HVAC HACKS #8: EFFICIENT COOLING WITH HVAC CHILLERS – ESSENTIAL TIPS & RULES OF THUMB

An Online Continuing Education Course for Engineers

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HVAC Hacks #8: Efficient Cooling with HVAC Chillers - Essential Tips & Rules of Thumb

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Looking for optimal cooling solutions for large buildings? Unleash efficient cooling with HVAC chillers!

Efficient cooling is crucial for large buildings to enhance performance and minimize energy usage. Chilled water systems, with chillers at their core, play an important role in achieving this goal. This course empowers you to unlock optimal solutions. You'll dive deep into chiller selection (scroll, screw, centrifugal), cutting-edge tech advancements, system design principles, maximizing cooling efficiency, and keeping operational costs in check.

This course includes several metrics and easy-to-understand "Rules of Thumb" guidelines based on experience and commonly accepted practices in the HVAC industry.

You can find **Key Rules of Thumb in Annexure - 1** for quick and easy reference. These guidelines, metrics, and thumb rules are based on sound engineering practices and the author's experience, but they may vary depending on operating conditions and other factors. This document is a live resource that will be updated regularly as new information becomes available.

Ready to explore different types of chillers, selection strategies, and options? Let's get started!

Important Note: Two additional modules focusing on the hydronic distribution network (Module #9) and heat rejection options (Module #10) are available in the HVAC Hacks series. By reading both these modules, you'll gain a comprehensive understanding of complete chilled water system design solutions for large, centralized HVAC applications.

CHAPTER - 1: CHILLED WATER SYSTEMS

A chilled water system is a type of HVAC (Heating, Ventilation, and Air Conditioning) system that uses chilled water as a coolant to regulate temperature in buildings. It works by circulating chilled water from a central chiller to air-handling units (AHUs) or fan coil units (FCUs), which cool the air within the building. The system consists of a chiller, chilled water pumps, piping, and heat exchangers, all working together to remove heat from the building and dissipate it via a cooling tower or air-cooled condenser. Chilled water systems are widely used in large-scale commercial, industrial, and institutional buildings due to their efficiency, scalability, and ability to provide precise temperature control. The choice of chilled water system depends on factors such as building size, load profile, and desired level of control.

Table 1. Key Components of Chilled Water System

	Components	Functions	Rules of Thumb
	Chiller	Cools water and rejects heat to a cooling tower (water-cooled) or the air (air-cooled).	1 Ton = 12,000 BTU/hr. Water-cooled is more efficient but needs cooling towers and more space.
	Chilled Water Pumps	Circulate chilled water throughout the building, ensuring that it reaches the air-handling units (AHUs), fan coil units (FCUs), or other heat exchangers.	2.4 GPM/Ton (chilled water) for 10°F range. 4-6 BHP per 100 Tons.
	Cooling Towers	Rejects heat in water-cooled systems.	3 GPM/Ton (condenser water) for 10°F range.
	AHUs and FCUs	Equipment that uses the chilled water to cool and condition the air, providing thermal comfort.	400 CFM per Ton. Fan coils enhance individual zone control.
	Piping Network	Distributes chilled water from the chiller to the cooling units and back.	Flow velocity 4-6 fps to minimize pressure drop and noise.
	Control Systems	Monitoring and control functions to optimize system performance and energy efficiency.	Use VFDs for pumps and fans. Building Management System (BMS) for large-scale development.
	Water Treatment System	Maintain good water quality to prevent scaling, corrosion, and microbial growth.	Maintain Langelier Saturation Index (LSI) between -0.5 and +0.5. Makeup water <3% of circulating flow.

These components work together to provide effective temperature control for both building environments and industrial processes.

Chilled Water Schematic

The schematic below illustrates a conventional air conditioning system for a large building.

