Chiller Selections for Central Plants: Lowest Overall Costs for Process Cooling

Clayton Penhallegon, Jr., PE,
Integrated Services Group
Keynote Speaker

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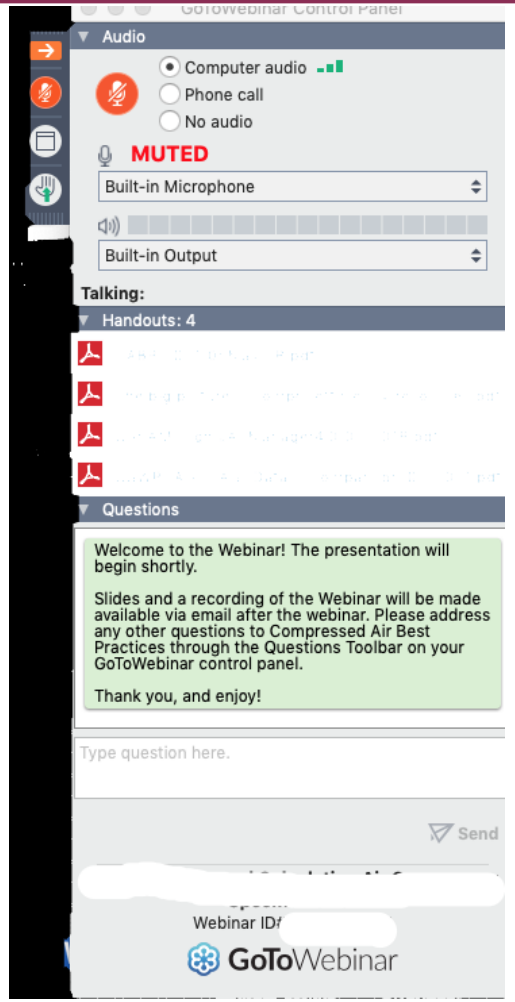
Q&A Format



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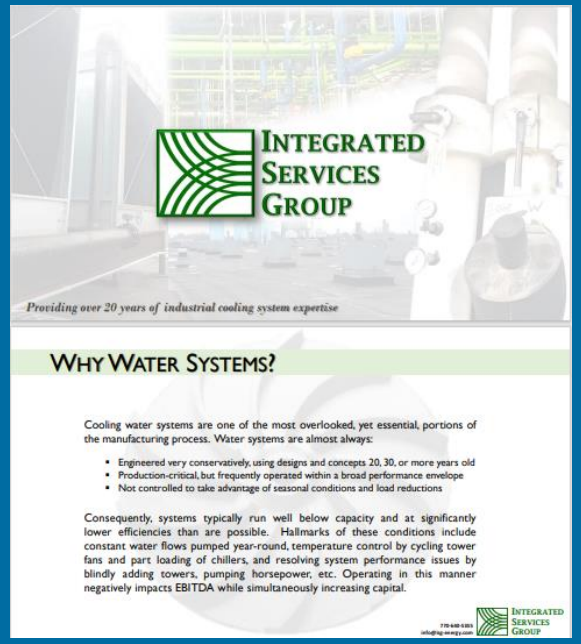

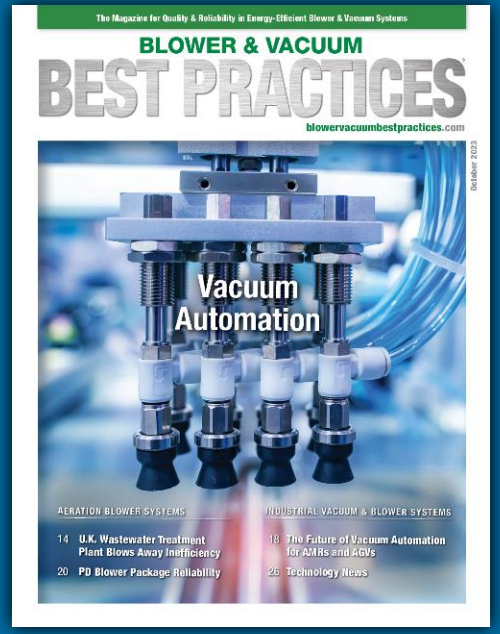

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Chiller Selections for Central Plants: Lowest Overall Costs for Process Cooling

