
Water-Cooled vs. Air-Cooled Chillers Efficiency and Applications

Levi Hoiriis
Integrated Services Group
Keynote Speaker

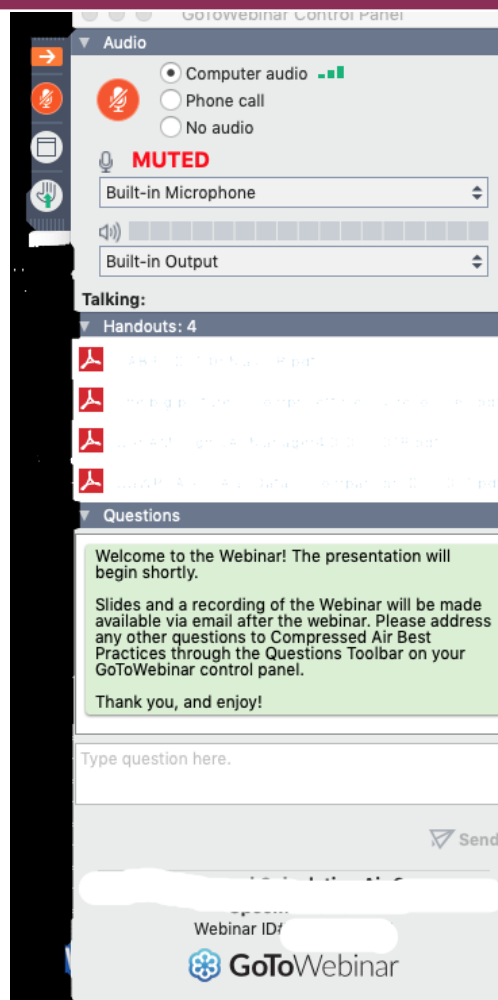
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WHY WATER SYSTEMS?

Cooling water systems are one of the most overlooked, yet essential, portions of the manufacturing process. Water systems are almost always:

- Engineered very conservatively, using designs and concepts 20, 30, or more years old
- Production-critical, but frequently operated within a broad performance envelope
- Not controlled to take advantage of seasonal conditions and load reductions

Consequently, systems typically run well below capacity and at significantly lower efficiencies than are possible. Hallmarks of these conditions include constant water flows pumped year-round, temperature control by cycling tower fans and part loading of chillers, and resolving system performance issues by blindly adding towers, pumping horsepower, etc. Operating in this manner negatively impacts EBITDA while simultaneously increasing capital.

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ENGINEERS NEWSLETTER

www.enr.com August 2025

A2L Refrigerants and ASHRAE® Standard 15

The HVACR industry is in the midst of another refrigerant transition. Some of the newer refrigerants under consideration are designated as being "near-flammable" (Class A2L) indicating that they can ignite under certain conditions. Existing codes and safety standards such as ASHRAE Standard 15 have been updated to include safety requirements that reflect the lower flammability nature of Class A2L refrigerants.

This Engineers Newsletter presents an overview of Standard 15's requirements for the safe design, installation, and operation of systems that use this class of refrigerants.

Phase Down of Higher-GWP Refrigerants

After the success of implementing the Montreal Protocol, an international treaty to reduce the presence of ozone-depleting substances in the atmosphere, the Kyoto Amendment addressed the issue of global warming by phasing down the supply of HFC refrigerants.

The U.S. American Innovation and Manufacturing Act mandated that the U.S. Environmental Protection Agency (EPA) phase down the supply of HFC refrigerants to the EPA to ensure "technology transition" that limit the global warming potential (GWP) of refrigerants used in various types of equipment.

Refer to Trane's "Designing Leaders" for the latest information on requirements for the GWP of refrigerants used in HVAC equipment.

This global urgency of the environmental impact of refrigerants has resulted in the development of newer refrigerants that have a lower GWP. Some of the newer refrigerants under consideration are designated as being "near-flammable." Class A2L, indicating that they can ignite under certain conditions.

TRANE

Refrigerant Safety Groups

ANSI/ASHRAE Standard 34, Designation and Safety Classification of Refrigerants, establishes a uniform system for assigning reference numbers, safety classifications, and performance expectations for all refrigerants. This standard classifies each refrigerant into a "safety group" according to its toxicity (Class A or B) and its flammability (Class 1, 2L, 2, or 3).

Toxicity classification. Section 6.1.2 of Standard 34 defines two toxicity classes based on allowable exposure:

- Class 1 refrigerants are at a lower degree of toxicity, as indicated by an OEL = 400 ppm.
- Class 2 refrigerants are at a higher degree of toxicity, as indicated by an OEL = 400 ppm.

Standard 34 defines two occupational exposure limit (OEL) as "the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers can be repeatedly exposed without adverse effects."

Flammability classification. The other designation for toxicity is followed by a number that indicates the refrigerant's safety group. Class 1 refrigerants are further divided into three sub-classes:

- Class 1A refrigerants have zero lower flammability limit (LFL) indicating that they ignite only under the most unfavorable conditions.
- Class 1B refrigerants have lower flammability characteristics than Class 1A, they have a higher LFL, but are still more difficult to ignite.
- Class 1C refrigerants have even higher LFL, and are the most difficult to ignite.

Class 2 refrigerants are subdivided into three sub-classes:

- Class 2A refrigerants have a lower LFL, and are more difficult to ignite.
- Class 2B refrigerants have a higher LFL, and are more difficult to ignite.
- Class 2C refrigerants have a higher LFL, and are more difficult to ignite.

The Class 2L definition was first added to Standard 34 in the 2016 published version. A flame propagation test is used to determine if a refrigerant is classified as 2L. Then a burning velocity test is used to determine how difficult it is to ignite. Refrigerants that are more difficult to ignite, and have a high LFL, are assigned the 2L classification.

TAEvo TECH

Air-Cooled Liquid Process Chiller
R-410a Nominal Cooling Capacity 2-63 Tons

With the acquisition of MTA, Trane has expanded its product portfolio to include purpose-built units for a myriad of industrial process cooling applications.

Well suited for both indoor and outdoor installation, the TAEvo TECH chiller helps enable applications that require high performance, reliability and continuity of operation in difficult industrial environments. The TAEvo TECH, offering 2-63 tons of cooling capacity, is designed for industrial use with space and functionality in mind, can fit in tight spaces and features a more forgiving tube evaporator.

