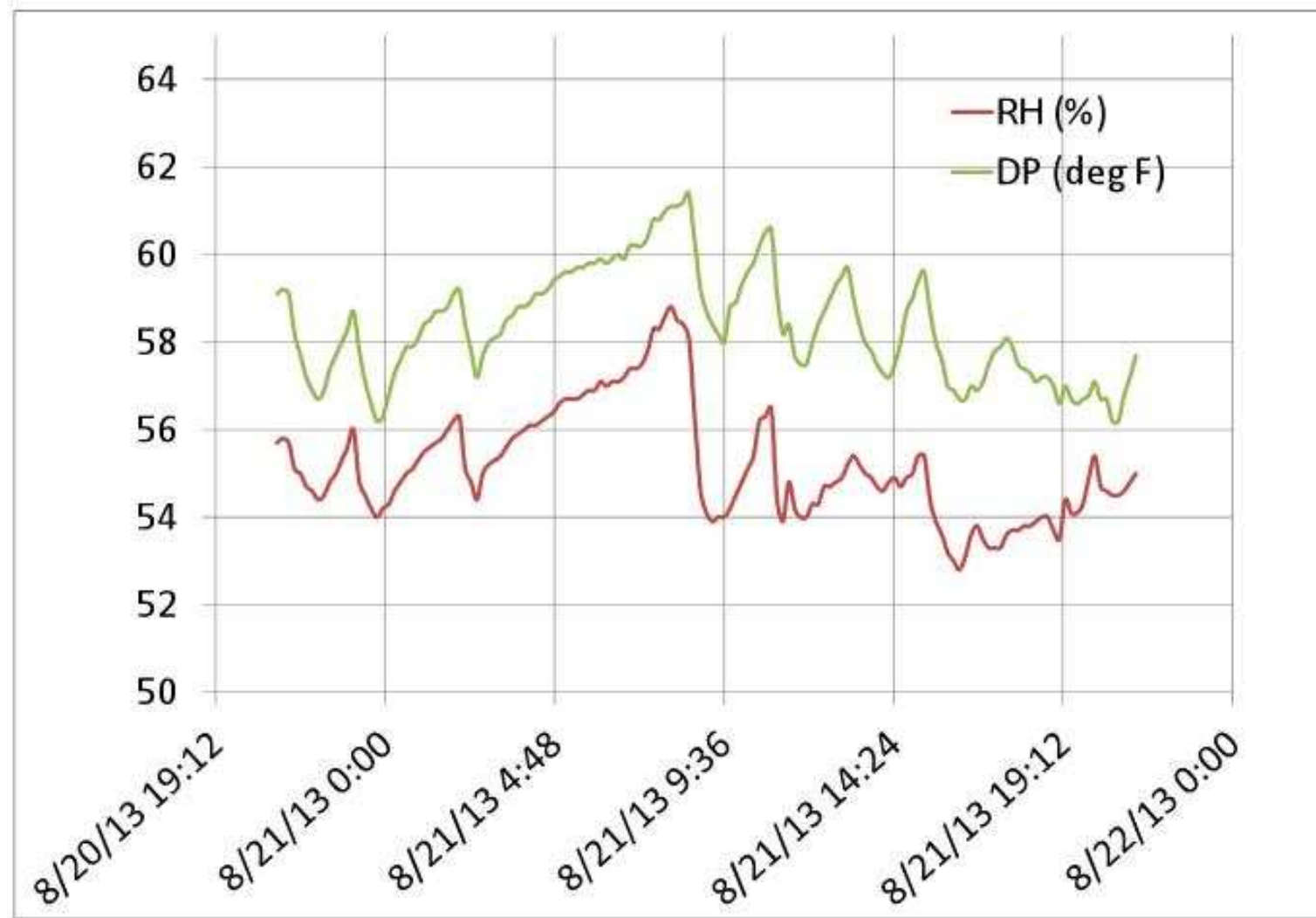
Control Layers are Imperfect



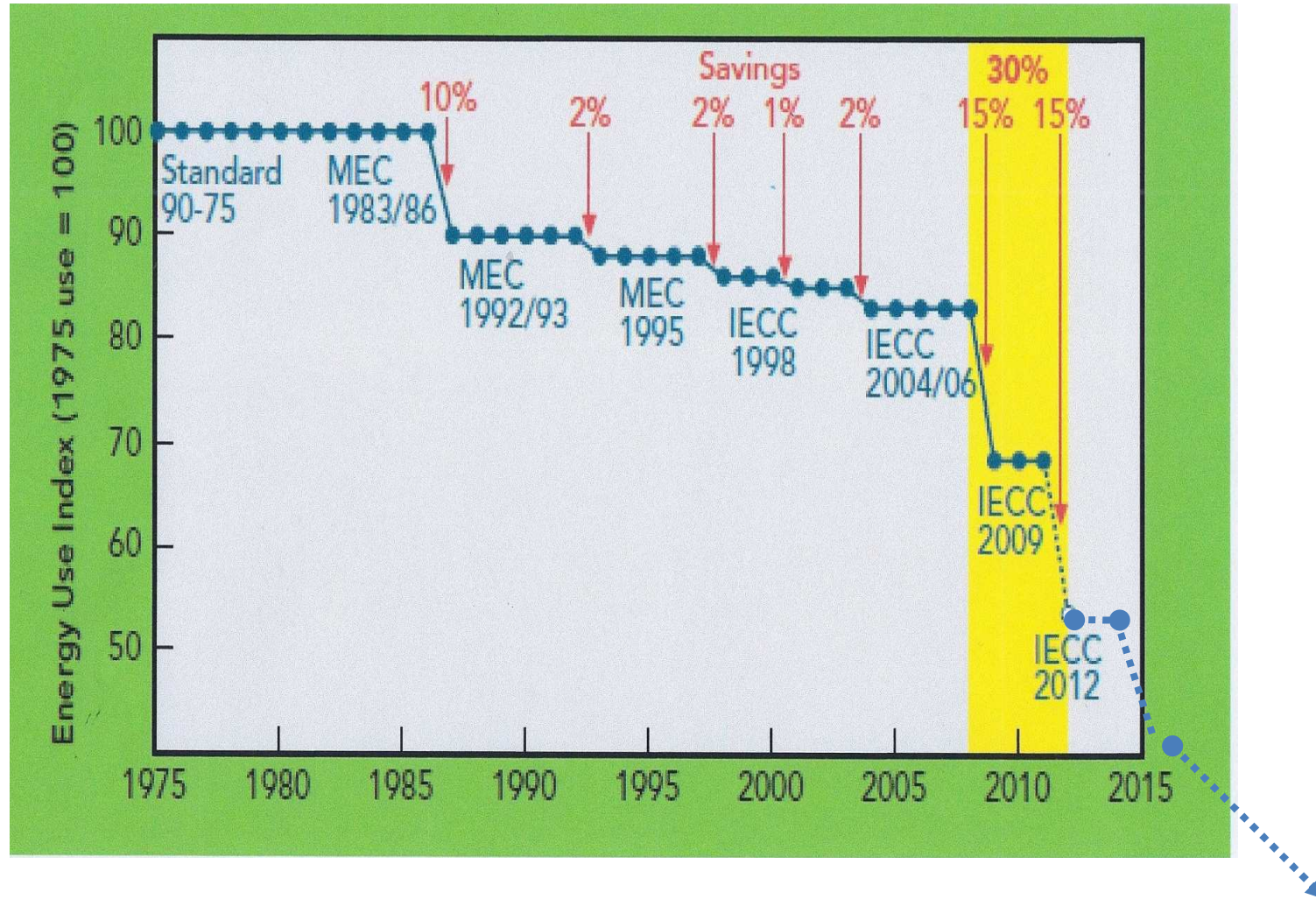
Daily, Hourly Load Variations



Typical Indoor Weather Pattern



Changing Energy Codes

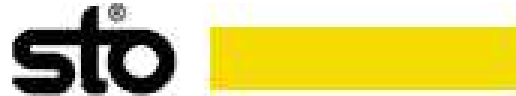


Moisture tolerance and resiliency following similar trend?

Changing Building Envelopes



Control Layer Products



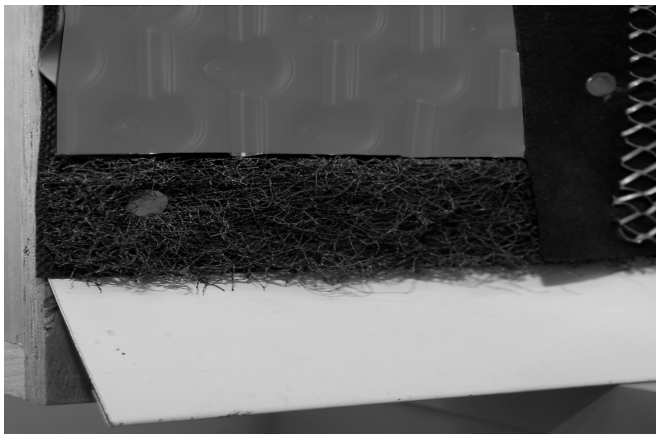
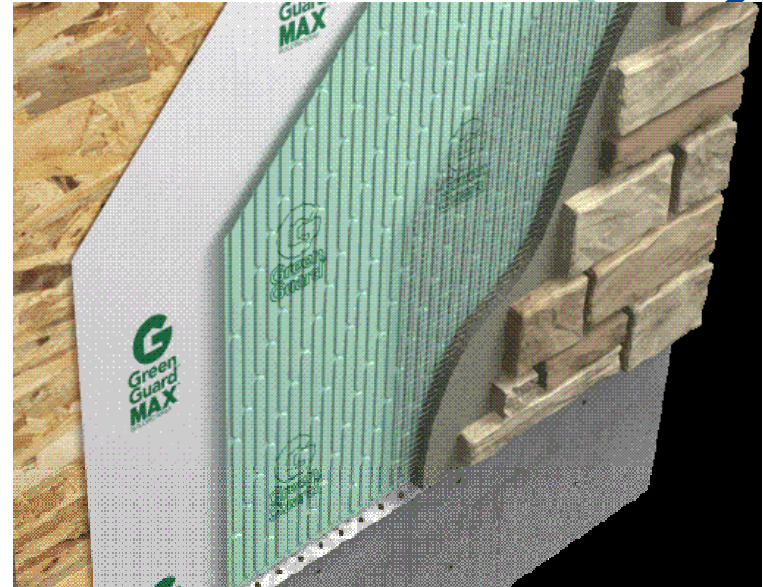
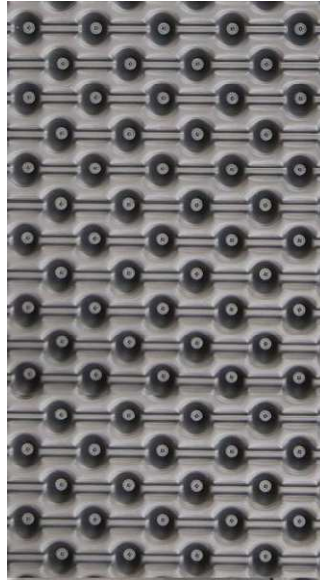
DELTA® protects property. Saves energy. Creates comfort.



There's something happening here



What it is, is very clear



Control & Kaos?