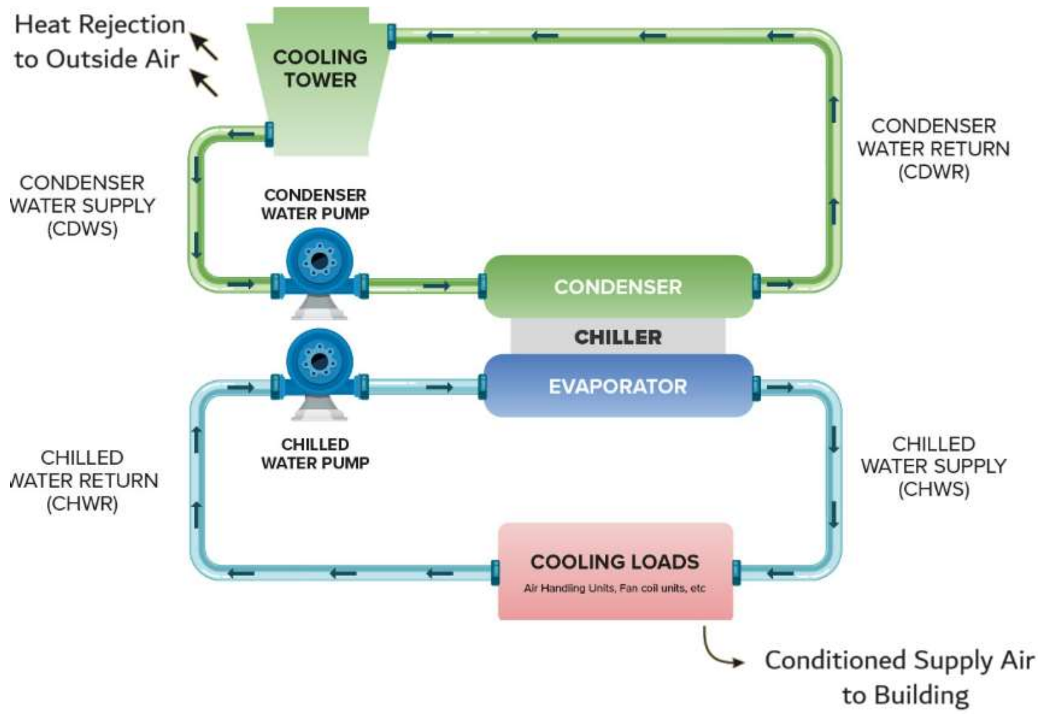

Figure 1. Chilled Water System Diagram

1.1 Why Chillers?

Chilled water systems are commonly used in large HVAC applications due to their efficiency, scalability, and ability to handle high cooling loads. Compared to direct expansion (DX) systems, chilled water systems are more versatile and can serve multiple zones from a central chiller, making them ideal for large-scale HVAC needs in large commercial offices, hotels, malls, schools, airports, hospitals, and industrial plants. Here's why chilled water systems are so popular for air conditioning systems:

Table 2. Reasons for Selecting Chilled Water System

	Benefits	Rules of Thumb
	Space Efficiency	A pound of water can store four times as much thermal energy as the same mass of air and has a much smaller volume due to its higher density. Water's thermal capacity allows for smaller piping (1-2” for 2.4 GPM/Ton) vs. large air ducts (8”-12” for 400 CFM/Ton).
	Efficiency	Chiller plants have a lower kW/Ton energy consumption compared to direct expansion (DX) type distributed cooling systems. Chiller systems operate at 0.6-1.0 kW/Ton, compared to 1.1-1.3 kW/Ton for decentralized air-based direct expansion (DX) type cooling systems.
	Flexibility & Scalability	A chilled water system can be easily modified to adapt to changing cooling demands by adding or removing components as needed. Chilled water systems support large capacities of up to 4000+ Tons for a single unit and can be configured in multiples. Chilled water systems are not constrained by distance and are good for long-distance distribution in high-rise buildings or multi-building campuses with appropriately sized circulator pumps.
	Durability	Chillers last ~25 years, longer than air-based systems (~15 years).
	Centralized Control	Enables independent zone control with a central plant, simplifying maintenance and operation.

The drawbacks are the complex design, high capital and installation costs, and longer project duration. While chillers can be more expensive to install compared to other air conditioning options, they can be more cost-effective in the long run due to their high cooling capacity, energy efficiency, and durability.

1.2 Types of HVAC Chillers

HVAC chillers are categorized based on the refrigeration cycle they operate on. These generally fall into two types: vapor compression and vapor absorption.

