Advantages and Pitfalls of VRF Air-to-air Heat Pump Systems

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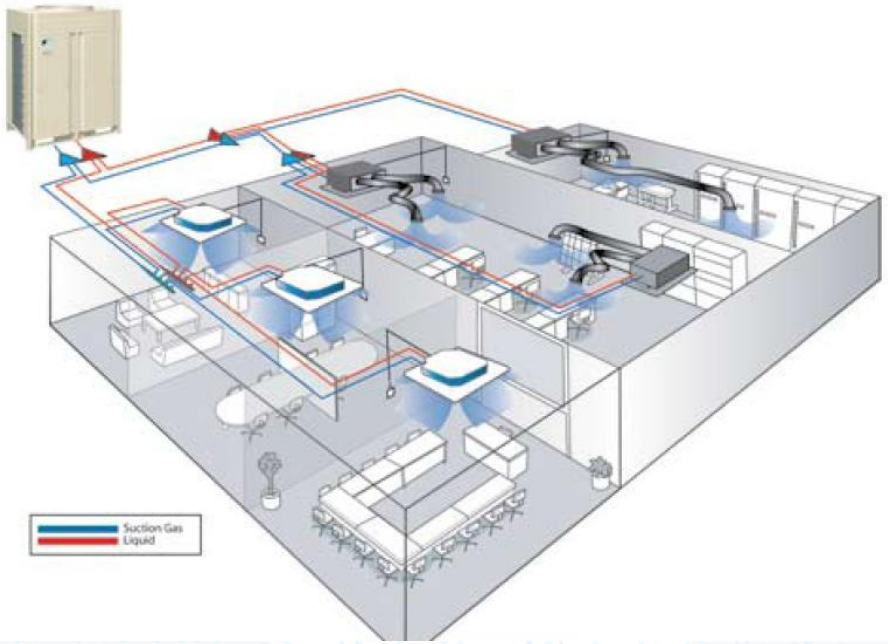
Objectives

- You will not understand the HP refrigeration cycle
- You will understand the refrigerator cycle
- You will understand what these systems look like
- You will have some idea of HP energy performance
- You will have some knowledge of system design issues
- You will hopefully avoid some of the things we have done wrong

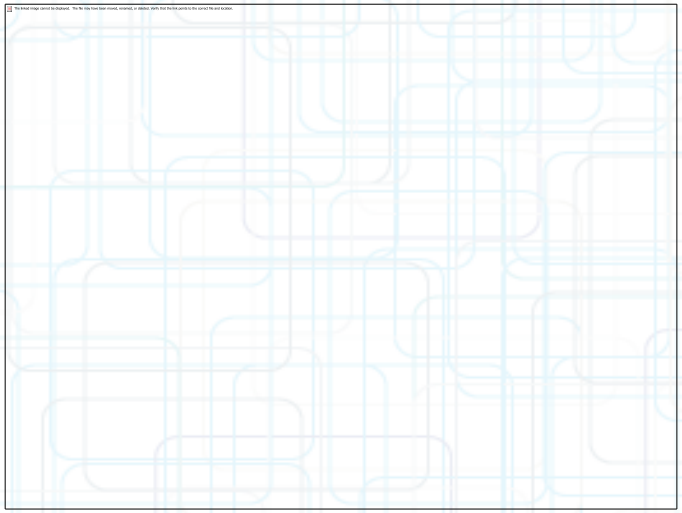
What is a VRF Heat Pump System?

Indoor units (many)
+
Outdoor units
(one or more)
+
Refrigerant piping
+
Branch Boxes or
Manifolds (maybe)
+
Controls



Indoor Units - Wall Mounted

- Sizes: 0.5-2 tons
- Fan power: 8-70 watts
- Good fit for offices, spaces with limited ductwork
- Caution advised when using in noise sensitive such as bedrooms, studios due to possible refrigerant sounds.



Ceiling Cassette

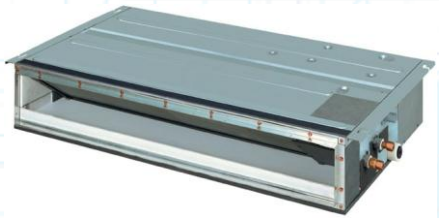
- Sizes: 0.5-3 tons
- Fan power: 15-50 watts
- Good fit for offices, suspended ceilings.
- Caution for spaces with ceilings over 12'

Floor Mounted

- Sizes: 0.5-2 tons
- Fan power: 15-65 watts
- Good fit to replace fan coil units.
- Use caution when using in noise sensitive such as bedrooms, studios.
- Available without covers to be concealed in casework

Ceiling Concealed / Slim AHU

- Sizes: 0.5-2 tons
- Fan power: 65-95 watts
- Great for hotel rooms, bedrooms, side-wall/soffit installations
- Use caution with ducting units due to low static pressure