ASHRAE® Standard 15

The purpose of ANSI/ASHRAE Standard 15, Safety Standard for Refrigeration Systems, is to specify safe practices for the design, construction, installation, and operation of all refrigeration systems. It applies to a broad range of systems, from a small window air conditioner to a large water chiller. Its requirements are intended to meet the needs of all users, but also to protect the public and the environment. It is not intended to be a prescriptive code, but rather a set of guidelines that can be adapted to a wide range of applications.

Figure 1. Refrigerant safety groups from ASHRAE® Standard 15

A3	B3	↑ Higher Flammability
A2	B2	
A2L	B2L	↑ Lower Flammability
A1	B1	
↑ Lower Toxicity		↑ Lower Toxicity

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The Inaugural European Best Practices Conference for On-Site Utilities Industrial Energy/Water Conservation and Food-Safe Systems

The Best Practices Magazines were founded in 2006 and the Best Practices EXPO in 2016. Since our first day, we've shared energy/water conservation and safety/reliability "Best Practices" to thousands of industrial design engineers, facility/maintenance managers, and technology professionals around the world.

European Technical Leaders are Featured Keynote Speakers at the 2-Day Conference

Vigorous NET ZERO and Energy/Water Conservation goals will focus on compressed air, vacuum and HVAC/Process cooling systems as they can represent 10-40% of the total energy consumption in a plant. Specified industrial-grade, energy/water-saving project close and hear success stories of projects delivering up to 50% of annual carbon reduction goals.

Compressed air, vacuum and chilled water systems can provide unlimited ingredients into food & beverage manufacturing. **Food-safe system design and quality verification will be a particular focus.**

COMPRESSED AIR Compressed Air Challenge Level 1 Fundamentals of Compressed Air Systems

This 8-hour introductory course delivered in the Spanish language with English subtitles on the powerpoint slides. It is designed to teach facility engineers, operators and maintenance staff how to achieve 15-25% cost savings through more effective production and use of compressed air. Participants will learn how to:

- Calculate the energy cost of compressed air in their facility.
- Improve compressed air system efficiency and reliability.
- Identify inappropriate uses of compressed air.
- Establish a baseline by which they can measure improvements in compressed air performance and efficiency.
- Find and fix leaks.
- Match system supply to actual production requirements for pressure and flow.
- Establish a leak prevention program, and
- Better control compressed air to improve productivity and profitability.
- Review the Fundamentals of Compressed Air Systems Workbook (English)

Safe & Reliable Verifying Food Safety & Quality Compliance

High-impact Energy Conservation Projects Achieving CO₂ Reduction Goals

Sustainable High-Volume Water Conservation Projects

Safe & Reliable Verifying Food Safety & Quality Compliance

GDH Institute
Juan Ledesma
Industrial Systems

Register at <https://cabexpo.com/event/industrial-sustainability-best-practices-conference/>

Sustainable, Safe & Reliable On-Site Utilities Powering Automation

COMPRESSED AIR | CHILLER & COOLING BEST PRACTICES

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Engineering

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All materials presented are educational. Each system is unique and must be evaluated on its own merits.

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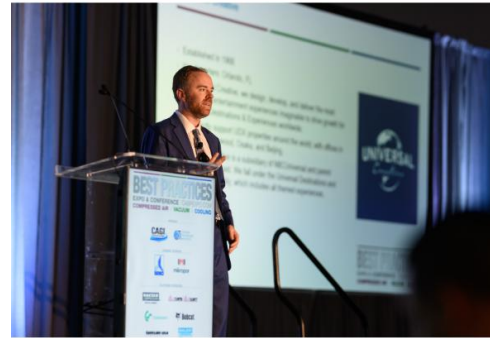
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Water-Cooled vs. Air-Cooled Chillers Efficiency and Applications

Introduction

Chiller & Cooling Best Practices® Magazine



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About the Speaker



Levi Hoiriis

Integrated Services Group

- Engineer, Integrated Services Group
- Expertise in thermal energy systems: chilled water, steam, and cogeneration
- Experience with industrial plants, campuses, and major US utilities
- Specializes in energy project planning, design, and economic modeling
- B.S. in Mechanical Engineering from Georgia Tech

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Presentation Outline

- Chiller technology choices
- Air vs Water Cooled Systems
- Impact of application specifics – industrial vs commercial applications



Chiller Technology Options

Scroll Compressor Chillers and Recommended Applications

Type	Condenser Cooling	Recommended Uses
Scroll compressors	Air	Smallest units only, limited hours of operation – replace compressors when failed (no repair)
Scroll compressors	Water	Not recommended for most applications



Air Cooled Scroll Compressor
Chiller – 60 to 250 tons



Water Cooled Scroll Compressor
Chiller – 10 to 240 tons

Screw Compressor Chillers and Recommended Applications

Type	Condenser Cooling	Recommended Uses
Oil-lubricated screw compressors	Air	Good choice for most applications – wide size range, economical with moderate power costs, rebuildable, multi-circuit designs available
Oil-lubricated screw compressors	Water	Good choice for smaller uses (<250 – 350 tons) – adequate size range (\approx 80 tons and up), economical with lower cost power, multi-circuit designs available, typically decades-long life with periodic rebuilds
VFD-controlled screw compressors	Air/Water	Higher efficiency than constant speed designs

Screw Compressor Chiller Examples



A-C VFD Screw Compressor Chiller – 150 to 575 tons



W-C Multi-Screw Compressor Chiller – 75 to 265 tons



W-C Single Screw Compressor Chiller – 150 to 435 tons

Centrifugal Chillers and Recommended Applications

Type	Condenser Cooling	Recommended Uses
Centrifugal compressors	Water	High efficiency for larger uses (300 – 1500+ tons) – core chiller design for many applications, typically decades-long life with rebuilds
Magnetic bearing centrifugal compressors	Air	Highest possible efficiencies (for Air-Cooled) across widest operating range – good choice for water constricted, high power cost locations
Magnetic bearing centrifugal compressors	Water	Highest possible efficiencies across widest operating range – good choice for all uses with higher energy costs, typically decades-long life w/ low maintenance

