Design Criteria for High Efficiency Centrifugal Chillers in District Cooling Plants

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AGENDA

Technical Requirements of Chillers in DCP

- Optimized Design parameters and Chiller Efficiency

Optimum Design Criteria

- Heat Transfer factors
- Addressing Design Criteria & Chiller Efficiency

Chiller Plant Efficiency

- System Part load Value
- Addressing Sustainability with Real World Efficiency
- Plant Room Evaluation Criteria

Case Study (Energy Cost Analysis comparison of 2 chiller plants)

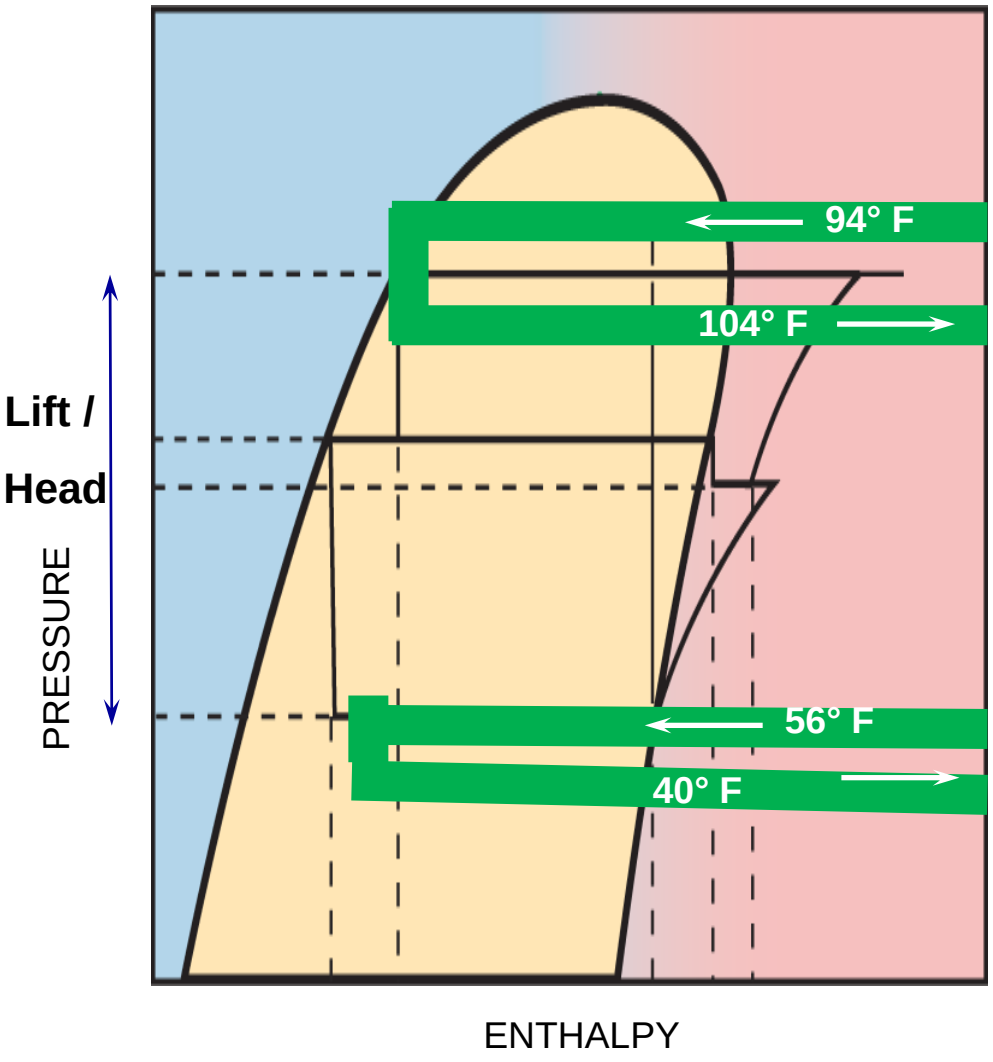
TECHNICAL REQUIREMENTS

Lowest cost of ownership over life cycle

Year-round energy efficiency	Lowest installed cost
Minimum maintenance cost	AHRI certified platform
Strong after market support	Reliability
Foot print	Sound
Plant room efficiency	Seismic

“We may expect air conditioning to be operated as a public utility and applied to extensive areas in our cities.”- Willis Carrier, 1940