Load & Part Load

Fixed Capacity & Variable Capacity

Load & Capacity



Load



Capacity



3 Types of People



1. Those who
can do math
2. and those
who can't.



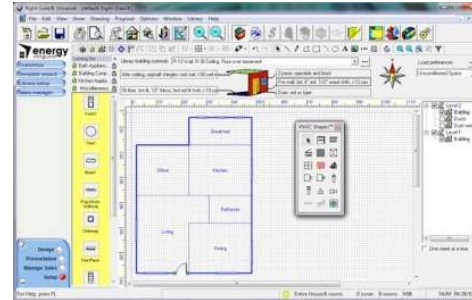
3 Types of Loads



Extreme Load



Design Load



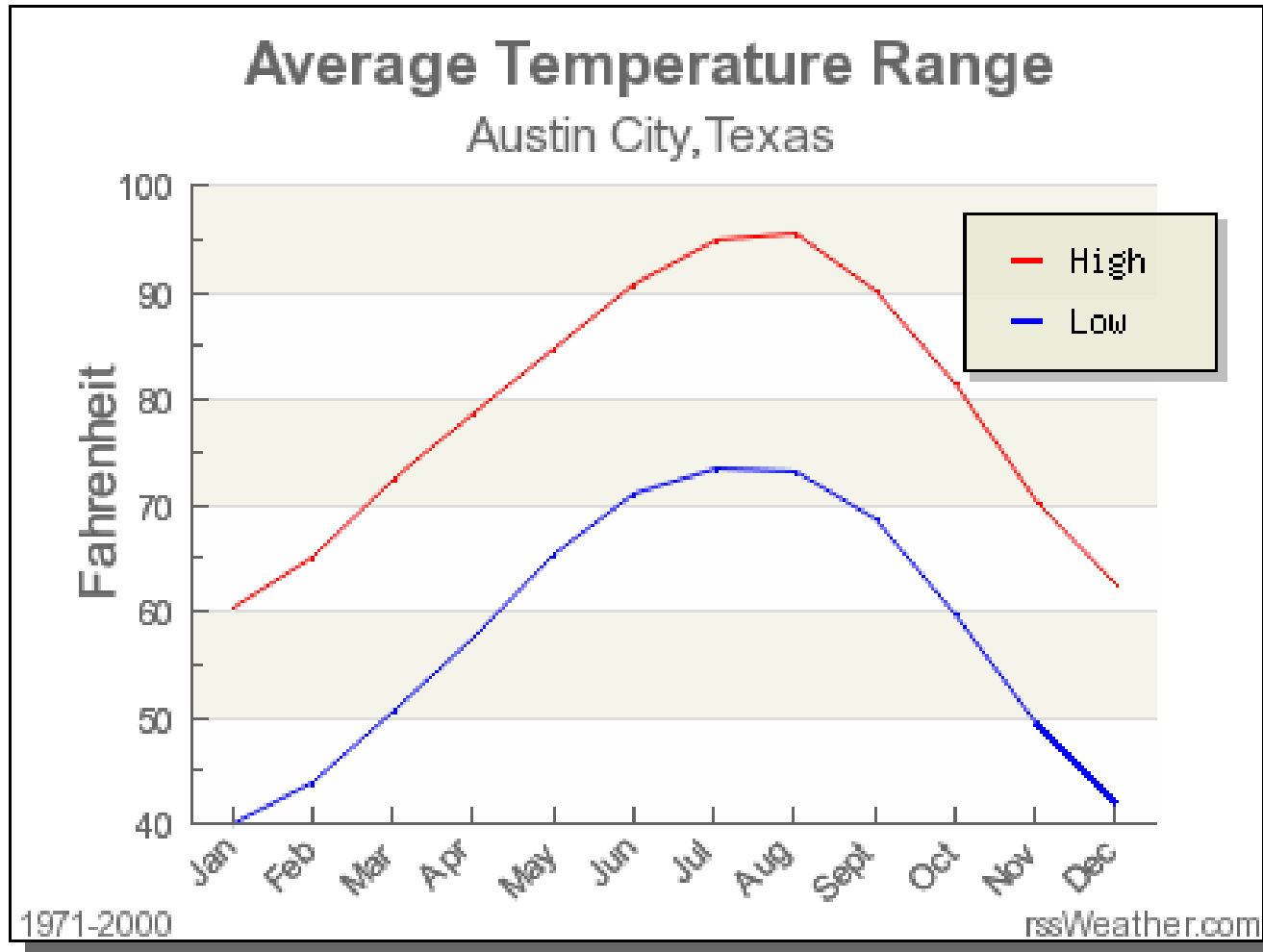
Part Load



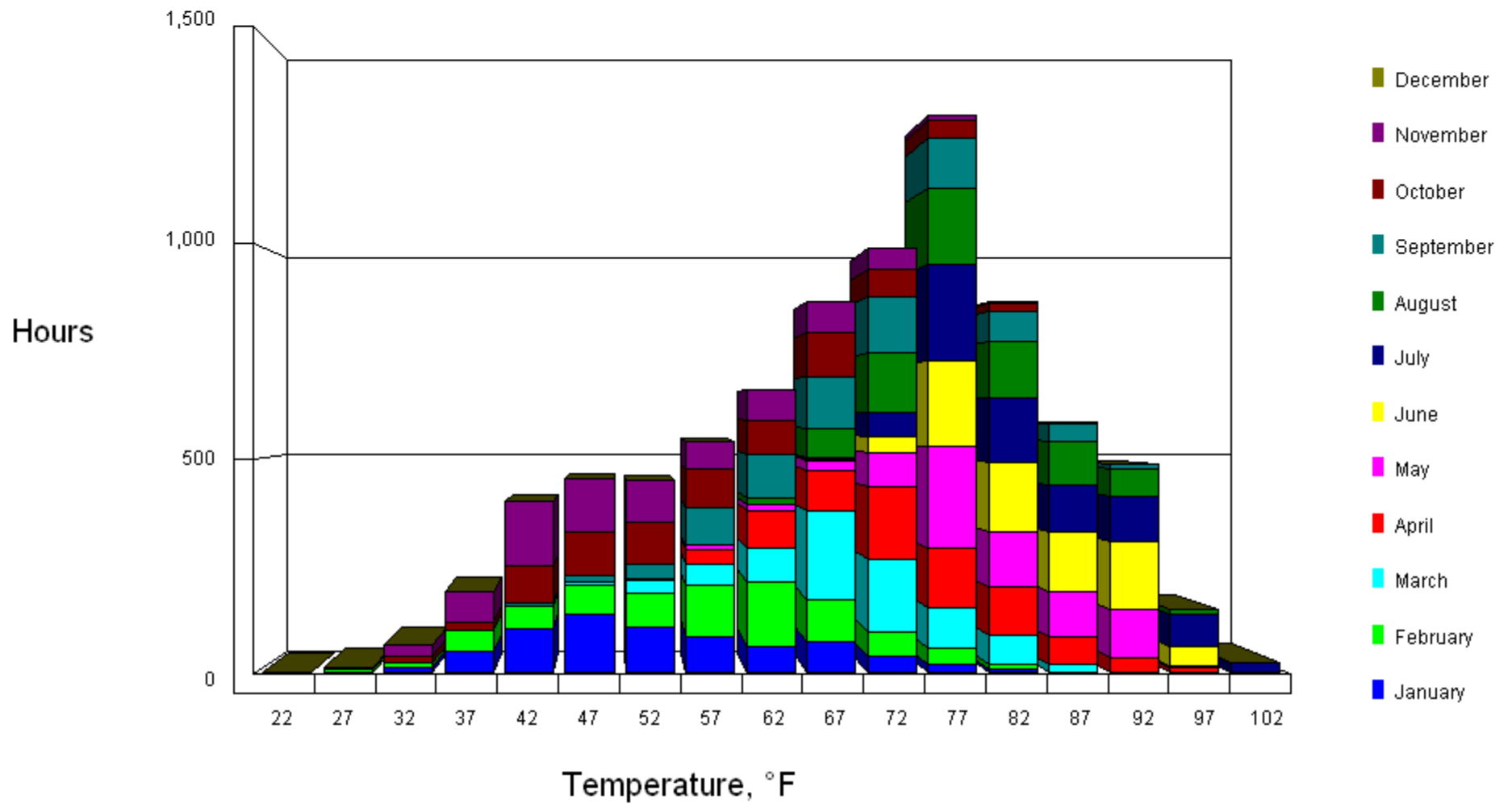
Variable Loads



Austin Climate



Bin Hours - Austin, Texas



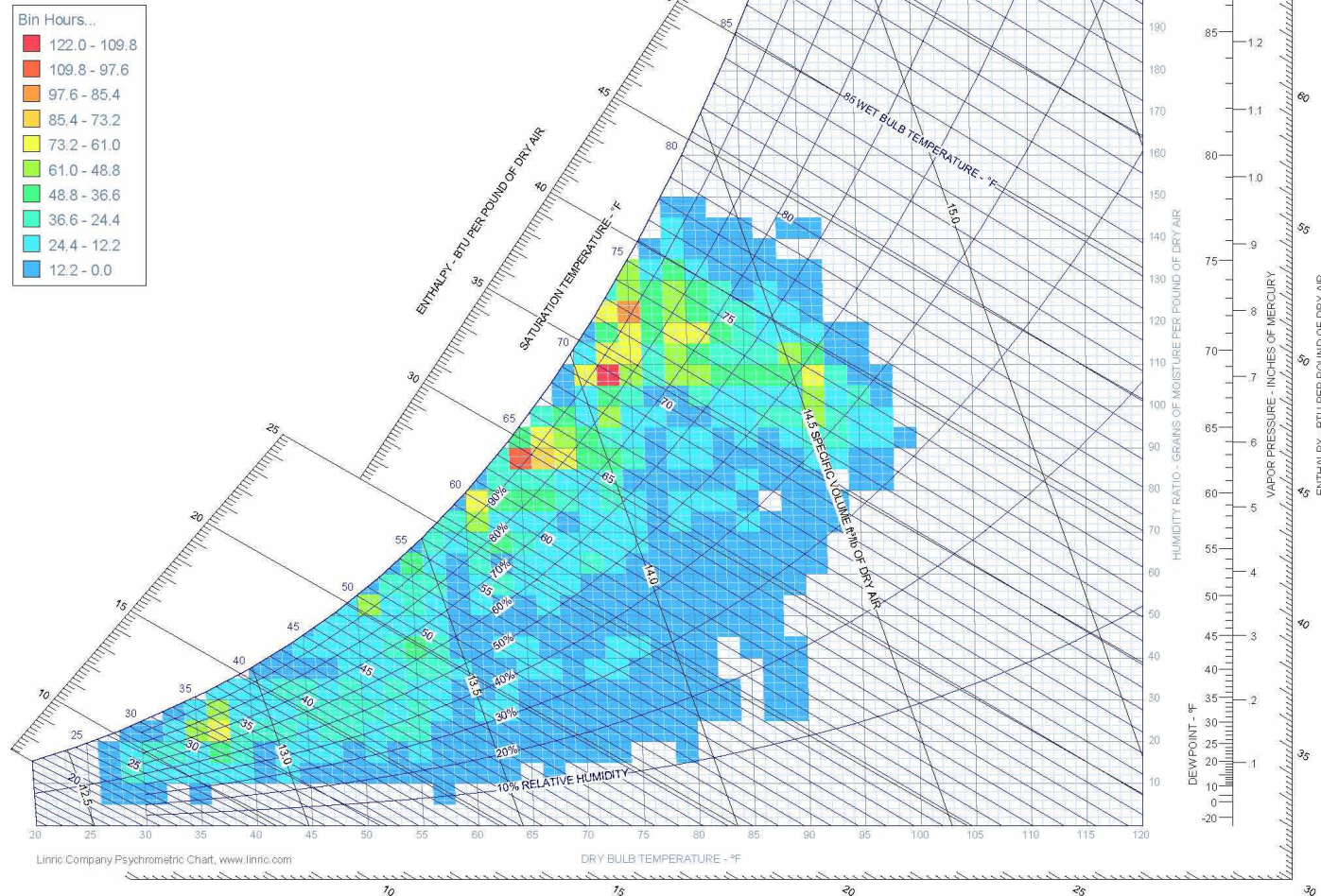
Austin Climate



PSYCHROMETRIC CHART

Austin, Texas USA

