Chilled Water Optimization Class

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Section 1 – Industry Ratings

Performance Metrics

Full Load, IPLV

Full Load has two components: 100% load and design conditions.

IPLV is a weighted average of four specific operating points.

AHRI 550/590 IPLV		
% Load	Weight	Condition
100%	1%	44 F / 85 F
75%	42%	44F / 75 F
50%	45%	44F / 65F
25%	12%	44F / 65F

ARI 550/590 section D2 states:

"*The equation (IPLV) was derived to provide a representation of the average part load efficiency* ***for a single chiller only****. …"*

Should We Use IPLV?

Should a chiller save equally everywhere?

City	IPLV	Savings
Chicago	0.327	$9,831
Dallas	0.327	$9,831
New York	0.327	$9,831
Las Vegas	0.327	$9,831
Honolulu	0.327	$9,831
Venezuela	0.327	$9,831

Full Load Tons (500) x 0.58 x (0.440 – 0.327) x 3,000 hours x $0.10/kwhr

Performance Metrics

Full Load, IPLV

The problem is utility company's design their chiller incentives off the IPLV formula!

Water-Cooled Chiller

$4 for IPLV improvement per ton*

New or replacement water-cooled chiller (centrifugal, scroll/helical-rotary, reciprocating).

Centrifugal

SIZE CATEGORY	MINIMUM QUALIFYING EFFICIENCY
< 300 tons	0.550 kW/ton-IPLV efficiency
300 - 399 tons	0.520 kW/ton-IPLV efficiency
≥ 400 tons	0.500 kW/ton-IPLV efficiency

*Efficiency incentive is paid for an efficiency rating above the qualifying efficiency. The incentive is $4.00 per 0.01 kW/ton IPLV for water-cooled chillers.

This further emphasizes the importance of this metrics to owners and engineers.

Is this right?

Performance Metrics

System based metrics – SPLV (System Part Load Value)

- Actual Local Weather
- Load Profile
- Operating Hours
- Economizer
- Pump, Tower Energy
- Chiller Staging