CENTRIFUGAL CHILLER IN A DCP



Optimized design parameters

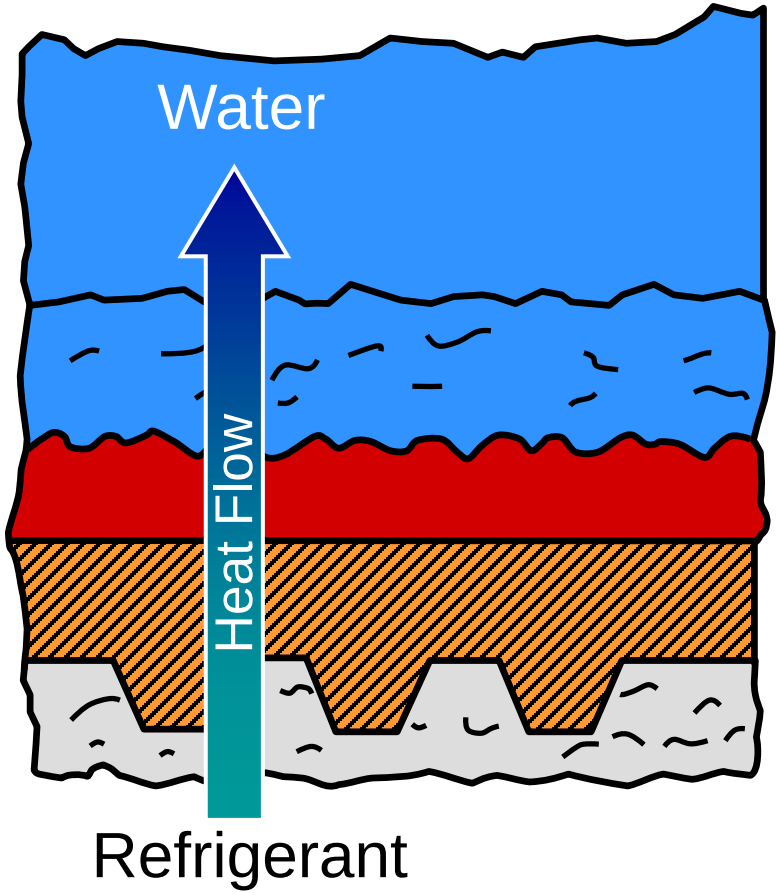
Reduces the lift

Reduces compressor power

Increases the chiller efficiency

RESISTANCES TO HEAT TRANSFER

Resistant Layers



- Water in Tube — Optimum water velocities result in min fouling rates
- Water Film R_W — AHRI 0.00025 fouling factor Basis of chiller ratings for condensers For evaporators 0.0001
- Scale (Fouling) R_F
- Metal R_M — Cu best Heat Transfer Coeff
- Refrigerant Film R_R — CuNi / SS options

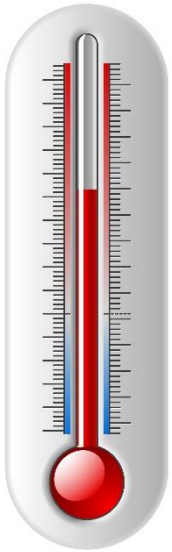
EVAPORATOR TUBING MATERIALS CHART

Tubing Materials Chart				
Application	Tube Material	Approximate Cost	Impact on Capacity	Impact on Specific Power consumption
Fresh Water	Copper	Baseline	Nil	Nil
Glycols	Copper	↑	↓	↓
Corrosive Water	CuNi	↑ ↑	↓	↓
Sea Water	Ti or CuNi	↑ ↑	↓ ↓	↓ ↓

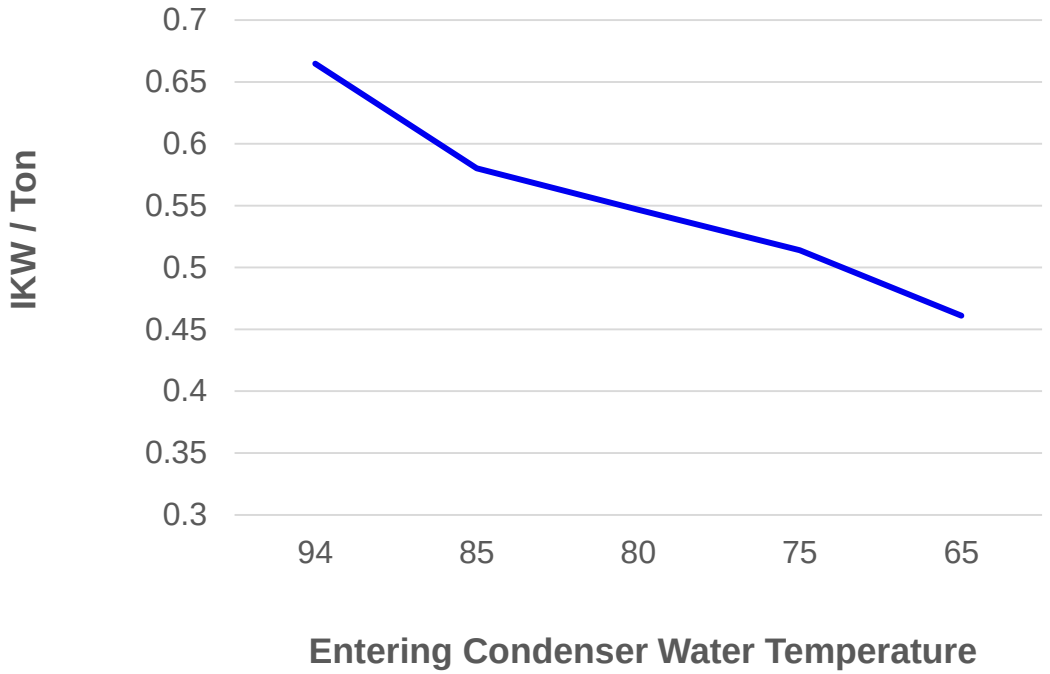
Considering the impact on first cost and heat transfer
Changing Tube material should be done only *if necessary*