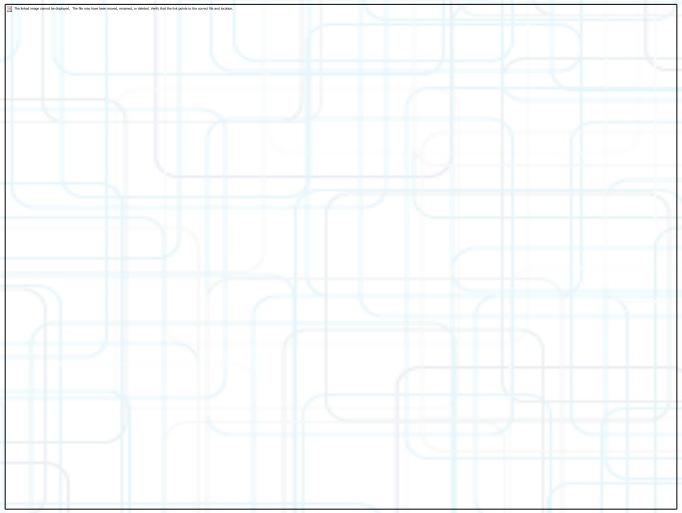


Vertical / Horizontal Ducted AHU

- Sizes: 0.5-8 tons
- Fan power: 30-230 watts
- Good fit residential, retrofit applications and large zones
- Highest indoor capacities available

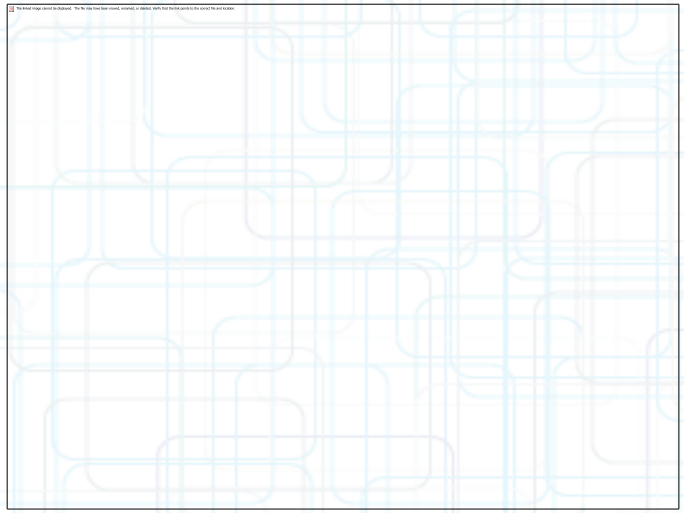
Outdoor Units – 3 & 4 Tons

- Sizes: 3 & 4-ton
- Heat/cool only
- Single phase power
- Up to 8 indoor units



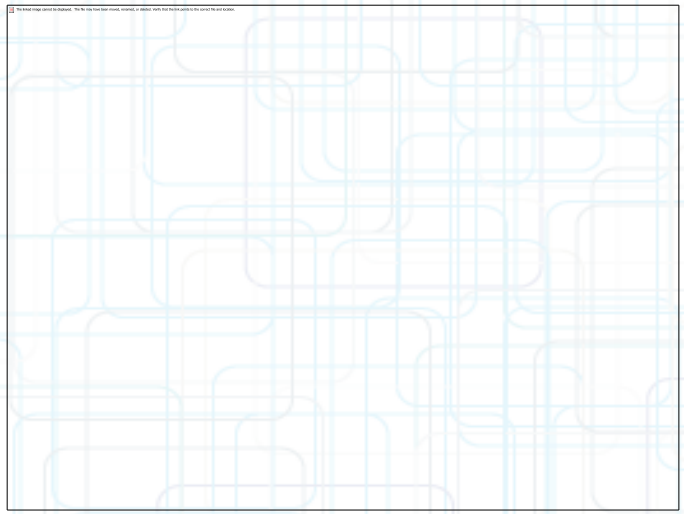
Outdoor Units – 6+ Tons

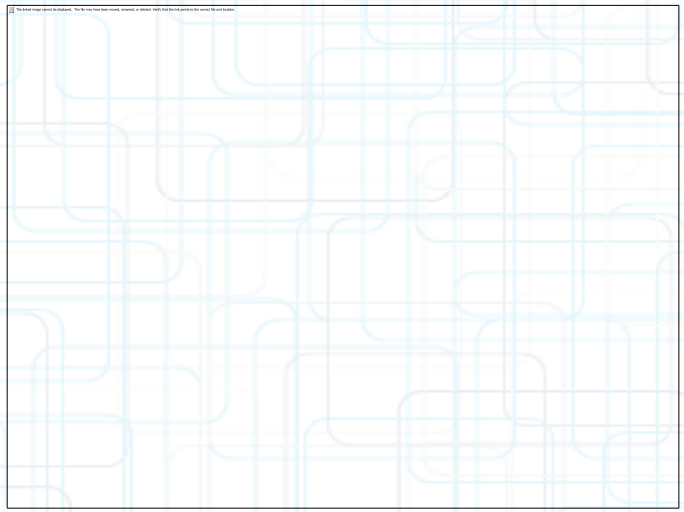
- Sizes: 6-30 tons (sizes 12+ are “twinned”)
- Heat/cool, Simultaneous or “Hyper-heat” type units available
- Requires 3-phase power
- Up to 41 indoor units (for 20 ton system)



Piping

- Generally 2-pipe branched piping (except 3-pipe HR type systems)
- Pipe sizes range from 1/4-1-5/8”.
- Some manufacturers require the use of special fittings for each branch
- Liquid and suction lines are both insulated (independently)
- Piping must be kept extremely clean, VERY IMPORTANT!