BAROMETRIC PRESSURE 29.281 inches of Mercury



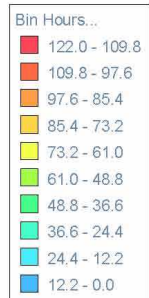
Austin Climate



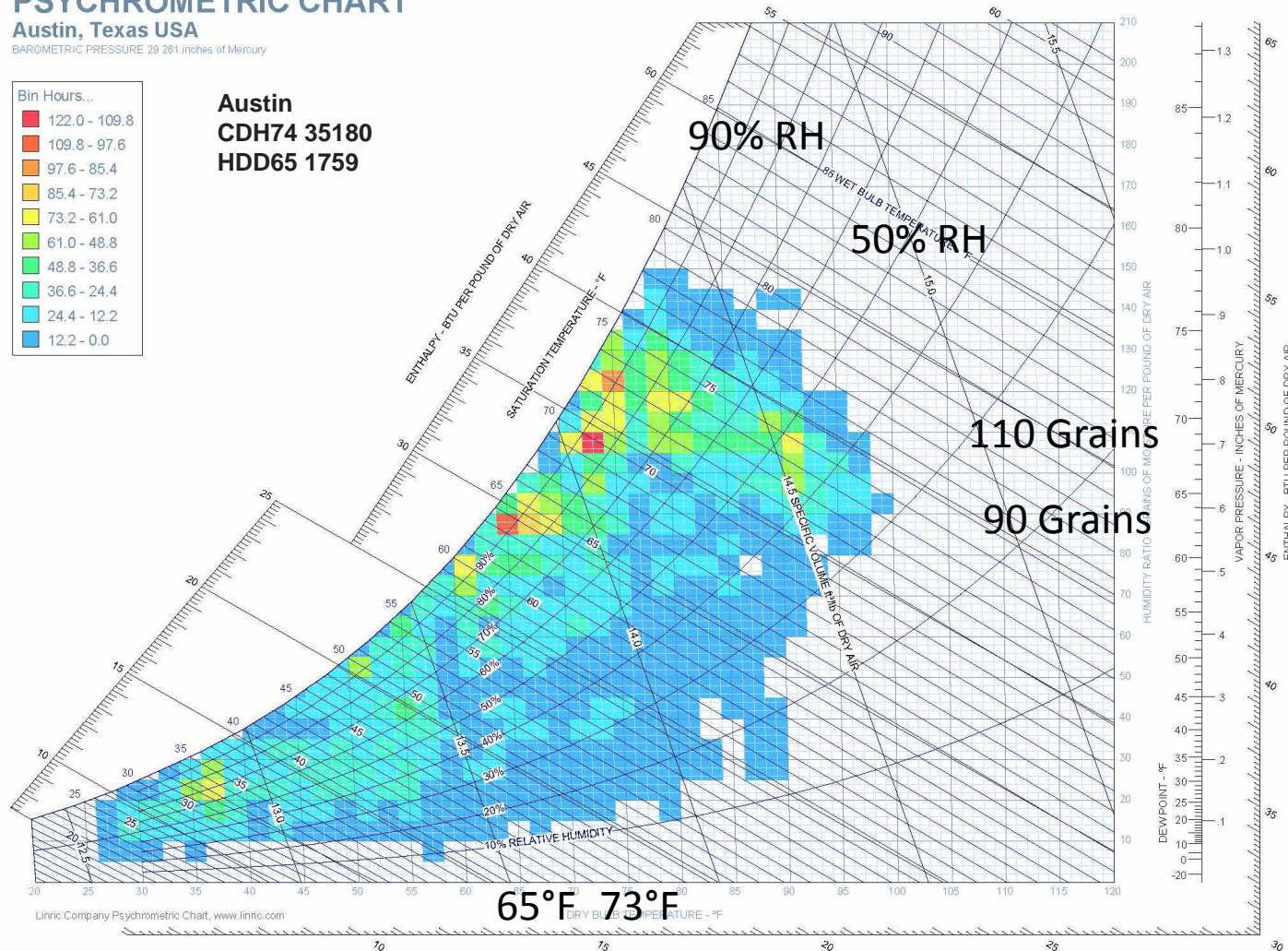
PSYCHROMETRIC CHART

Austin, Texas USA

BAROMETRIC PRESSURE 29.281 inches of Mercury



Austin
CDH74 35180
HDD65 1759



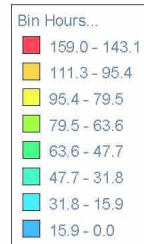
Atlanta Climate



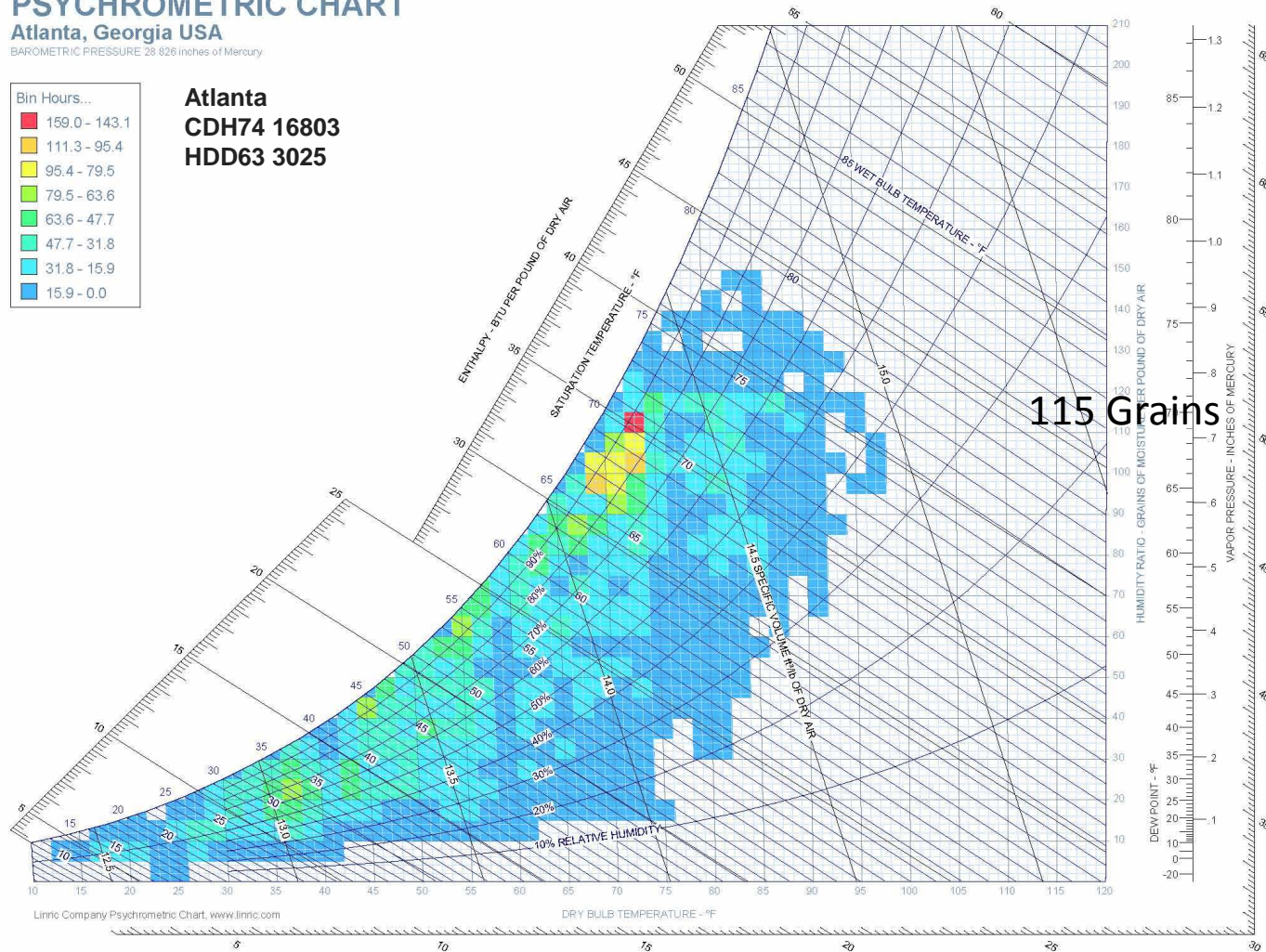
PSYCHROMETRIC CHART

Atlanta, Georgia USA

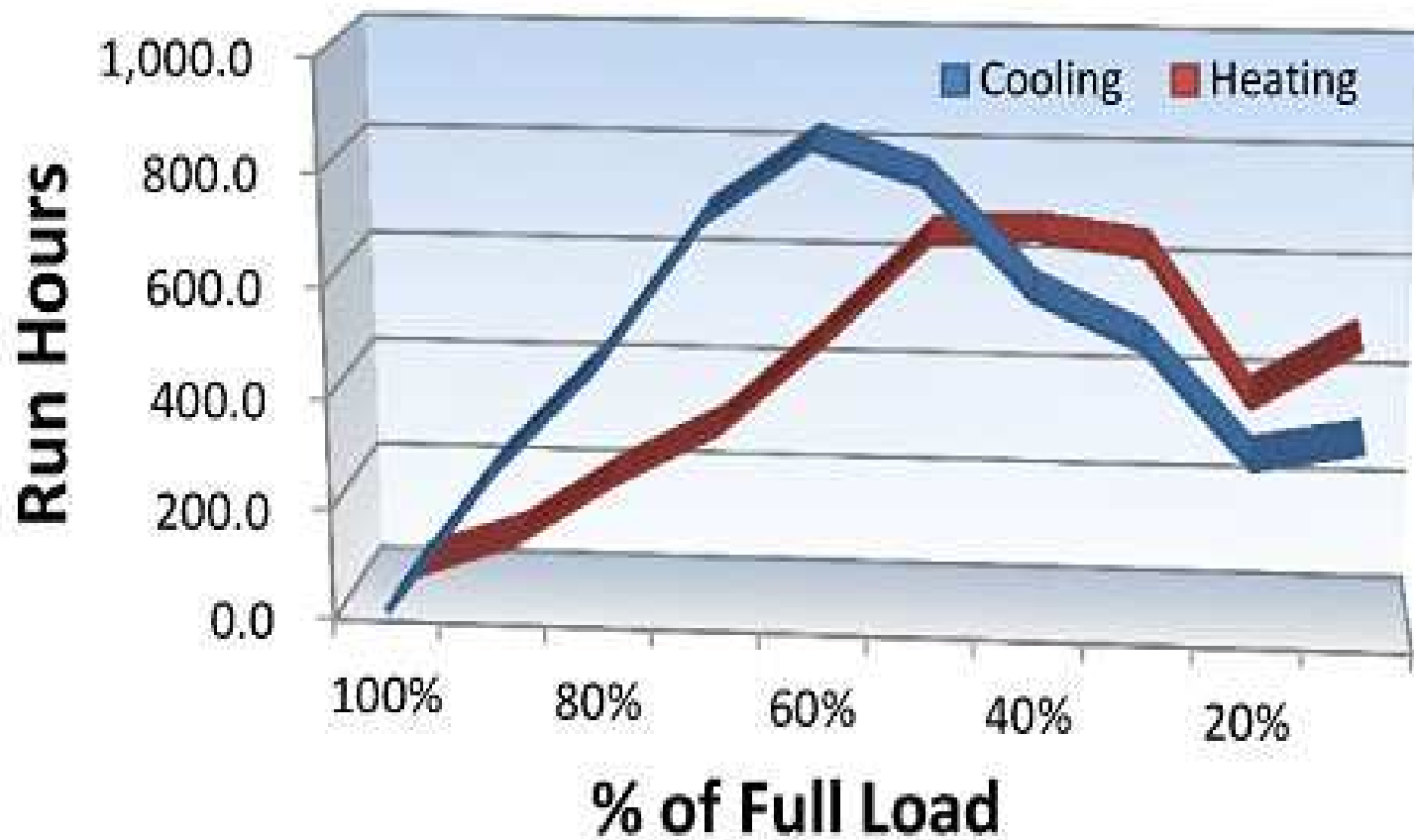
BAROMETRIC PRESSURE 29.926 inches of Mercury