TEMPERATURE EFFECT

Effect of Reduced Cooling Tower Water Temperature



Efficiency increased approx 1.3 - 2% for every 1° F decrease in CEWT



All points shown reflect a fully loaded, 2500-ton centrifugal chiller

PRESSURE RATINGS

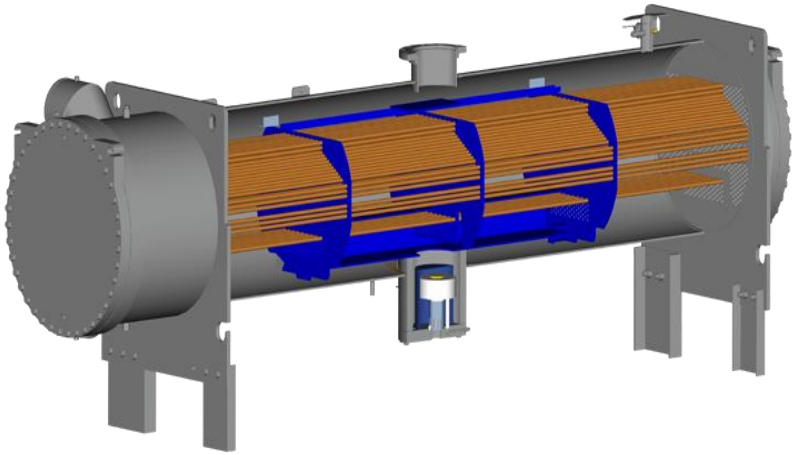
Myth: Higher pressure ratings are required

Reality

Pressure Rating (psig)	Pricing	Application
150	Standard	Standard for DCP
300	?? Required	

TUBE THICKNESS

Impact of higher tube thickness



Cu Tube Thickness	IKW / TR	Pressure Drop	Price Impact
0.025 in	Baseline		
0.028 in	↑	↑	↑
0.035 in	↑	↑	↑

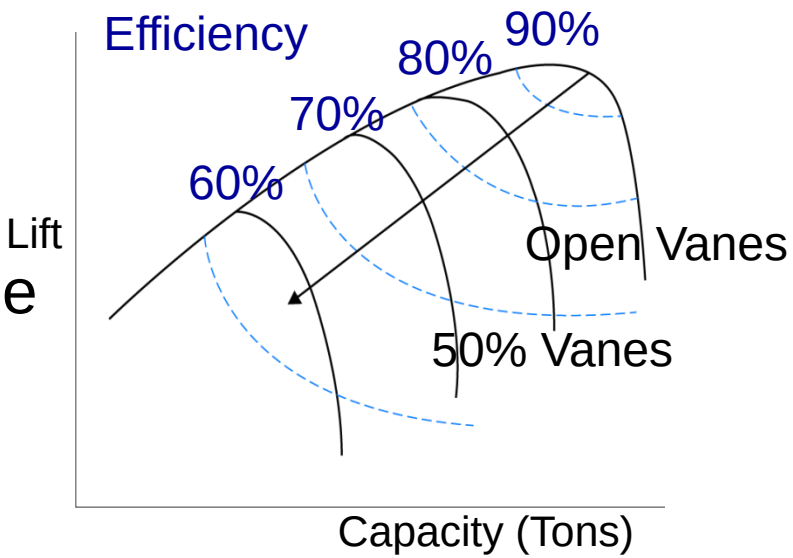
Water Quality, Flow Rates, pressure drop and fluid velocity influence selection of tube thickness