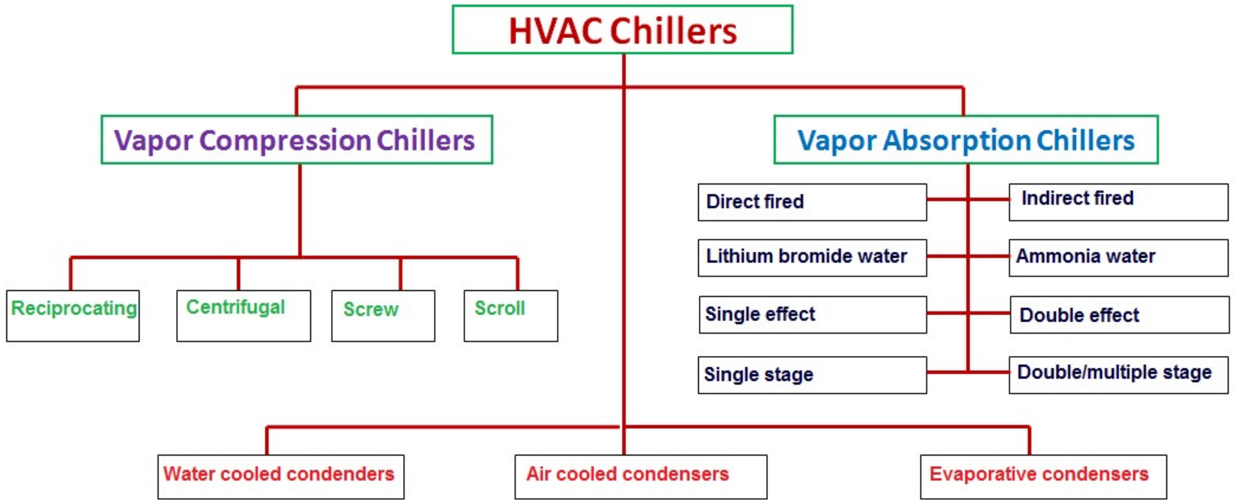

Figure 2. Types of HVAC Chillers

Both vapor compression and vapor absorption methods utilize a refrigerant to absorb and release heat for cooling purposes. However, they differ in how they produce the cooling effect and the energy source they employ.

1.3 Vapor Compression Chillers

Vapor compression chillers employ a compressor to pressurize the refrigerant, causing it to undergo a phase change from liquid to gas and back to liquid through heat exchangers. These chillers are typically the largest energy consumers in buildings. Therefore, it's crucial to gather information about various types of chillers, their characteristics, advantages, and limitations to make informed technical, engineering, and economic decisions when selecting, procuring, and implementing chillers.

1.4 Vapor Absorption Chillers

Unlike vapor compressor systems, vapor absorption chillers do not use a compressor. Instead, they rely on an absorbent substance like lithium bromide or ammonia for the cooling process. Vapor absorption refrigeration typically uses thermal energy, such as heat from a steam or hot water source, to drive the absorption process. This method requires minimal electricity to operate solution pumps.