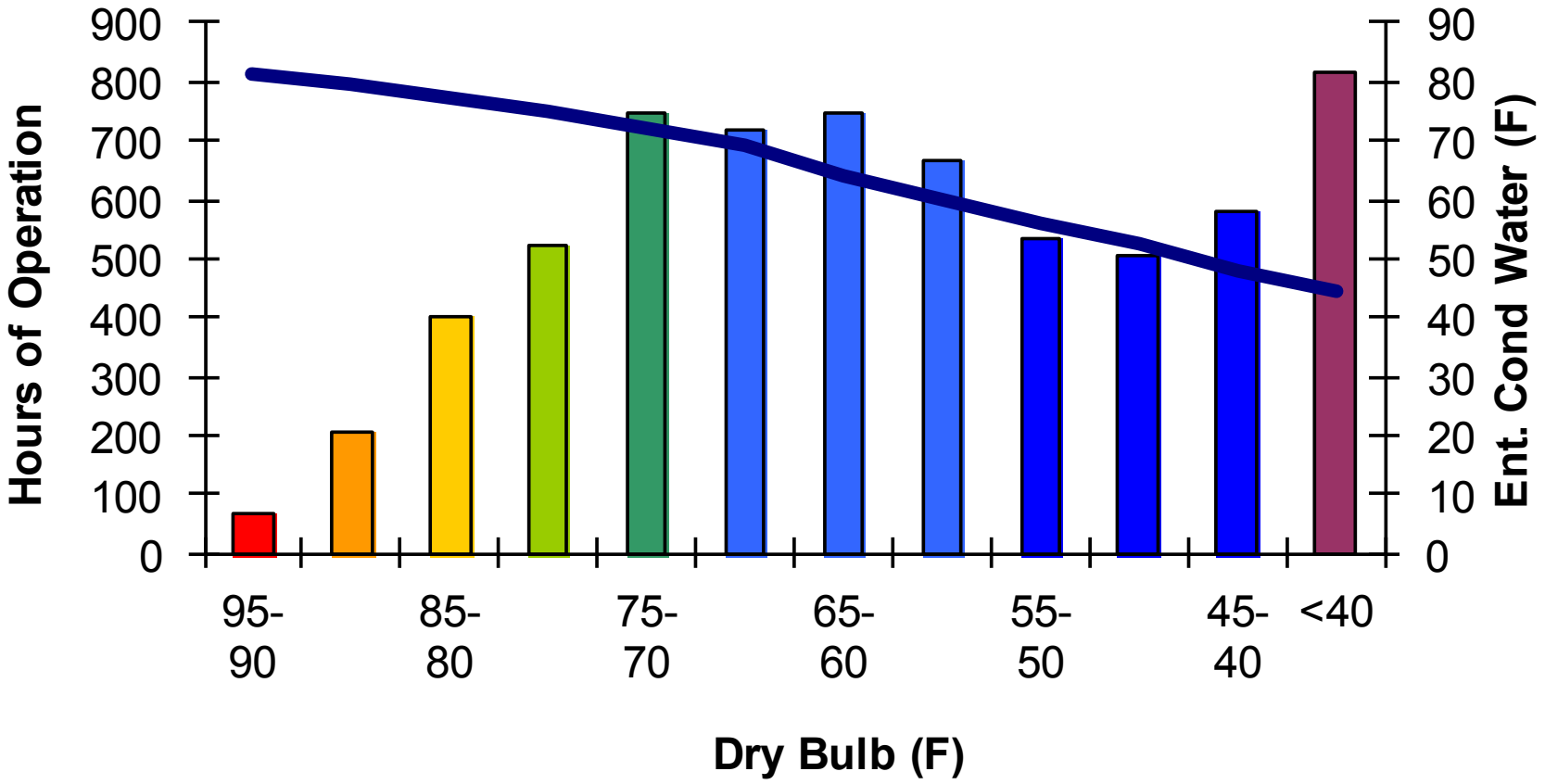
ARI 550/590 section D2 states:

"*The equation (IPLV) was derived to provide a representation of the average part load efficiency* ***for a single chiller only****. However, it is best to use a comprehensive analysis that reflects the actual weather data, building load characteristics, operational hours, economizer capabilities and energy drawn by auxiliaries such as pumps and cooling towers, when calculating the chiller and system efficiency. This becomes increasingly important with multiple chiller systems because individual chillers operating within multiple chiller systems are more heavily loaded than single chillers within single chiller systems.*"