Centrifugal Compressor Chiller Examples

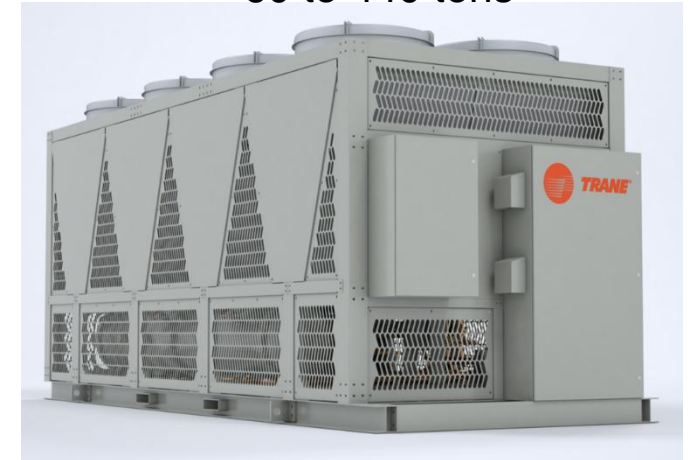


W-C VFD Centrifugal
Compressor Chiller – 250 to
3000 tons



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

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





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

Central Plant Chillers: Air-Cooled or Water-Cooled



Air-Cooled Chiller



Cooling Tower



Water-Cooled Chiller

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

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

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 & non-CHW 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 & non-CHW 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

¹Temperature Control Units



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*
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 @ 10¢ / kWh	Estimated Annual Maint. Per Ton
Air-Cooled Screw	150 - 500	\$1280	\$125	\$50
W-C Screw (1 comp)	150 - 650	\$1480	\$105	\$35
W-C VFD Screw	150 - 650	\$1530	\$95	\$35
Centrifugal (1 comp)	250 - 1350	\$1620	\$91	\$30
VFD Centrifugal	250 - 1350	\$1670	\$75	\$30
Mag. Brg. VFD Cent.	125 - 750	\$1830	\$68	\$20
Free Cooling (seasonal)	0 – 1500+	\$2000	\$40	\$20

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

Catalog vs Selection Chillers

Most smaller (air-cooled and water-cooled) chillers are “catalog” chillers

- Fixed range of sizes (rating based on standard conditions)
- May have high efficiency build options, low ambient (for A-C), etc.
- Essentially no ability to select specific features for application criteria
- May require either oversizing (e.g. for low ΔT use without high evap DP) or other sub-optimal choice to meet requirements

Larger chillers (screw, centrifugal, VFD and / or mag bearing) are typically engineered builds from a “selection” of available components

- Wide range of choices allows efficient tailoring of chillers to specific situations



Air-Cooled and Water-Cooled Systems Application Example

Application Example Scenario – Typical Commercial Conditions

Requirements:

- 44° chilled water (CHW) required
- 500 tons running load average load, 750 tons peak load
- Standard 10° supply – return CHW temperature difference (“delta T”) with 2.4 GPM per ton required flow
- 2400 hours per year operating hours at average load

Note: Cooling system costs outside of central plant equipment assumed equal – plant piping, electrical infrastructure, mechanical room space value, etc.

Application Example Scenario – Typical Commercial Conditions

Requirements:

- 44° chilled water (CHW) required, 500 tons average load, 750 tons peak load
- 10° supply – return delta T, 2400 hours per year average load operating hours

Air-Cooled Capital & Operating Costs

- Two 400 ton A-C chillers, installed capital cost ≈ \$1.02 mil.
- Annual operating cost @ 10¢ per kWh, 500 tons avg., 2400 hours - \$150,000

Energy Cost Calculations @ 10¢ per kWh:

500 tons X 2400 hours / 1000 ton-hrs X \$125 per 1000 ton-hrs

Use correct \$ per 1000 ton-hrs value, prorate for actual cost per kWh

Application Example Scenario – Typical Commercial Conditions

Requirements:

- 44° chilled water (CHW) required, 500 tons average load, 750 tons peak load
- 10° supply – return delta T, 2400 hours per year average load operating hours

Air-Cooled Capital & Operating Costs

- Two 400 ton A-C chillers, installed capital cost ≈ \$1.02 mil.
- Annual operating cost @ 10¢ per kWh, 500 tons avg., 2400 hours - \$150,000

Water-Cooled Capital & Operating Costs

- Two 400 ton W-C chillers, installed capital cost ≈ \$1.34 mil.
- Annual operating cost @ 10¢ per kWh, 500 tons avg., 2400 hours - \$90,000
- 5.33 year energy-only simple payback vs. A-C option, plus tower water costs

Application Example Scenario – Typical Industrial Conditions

Requirements:

- 50° chilled water (CHW) required
- 500 tons running load average load, 750 tons peak load
- 8° supply – return CHW delta T with 3.2 GPM per ton flow
- 6800 hours per year operating hours at average load

Note: Cooling system costs outside of central plant equipment again assumed equal – plant piping, electrical infrastructure, mechanical room space value, etc.

Application Example Scenario – Typical Industrial Conditions

Requirements:

- 50° chilled water (CHW) required, 500 tons average load, 750 tons peak load
- 8° supply – return delta T, 6800 hours per year average load operating hours

Air-Cooled Capital & Operating Costs

- Two 500 ton A-C chillers due to reduced delta T – “**Catalog chillers**”
- Installed capital cost ≈ \$1.275 mil.
- Annual operating cost @ 10¢ per kWh, 500 tons avg., 6800 hours - \$425,000

Application Example Scenario – Typical Industrial Conditions

Requirements:

- 50° chilled water (CHW) required, 500 tons average load, 750 tons peak load
- 8° supply – return delta T, 6800 hours per year average load operating hours

Air-Cooled Capital & Operating Costs

- Two 500 ton A-C chillers, installed capital cost \approx \$1.275 mil. **“Catalog chillers”**
- Annual operating cost @ 10¢ per kWh, 500 tons avg., 6800 hours - \$425,000

Water-Cooled Capital & Operating Costs

- Two 400 ton W-C chillers, installed capital cost \approx \$1.34 mil. **“Selection chillers”**
- Annual operating cost @ 10¢ per kWh, 500 tons avg., 6800 hours - \$255,000
- 0.38 year energy-only simple payback vs. A-C option, plus tower water costs

Industrial Application Analysis Criteria Distinctions

Required CHW temperature(s)

- Frequently 50 - 60°F vs. AHRI standard 44°F
- May require multiple temperatures at significant enough condition differences to warrant system capabilities vs. using TCUs

Hours of operation – typically much higher in industrial applications

Seasonal implications – many process loads substantially unaffected by outdoor conditions, potential for seasonal optimization (adjusted setpoint)

Known or potential future load growth – very common in industry, often unlikely in commercial applications

Known or potential changes in required temperatures – design for adaptability

Summary

- Chiller type (and system design) driven by cooling load characteristics and application details (location, total size, power costs, water availability, etc.)