Right chiller selections can help in selection of optimized tube thickness

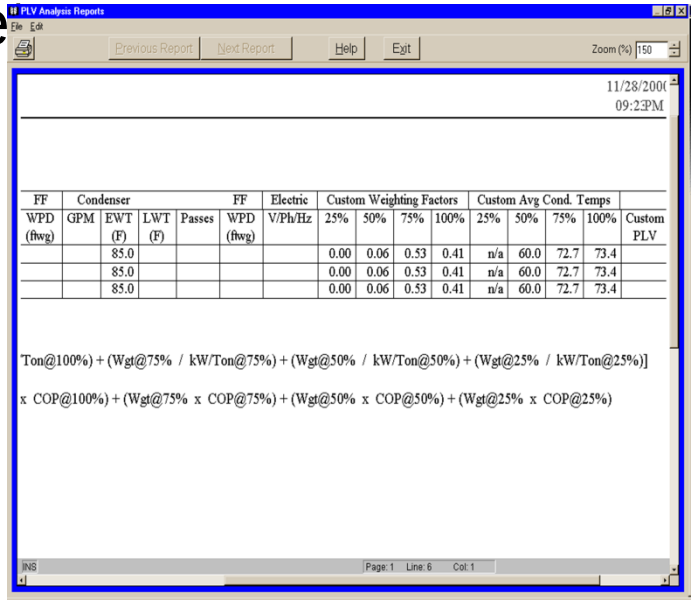
ENERGY EFFICIENCY

Year Round Energy Design

Understanding and taking advantage of the Compressor Map.



Capitalizing on part load (tons and wet bulb) conditions to Increase plant Efficiency (SPLV)



PLANT ROOM EVALUATION CRITERIA

- Total number of starters and the electrical infrastructure cost
- Plant room footprint and associated cost
- Spares inventory cost
- Simplicity, reliability and maintenance
- Cost of sound insulation
- Plant room efficiency (chillers, pumps, CT)
- Maintenance of heat rejection contributors, water
- Redundancy comparison of the complete system

CHILLER PLANT FLOW DESIGNS

Types	Efficiency Improvement	Advantages
Parallel	Reference	Smaller and simpler plants
Series	3-4 %	Better part load pump energy
Series Counterflow	5-7%	Best chiller energy performance Upstream chiller (high-side) can not perform as downstream one (low-side).

SYSTEM PART LOAD PERFORMANCE

Customized Evaluation

Full load IKW/TR is easy but not very accurate

Operating cost of 2 chiller plants with same full load IKW/ TR may be different

Designer to consider

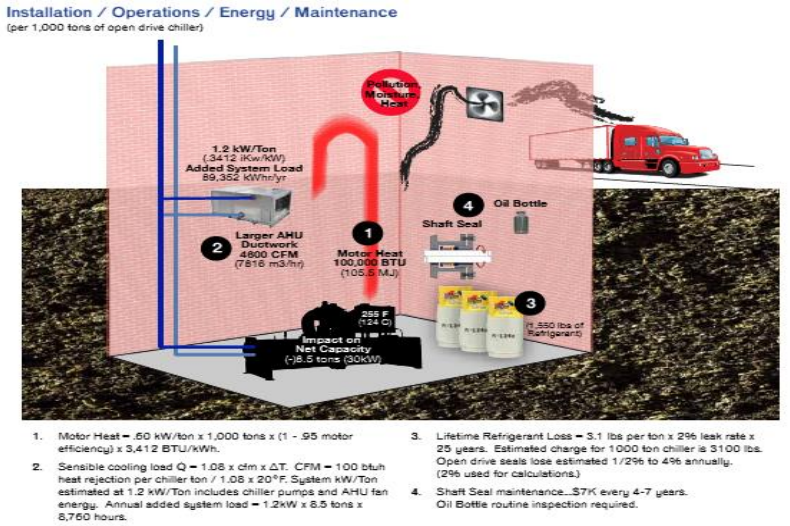
- ✓ Weighted Performance at Real world Conditions and Part Load
- ✓ Pressure Drops
- ✓ Heat Rejection in the plant room
- ✓ Cooling water Heat Rejection