Atlanta
CDH74 16803
HDD63 3025

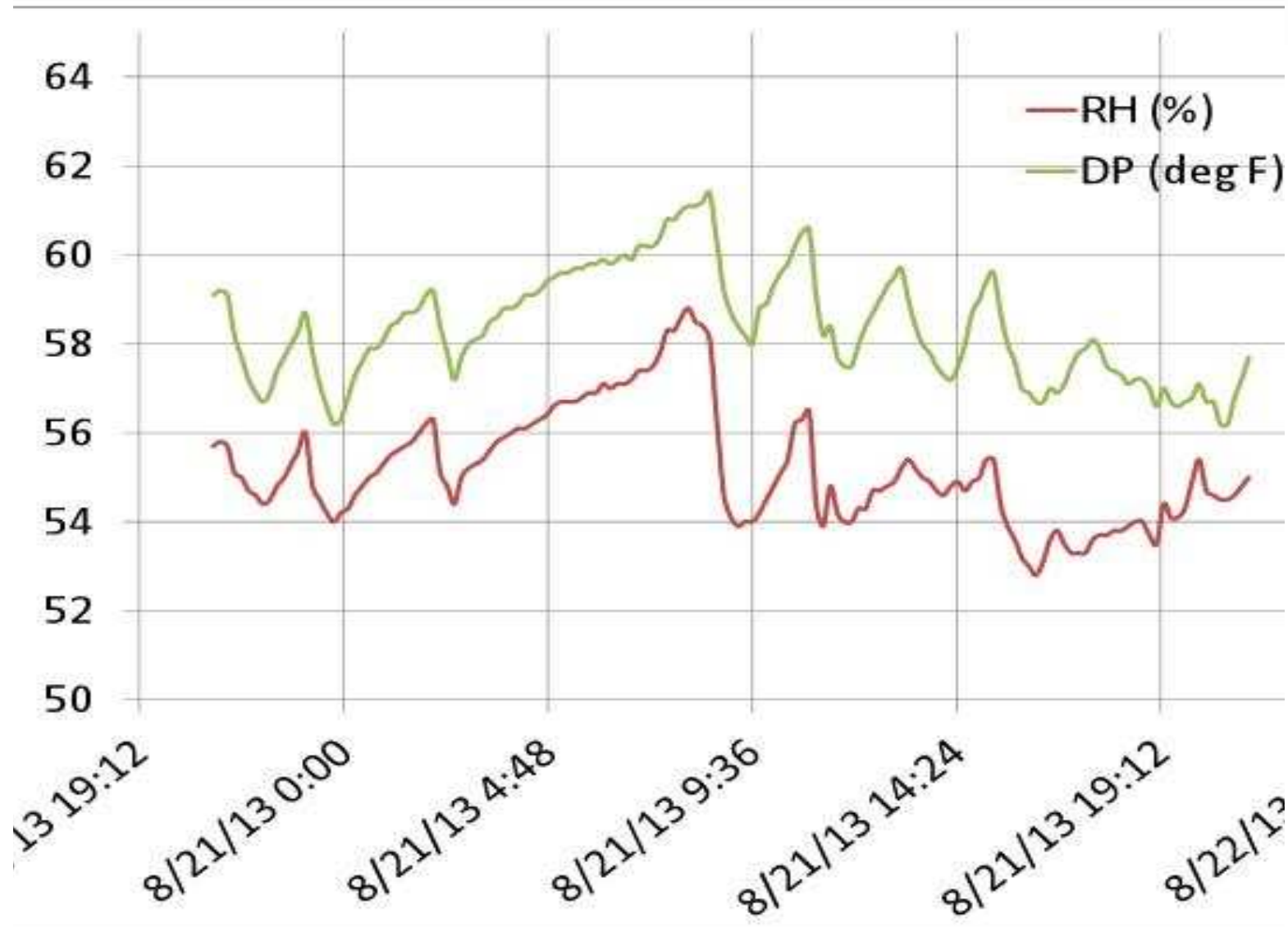


Part Load Hours



Source: HTS Engineering

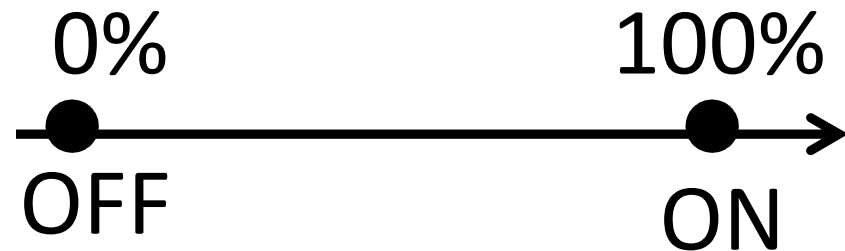
No Cooling. No Dehu.



Fixed Capacity



Single Speed



- Dot represents Equipment Operating Point & Percentage of Rated Capacity Delivered to Load (idealized)

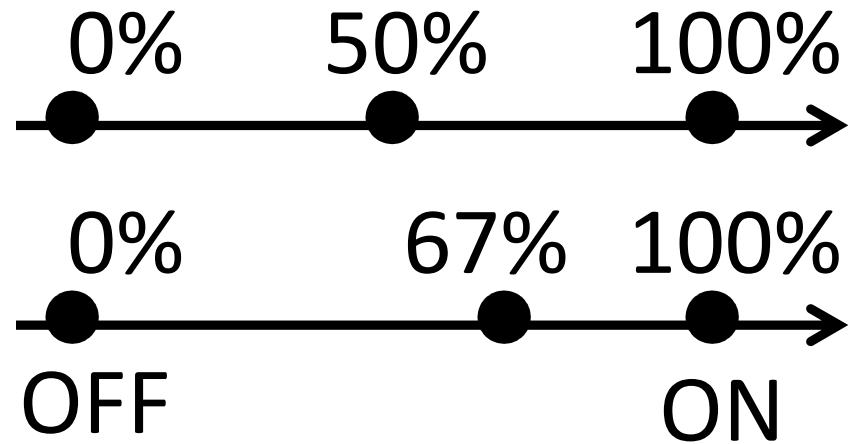
Majority of US Market



Dual Capacity



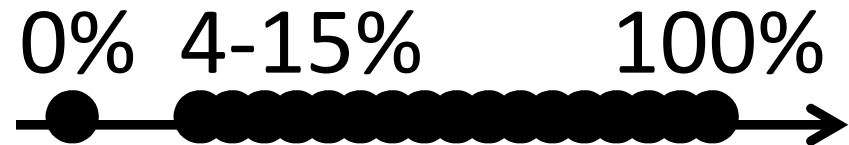
Dual Stage & Unloaders



Variable Capacity



Inverter Scroll Compressor



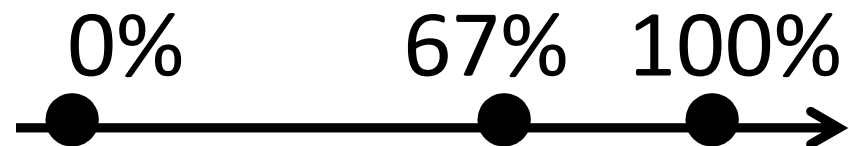
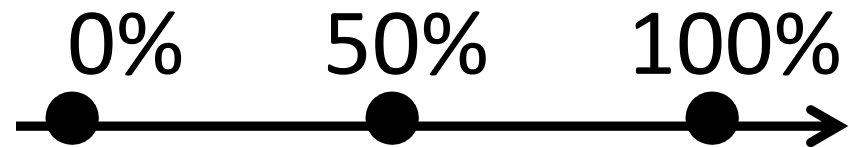
3 Types of Capacity



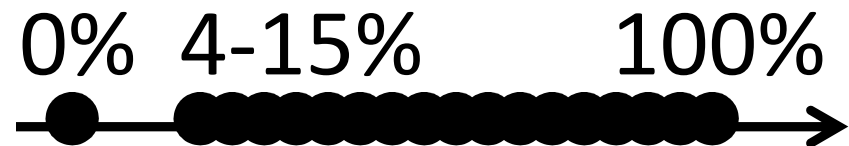
Single Speed



Dual Stage &
Unloaders



Variable Capacity



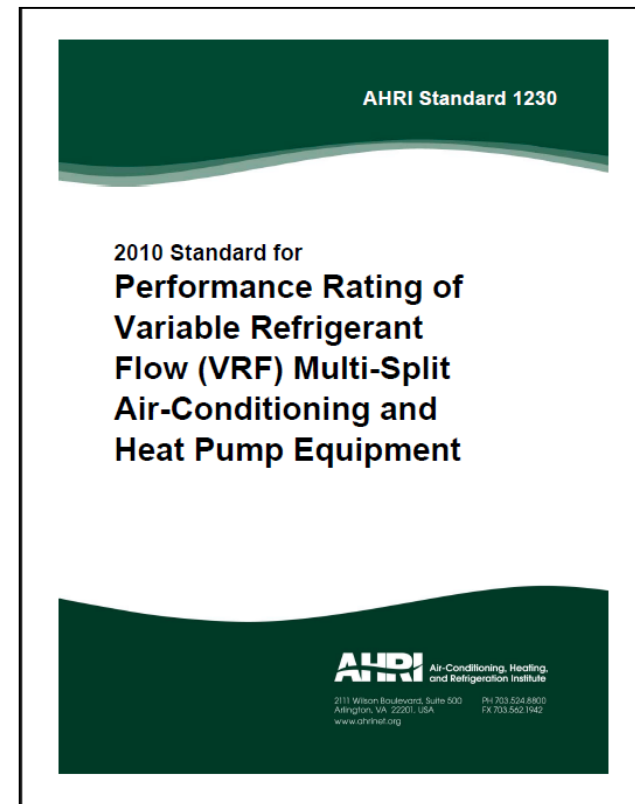


VRF & Industry Performance Metrics

AHRI 1230-2010



- Full Load
 - EER
 - COP @47F
 - COP @17F
- Part Load
 - IEER
- Heat Recovery
 - SCHE



Performance Metrics



Rated at Full Capacity Conditions

- **EER** – Energy Efficiency Rating = Btuh's per Watt
- **SEER** – Seasonally adjusted; per AHRI formula
- **HSPF** – Heating Seasonal Performance Factor
- **COP** – Coefficiency of Performance = In North America, typically rated for Heat Pumps at 17 & 47 degrees Fahrenheit.

Performance Metrics



Rated at Part-Load capacities
(25%, 50%, 75% & 100%)

- **IEER** – Integrated Energy Efficiency Rating; Took the place of IPLV
- **SCHE** – Simultaneous Cooling & Heating Efficiency

Efficiency of Heat Recovery at simultaneous 50% heating & 50% cooling

IEER



$$\text{IEER} = (0.020 \cdot A) + (0.617 \cdot B) + (0.238 \cdot C) + (0.125 \cdot D)$$

Where:

A = EER at 100% net capacity at AHRI standard rating conditions

B = EER at 75% net capacity and reduced ambient (see Table 11)

C = EER at 50% net capacity and reduced ambient (see Table 11)

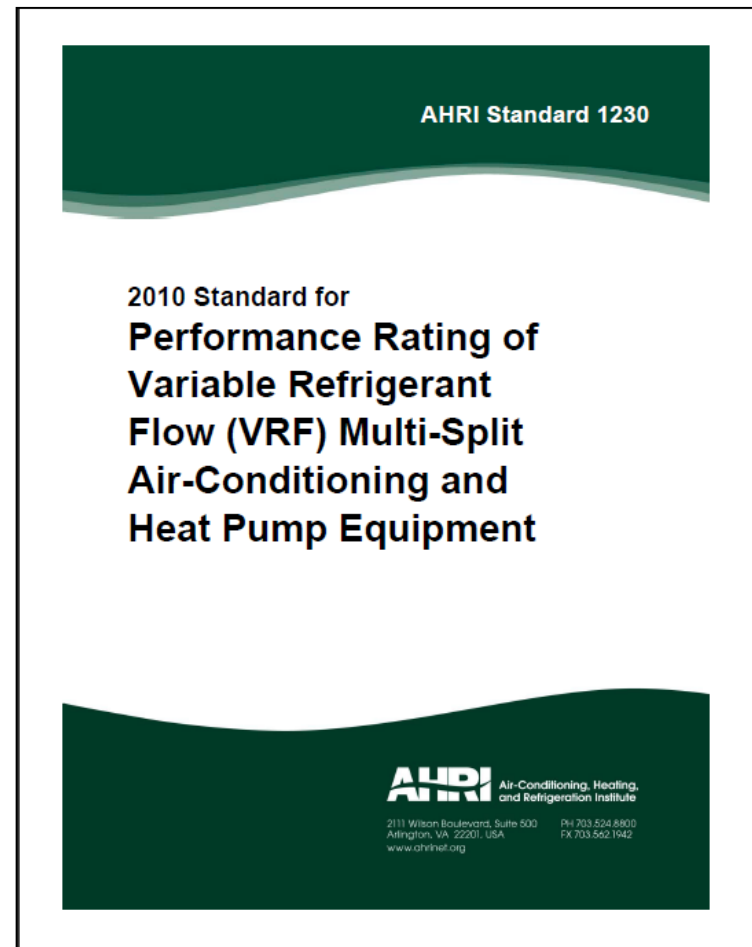
D = EER at 25% net capacity and reduced ambient (see Table 11)

(IPLV@0.1,0.5,0.3,0.1)

> 65kBtuh Only



Part load metrics
only apply to
equipment with
capacities >
65kBtuh



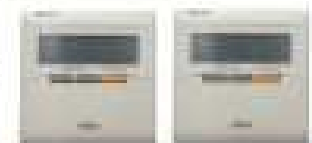
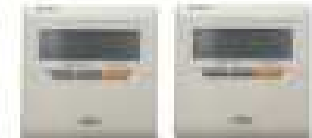


VRF HVAC Technologies

VRF Technology



VRF Technology



Outdoor Condensing Units



S-Series
3-5 Tons
1 Φ
14x38x54



R2, Y, H2iY
6-24 (30) Tons
3 Φ
30x48x65



WR2, WY,
6-24 (30) Tons
3 Φ
21x34x43





VRF Outdoor Units

Manufacturer	Lennox		Mitsubishi
Model Number	XP25-036		PUMY-P36
Cooling Cap (kBtuh)	35.2		36
Heating Cap (kBtuh)	31		40
Pwr Htg (kW)			2.93
Pwr Clg (W)			3.22
Current Clg (A)	LRA 18, RLA 14		15.2
Current Htg (A)			12.9
Dims (WxDxH)	30x39x36 (48)		13x38x54
Weight (Lbs)			287
Sound P (dB(A))	58/73 (min/max)		49/51 (min/max)