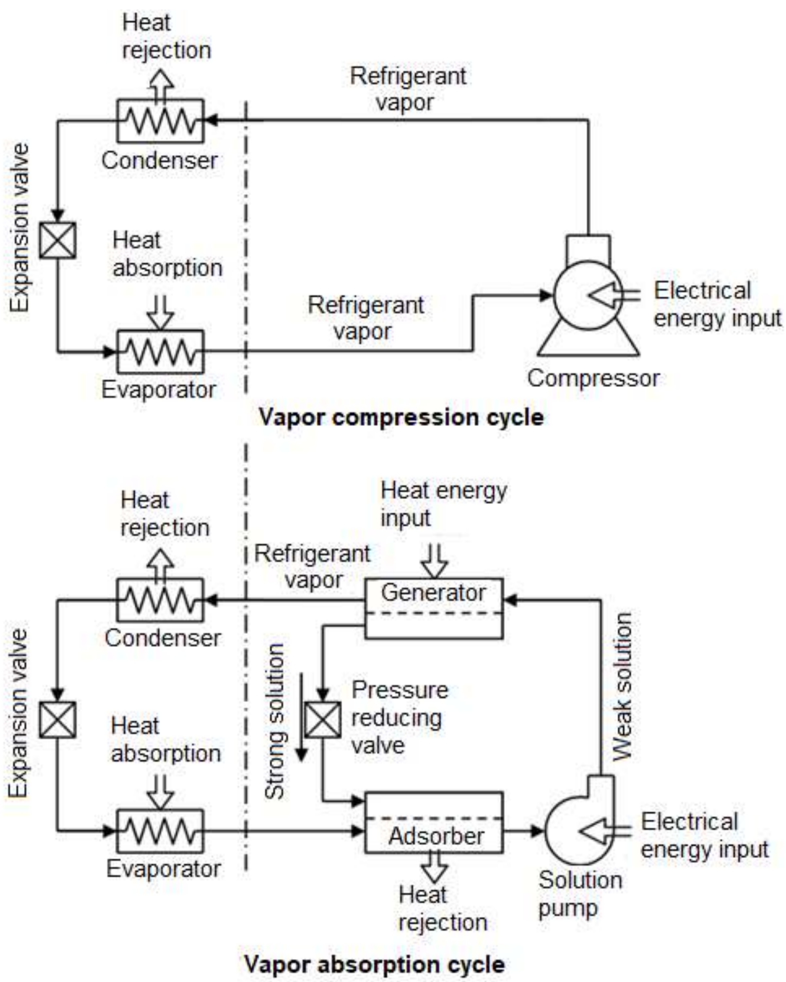

Figure 3. Vapor Compression and Vapor Absorption Refrigeration Cycle

Table 3. Vapor Compression Vs. Vapor Absorption Systems

Parameters	Vapor Compression	Vapor Absorption
Working Principle	Compression & Phase Change	Absorption & Heating
Energy Source	Electricity	Thermal (Steam/Hot Water)
Energy Performance (COP)	3 - 6	0.7 - 1.4 (better with waste heat)
Performance at Part Load	Reduces Significantly	No Impact
Heat Rejection	1.25x Cooling Effect (approx. 15000 Btu/Ton to condenser).	2.4x Cooling Effect (approx. 28000 Btu/Ton for single stage and 21000 Btu/Ton for dual stage machine).
Noise & Vibration	High, need a strong foundation.	Low, practically very quiet. No moving parts.
Leakage	High Pressure = High Leaks	Negligible

Parameters	Vapor Compression	Vapor Absorption
First Cost	Lower	Higher. Incur 50 to 100% higher cost due to machine characteristics as well additional costs associated with bigger cooling tower, combustion air and venting (stack).
Operating Cost	Higher Electricity Costs	Low electric costs. Fuel costs dictate the economics.
Maintenance	Refrigerant Leaks	Crystallization Risk
Refrigerant	Halocarbons (HFCs)	Water & Lithium Bromide (LiBr)
Environmental Impact	High Global Warming Poten ...	... n or Greenhouse Effect

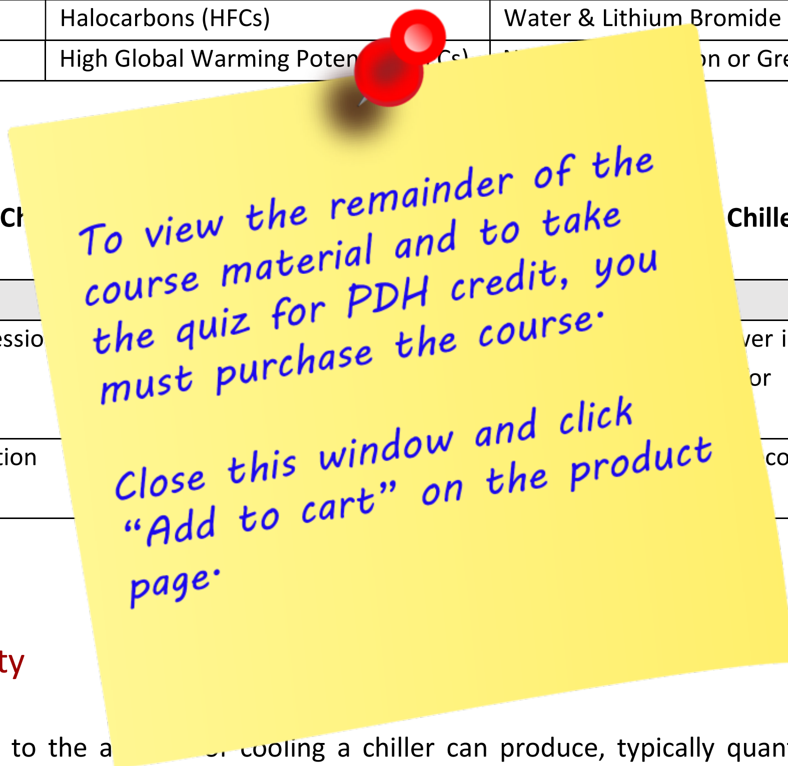

Table 4. Ch ... Chillers

	Benefits	
	Vapor Compressio ...	... ver initial costs. Best ... or residential and
	Vapor Absorption	... covery or cheaper

1.5 Chiller Capacity

Chiller capacity refers to the a ... cooling a chiller can produce, typically quantified in Tons of refrigeration (TR) or simply "Tons."

Tonnage refers to cooling power, not the weight of the chiller. One Ton chiller removes heat at a rate of 12,000 BTU/hr.

Connecting the Dots

1 Ton of cooling is equivalent to cooling generated by melting one Ton (2000 lbs.) of ice in 24 hours.

To melt 1 pound of ice, you need 144 BTU (because ice absorbs heat as it melts without changing temperature).

1 Ton (2,000 lbs.) of ice requires 2,000 lbs. x 144 BTU/lb. = 288,000 Btu to melt.

Dividing by 24 hours for the timeframe, we get 1 Ton = $\frac{288,000}{24} = 12000\ BTU/hr$.