Introduction

Chiller & Cooling Best Practices® Magazine

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About the Speaker

Clayton Penhallegon, Jr.
Integrated Services Group

- Principal Engineer, Integrated Services Group
- >25 years of experience in industrial energy efficiency
- Bachelor of Mechanical Engineering from Georgia Tech
- Registered P.E. for >30 years

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Presentation Outline

- Central plants vs. distributed systems
- Chiller technology choices
- Chiller type linkage to system design
- Impact of application specifics – choosing chiller types based on cooling load size, process requirements, locational factors, plant & corporate capabilities, etc.

How to Choose Between Distributed and Central Cooling Systems?

Two Conceptual System Designs – Distributed vs. Central

Distributed Systems:

- Individual chillers at each line / cluster (typically Portable chillers)
- Packaged systems with pumps & expansion tank
- Typically plug & play operation

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Distributed Systems:

- Individual chillers at each line / cluster (typically Portable chillers)
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- Typically plug & play operation

Central Systems:

- Larger chillers and / or groups handle multiple lines & plant needs
- Pumping and other system requirements met with separate components
- Custom designed to meet particular location & requirements

Distributed Chillers: Air-Cooled or Water-Cooled

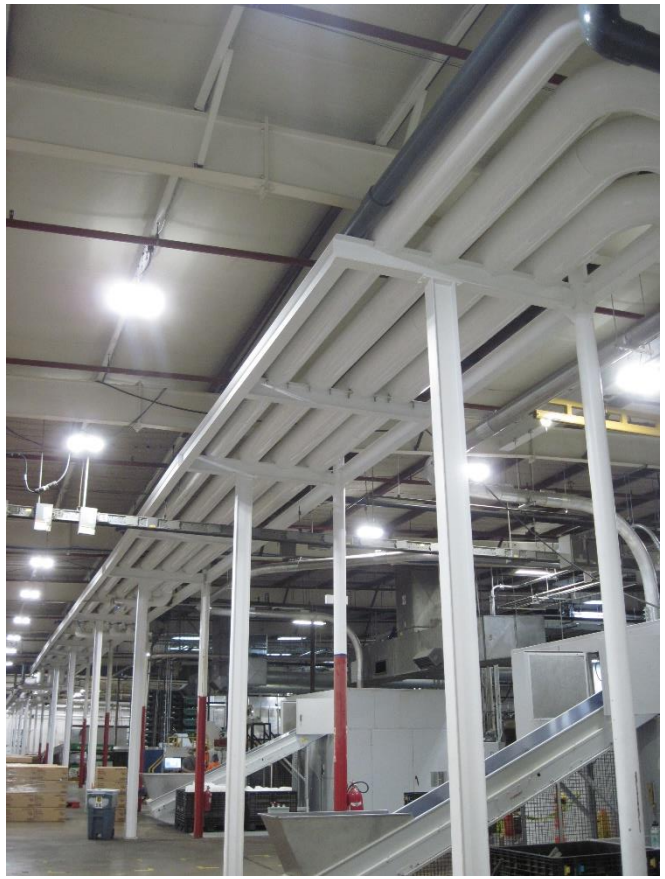
Central Plant Chillers: Air-Cooled or Water-Cooled