Chicago Weather Profile

> 7,500 hours / year with <75F

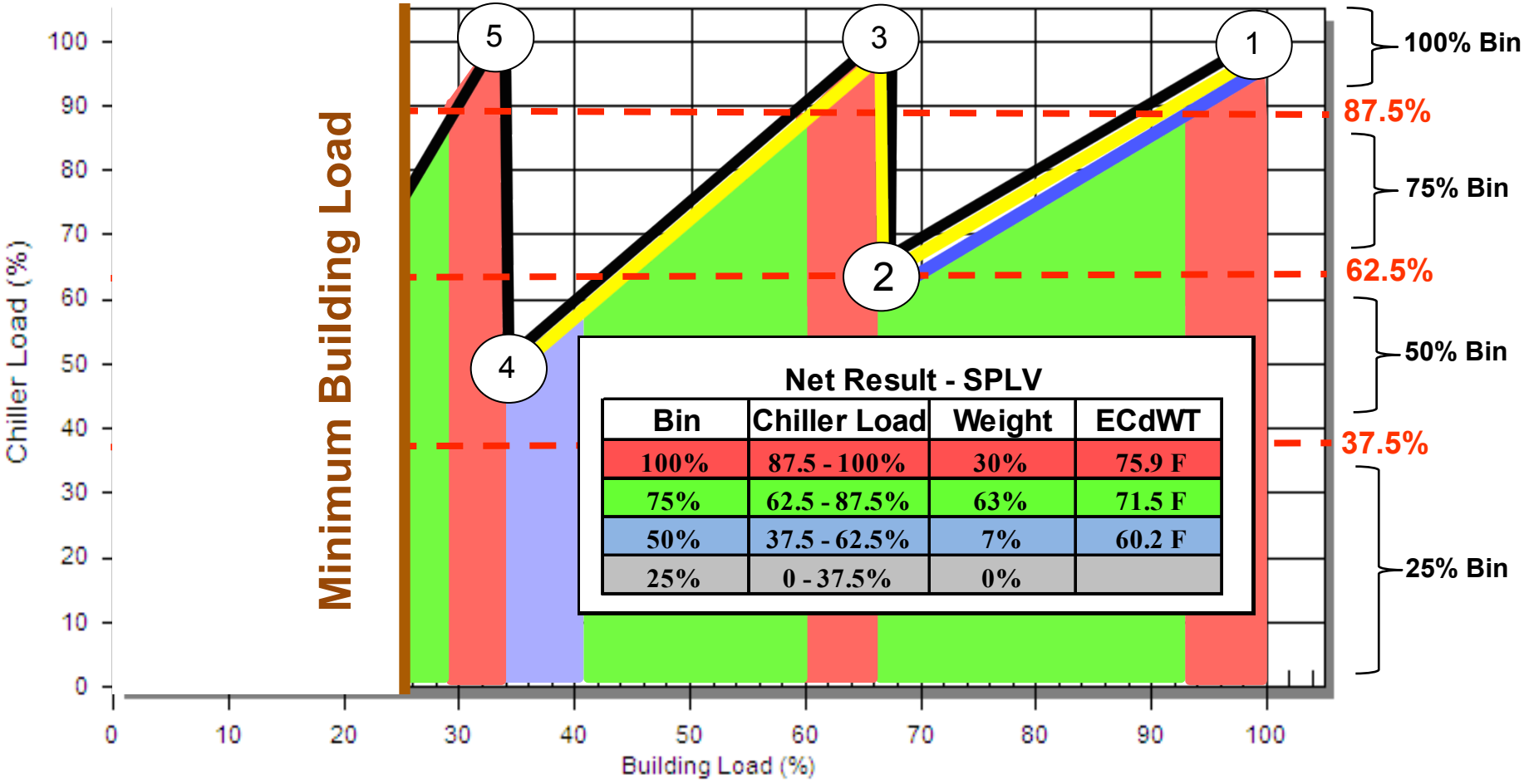
86% of hours have less than 75°F (23.9°C) entering condenser water



Chiller Staging

Chicago Office Building

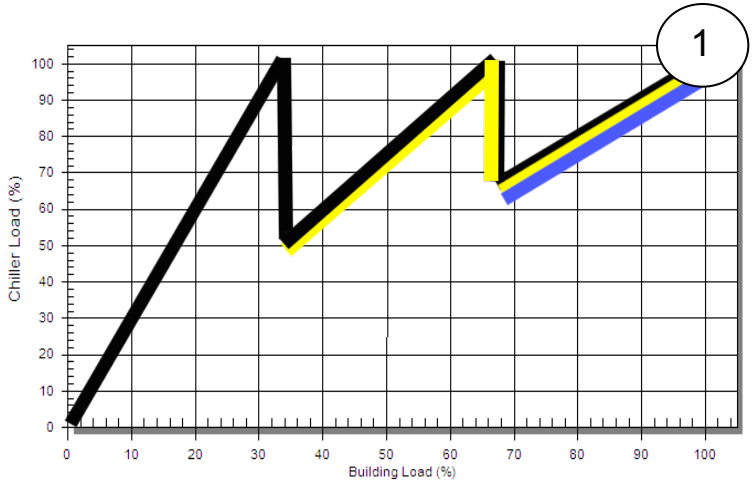
3 x 400 Ton Chillers: CH-1 (black), CH-2 (Yellow), CH-3 (Blue)



Performance Metrics

100% *Building* Load

- Design Day Weather
- Fully Leased
- Fully Occupied
- Full Solar Load
- Full Equipment and Lighting Load
- Full Ventilation Rates



(1) < 1% of the operating hours – OR MAYBE NEVER

Are the chillers sized to meet the building load exactly … or were they maybe oversized … just a little.