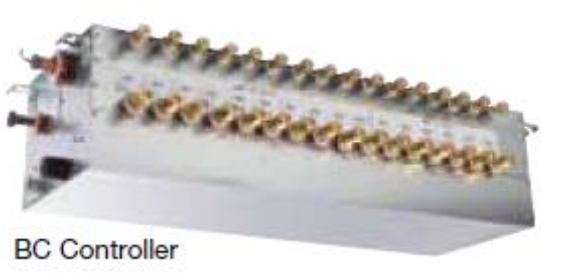


Heat Recovery / Simultaneous Components

Branch Selector Box

- Used with 3-pipe systems
- One BS box per heat/cool zone

BC Controller



- Used with 2-pipe systems
- One BC serves 5-16 heat/cool zones
- Also can be set-up with main/sub-zones

Controls

Programmable Controller

Central Controller

Simple Controller

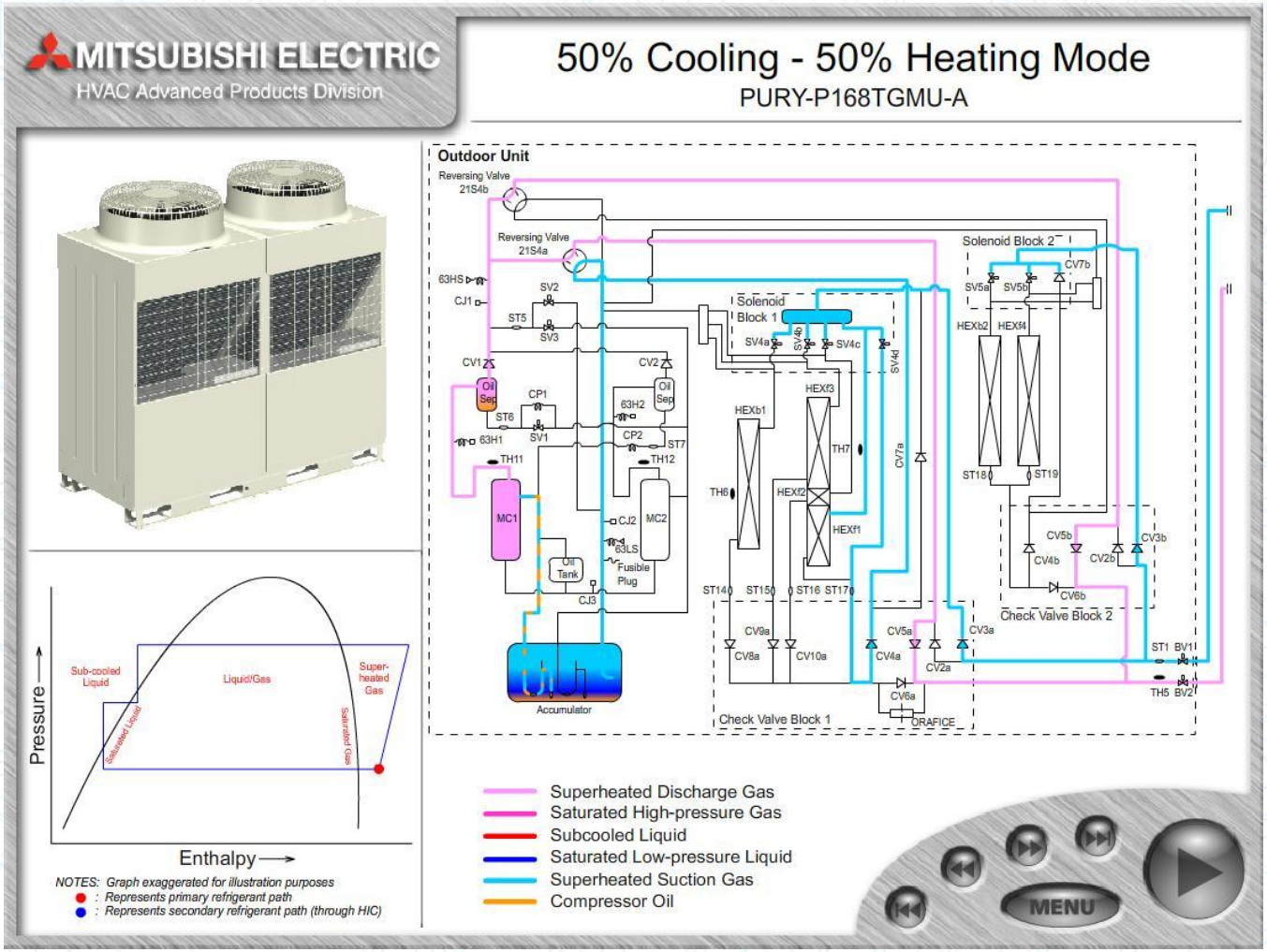
Gateways

BACnet

LonWorks®

How do they work?

Long Answer.....



How do they work?

Short Answer.....