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- Air-Cooled central plant system is least cost option for small plant systems with no other need for tower water

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- Chiller type (and system design) driven by cooling load characteristics and application details (location, total size, power costs, water availability, etc.)
- Air-Cooled central plant system is least cost option for small plant systems with no other 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.

Summary

- Chiller type (and system design) driven by cooling load characteristics and application details (location, total size, power costs, water availability, etc.)
- Air-Cooled central plant system is least cost option for small plant systems with no other 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

Water-Cooled and Air-Cooled Chillers: Selection for Efficiency and Applications

March 20, 2025

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About the Speaker



Ben Sykora
Trane

- Applications Engineer at Trane Commercial (since 2024).
- Specialist in hydronic systems, heat pumps, and VFDs.
- Former power electronics engineer for Trane Commercial HVAC.
- Certified Professional Engineer with a master's in Electrical Engineering and 13 patents.
- Served 6 years in the US Navy as a "nuke electrician's mate."

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March 20, 2025

Advancements in Industrial Chiller Technology:

Exploring Modern Trends and Innovations

Ben Sykora

Applications Engineer, Trane®

Agenda

What trends will affect decision making for industrial users in the next 2-5 Years?



- New Refrigerant Types
- Chiller Applications
 - Compressor “lift”
 - Vapor injection
 - Multistage
 - Cascaded compressors or chillers
- Chiller Efficiency Tradeoffs
 - Efficiency vs lift



Distributed Process Chillers
1-50T



Air-Cooled Chillers
20-650T



Water-Cooled Chillers
80-4000T+



New Refrigerant Types

Why Refrigerants are Transitioning and “Decarbonization is the New Trend”



ODP

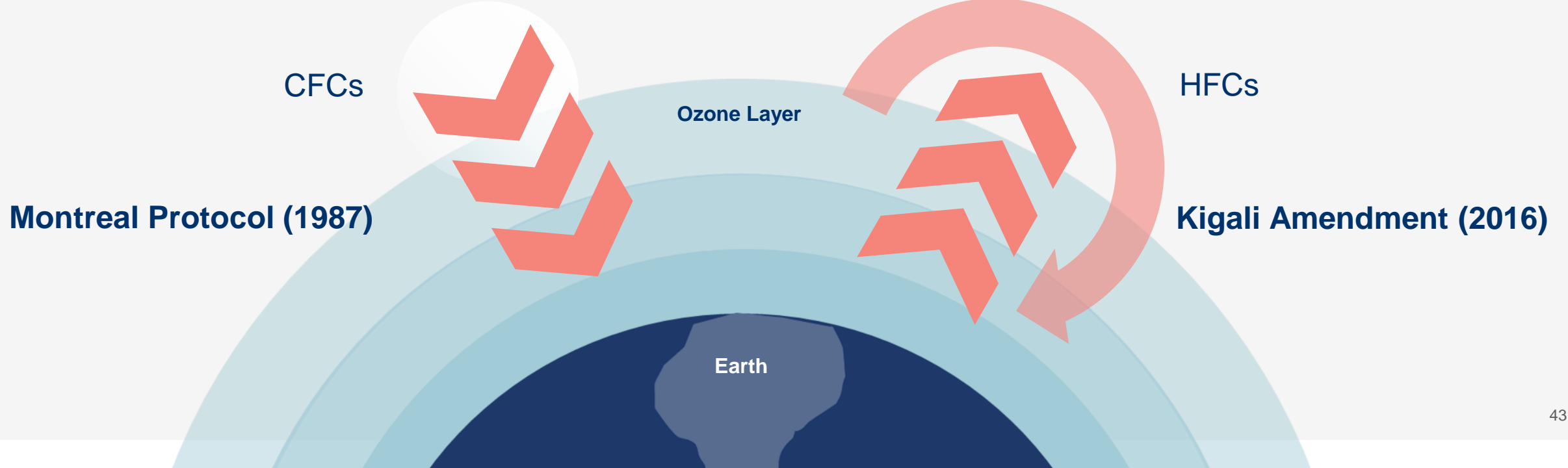
Ozone Depletion Potential - *Past Concern*

Potential of a substance to **reduce the amount of ozone** in the atmosphere which blocks harmful radiation

GWP

Global Warming Potential - *Current Concern*

Potential for a gas to **trap heat** in the atmosphere - contributing to climate change



Next-Generation Refrigerants

Safety

- ASHRAE® Standard 34: Designation and Safety Classification of Refrigerants
- Toxicity: Occupational exposure limit (ppm in a workday)
- Flammability: Ignition and burn velocity
- New refrigerants A2L: **R-32 and R-454B**
 - Low toxicity (A)
 - Hard to ignite (needs an open flame)
 - Low burning velocity

A3	B3
A2	B2
A2L	B2L
A1	B1



- CLASS 3**
Higher flammability
explosive, like propane
(R290), Isobutane (R600a)
- CLASS 2**
Flammable, R152a
- CLASS 2L**
Lower flammability
<10 cm/sec burning velocity,
R32, R1234yf, R454b
- CLASS 1**
No-flame propagation
R123, R134a, R404A,
R410A, etc., called
nonflammable



ASHRAE® Standard 15-2022

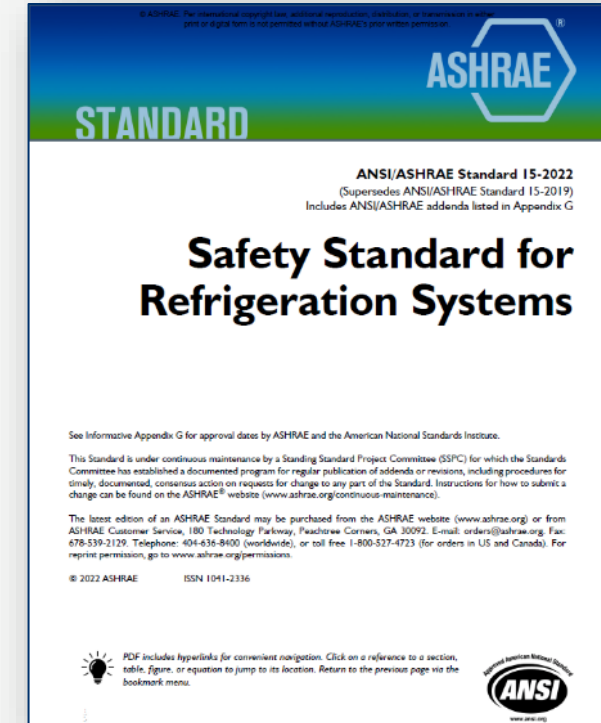


ASHRAE® Standard 15: Safety Standard for Refrigeration Systems

- Design, construction, installation and operation of refrigeration systems
- New systems, replacements, alterations and conversions.

