CascadeEnergy®

Industrial Refrigeration Efficiency FACTS AND FIGURES

1 TOP 10 CATEGORIES OF REFRIGERATION
O&M Energy Savings

1	Optimize suction pressure (**2%** compressor savings per °F)	6	Reduce loads
2	Optimize condensing pressure (**1.5%** compressor savings per °F)	7	Keep frost out
3	Use your best part load option	8	Optimize defrost
4	Condenser water delivery: nozzles, pumps, and treatment	9	Calibrate
5	Re-commission evaporator valves and regulators	10	Document, standardize

2 COMPRESSOR "LIFT"
Suction Pressure and Discharge Pressure

Increasing suction temperature **increases capacity**: **2%** compressor savings per °F

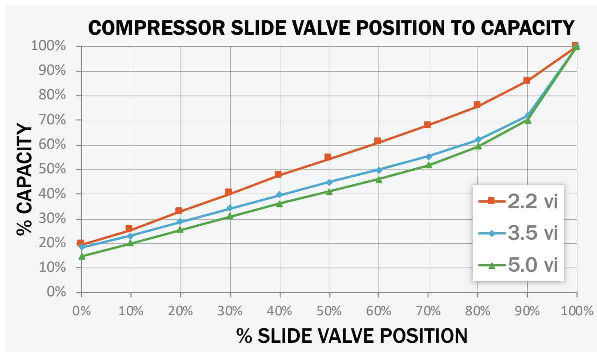
Decreasing condensing temperature **decreases power: 1.5%** compressor savings per °F

Raising your suction temperature by 5°F could improve full load compressor efficiency by 10%

3 SLIDE VALVE POSITION ≠ CAPACITY

% SLIDE VALVE	% CAPACITY		
	2.2 vi	3.5 vi	5.0 vi
100%	100%	100%	100%
90%	86%	72%	70%
80%	76%	62%	59%
70%	68%	55%	52%
60%	61%	50%	46%
50%	54%	45%	41%
40%	48%	40%	36%
30%	40%	34%	31%
20%	33%	29%	26%
10%	26%	23%	20%
0%	19%	18%	15%

Up to 10% compressor power penalty for running improper vi.

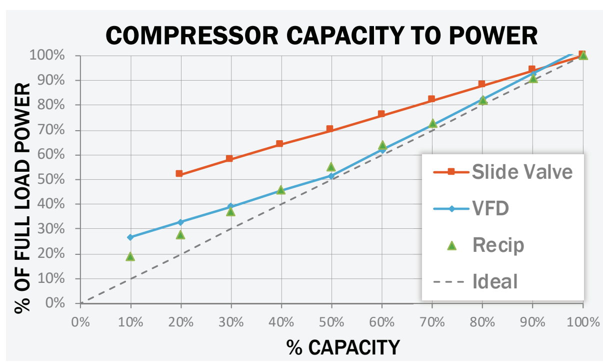


~15% capacity at 0% SV.

4 COMPRESSOR PART LOAD

% SLIDE VALVE	% POWER			VFD % SAVINGS
	RECIP	SLIDE VALVE	VFD	
100%	100%	100%	103%	-3%
90%	91%	94%	93%	1%
80%	82%	88%	82%	6%
70%	73%	82%	72%	12%
60%	64%	76%	62%	19%
50%	55%	70%	52%	26%
40%	46%	64%	45%	29%
30%	37%	58%	39%	32%
20%	28%	52%	33%	37%
10%	19%		27%	
0%				

*VFD Inverter Efficiency ≈ 97%



Avoid using slide valve to trim.

Avoid using VFD base loaded.

5 CONDENSER PERFORMANCE

Wet vs. Dry Operation	% Capacity	% Power
Running Pumps Only (fans off, pumps on):	**10%**	**~25%**
Running Fans Only (pumps off, fans at 100%):	**10-30%**	**~75%**

Scale Thickness	1/64"	1/32"	1/16"
% of Original Capacity	**85%**	**75%**	**55%**

Wet Bulb (WB) Approach Condensing Pressure Control

Floating head pressure set point (°F) = WB temperature + WB approach set point

Use a 10-14°F wet bulb approach set point to help keep your condenser fans in the "sweet spot" of 40-70% speed.

SATURATED AMMONIA R-717

Pressure (psig or -inHg)	Temperature (°F)	Pressure (psig or -inHg)	Temperature (°F)
-20	-64	40	26
-19	-61	42	27
-18	-58	44	29
-17	-56	46	31
-16	-54	48	32
-15	-51	50	34
-14	-49	52	35
-13	-47	54	37
-12	-46	56	38
-11	-44	58	40
-10	-42	60	41
-9	-40	62	42
-8	-39	64	44
-7	-37	66	45
-6	-36	68	46
-5	-34	70	47
-4	-33	72	49
-3	-32	74	50
-2	-30	76	51
-1	-29	78	52
0	-28	80	53
1	-26	82	54
2	-23	84	55
3	-21	86	56
4	-19	88	57
5	-17	90	59
6	-15	92	60
7	-14	94	61
8	-12	96	62
9	-10	98	63
10	-8	100	63
11	-7	105	66
12	-5	110	68
13	-4	115	70
14	-2	120	73
15	-1	125	75
16	0	130	77
17	2	135	79
18	3	140	81
19	4	145	83
20	6	150	84
22	8	155	86
24	10	160	88
26	12	165	90
28	15	170	91
30	17	175	93
32	19	180	95
34	20	185	96
36	22	190	98
38	24	195	99