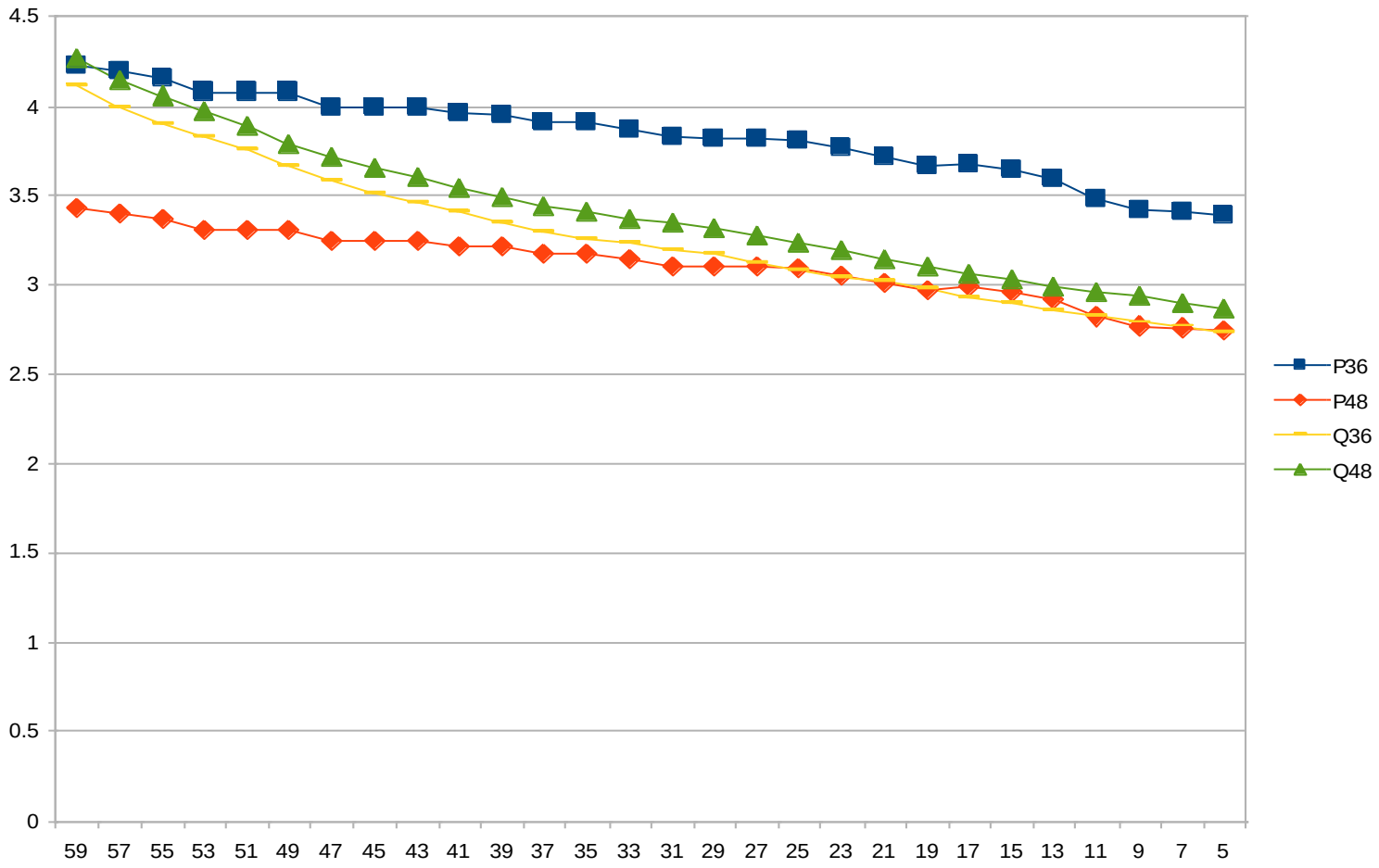
Technology

- Old technology – didn't work below 38 F
  - Gave ASHP's a bad name
- New technology = greatly enhanced performance
- Recent advancements
  - R-410A refrigerant
  - Inverter driven compressors and fans
  - Variable refrigerant flow
  - ECM fan motors on indoor units
  - Long piping distances allowed