Determine safety requirements

- ✓ Lookup safety group classification of the refrigerant (Std 34)
- ✓ Determine occupancy classification of the building (S. 4)
- ✓ Determine “system probability” classification

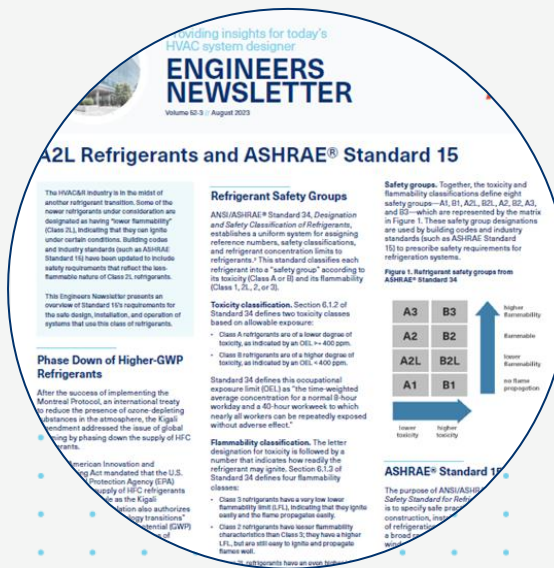


Reference links for “Engineering Newsletter” on ASHRAE 15 on the last slide.

Where to Learn More on ASHRAE® Standard 15



→ Trane Engineers Newsletter LIVE: ASHRAE® Standard 15 2022



→ Trane Engineers Newsletter: A2L Refrigerants and ASHRAE® Standard 15



→ Applications Engineering Manuals and Guides

Common Refrigerant Types



Pressure	Refrigerant	GWP	Class
Low	R-123	77	B1
	R-514A	1.7	B1
	R-1233zd(E)	1	A1
Medium	R-134a	1430	A1
	R-513A	630	A1
	R-515B	298	A1
	R-1234yf	6	A2L
	R-1234ze(E)	4	A2L
High	R-410A	2088	A1
	R-454B	467	A2L
	R-32	675	A2L



Chiller Applications – What's Changing?

Chiller Applications

Wide Range of Compressor and Chiller Lift Requirements



Application	Data Center	Water Cooled Chiller	Air Cooled Chiller	Low Temp Process	Heat Recovery	High Temp Heat Recov.
Evaporator (F)	60	40	40	20	40	40
Condenser (F)	90	90	110	110	140	180
“Lift” (F)	30	50	70	90	100	140

*Heat Pumps are driving new technology for high lift compressors
Data Centers are driving new technology for low lift chillers*

Chiller Technology for Low Lift



***Example Centrifugal
Air Cooled Chiller***

Example Ratings for Centrifugal AC Chiller

- Chilled water: 38-86F
- Ambient Temp: 0-122F

Compressor Technology

- High Speed Centrifugal Compressors
- Magnetic Bearings

Compressor Technology for Higher Lift



✓ Vapor Injection Compressors

- Interstage inlet port extends operating map

Alternate Refrigerants

Multi-stage Compressors

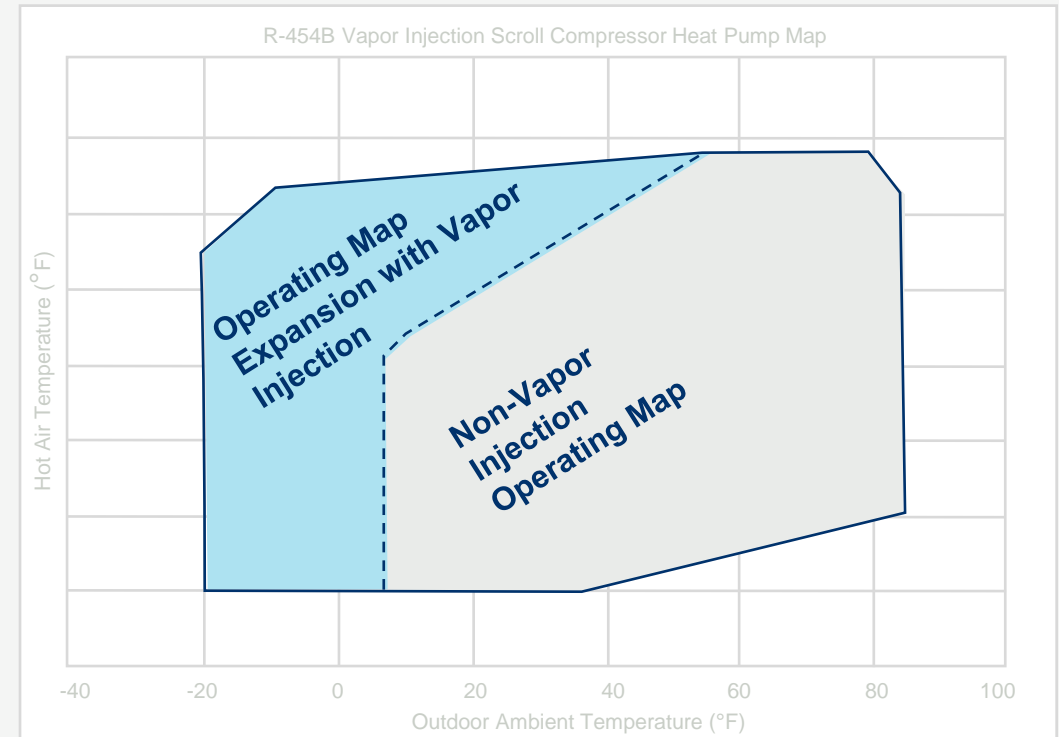
- Discharge of one stage feeds the next

Cascaded Compressors

- Discharge of one compressor feeds the next

Cascaded Chillers

- Condenser of one chiller hooked up to the evaporator of next.