Indoor Units



Space Mounted



Ceiling Recessed



Concealed Ducted

Space Mounted



Wall Mounted
6-30kBtuh



Ceiling Suspended
15-36kBtuh



Floor Standing
6-24kBtuh



Wall Units



Trane 4MYW6 9-22 kBtuh



Fujitsu Halcyon ASUxxRLF 7-24 kBtuh



Gree GWCxx 9-36 kBtuh



Floor Standing



LG ARNUxxxCE 7.5-24.2 kBtuh

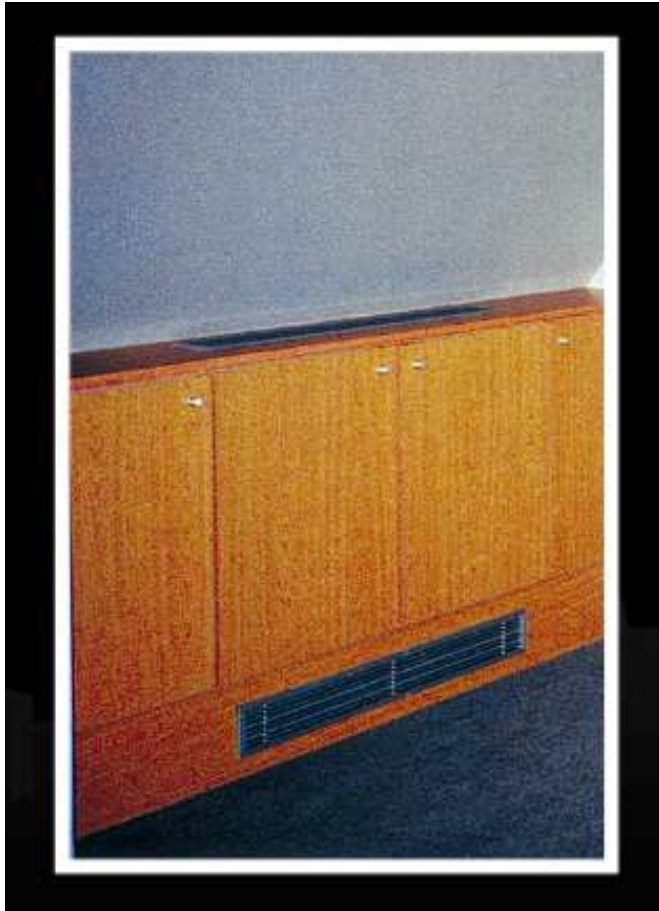


Mitsubishi PFFY-PxxNEMU-E 6-24 kBtuh



Panasonic S-xxMR1U6 7-24 kBtuh

Floor Standing



sample image for reference

Image Source: Mitsubishi Electronics

Space Mounted: Choices



LG Electronics
ART COOL



Ceiling Recessed



4-Way Large Cassette
33"x33", 12-36kBtuh



4-Way Small Cassette
22.5"x22.5", 12-36kBtuh



One Way Cassette
16"x32", 6-15kBtuh

Concealed Ducted



Low (0.2iwc)
Medium (0.6iwc)
High Static (0.8iwc)

6 - 96kBtuh
(1/2 to 8 Tons)



VRF Multi-Split Air Handlers



Panasonic S-xxMM1U6 0.7-18 kBtuh



Daikin FXMQxxPVJU 0.6-4.0 kBtuh



Carrier/Toshiba MMD4 2.5-4.0 kBtuh

Vertical Ducted



horizontal



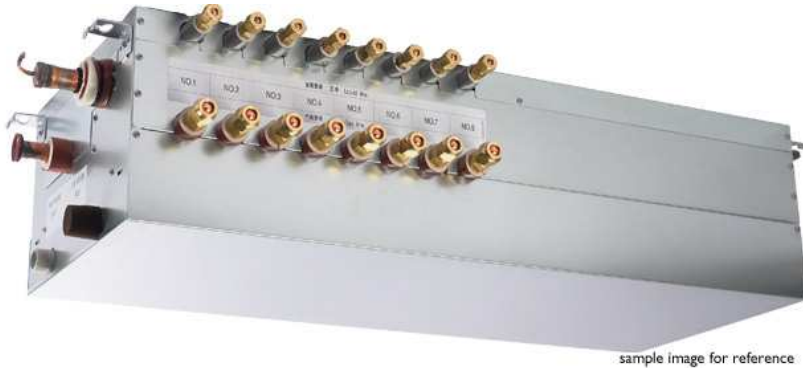
Vertical (Up or Down Flow)
& Horizontal Left Air Handler
0.3, 0.5, 0.8 iwc, 12-54kBtuh



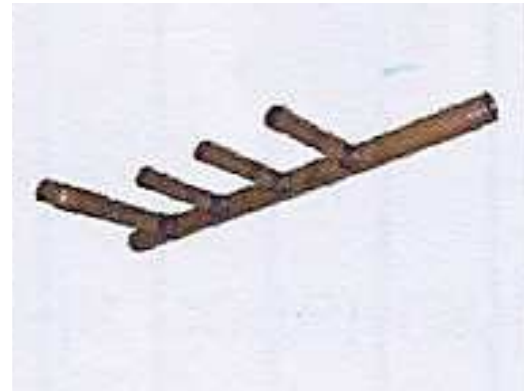
Vertical (Horizontal) Air Handlers

Manufacturer	LG	Mitsubishi	DAIKIN
Model Number	ARNU183NJA2	PVFY-P18E00A	FXMQ18PVJU
Cooling Cap (kBtuh)	18	18	18
Heating Cap (kBtuh)	20	20	20
Pwr Htg (W)	0.08	0.18	0.21
Pwr Clg (W)	0.08	0.18	0.21
Current Clg (A)	0.36	1.22	1.6
Current Htg (A)	0.36	1.22	1.6
Dims (WxDxH)	18 x 21.3 x 48.6	17-3/4 x 21 x 42-3/4	39-3/8 x 27-1/2 x 11-3/4
Weight (Lbs)	117	98	80
Sound P (dB(A))	39/41/42	35/35/36	37/41
CFM (L-M-H)	380/480/530	402/485/520	529/582/635
	0.3, 0.5	0.3, 0.5, 0.8	0.2, 0.8

Branch Boxes, Splitters & Joints



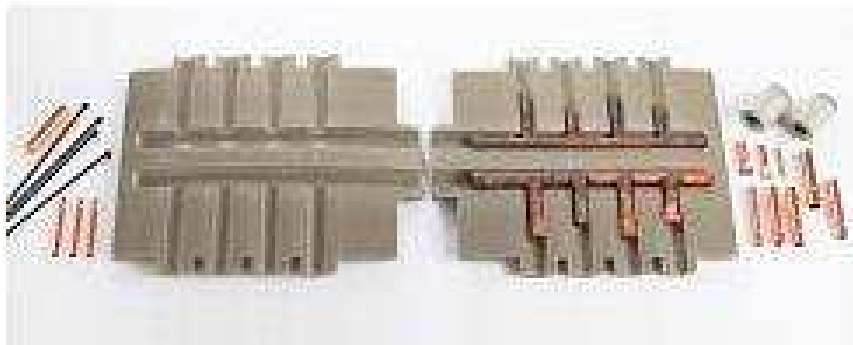
sample image for reference



VRF: Other Parts



Filter Chassis



Piping Headers & Joints



PC Connection

Concealed Ducted



Concealed Ducted



Concealed Ducted

VRF and Existing Buildings



- Less intrusive to existing architecture
- Small refrigerant piping instead of large ductwork
- Outdoor installation flexibility

How?



Variable Refrigerant Flow



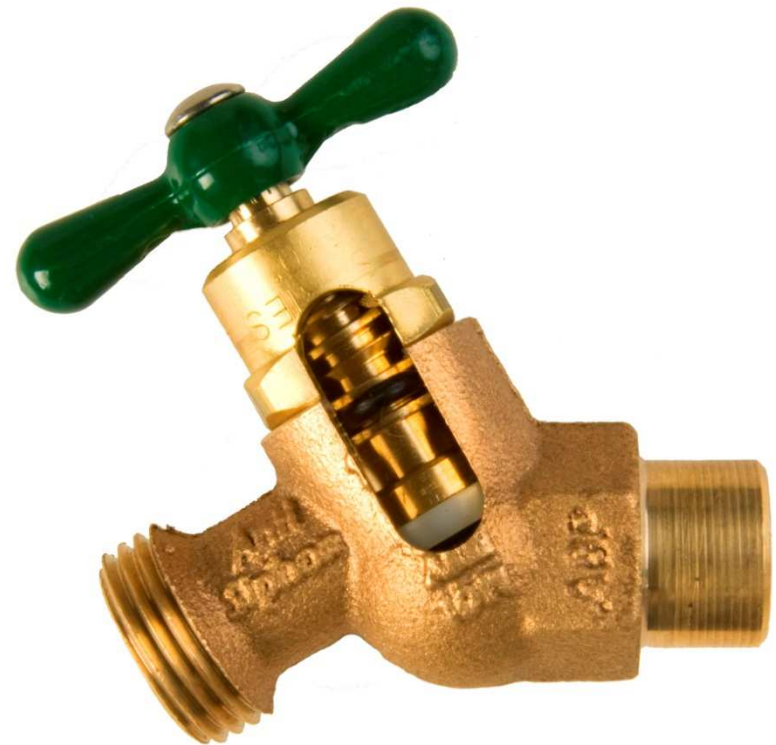
Variable Refrigerant Flow



Linear Electronic Expansion Valve (LEV)

- LEV opens & closes a precise amount w/ each control pulse to its windings
- Thousands of pulses per full open/close
- Precision microprocessor based control