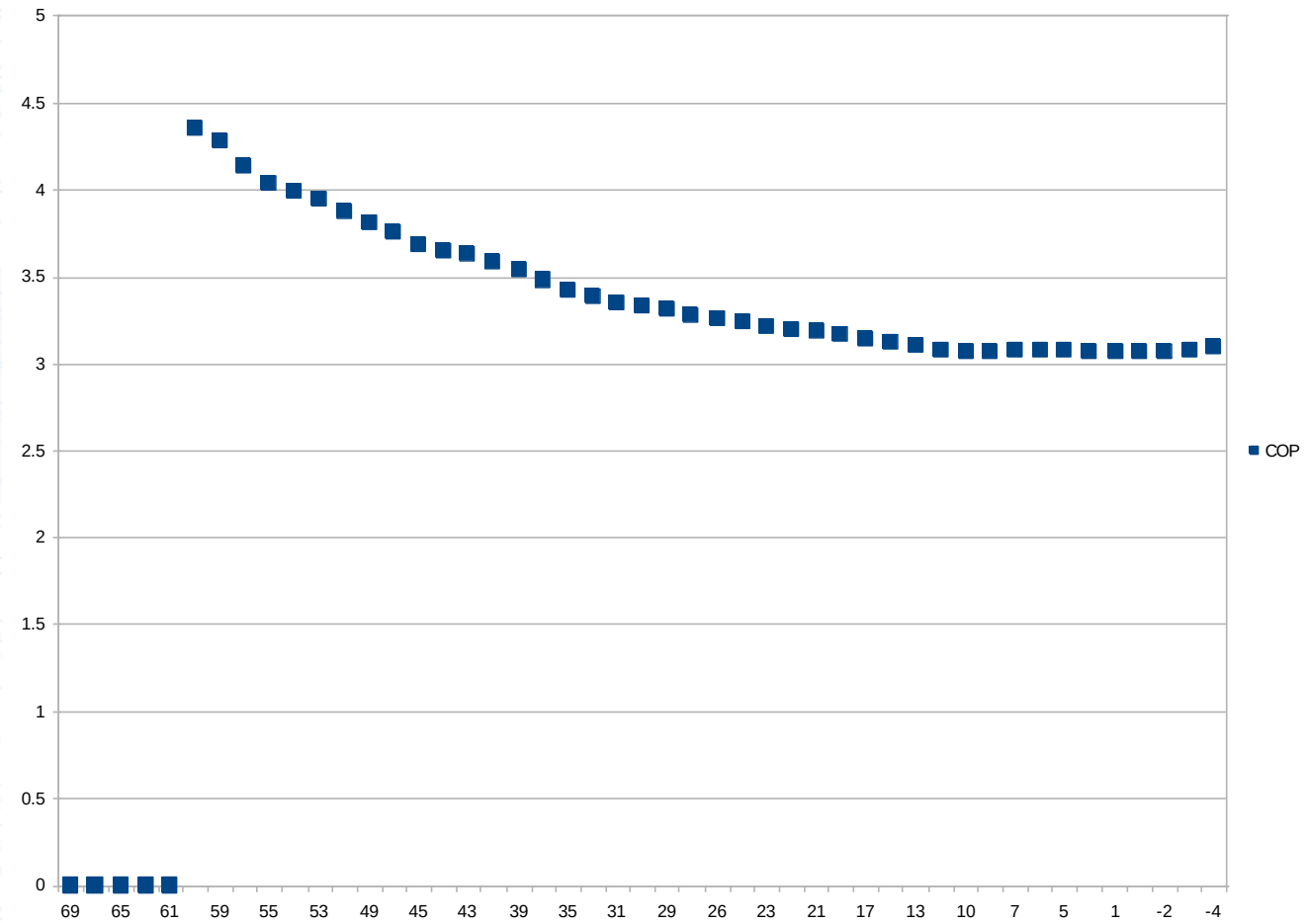
Energy Efficiency

- COP – Coefficient of Performance :
  - $\frac{\text{Useful energy output}}{\text{Costly energy input}}$
  - Used to evaluate equipment efficiency
  - COP is dimensionless
  - COP's do not include indoor fan power
    - Ductless fan power 8-60 watts
    - Ducted fan power 75-200 watts
  - Typical COP's are 3-4.5 for VRF ASHP's

3 & 4-ton Unit
COP vs. OA Temperature



16-ton Unit COP vs. OA Temperature



Low Temperature Performance

Published Ratings:

- 3-4 Ton Rated down to 0 F
- 6+ Ton Rated down to -4 F
- Hyper-heat Rated down to -13 F (@ 75% of nominal capacity)
- Systems continue to heat down to -15 to -20 F at unknown capacity