Vapor injected scroll compressor 110-130F lift

Compressor Technology for Higher Lift



Example screw compressor
R513A: ~100F lift
R515B: ~125F lift

Vapor Injection Compressors

- Interstage inlet port extends operating map

✓ Alternate Refrigerants

Multi-stage Compressors

- Discharge of one stage feeds the next

Cascaded Compressors

- Discharge of one compressor feeds the next

Cascaded Chillers

- Condenser of one chiller hooked up to the evaporator of next.

Compressor Technology for Higher Lift



Vapor Injection Compressors

- Interstage inlet port extends operating map

Alternate Refrigerants

✓ Multi-stage Compressors

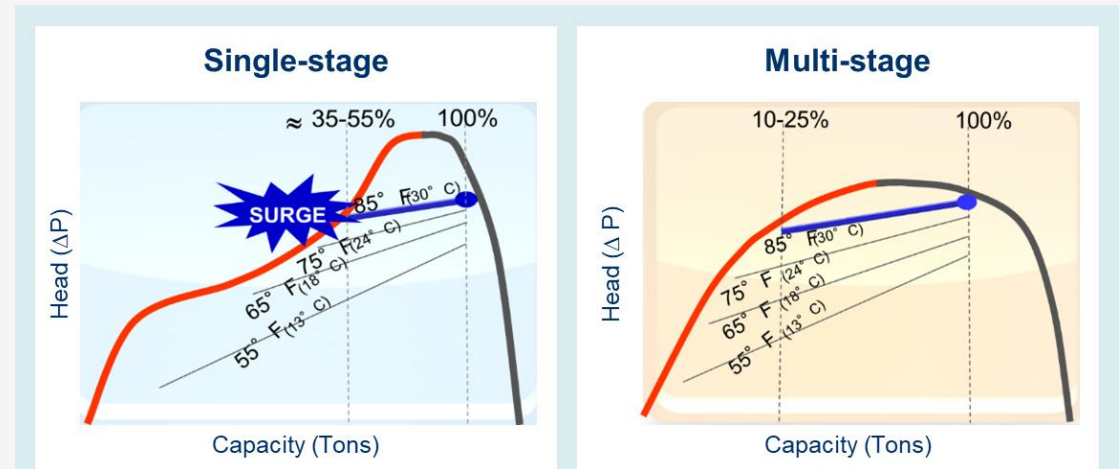
- Discharge of one stage feeds the next

Cascaded Compressors

- Discharge of one compressor feeds the next

Cascaded Chillers

- Condenser of one chiller hooked up to the evaporator of next.



Compressor Technology for Higher Lift



Vapor Injection Compressors

- Interstage inlet port extends operating map

Alternate Refrigerants

Multi-stage Compressors

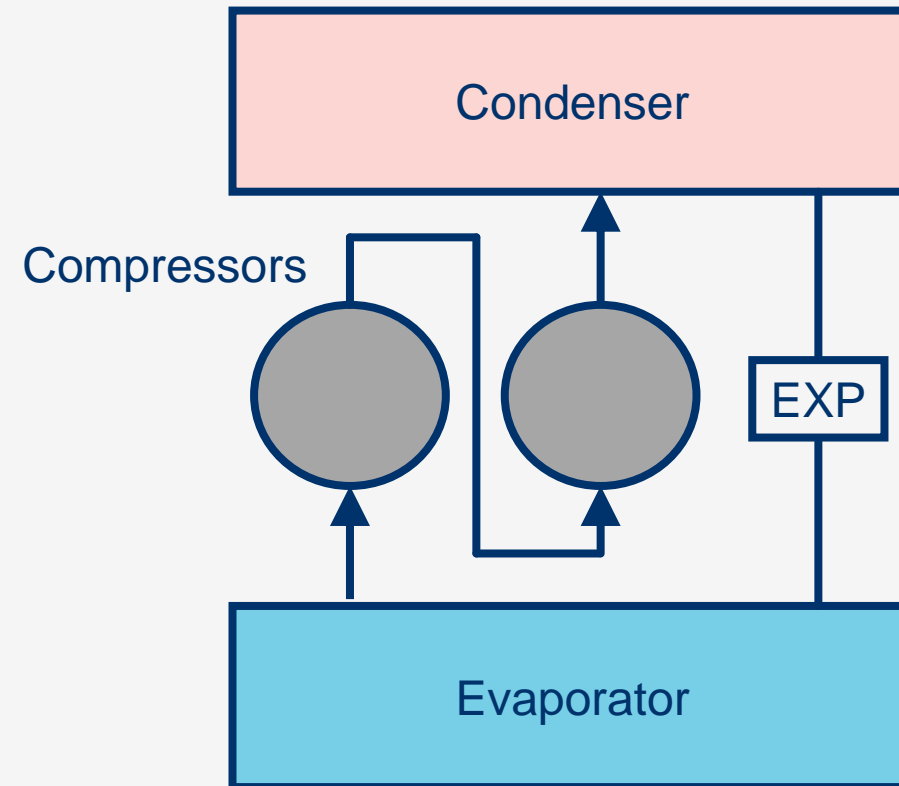
- Discharge of one stage feeds the next

✓ Cascaded Compressors

- Discharge of one compressor feeds the next

Cascaded Chillers

- Condenser of one chiller hooked up to the evaporator of next.