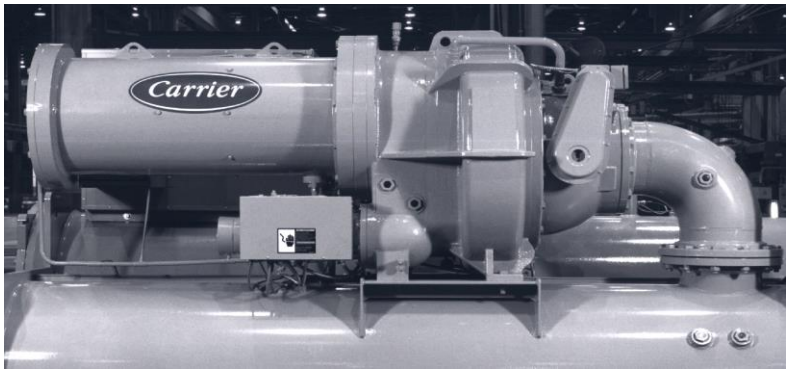
SEMI-HERMETIC ADVANTAGE

Refrigerant cooled motor keeps motor heat out of the mechanical room

Minimizes alignment, vibration and shaft seal maintenance of open motors

Power is Net KW / TR

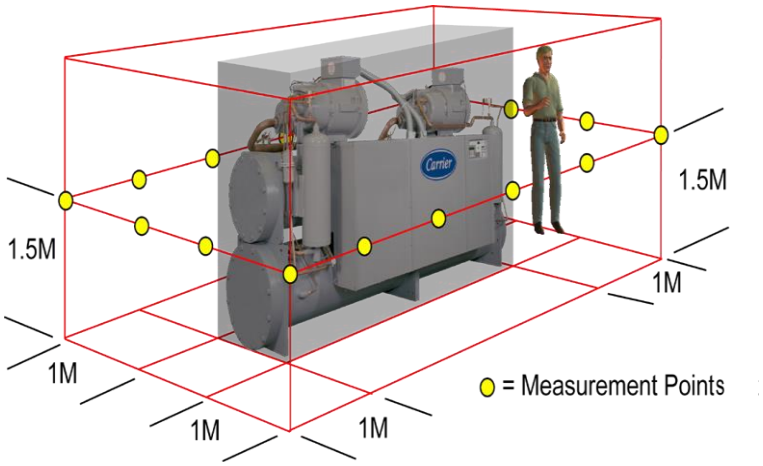




Semi Hermetic Field Serviceable

ACOUSTICS IN A SEQUENCED PLANT

% Load	Capacity, TR	No. of Chillers	Load on Each TR	Chiller Loading / Unloading Profile					
				CH-1	CH-2	CH-3	CH-4	CH-5	CH-6
100	30000	6	5000	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
83.30	25000	6	4165	83.30%	83.30%	83.30%	83.30%	83.30%	83.30%
83.30	25000	5	5000	100.00%	100.00%	100.00%	100.00%	100.00%	
75.00	22500	5	3750	75.00%	75.00%	75.00%	75.00%	75.00%	
66.67	20000	4	5000	100.00%	100.00%	100.00%	100.00%		
50.00	15000	3	5000	100.00%	100.00%	100.00%			
40.00	12000	3	4000	80.00%	80.00%	80.00%			
33.30	10000	2	5000	100.00%	100.00%				
25.00	7500	2	3750	75.00%	75.00%				
16.67	5000	1	5000	100.00%					



Sound Attenuation Techniques

- Sound power at source
- Insulation at compressor discharge
- Compressor acoustic jacket lining
- Condenser water insulation

WATER TREATMENT

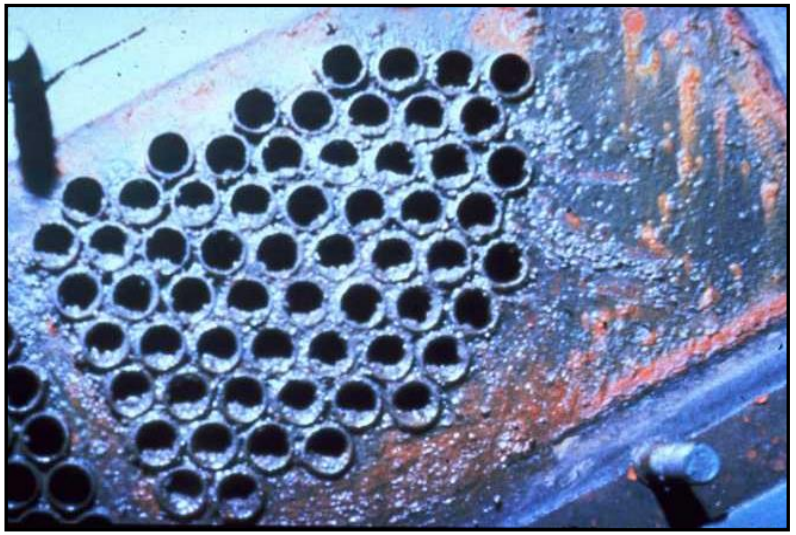
Challenges

Water Availability

TSE Treatment

Cooling tower fill and tubes affected by:

- Scale
- Corrosion
- Sludge
- Contamination



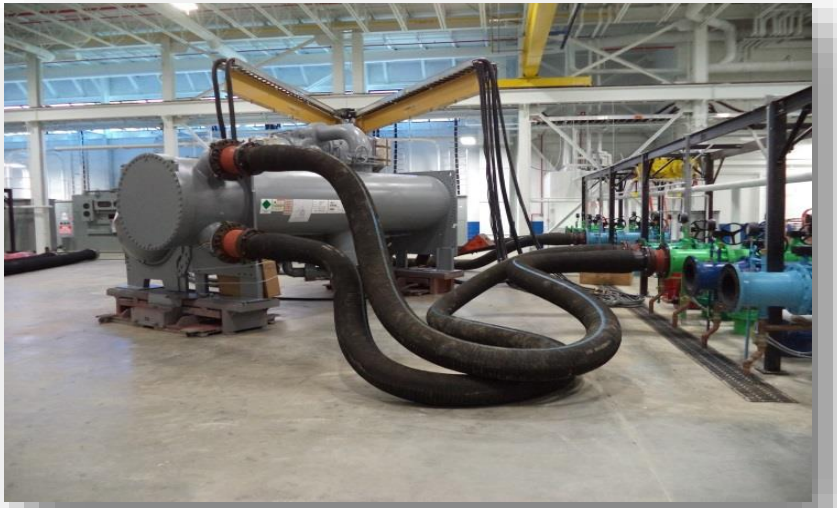
Potential Solutions

Different Metallurgy in Tubes…performance penalty

Water Treatment at Source

Closed type Cooling Tower

MANUFACTURER CAPABILITY EVALUATION



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Certificate of Product Ratings

AHRI Certified Reference Number: 71212 Date: 3/3/2010 †Status: Active

Product: Water-Cooled Chilling Packages
Model Designation: 19XR (561-507, 50/60 HZ)
Manufacturer: CARRIER CORPORATION
Trade/Brand name: CARRIER

Rated as follows in accordance with AHRI Standard 550/590-2003 for Water Chilling Packages using the Vapor Compression Cycle (Water-Cooled) and subject to verification of rating accuracy by AHRI-sponsored, independent, third party testing:

Refrigerant Used:	R-134A;
Compressor Designation:	562-507
Compressor Type:	Centrifugal
Software Version Number:	Version 4.39o
Country Of Origin:	Carrier North American Operations (USA)

† Models with an 'Active' status are those that are currently in production. Models with a 'Discontinued' status are those that the manufacturer has elected to stop producing, yet stock is still available. Models with an 'Obsolete' status are those that the manufacturer is required to stop manufacturing due to an AHRI certification program test failure.

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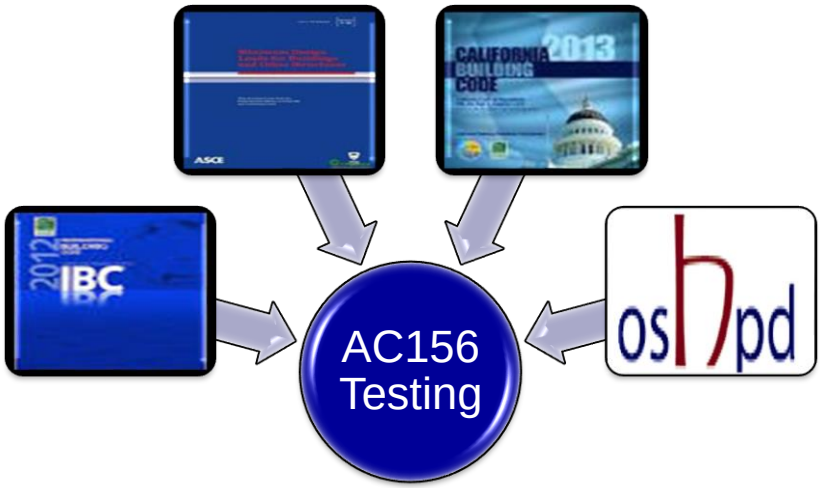

ASME

ISO International Organization for Standardization

MERITS OF AHRI CERTIFIED PERFORMANCE

AHRI 550/590 is an International Standard defining performance rating of Water chilling packages

Manufacturers sometimes require to over rate the chillers to meet tender requirements of ZT.

Compressor selection can be optimized for actual operating point and conditions, and need not be done for hypothetical conditions

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Refrigerant Used:	R-134A;
Compressor Designation:	562-567
Compressor Type:	Centrifugal
Software Version Number:	Version 4.39o
Country Of Origin:	Carrier North American Operations (USA)

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SERVICE CAPABILITY EVALUATION

- Start up and commissioning
- Fully-manned operation and service contract
- Technical Capability Evaluation versus no. of technicians
- Local Presence & References
- Ready Availability of Spare Parts