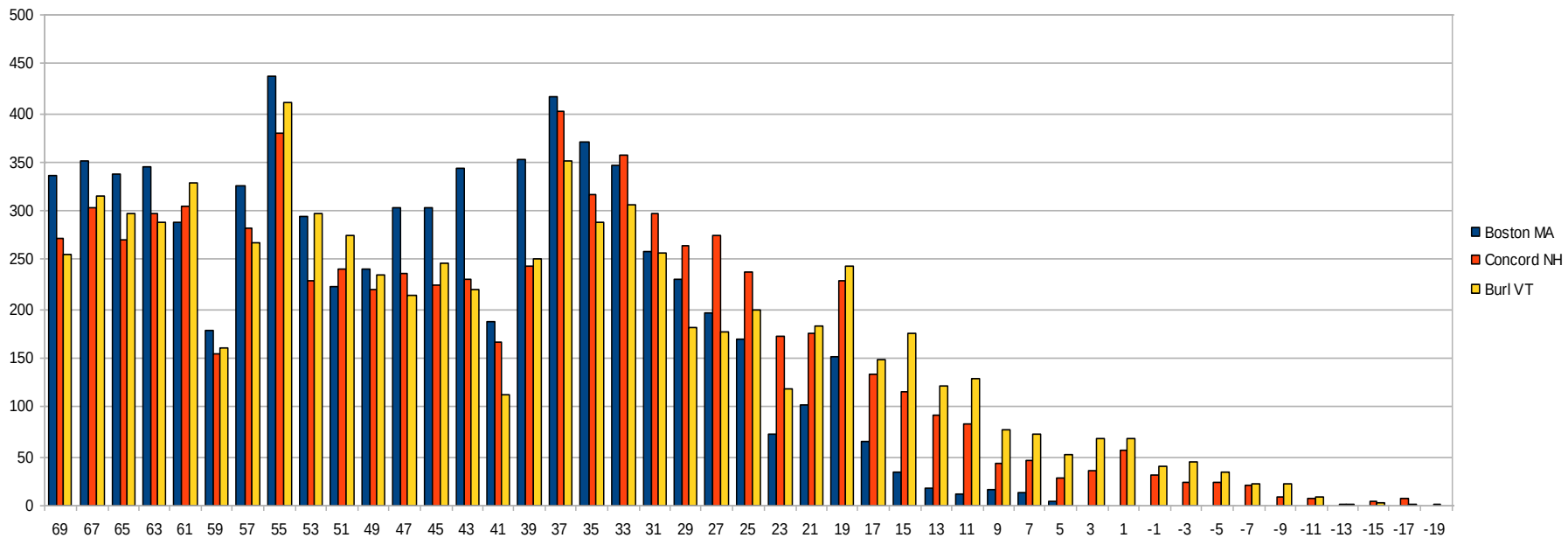
Factors Effecting Annual Performance

- Weather
- Building heat loss factor
- Equipment selections

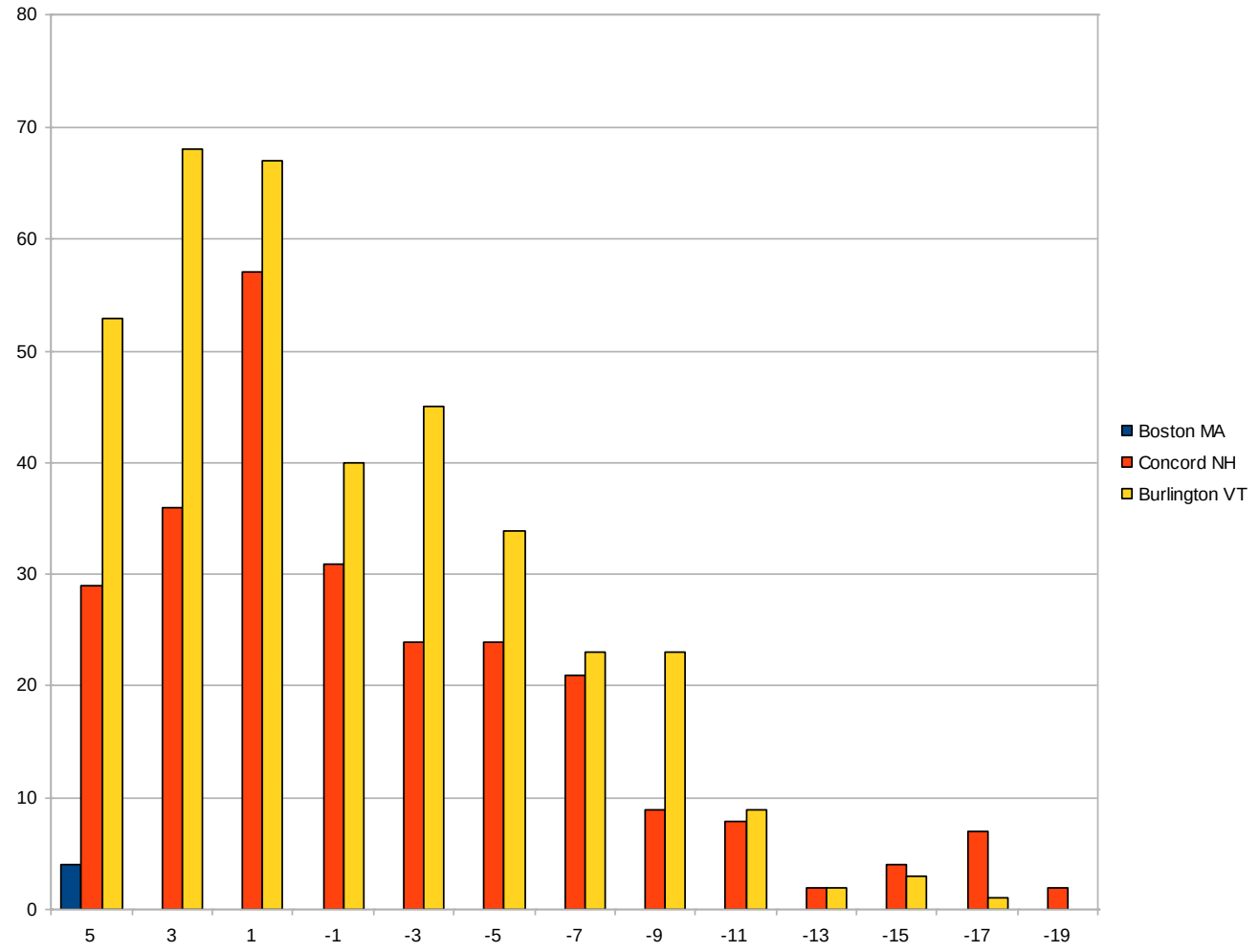
Case Study Performance:

  - Burlington, VT
  - 17,000 sq-ft building
  - Building heat loss coefficient = 3.8 Btu/sq-ft-DD (UA = 2700 Btu/hr-F)
  - Internal gains = 4 Btu/sq-ft
  - 16-ton heat pump