Variable Refrigerant Flow



Inverter Drive



60Hz VAC
In

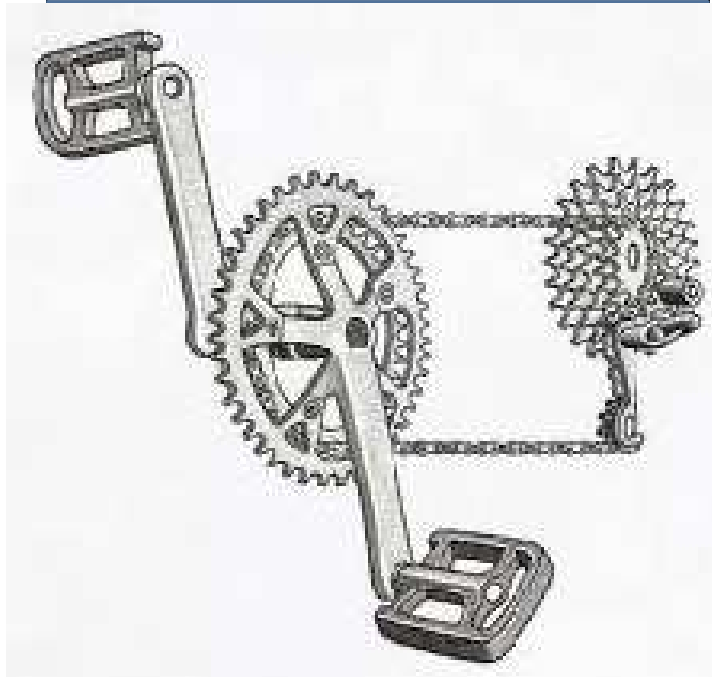


**Inverter Circuit:
Variable Frequency
& Voltage Output**



**Variable
Capacity**

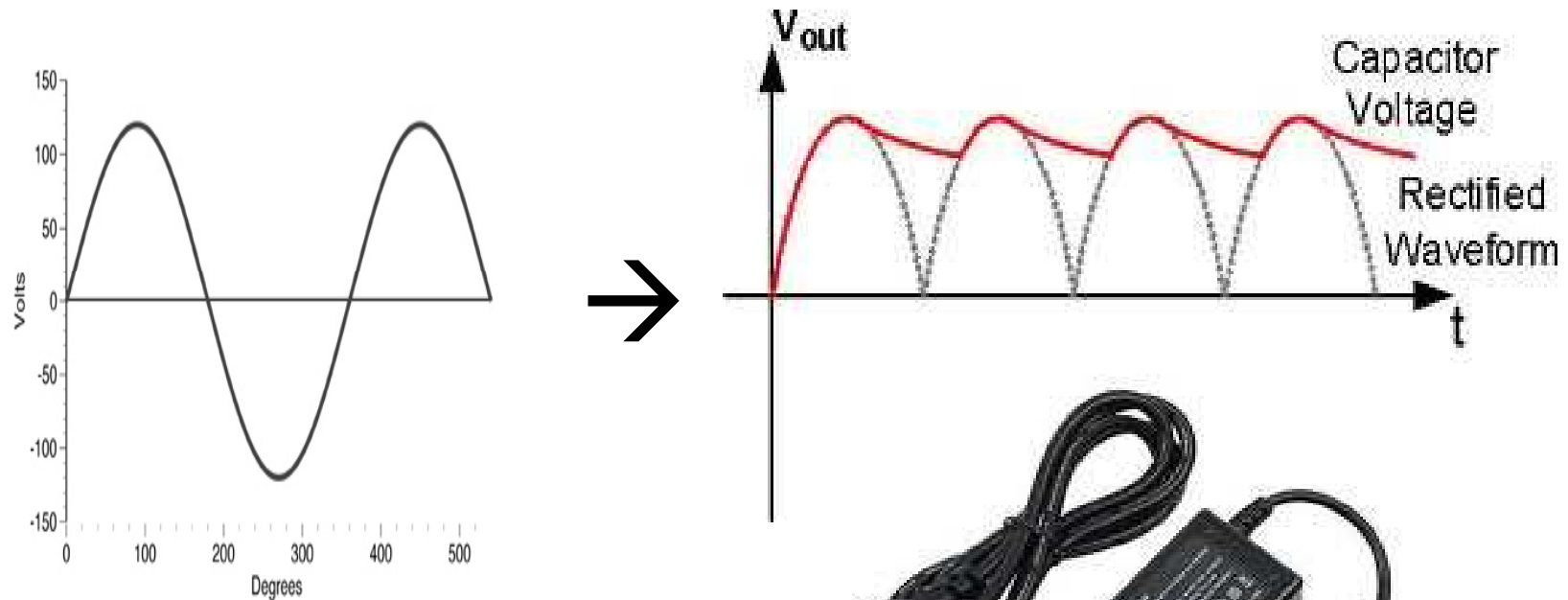
15 – 125 Hz
VAC Out



Inverter Circuit: Step 1



AC \rightarrow DC



Inverter Circuit: Step 2

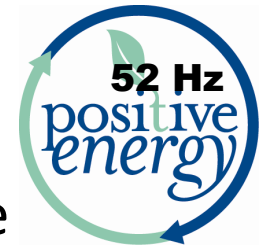


DC \rightarrow AC

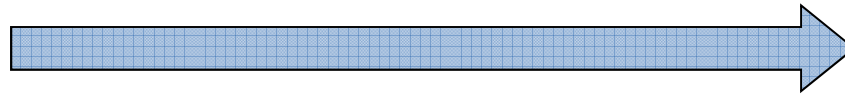


POWERING YOUR FUTURE

DC to AC on Demand

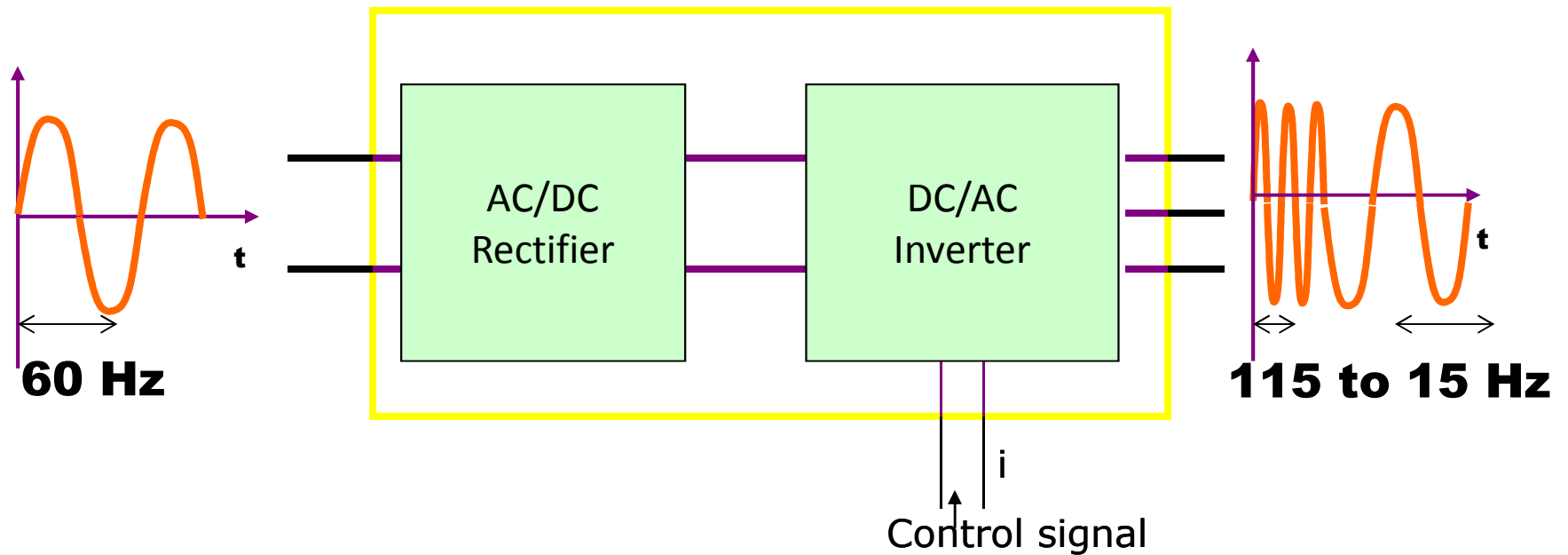


Fixed Input
Power
Frequency
60Hz



Variable
Frequency
Output to
Compressor
Motor

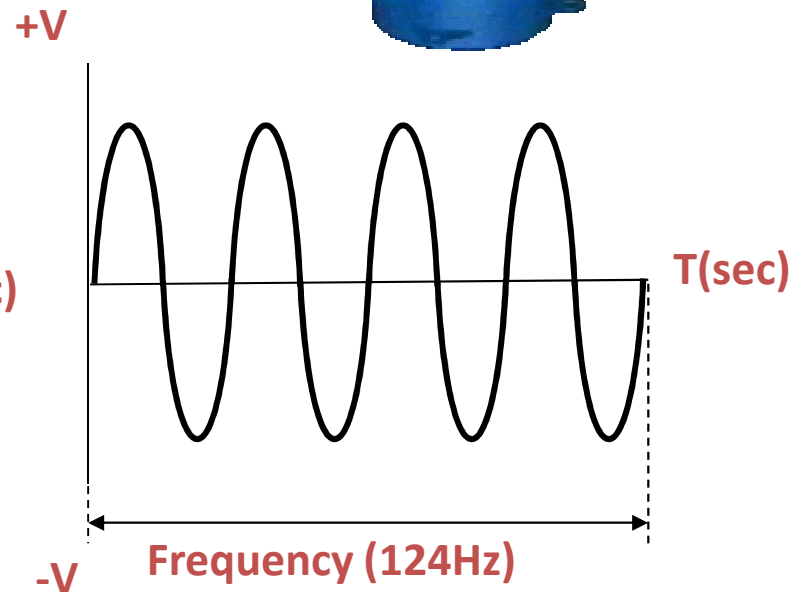
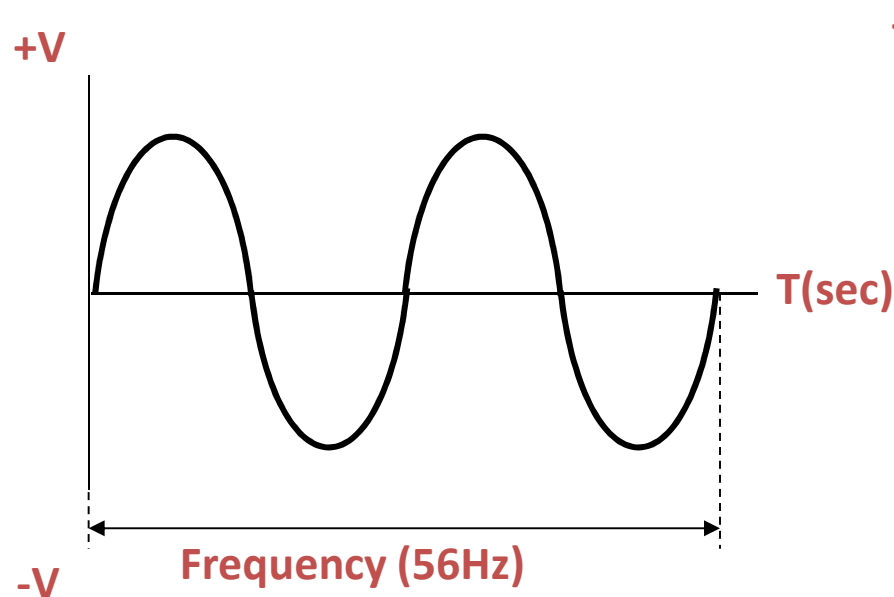
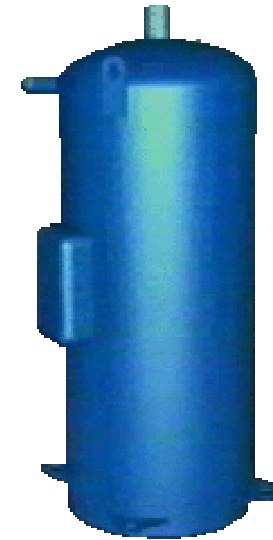
Inverter



Inverter Scroll Compressor



- 30 to 40% Efficiency Improvement
- Soft-starts with no electrical inrush
- Longer life due to soft-starts