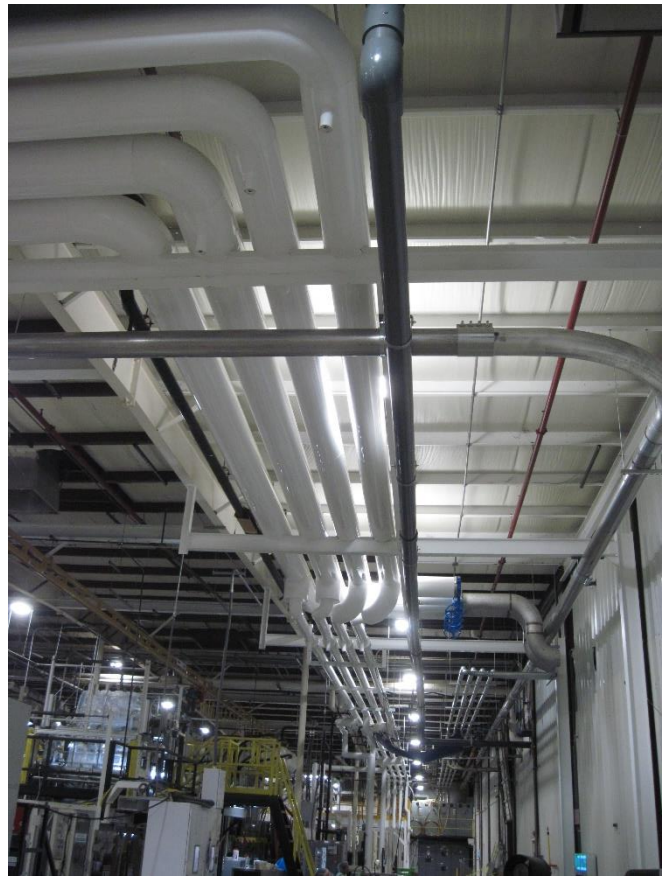
Air-Cooled Chiller

Cooling Tower

Water-Cooled Chiller

Central Plant System Features





Distributed System Features, Pros & Cons

Advantages:

- Individual units sized for required line load (typically conservatively sized)
- Integral pumping frequently provided
- Control embedded in chiller units
- Operation and maintenance simple and straightforward

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Disadvantages:

- High capital cost per ton
- Relatively poor delivered efficiency
- Energy & maintenance cost per ton-hour relatively high

Central System Features, Pros & Cons

Advantages:

- Custom design can meet evolving and / or specific application requirements
- Total design control supports higher level performance (N+1 efficiency, etc.)
- Lower or competitive total capital cost due to scale economies
- Lower energy & maintenance costs, higher equipment reliability
- Floor space savings from utility supply piping design

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Disadvantages:

- Requires dedicated space for system and installation of piping
- Effective operation requires higher operator knowledge, engineering support

Application Characteristics Drive System Design

Cooling requirements underlying system-type decision

- Size of cooling loads - # of points, individual and total loads
- Operating hours and starts & stops – 1 shift, 24/5, 24/7, mixed?
- Expectation of growth – how much, how fast?
- Expected lifespan of systems – years or decades?

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Opposite example situations

- Small start-up – Satellite plant – Dedicated on-site with fixed term contract
- New large plant – Consolidation plant – Upgrading outgrown systems

Distributed or Central Plant Cooling?

Distributed	Central Plant
Smaller heat load per line (<20 – 50 tons)	Higher heat loads per line (50+ tons)
Few lines (<3 – 4)	More lines (6 – 8+)
Uncertain or unlikely growth	Planned growth with high confidence
Limited operating hours (< 24/5)	24/5 operation or greater
Air-cooled auxiliaries (air compressors, dryers, vacuum pumps, process equipment, etc.	Water-cooled auxiliaries

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	Replacement of outgrown systems

How to Choose Between Air-Cooled and Water-Cooled Systems?