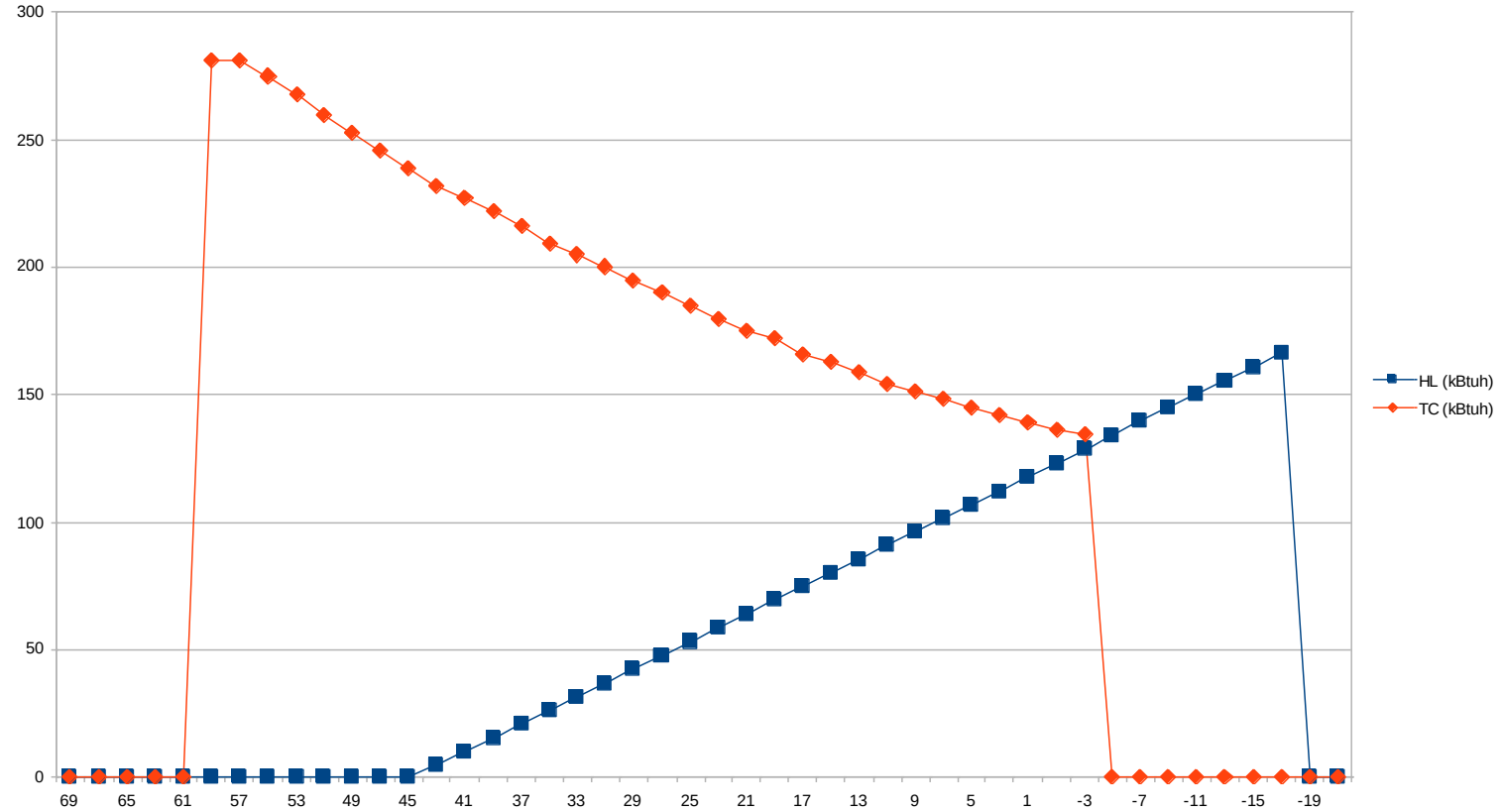
Weather - Bin Data Chart



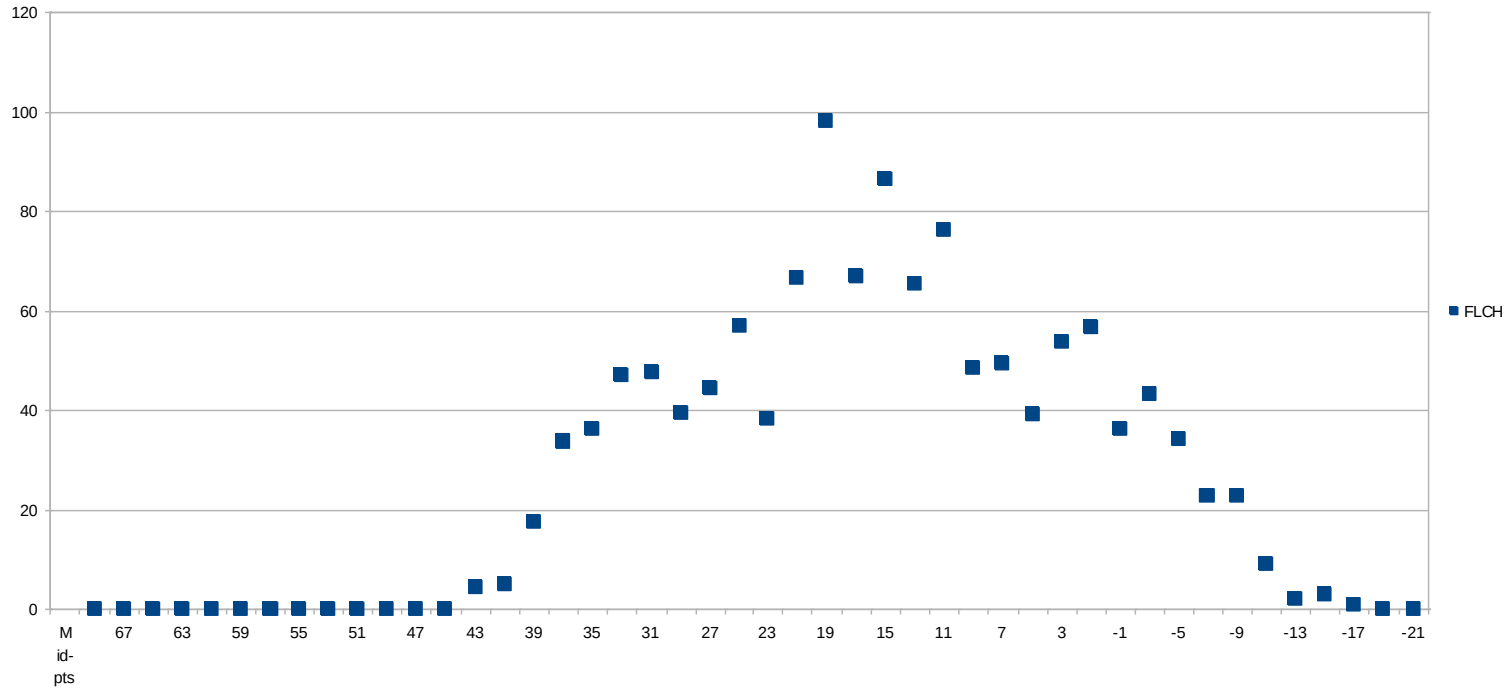
Low Temperature Bin Data



Building Load vs. System Capacity



16-ton Unit Full Load Compressor Hours



BIN Analysis

		Burlington	Gross Load	Gross Load-IG	HP Capacity	FLCH	PI (Outdoor)	EI (Outdoor)	EI (Indoor)	BIN COP
DB (F)	Mid-pts	Hours	kBtuh	kBtuh	kBtuh	Hours	kW	kWh	kWh	-
42 to 44	43	220	72.7	4.7	232	4.4	18.8	83	5	3.62
40 to 42	41	113	78.1	10.1	227	5.0	18.6	93	6	3.58
38 to 40	39	253	83.4	15.4	222	17.6	18.4	324	22	3.54
36 to 38	37	352	88.8	20.8	216	33.9	18.2	618	42	3.48
34 to 36	35	288	94.2	26.2	209	36.1	17.9	646	45	3.42
32 to 34	33	306	99.6	31.6	205	47.2	17.7	835	58	3.39
30 to 32	31	257	105.0	37.0	200	47.5	17.5	831	59	3.35
28 to 30	29	182	110.4	42.4	195	39.5	17.3	684	49	3.30
26 to 28	27	177	115.7	47.7	190	44.5	17.0	756	55	3.27
24 to 26	25	199	121.1	53.1	185	57.1	16.7	954	71	3.25
22 to 24	23	118	126.5	58.5	180	38.4	16.4	629	47	3.22
20 to 22	21	183	131.9	63.9	175	66.8	16.1	1076	82	3.18

Monitored Performance

- K&L system is (2) 4-ton units, 1 ducted indoor unit, (4) ductless indoor units.
- Provided heating down to -18 F.
- Average seasonal heating COP of 2.0 calculated for K&L system for first full year.
- Saved 30% in heating energy costs compared to (oil fired boiler with oil @ $3.00/gal).

System Design Notes

Sizing:

- Requires using (and trusting) manufacturer's software
- System runs down to (most) design temperatures, but at unknown heat capacity
- Capacities fluctuate based on equipment combinations (combination factor)
- Systems do not “scale” linearly (12-ton system does not have 120% capacity of 10-ton system)
- System heating capacity goes down as demand goes up (as it gets colder outside)
- Rule of thumb: Size for about 60% of rated nominal capacity when sizing for heating (i.e. use 5-ton heat pump for 3-ton load)

System Design Notes

Back-up systems:

- Supplemental/Low temp vs. Full back-up/redundant system vs. No back-up