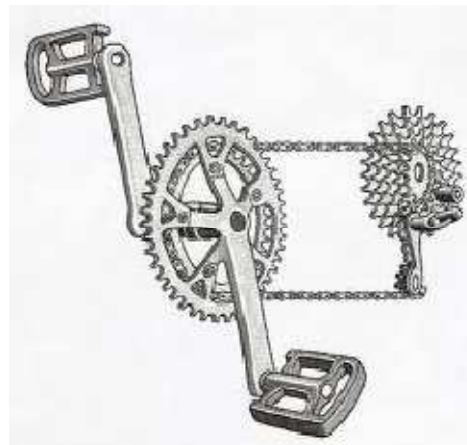
Inverter Drive



15 Hz
Low Part Load



125Hz
Peak Load



Conventional Comfort

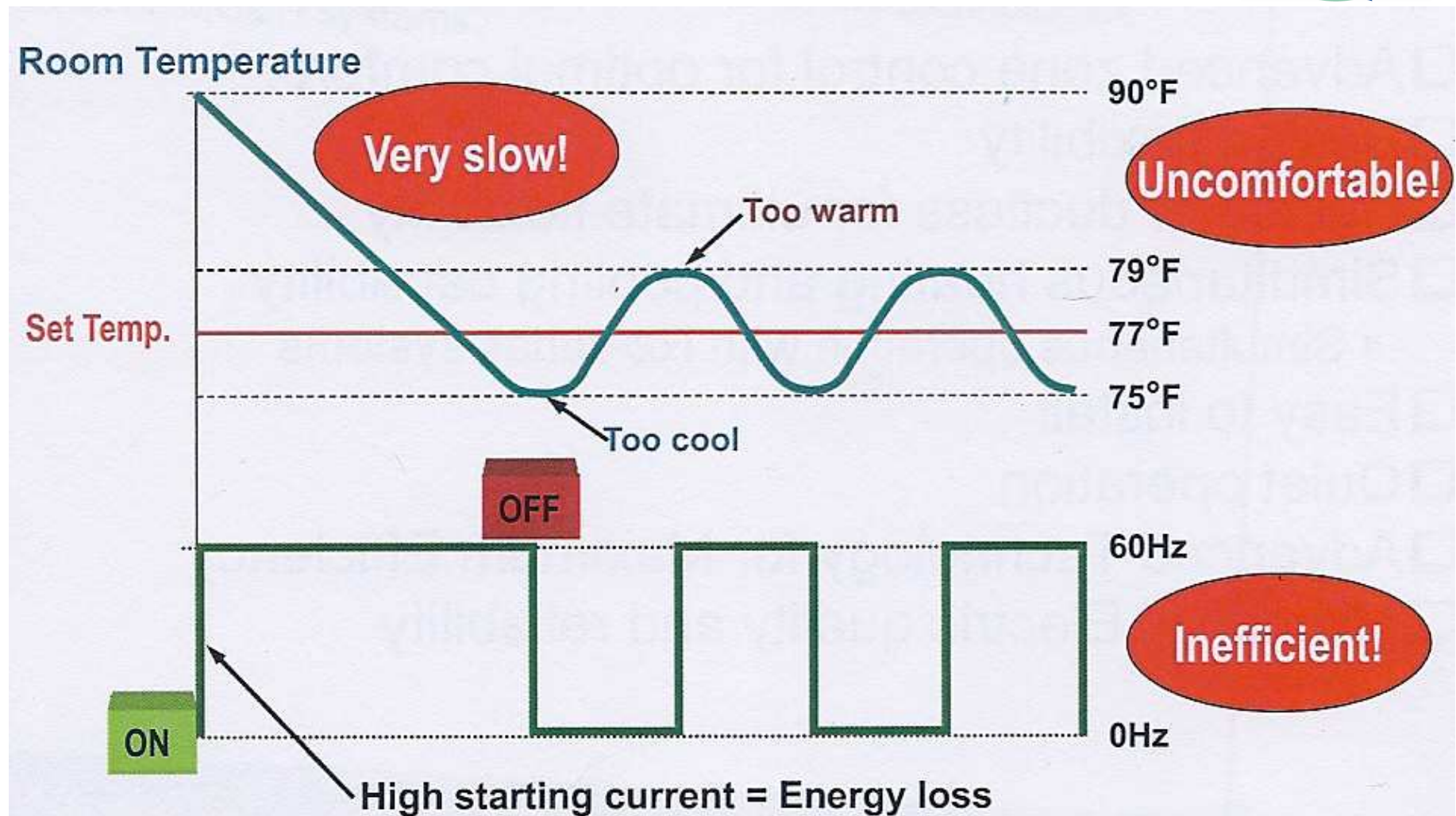


Image Source: Mitsubishi Electronics

VRF Comfort

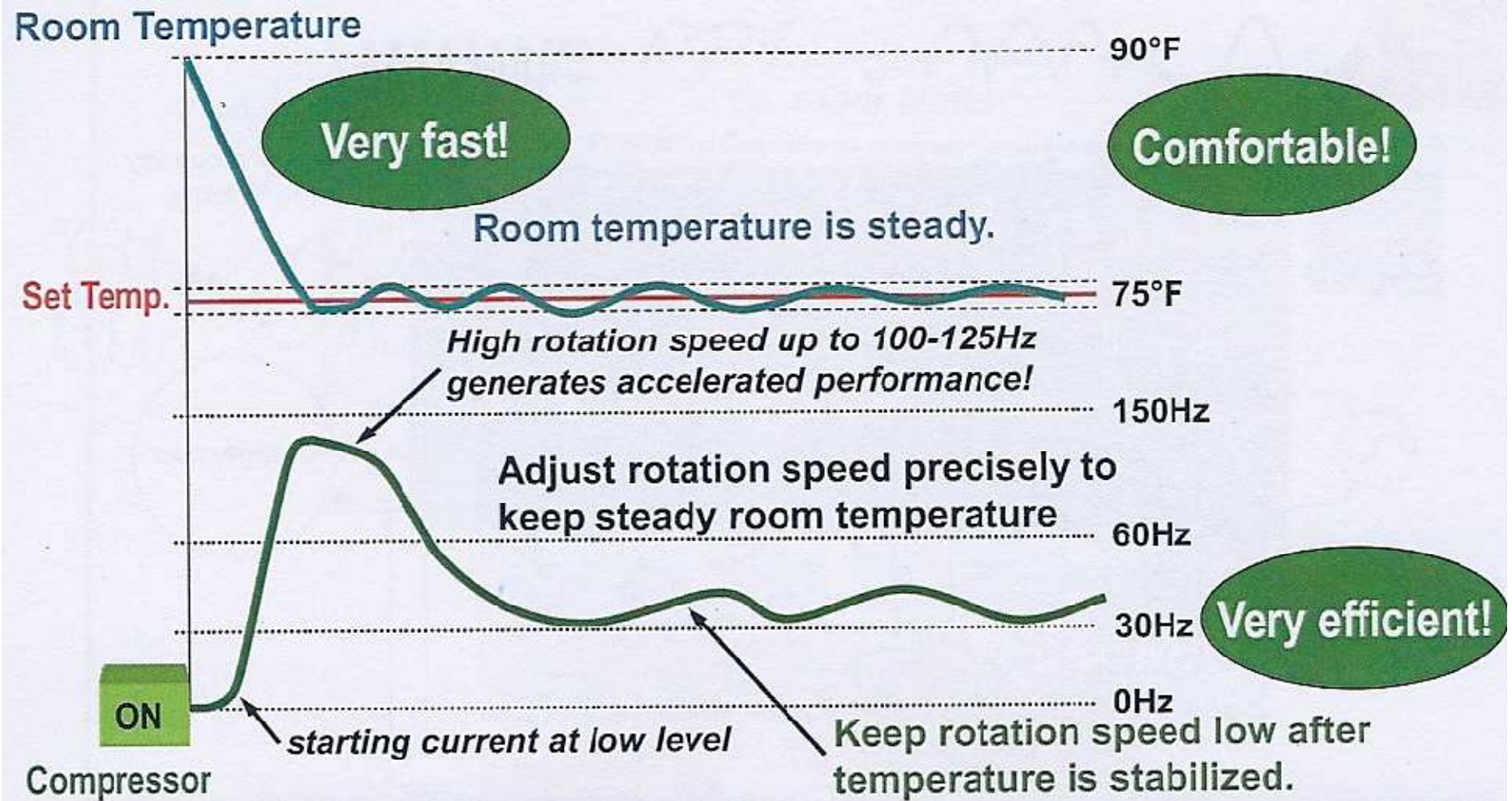
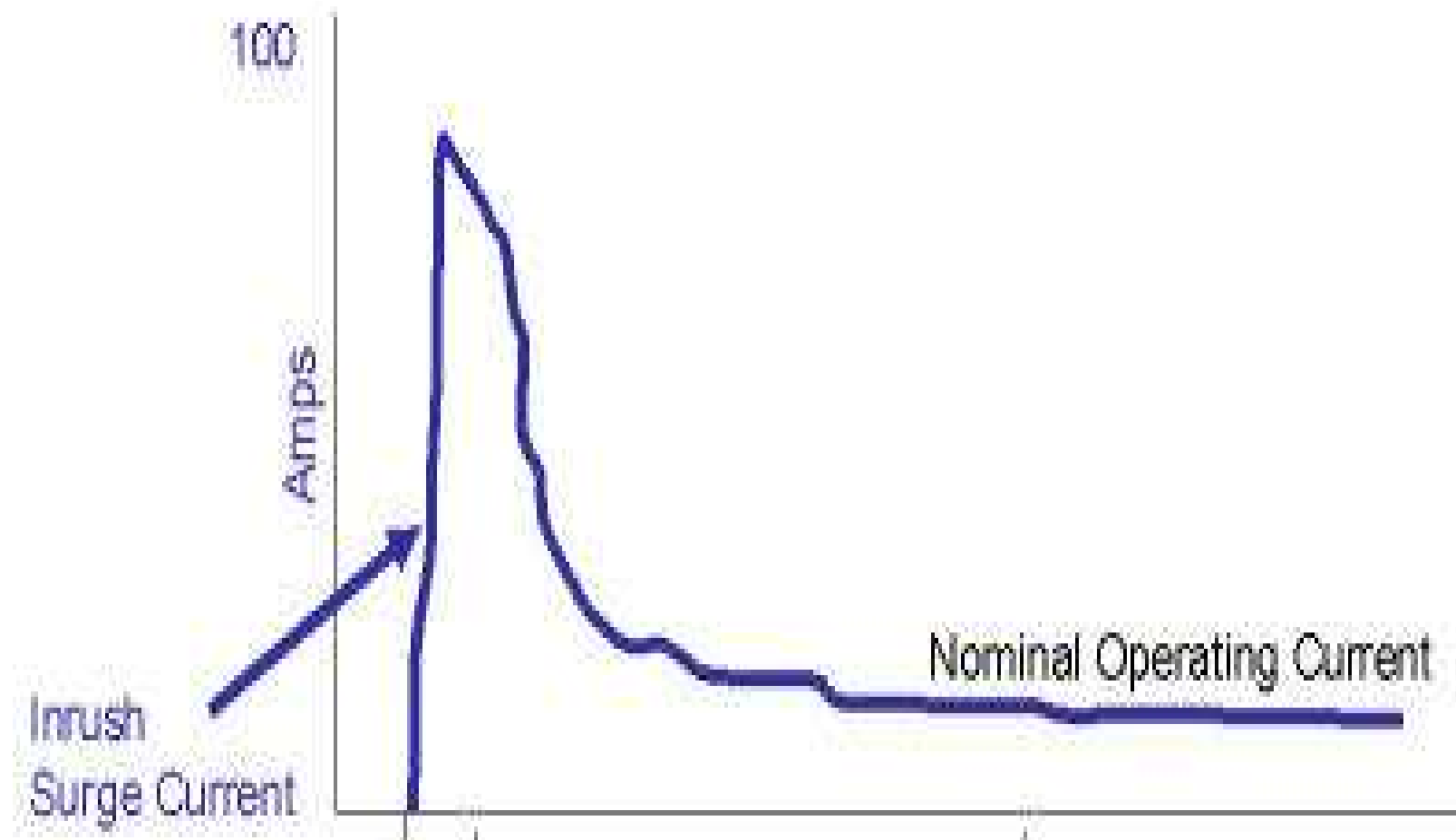
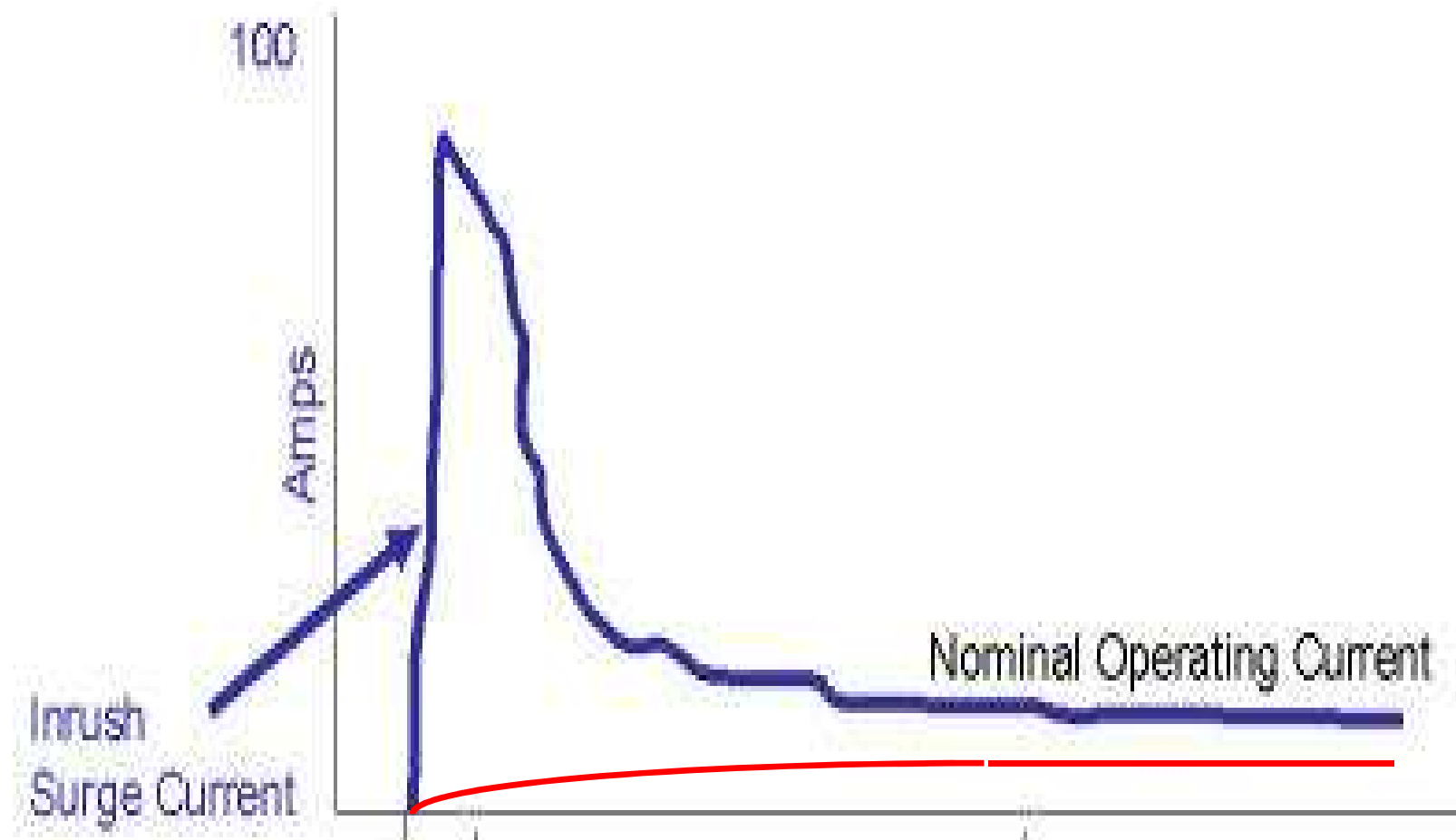