What is the impact of oversizing?

Impact on Oversizing - Centrifugal!

Tag Name: CH-1,2 600 Tons - 19XRV

Chiller
- Chiller Model **19XRV5054436LCH64**
- Starter / VFD ..... **VFD - Unit Mounted (STD Tier)**
- Refrigerant Type **R-134a**
- Isolation Valve ..... **Installed**
- Operation Type ..... **Cooling**

Cooler
- Size **50**
- Waterbox Type ..... **Nozzle-in-Head, 150 psi**
- Passes **2**
- Nozzle Arrangement ..... **D (Nozzles on Compressor End)**
- Tubing ..... **Super E3 (SUPE3), .025 in, Copper**
- Fluid Type ..... **Fresh Water**
- Fouling Factor (hr-sqft-F)/BTU **0.00010**

Compressor
- Size **436**

Weights
- Total Rigging Weight ..... **22311** lb
- Total Operating Weight ..... **24851** lb
- Refrigerant Weight ..... **1196** lb

Condenser
- Size **54**
- Waterbox Type ..... **Nozzle-in-Head, 150 psi**
- Passes **2**
- Nozzle Arrangement ..... **Will Advise**
- Tubing ..... **Spike Fin III (SPK3), .025 in, Copper**
- Fluid Type ..... **Fresh Water**
- Fouling Factor (hr-sqft-F)/BTU **0.00025**

Motor
- Size ..... **LCH**
- Line Voltage/Hertz **460-3-60**

Flow Controls
- Float Valve Size **8**
- Flasc Orifice **29**

Output Type	Full Load	Part Load	Part Load	Part Load
Percent Load	100.00	75.00	50.00	25.00
Chiller Capacity	600.0 Tons	450.0 Tons	300.0 Tons	150.0 Tons
Chiller Input kW	375.7 kW	202.2 kW	100.4 kW	64.7 kW
Chiller Input Power	0.6262 kW/Ton	0.4494 kW/Ton	0.3347 kW/Ton	0.4314 kW/Ton
Chiller COP	5.616	7.827	10.507	8.153
NPLV	0.389 kW/Ton	N/A	N/A	N/A

NPLV = .389
600 Tons

Chiller
- Chiller Model **19XRV5054436LCH64**
- Starter / VFD ..... **VFD - Unit Mounted (STD Tier)**
- Refrigerant Type **R-134a**
- Isolation Valve ..... **Installed**
- Operation Type ..... **Cooling**

Cooler
- Size **50**
- Waterbox Type ..... **Nozzle-in-Head, 150 psi**
- Passes **2**
- Nozzle Arrangement ..... **D (Nozzles on Compressor End)**
- Tubing ..... **Super E3 (SUPE3), .025 in, Copper**
- Fluid Type ..... **Fresh Water**
- Fouling Factor (hr-sqft-F)/BTU **0.00010**

Compressor
- Size **436**

Weights
- Total Rigging Weight ..... **21718** lb
- Total Operating Weight ..... **24258** lb
- Refrigerant Weight ..... **1196** lb

Condenser
- Size **54**
- Waterbox Type ..... **Nozzle-in-Head, 150 psi**
- Passes **2**
- Nozzle Arrangement ..... **Will Advise**
- Tubing ..... **Spike Fin III (SPK3), .025 in, Copper**
- Fluid Type ..... **Fresh Water**
- Fouling Factor (hr-sqft-F)/BTU **0.00025**

Motor
- Size ..... **LCH**
- Line Voltage/Hertz **460-3-60**

Flow Controls
- Float Valve Size **8**
- Flasc Orifice **29**

Output Type	Full Load	Part Load	Part Load	Part Load
Percent Load	100.00	75.00	50.00	25.00
Chiller Capacity	500.0 Tons *	375.0 Tons	250.0 Tons	125.0 Tons
Chiller Input kW	294.8 kW	179.2 kW	86.4 kW	60.4 kW
Chiller Input Power	0.5896 kW/Ton	0.4778 kW/Ton	0.3455 kW/Ton	0.4833 kW/Ton
Chiller COP	5.965	7.360	10.178	7.277
NPLV	0.409 kW/Ton	N/A	N/A	N/A

NPLV = .409
500 Tons

Impact on Oversizing – Screw Chiller!