Tube cleaning

Re-tubing

Replacement services

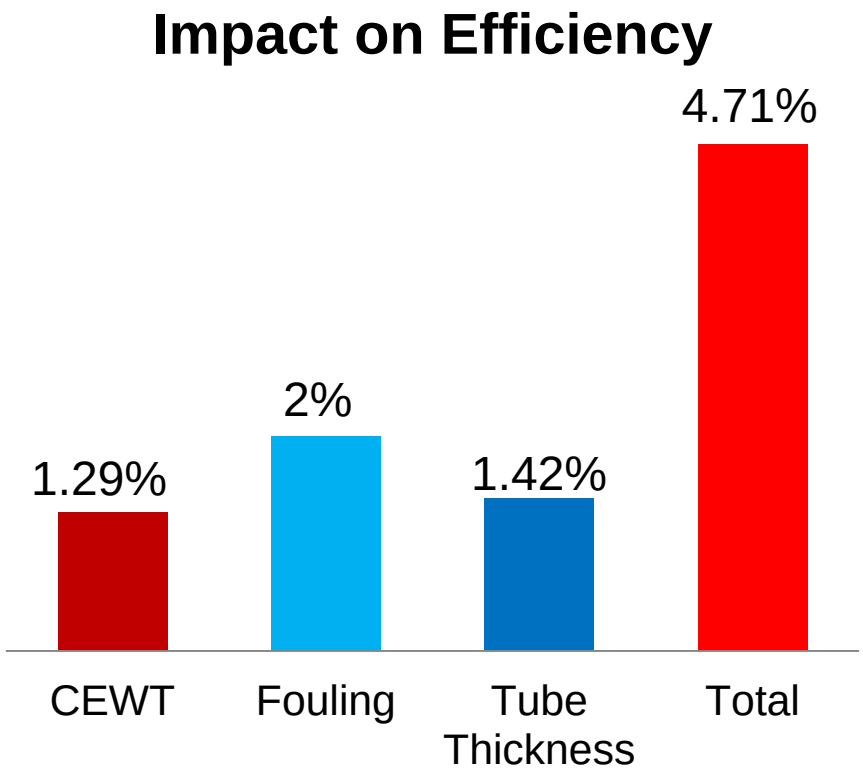
Eddy current testing

ENERGY COST ANALYSIS 20000 TR DCP

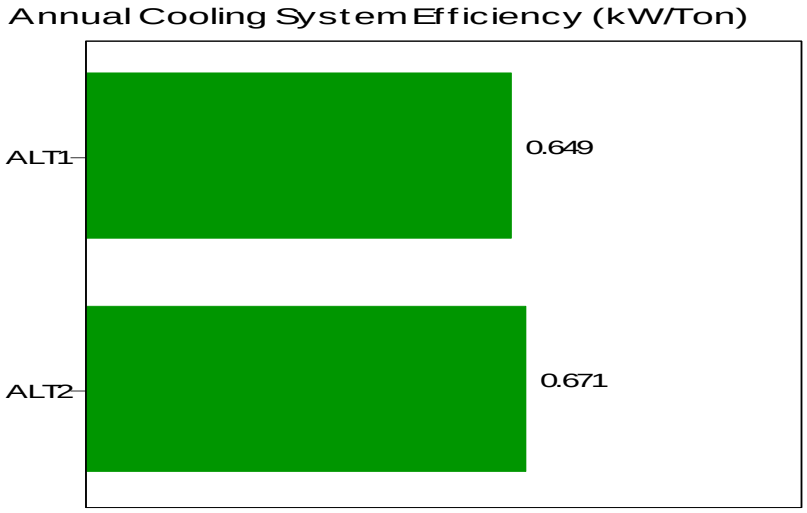
Design	94F	95F
Config(TR)	5000 x 4	5000 x 4
Ch W (F)	40/56	40/56
Co EWT(F)	94/105.4	95/106.5
Flow Cooler GPM	7,500	7,500
Flow Condenser GPM	12,500	12,500
Chw Pressure drop (ft)	19.8	20.7
Co Pressure Drop (ft)	19.7	21.9
Fouling factor	0.0001 / 0.00025	0.00025 / 0.0005
Tube Thickness (mm)	0.025 /0.025	0.025/ 0.035
IKW/TR per 5000 TR	0.646	0.678