Air-Cooled System Features, Pros & Cons

Advantages:

- Simple system design when only chilled water (CHW) required
- Fewer components overall
- Outdoor chillers minimize space requirements inside building
- Saves water in locations with limited availability or high costs

Air-Cooled System Features, Pros & Cons

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Disadvantages:

- High capital cost per ton above cost crossover threshold
- Relatively poor chiller efficiency (for most chiller designs)
- Equipment life generally less than water-cooled chillers

Water-Cooled System Features, Pros & Cons

Advantages:

- Cooling tower water available for machine & process cooling
- Highest possible system efficiencies – chiller & free cooling modes
- Lower or competitive total capital cost above crossover threshold
- Lowest energy costs, competitive maintenance costs

Water-Cooled System Features, Pros & Cons

Advantages:

- Cooling tower water available for machine & process cooling
- Highest possible system efficiencies – chiller & free cooling modes
- Lower or competitive total capital cost above crossover threshold
- Lowest energy costs, competitive maintenance costs

Disadvantages:

- Requires dedicated space for system and installation of piping
- Effective operation requires higher operator knowledge, engineering support
- Consumes notable water amounts for tower, requires constant treatment vigilance

Air-Cooled or Water-Cooled Chillers?

Air-Cooled	Water-Cooled
Smaller total heat loads (<100 – 250 tons)	Higher total heat loads (500+ tons)
Simple water requirements (one temperature and / or all lines with TCUs[1]	Multiple water temp applications – CHW, tower-temp (85°F) uses
Significant concern about water supply	Free Cooling enabling climate (> ≈2000 hrs)
Limited plant staff resources	More capable staff or dedicated operators
Air-cooled auxiliaries (air compressors, dryers, vacuum pumps, process equipment, etc.	Water-cooled auxiliaries

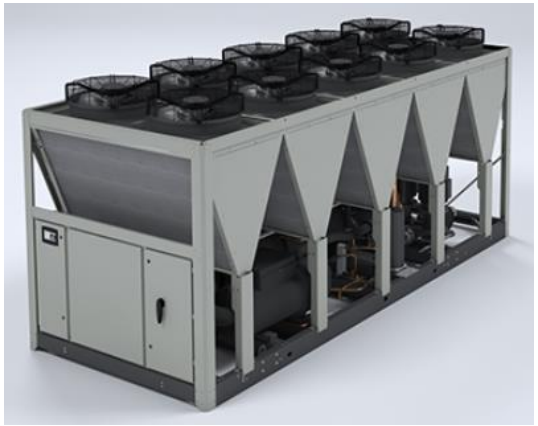
[1]Temperature Control Units

How to Choose Between Air-Cooled Chiller Types?

Air-Cooled Chiller Examples

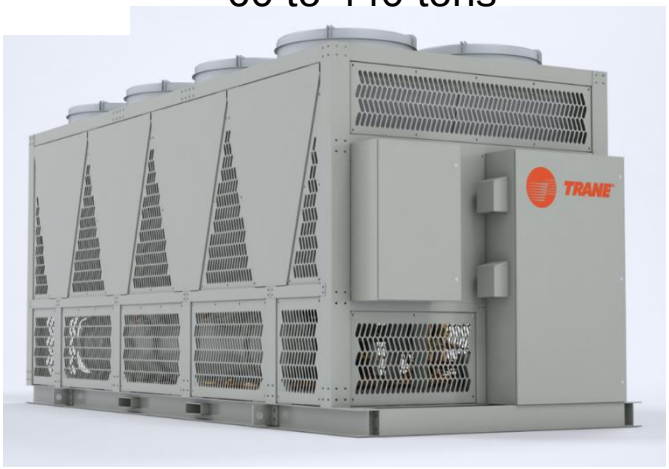
Scroll Compressor Chiller –
60 to 250 tons

VFD Screw Compressor
Chiller – 150 to 575 tons



Screw Compressor Chiller –
115 to 520 tons

Magnetic Bearing VFD
Centrifugal Comp. Chiller –
60 to 440 tons



Air-Cooled Chiller Types and Recommended Applications

Type	Recommended Uses
Scroll compressors	Smallest units only, limited hours of operation – replace compressors when failed (no repair)
Oil-lubricated screw compressors	Good choice for most applications – wide size range, economical with moderate power costs, rebuildable, multi-circuit designs available
VFD-controlled screw compressors	Higher efficiency than constant speed designs
Magnetic bearing centrifugal compressors	Highest possible efficiencies (for Air-Cooled) across widest operating range – good choice for water constricted, high power cost locations

How to Choose Between Water-Cooled Chiller Types?