Chiller
- Chiller Model **23XRV5757ERVR450-**
- Starter / VFD ..... **VFD - Unit Mounted (STD Tier)**
- Refrigerant Type **R-134a**
- Isolation Valve ..... **Installed**
- Automatic Hot Gas Bypass ..... **Installed**
- Operation Type ..... **Cooling**

Cooler
- Size **57**
- Waterbox Type ..... **Nozzle-in-Head, 150 psi**
- Passes **3**
- Nozzle Arrangement ..... **E (Drive End Inlet)**
- Tubing ..... **Super E3 (SUPE3), .025 in, Copper**
- Fluid Type ..... **Fresh Water**
- Fouling Factor (hr-sqft-F)/BTU **0.00010**

Compressor
- Size ..... **R (FL Opt.)**
- Economizer ..... **Yes**

Weights
- Total Rigging Weight ..... **24800** lb
- Total Operating Weight ..... **28810** lb
- Refrigerant Weight ..... **1430** lb

Condenser
- Size **57**
- Waterbox Type ..... **Nozzle-in-Head, 150 psi**
- Passes **3**
- Nozzle Arrangement ..... **T (Drive End Inlet)**
- Tubing ..... **Spike Fin III (SPK3), .025 in, Copper**
- Fluid Type ..... **Fresh Water**
- Fouling Factor (hr-sqft-F)/BTU **0.00025**

Motor
- Size ..... **V (R comp)**
- Line Voltage/Hertz **460-3-60**

Flow Controls
- Flasc Orifice **25**

Output Type	Full Load	Part Load	Part Load	Part Load
Percent Load	100.00	75.00	50.00	25.00
Chiller Capacity	535.0 Tons	401.3 Tons	267.5 Tons	133.8 Tons
Chiller Input kW	304.9 kW	165.0 kW	76.7 kW	40.0 kW
Chiller Input Power	0.5700 kW/Ton	0.4112 kW/Ton	0.2869 kW/Ton	0.2987 kW/Ton
Chiller COP	6.170	8.553	12.258	11.773
NPLV	0.332 kW/Ton	N/A	N/A	N/A

NPLV = .332
535 Tons

Chiller
- Chiller Model **23XRV5757ERVR450-**
- Starter / VFD ..... **VFD - Unit Mounted (STD Tier)**
- Refrigerant Type **R-134a**
- Isolation Valve ..... **Installed**
- Automatic Hot Gas Bypass ..... **Installed**
- Operation Type ..... **Cooling**

Cooler
- Size **57**
- Waterbox Type ..... **Nozzle-in-Head, 150 psi**
- Passes **3**
- Nozzle Arrangement ..... **E (Drive End Inlet)**
- Tubing ..... **Super E3 (SUPE3), .025 in, Copper**
- Fluid Type ..... **Fresh Water**
- Fouling Factor (hr-sqft-F)/BTU **0.00010**

Compressor
- Size ..... **R (FL Opt.)**
- Economizer ..... **Yes**

Weights
- Total Rigging Weight ..... **24800** lb
- Total Operating Weight ..... **28810** lb
- Refrigerant Weight ..... **1430** lb

Condenser
- Size **57**
- Waterbox Type ..... **Nozzle-in-Head, 150 psi**
- Passes **3**
- Nozzle Arrangement ..... **T (Drive End Inlet)**
- Tubing ..... **Spike Fin III (SPK3), .025 in, Copper**
- Fluid Type ..... **Fresh Water**
- Fouling Factor (hr-sqft-F)/BTU **0.00025**