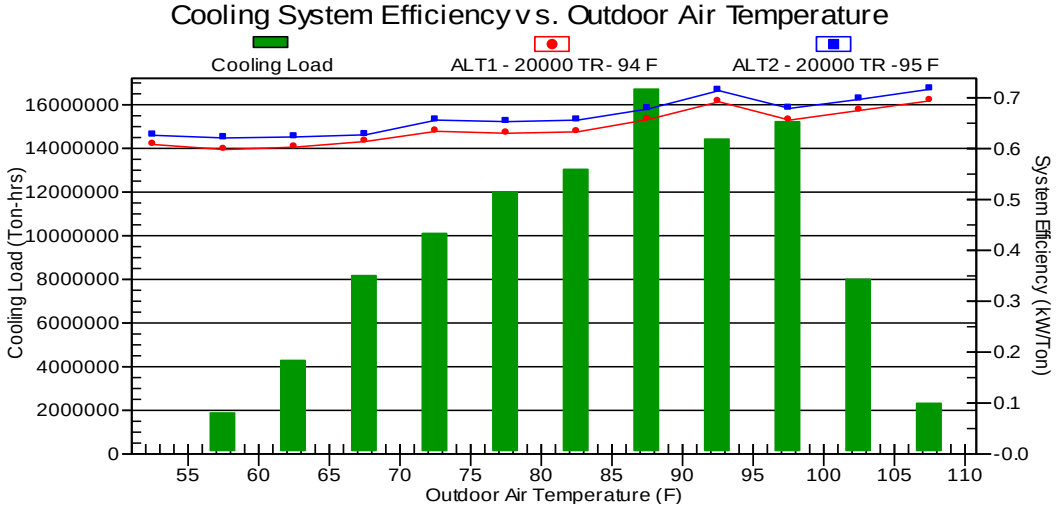
Power Cost : $ 0.12 / KWH

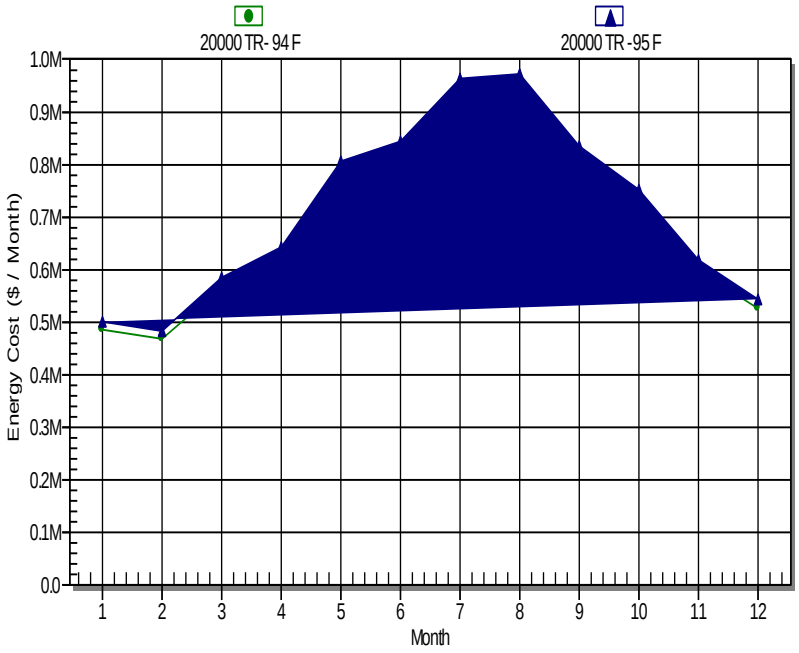
Estimated Energy Savings
> $ 6.9 M over 25 years

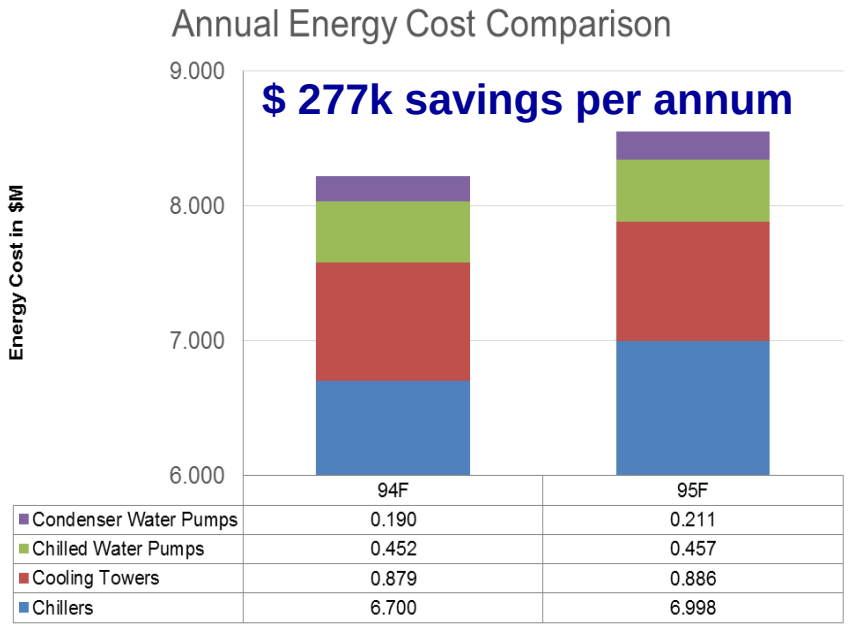


ENERGY COST OF OWNERSHIP EVALUATION









SUMMARY

Chillers operate < 1 % at design conditions. Sustainability is achieved by optimizing year round energy efficiency.

Implement optimized design parameters to reduce lift and increase chiller efficiency.

International accreditations like AHRI , ASME, etc. secure the owner's interest.

Comprehensive cost of ownership of chilled water plant room needs to be considered.

Full load KW / TR is easy to evaluate but may not be the cheapest to own.

Life cycle cost analysis should be used to select most optimal solution