Cascaded Centrifugal Compressors ~130F lift

Compressor Technology for Higher Lift



Vapor Injection Compressors

- Interstage inlet port extends operating map

Alternate Refrigerants

Multi-stage Compressors

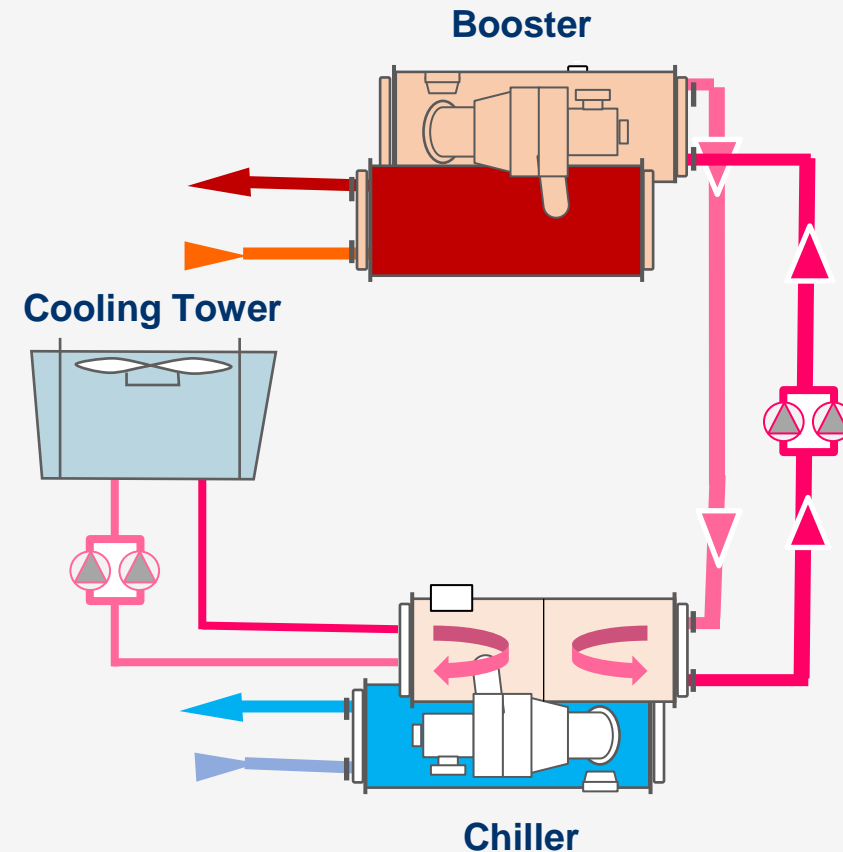
- Discharge of one stage feeds the next

Cascaded Compressors

- Discharge of one compressor feeds the next

✓ Cascaded Chillers

- Condenser of one chiller hooked up to the evaporator of next.



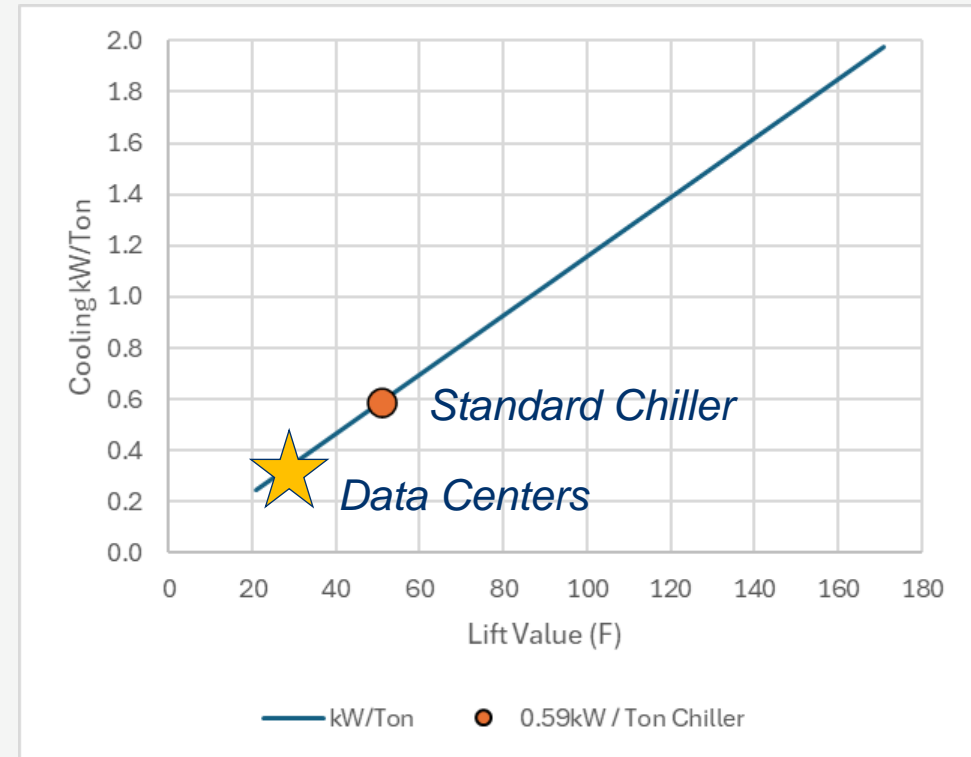
Cascaded Centrifugal Chillers ~140F lift
Centrifugal Chiller + Screw Booster ~170F lift

Efficiency Impact of High Lift

Chiller Efficiency

- Compressor Power is proportional to lift
“Carnot Efficiency”
- High lift = higher power = lower efficiency

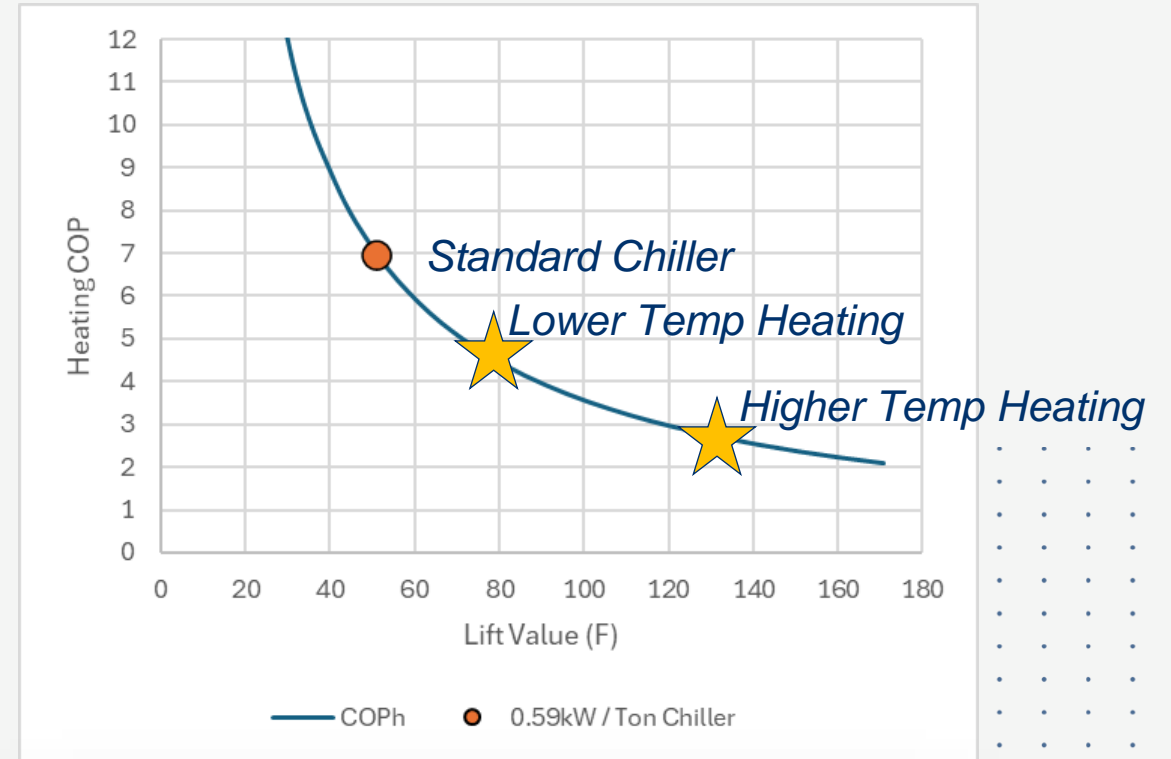
- $$\frac{kW}{Ton} = \frac{\text{Electrical } kW \text{ input}}{\text{Cooling Tons output}}$$