Motor
- Size ..... **V (R comp)**
- Line Voltage/Hertz **460-3-60**

Flow Controls
- Flasc Orifice **25**

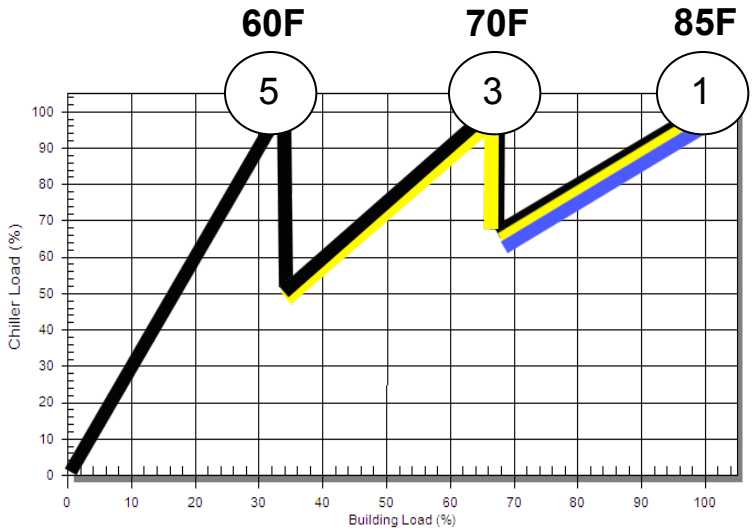
Output Type	Full Load	Part Load	Part Load	Part Load
Percent Load	100.00	75.00	50.00	25.00
Chiller Capacity	435.0 Tons	326.3 Tons	217.5 Tons	108.8 Tons
Chiller Input kW	230.5 kW	130.0 kW	62.9 kW	35.1 kW
Chiller Input Power	0.5298 kW/Ton	0.3983 kW/Ton	0.2892 kW/Ton	0.3227 kW/Ton
Chiller COP	6.638	8.829	12.160	10.897
NPLV	0.333 kW/Ton	N/A	N/A	N/A