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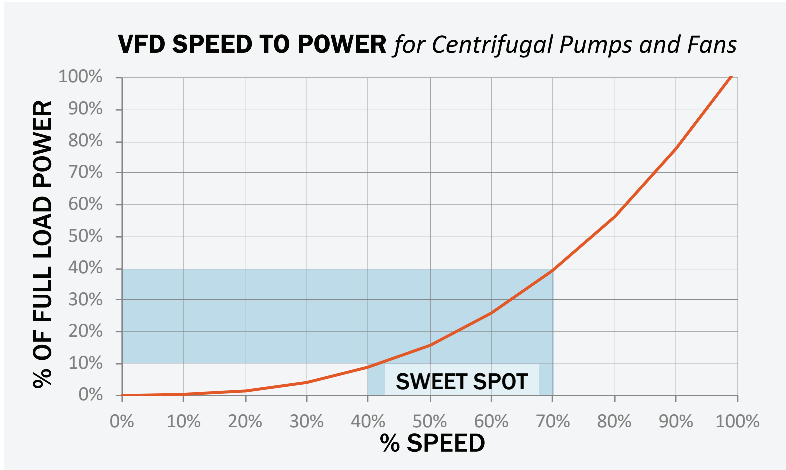
6 CENTRIFUGAL FAN AND PUMP VFD POWER RELATIONSHIP

% LOADING	CYCLING % POWER	VFD % POWER	VFD % SAVINGS
110%	100%	133%	-33%
100%	100%	103%	-3%
90%	90%	78%	14%
80%	80%	56%	29%
70%	70%	39%	44%
60%	60%	26%	57%
50%	50%	16%	68%
40%	40%	9%	78%
30%	30%	4%	87%
20%	20%	1%	93%
10%	10%	0%	98%
0%	0%	0%	0%
VFD Inverter Efficiency ≈ 97%			
AFFINITY LAWS:		REAL WORLD:	
Flow ∞ Speed Pressure ∞ $(Speed)^2$ Power ∞ $(Speed)^3$		% Power = $(\% \text{ Speed})^{2.7}$	



REMEMBER: Cubic law only applies to variable torque centrifugal pumps and fans. For constant torque loads such as conveyors or screw compressors, VFD % speed ≈ % power.

7 EVAPORATOR DEFINITIONS

Evaporator temperature difference (TD)
= Entering Air °F - Refrigerant °F

Refrigerant-to-air evaporators are typically rated for a 10 to 12°F TD.

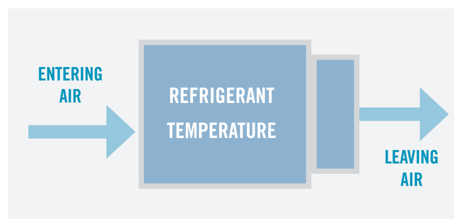
Refrigerant-to-liquid evaporators are typically rated for a 5 to 6°F TD.

Raise suction pressure to provide rated evaporator TD.

Evaporator air delta temperature (ΔT)
= Entering Air °F - Leaving Air °F

A good air ΔT is ~ 5°F
(around half of the evaporator TD).

< 3°F air ΔT could indicated the evaporator is underperforming.



8 CALCULATING kWh

Calculating kWh from BHP:

BHP ≈ Motor Nameplate HP x 80% x "% of Full Load Power"

$$\frac{\text{Brake Horse power} \times 0.746}{\text{Motor Efficiency}} \times \text{hours} = \text{kWh}$$

For three phase power (use caution when using amps from a VFD panel readout):

$$\text{kWh} = \frac{\text{Amps} \times \text{Volts} \times \text{PF} \times 1.73}{1000} \times \text{Hours}$$

9 MOTOR EFFICIENCY AND POWER FACTOR

MOTOR NAME PLATE HP	STANDARD EFF.	PREMIUM EFF.	APPROX. FL POWER FACTOR
1	74%	82%	0.62
5	84%	90%	0.70
10	87%	91%	0.73
25	90%	93%	0.77
50	91%	94%	0.80
100	92.2%	94.7%	0.82
250	93.3%	95.2%	0.85
500	94.0%	95.5%	0.91
1000	94.5%	95.7%	0.92

11 CONVERSIONS

$$1{,}000 \frac{\text{Watt}}{\text{kW}} \qquad 0.284 \frac{\text{TR}}{1 \text{ kW}}$$

$$12{,}000 \frac{\text{BTUH}}{\text{TR}} \qquad 3{,}412 \frac{\text{BTUH}}{\text{kW}}$$

10 DEFINITIONS

NAME	DEFINITION
Efficiency	Doing more with less. "What you want" divided by "What it costs"
BHP	Brake Horsepower, the actual shaft power
TR	Tons of Refrigeration
BTU	British Thermal Unit, enough energy to raise 1 pound of water by 1°F
BTUH	BTUs per Hour
kW	Kilowatt, unit of power (1,000 watts)
kWh	Kilowatt Hour, units of energy (kW x hours)
kVA	Kilovolt-amps, "Apparent Power" = Volts x Amps x 1.73 / 1,000 (skip x 1.73 if single phase)
kVAR	Kilovolt-amps reactive - "Reactive Power," non-useful power that the utility still has to carry
PF	Power Factor = kW / kVA, or % of power that is "real"

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