- Full back-up can be very expensive to install if electric resistance is not permitted (State of VT)
- Back-up can harm efficiency if improperly controlled (i.e. switching to elec. resistance too soon)
- Back Options include: Electric resistance; hydronic; wood/pellet/gas stoves and fireplaces
- Owner needs to make ultimate decision

System Design Notes

Heat/Cool vs. Simultaneous/Heat Recovery:

- Two major criteria:
  - Owner project requirements
  - Heating/cooling diversity (opportunity for energy recovery)
- Higher first cost
- Hyper-heat not available
- Heat recovery system layouts vary between manufacturers (substitutions more difficult)
- Heat recovery efficiency/savings is extremely difficult to predict or model model

System Design Notes

Controls:

- Controls included in system for better or worse
- Correct wiring is essential (use specified wire!)
- Lacking some basic, expected features (i.e. separate heat/cool setpoints with deadband)
- Controls are improving with new releases
- BACnet and LON gateways available for system integrations

Final Miscellaneous Thoughts

- Condensate piping/pumping - Lots of indoor units means lots of condensate to collect
- Factory start-up recommended for every project
- Refrigerant piping must be kept clean
- Install outdoor units on raised equipment rails or pads. Consider roofs to prevent snow build-up.
- For future units design system for final capacity and provide taps & shut-off valves
- Use rigid refrigerant piping in exposed areas
- Indoor units are quiet but refrigerant flow noises can sometimes be heard
- Highly technical equipment requires well trained technicians for start-up and service
- Night setback?

Net-Zero Project with VRF

Illustration courtesy of WMA&P

Putney Field House
Putney, VT

William Maclay Architects & Planners
14,000 square feet

PV's

- 3000 ft^2 fixed, 43 kW
- $430,000 ($10 / watt)
- 44% of PV array for HP's
  - 1320 ft^2, 19 kW
  - $190,000 ($13.57 / ft^2)

Heat Pumps

- 30 tons
- $5,000 / ton total
- Heat Pumps $150,000 ($11 / ft^2)

Questions

?