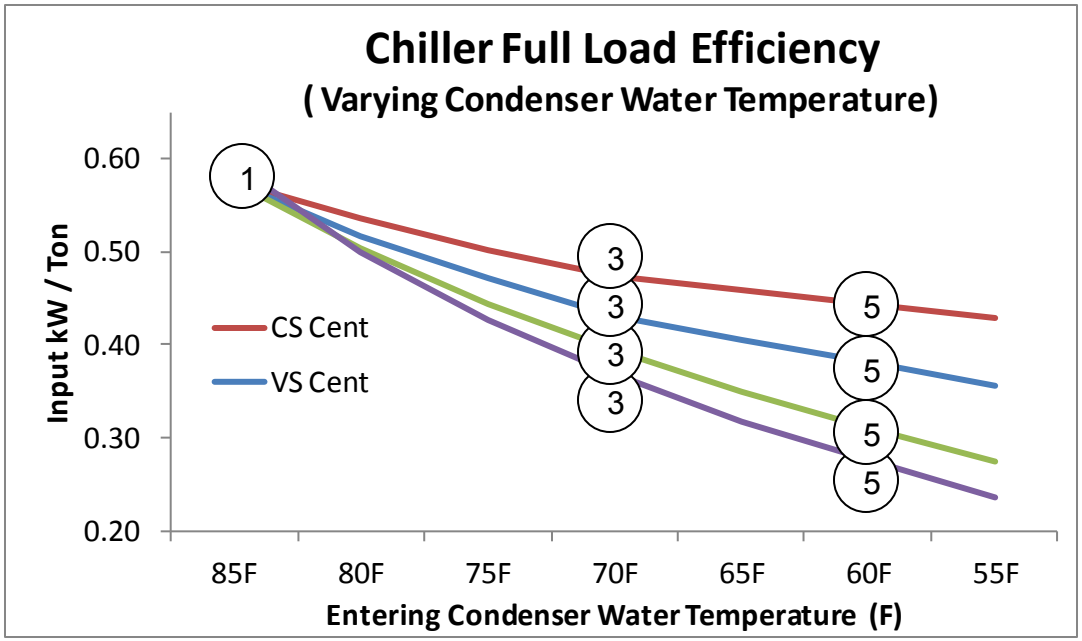
NPLV = .333
435 Tons

Performance Metrics

100% *Chiller* Load

- ✔ Design Leaving Chilled Water
- ✔ Design Entering Condenser Water
- ✔ No Low Delta T Syndrome!
- ✔ No safety factors when chillers sized
- ✔ Tubes fouled to AHRI selection level
- ✔ ***Assumes Chillers not oversized !!!***





- Far more ton-hours occur at points 3 and 5 than at point 1
- Variable speed chillers have better 100% load efficiency at points 3 and 5 due to lower lift.

Performance Metrics

SPLV vs. IPLV

Weighting *significantly* different.

- SPLV reflects multiple chiller plant staging
- SPLV reflects local condenser water temperatures

3 chiller office, Chicago		IPLV		SPLV	
Bin	Chiller Load	Weight	ECdWT	Weight	ECdWT
100%	87.5 - 100%	1%	85 F	30%	75.9 F
75%	62.5 - 87.5%	42%	75 F	63%	71.5 F
50%	37.5 - 62.5%	45%	65 F	7%	60.2 F
25%	0 - 37.5%	12%	65 F	0%	0

Performance Metric

IPLV weighting issue (multiple chillers)

3 chiller office, Chicago		IPLV		SPLV	
Bin	Chiller Load	Weight	ECdWT	Weight	ECdWT
100%	87.5 - 100%	1%	85 F	30%	75.9 F
75%	62.5 - 87.5%	42%	75 F	63%	71.5 F
50%	37.5 - 62.5%	45%	65 F	7%	60.2 F
25%	0 - 37.5%	12%	65 F	0%	0

		Chiller A	Chiller B
IPLV (kW/ Ton) Single Chiller Plant	100%	0.640	0.536
	75%	0.420	0.399
	50%	0.280	0.291
	25%	0.260	0.341
	IPLV	0.325	0.337
Actual Plant	SPLV	.399	.373

75% Load *"The Life Cycle Point"*

Large Manufacturer's Worldwide Study

2,000 Ton Hotel, with (4) 500 Ton chillers

	100%	75%	50%	25%
Athens	41.4%	58.6%	0.0%	0.0%
Bangkok	65.1%	34.9%	0.0%	0.0%
Chicago	36.0%	64.0%	0.0%	0.0%
Darwin	36.1%	63.9%	0.0%	0.0%
Edmonton	60.5%	39.5%	0.0%	0.0%
Frankfurt	64.6%	35.4%	0.0%	0.0%
Guangzhou	36.1%	63.9%	0.0%	0.0%
Hong Kong	28.5%	71.5%	0.0%	0.0%
Istanbul	67.9%	32.1%	0.0%	0.0%
Jakarta	31.9%	68.1%	0.0%	0.0%
Kuala Lumpur	41.4%	58.6%	0.0%	0.0%
London	58.0%	42.0%	0.0%	0.0%
Moscow	59.2%	40.8%	0.0%	0.0%

	100%	75%	50%	25%
New Delhi	48.1%	51.9%	0.0%	0.0%
Osaka	34.0%	66.0%	0.0%	0.0%
Paris	63.5%	36.5%	0.0%	0.0%
Quito	74.9%	25.1%	0.0%	0.0%
Rio de-Janiero	52.8%	47.2%	0.0%	0.0%
Singapore	24.3%	75.7%	0.0%	0.0%
Taipei	35.2%	64.8%	0.0%	0.0%
Ulsan	39.3%	60.7%	0.0%	0.0%
Vienna	67.3%	32.7%	0.0%	0.0%
Warsaw	62.6%	37.4%	0.0%	0.0%
Xiamen	35.2%	64.8%	0.0%	0.0%
Yuma	39.5%	60.5%	0.0%	0.0%
Zurich	60.4%	39.6%	0.0%	0.0%