Efficiency Impact of High Lift

Heating Efficiency

- Compressor Power is proportional to lift
“Carnot Efficiency”
- High lift = higher power = lower efficiency
- $COP = \frac{\text{Heating kW output}}{\text{electrical kW input}}$
- COP = “Coefficient of Performance”



Thumb rule: 1% efficiency penalty
per 1F over 105F

Efficiency Impact of High Lift

Heat Recovery Efficiency - Include Heating AND Cooling output



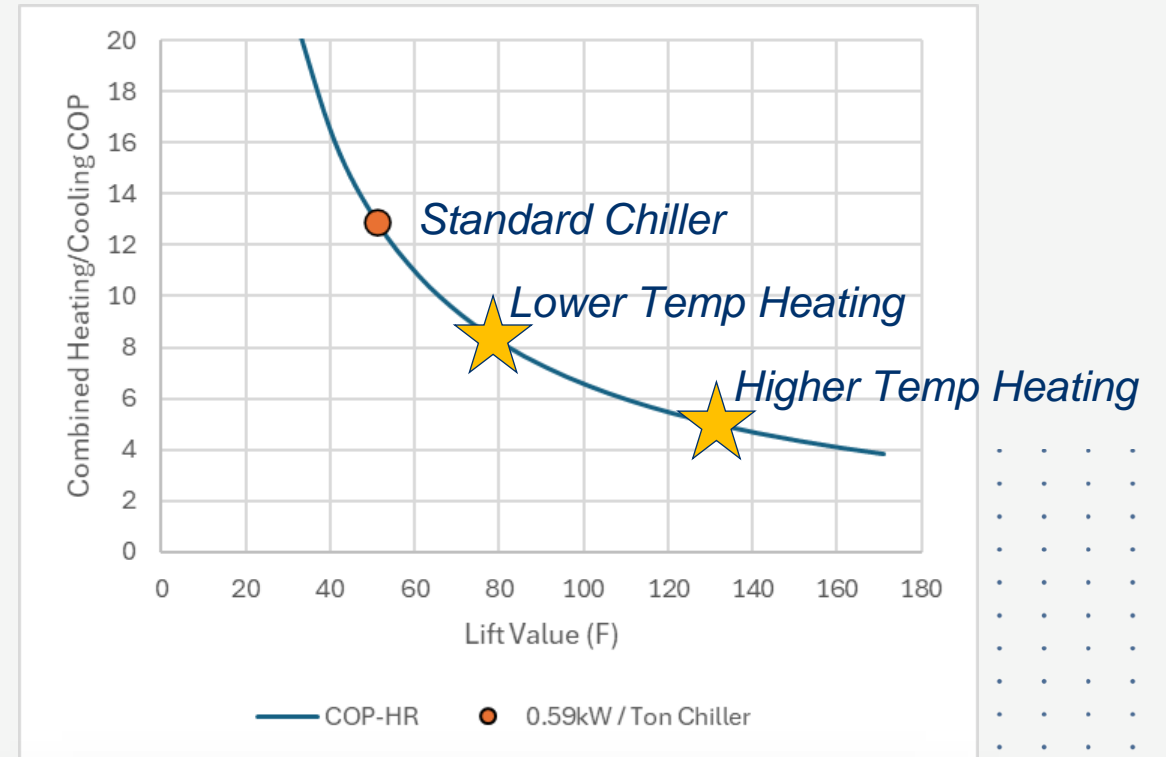
- Compressor Power is proportional to lift
“Carnot Efficiency”
- High lift = higher power = lower efficiency

$$COP = \frac{\text{Heating kW} + \text{Cooling kW}}{\text{electrical kW input}}$$

References:

[ASHRAE® “A Guide for Applying Heat Pumps and Beyond”.](#)

[Engineering Newsletter “Heating with Lower-Temperature Hot Water”.](#)



Thumb rule: 1% efficiency penalty
per 1F over 105F

Summary



✓• **New refrigerant types for lower Global Warming Potential (GWP)**

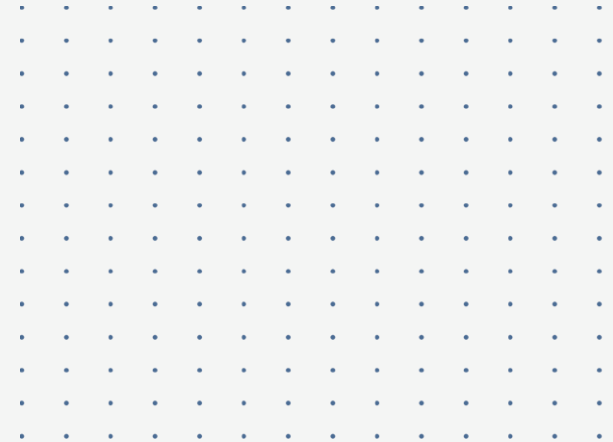
- ASHRAE® 15

✓• **New compressor technologies for high and low lift applications**

- Vapor injection
- Refrigerant types
- Multistage
- Cascaded compressors or chillers

✓• **Tradeoffs between compressor lift and efficiency**

- Low lift = high efficiency
- High lift = reduced efficiency





Thank You!

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Water-Cooled vs. Air-Cooled Chillers Efficiency and Applications

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