Image Source: Mitsubishi Electronics

Compressor Motor Current



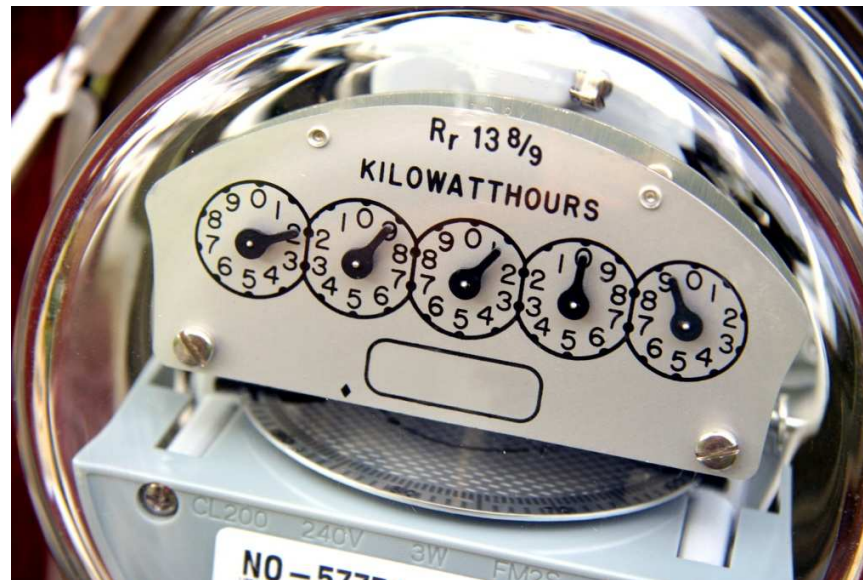
Compressor Motor Current



Operating Currents



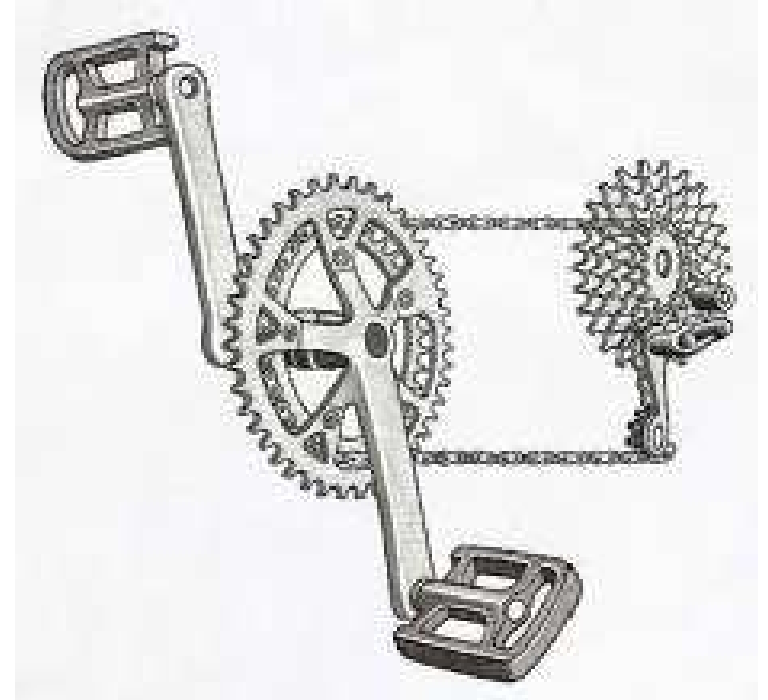
	Indoor Unit (A)	Outdoor Unit (A)
Conventional	3 - 12	20 - 100
VRFZ	0.15 - 6	2-25



Recap: Inverter Benefits



- Precise control & stability of indoor conditions
- Low starting currents
- Long run times
- Reduces compressor cycling
- Improved durability/longevity
- Variable capacity operation
- Rapid ramp up to meet load
- Minimum capacity to as low as 4% of rated

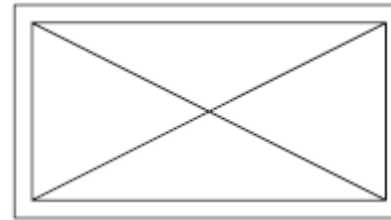


VRF Space Savings

Space Required to
Deliver 20 tons of Cooling

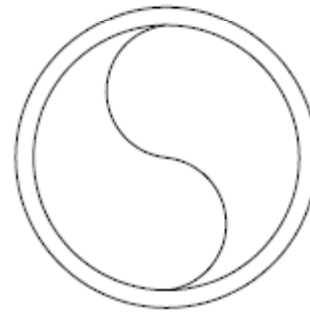


Rectangular Ductwork (DX System)



40" x 20"

Round Ductwork (DX System)



30" Round

Piping (4 -Pipe System)



3" CHWS&R, 3" HWS&R

Piping (VRF)



1³/₈" Gas 1¹/₈" Liquid

Quiet Operation

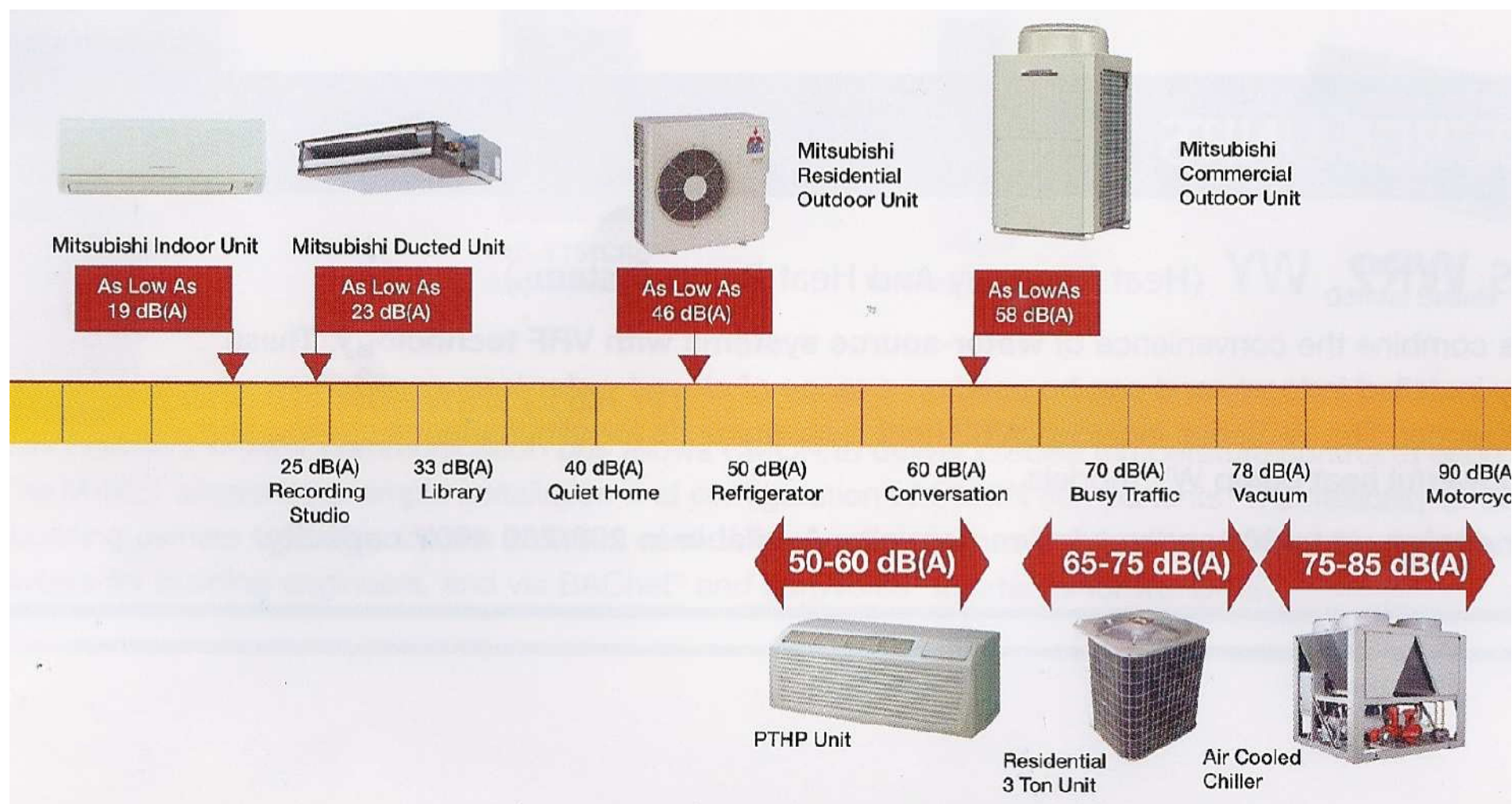


Image Source: Mitsubishi Electronics

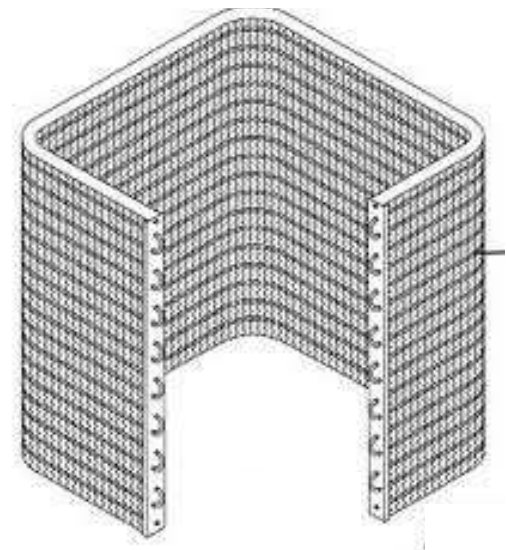
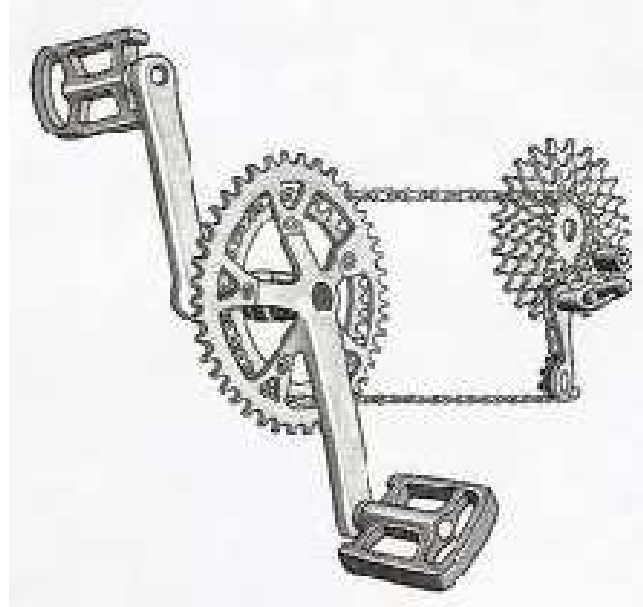
VRF & Energy Modeling



- Energy Plus
- EnergyPro
- Others using DOE2.1 engine



VRF, Inverter-Drive & Beyond



Pricing Comparison



k\$/Ton	\$1.5	\$2.0	\$2.5	\$3.0	\$3.5	\$4.0	\$4.5	\$5.0	\$5.5	\$6.0	\$6.5	\$7.0	\$7.5	\$8.0	\$8.5	\$9.0	\$9.5	\$10.0
Base																		
Mid-Range																		
Top-End																		
VRFZ																		
GSHP																		

*GSHP pricing does not include 30% Federal tax credit





Summary

VRF Benefits



- Efficient part-load performance
- Versatility
- Comfort/control
- Multiple independent indoor zones
- Quiet operation
- Improved latent control & filtration w/ longer run times
- Reduced need for ductwork & associated duct losses/impacts
- Easy of installation
- Many units are ventilation compatible
- High reliability/low maintenance

VRF Issues & Concerns



- Market Inertia
- Lack of 3rd party performance data
- Inappropriate industry rating metrics
- Cost
- Installer/Service training & skills
- Complexity
- Power sensitivity
- Supplemental heating integration
- Filtration concerns
- Costly to service/cleaning condenser coils
- Lack of control based on latent (most units)
- Need for supplement dehumidification at low loads

Thank You