75% Load *"The Life Cycle Point"*

Large Manufacturer's Worldwide Study

2,000 Ton Hotel, with (4) 500 Ton chillers

	100%	75%	50%	25%
Athens	41.4%	58.6%	0.0%	0.0%
Bangkok	65.1%	34.9%	0.0%	0.0%
Chicago	36.0%	64.0%	0.0%	0.0%
Darwin	36.1%	63.9%	0.0%	0.0%
Edmonton	60.5%	39.5%	0.0%	0.0%
Frankfurt	64.6%	35.4%	0.0%	0.0%
Guangzhou	36.1%	63.9%	0.0%	0.0%
Hong Kong	28.5%	71.5%	0.0%	0.0%
Istanbul	67.9%	32.1%	0.0%	0.0%
Jakarta	31.9%	68.1%	0.0%	0.0%
Kuala Lumpur	41.4%	58.6%	0.0%	0.0%
London	58.0%	42.0%	0.0%	0.0%
Moscow	59.2%	40.8%	0.0%	0.0%

	100%	75%	50%	25%
New Delhi	48.1%	51.9%	0.0%	0.0%
Osaka	34.0%	66.0%	0.0%	0.0%
Paris	63.5%	36.5%	0.0%	0.0%
Quito	74.9%	25.1%	0.0%	0.0%
Rio de-Janiero	52.8%	47.2%	0.0%	0.0%
Singapore	24.3%	75.7%	0.0%	0.0%
Taipei	35.2%	64.8%	0.0%	0.0%
Ulsan	39.3%	60.7%	0.0%	0.0%
Vienna	67.3%	32.7%	0.0%	0.0%
Warsaw	62.6%	37.4%	0.0%	0.0%
Xiamen	35.2%	64.8%	0.0%	0.0%
Yuma	39.5%	60.5%	0.0%	0.0%
Zurich	60.4%	39.6%	0.0%	0.0%

Where is the 50% or 25% Load?

75% Load *"The Life Cycle Point"*

Large Manufacturer's Worldwide Study

600 Ton Office, with (2) 300 Ton chillers

	100%	75%	50%	25%
Athens	29.8%	59.9%	10.3%	0.0%
Bangkok	30.2%	66.4%	3.5%	0.0%
Chicago	23.7%	64.7%	11.5%	0.0%
Darwin	48.1%	49.5%	2.4%	0.0%
Edmonton	13.9%	60.3%	25.8%	0.0%
Frankfurt	32.5%	45.7%	21.8%	0.0%
Guangzhou	35.1%	55.3%	9.6%	0.0%
Hong Kong	32.9%	56.4%	10.7%	0.0%
Istanbul	31.5%	52.7%	15.8%	0.0%
Jakarta	33.4%	66.6%	0.0%	0.0%
Kuala Lumpur	57.2%	42.8%	0.0%	0.0%
London	5.1%	60.2%	34.7%	0.0%
Moscow	20.2%	57.6%	22.2%	0.0%

	100%	75%	50%	25%
New Delhi	22.1%	62.4%	15.5%	0.0%
Osaka	31.8%	54.8%	13.4%	0.0%
Paris	29.7%	49.0%	21.3%	0.0%
Quito	3.2%	53.3%	43.5%	0.0%
Rio de-Janiero	8.8%	72.7%	18.5%	0.0%
Singapore	41.5%	58.5%	0.0%	0.0%
Taipei	36.8%	53.9%	9.3%	0.0%
Ulsan	23.0%	59.7%	17.2%	0.0%
Vienna	30.9%	48.2%	20.9%	0.0%
Warsaw	21.6%	53.9%	24.5%	0.0%
Xiamen	36.8%	53.9%	9.3%	0.0%
Yuma	24.7%	56.0%	19.3%	0.0%
Zurich	20.4%	58.2%	21.4%	0.0%

Where is the 50% or 25% Load?