Water-Cooled Chiller Examples

Scroll Compressor Chiller – 10 to 240 tons

Multi-Screw Compressor Chiller – 75 to 265 tons

VFD Centrifugal Compressor Chiller – 250 to 3000 tons

Single Screw Compressor Chiller – 150 to 435 tons

Magnetic Bearing VFD Centrifugal Comp. Chiller – 300 to 700 tons

Water-Cooled Chiller Types and Recommended Applications

Type	Recommended Uses
Scroll compressors	Not recommended for most applications
Oil-lubricated screw compressors	Good choice for smaller uses (<250 – 350 tons) – adequate size range (≈ 80 tons and up), economical with lower cost power, multi-circuit designs available, typically decades-long life with periodic rebuilds
Centrifugal compressors	High efficiency for larger uses (300 – 1500+ tons) – core chiller design for many applications, typically decades-long life with rebuilds
Magnetic bearing centrifugal compressors	Highest possible efficiencies across widest operating range – good choice for all uses with higher energy costs, typically decades-long life w/ low maintenance

Performance and Cost Distinctions Between Chiller and System Types

Central Plant Chillers Drive Overall System Performance

Chiller Type	Size Range	Nom. kW/ton	Annual kW/ton	System kW/ton*
Distributed Air-Cooled	5 - 20	1.35	1.75	2.0+
Air-Cooled Screw	150 - 500	1.225	0.875	1.250
W-C Screw (1 comp)	150 - 650	0.675	0.525	1.050
W-C VFD Screw	150 - 650	0.625	0.475	0.950
Centrifugal (1 comp)	250 - 1350	0.575	0.435	0.900
VFD Centrifugal	250 - 1350	0.550	0.350	0.750
Mag. Brg. VFD Cent.	125 - 750	0.525	0.325	0.675
Free Cooling (seasonal)	0 – 1500+	0.075	0.05	0.400

* Assumes system controlled to leverage chiller efficiency

Central Plant Chillers Installation & Operating Costs*

Chiller Type	Size Range	Installed Cost per Ton	Cost per 1000 ton -hrs @ 7.5¢ / kWh	Estimated Annual Maint. Per Ton
Distributed Air-Cooled	5 - 20	$2030	$150	$110
Air-Cooled Screw	150 - 500	$1280	$94	$50
W-C Screw (1 comp)	150 - 650	$1480	$79	$35
W-C VFD Screw	150 - 650	$1530	$71	$35
Centrifugal (1 comp)	250 - 1350	$1620	$68	$30
VFD Centrifugal	250 - 1350	$1670	$56	$30
Mag. Brg. VFD Cent.	125 - 750	$1830	$51	$20
Free Cooling (seasonal)	0 – 1500+	$2000	$30	$20

* Actual costs are widely variable based on site conditions, power costs, water quality & treatment, operating schedules, etc.

Summary

- Chiller type (and system design) driven by cooling load characteristics and application details (location, total size, power costs, water availability, etc.)
- Air-cooled, distributed chiller package units are least cost for very small systems, although cost per total ton-hour delivered is relatively high

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- Water-Cooled central plant system is least cost option for medium to larger systems with typical application details – operating hours, power costs, water cost / availability, etc.

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- Air-Cooled central plant system is least cost option for small plant systems that are large enough to benefit from central system efficiency and with no need for tower water
- Water-Cooled central plant system is least cost option for medium to larger systems with typical application details – operating hours, power costs, water cost / availability, etc.
- Specific situations may benefit from other choices or hybrids (e.g. air-cooled chillers with cooling tower for other uses), refer to unbiased technical consultants for help with system development and equipment specification

Chiller Selections for Central Plants: Lowest Overall Costs for Process Cooling

November 9, 2023

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Q&A

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Tom Taranto
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