

Module 4

District cooling

Part of the SHaKE Educational Package on District Heating and Cooling Systems

QUESTION BANK

Self-study, revision and assessment questions with suggested answers

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SELF-STUDY

Answer at least five questions of your choice for each section justifying them and explaining why the answer is correct. (five questions of each section are mandatory)

4.1. District Cooling Systems and Heat Pumps

1. Define the basic principles of heating and cooling and provide examples of their applications.
2. Explain how heat pumps work and differentiate them from chillers.
3. What is meant by simultaneous heating and cooling (SHC) in district networks? Provide examples.
4. Describe the role of heat pumps in SHC and how inverter-controlled compressors affect output.
5. Explain the benefits and challenges of integrating SHC systems in district networks.
6. What is the difference between reversible and non-reversible heat pumps?
7. Identify key components in a simultaneous heating and cooling (SHC) system.
8. Discuss the advantages of SHC systems in terms of energy, economy, and flexibility.
9. Explain the challenges associated with designing SHC systems.
10. Provide examples of typical SHC applications in mixed-use urban or industrial areas.
11. What future trends are expected in SHC systems and district cooling networks?

4.2. Cooling Technologies and Absorption Systems

1. Define what a chiller is and explain its operational principle.
2. Differentiate between air-cooled and water-cooled chillers. Include their advantages and disadvantages.
3. Draw a basic diagram of a water-cooled chiller system and explain the flow of heat.
4. What are the typical efficiency metrics used for chillers? Define EER and SEER.
5. Explain how cooling towers operate and their role in water-cooled systems.
6. List the main applications of chillers in industry and buildings.
7. Describe the operation of an absorption refrigeration machine.
8. Compare vapor compression and vapor absorption refrigeration technologies.
9. Identify the main components in an absorption refrigeration system and explain their function.
10. Distinguish between the $\text{NH}_3\text{-H}_2\text{O}$ and $\text{LiBr-H}_2\text{O}$ absorption systems. Where is each used?
11. What are the advantages and disadvantages of absorption systems?
12. Define COP for absorption machines and explain how it differs from compression systems.

4.3. Refrigerants

1. Define what a refrigerant is and distinguish between primary and secondary refrigerants.
2. Explain the classification of refrigerants into pure, azeotropic, and zeotropic.
3. Describe the four generations of refrigerants and their evolution over time.
4. Compare HFCs, HFOs, and natural refrigerants in terms of environmental impact.
5. What is GWP? Why is it important when selecting refrigerants?
6. Define TEWI and LCCP. How do they help in evaluating environmental performance?
7. What is TFA and how is it formed from certain refrigerants? Why is it a concern?
8. Define PFAS and discuss its relevance in the context of refrigerants.
9. List the main natural refrigerants and explain the pros and cons of each.
10. Describe the safety classification of refrigerants under ASHRAE 34.



11. Explain how refrigerant properties such as viscosity, thermal conductivity, and boiling point affect system design.

4.4. Heat Pumps, Configurations, and Integration

1. What factors must be considered when selecting a heat pump for district heating or cooling applications?
2. Explain how operational temperatures affect the COP of a heat pump.
3. Describe different configurations of heat pump integration into DHN and DCN.
4. Provide examples of simultaneous heating and cooling applications with temperature ranges and technologies.
5. Discuss the influence of temperature difference between heat source and sink on energy efficiency.
6. How does integration with TES or CHP systems affect heat pump performance?
7. Compare environmental impacts of heat pumps vs. fossil fuel boilers.
8. How can waste heat and renewable heat be used to enhance the efficiency of heat pumps?
9. Describe the benefits and limitations of using ejectors in combination with heat pumps.
10. Explain the concept of combined COP and its importance in simultaneous heating and cooling.

4.5. Thermal Energy Storage and Hybrid Systems

1. Define thermal energy storage (TES) and explain its role in district cooling.
2. Differentiate between sensible heat, latent heat, and thermochemical TES systems.
3. What are the advantages and disadvantages of latent heat storage systems?
4. Explain how TES can contribute to peak load shifting in cooling systems.
5. Describe the integration of TES tanks into district cooling networks.
6. List key applications where TES is especially beneficial.
7. What parameters define the recharge and discharge efficiency of TES systems?
8. Explain how combining vapor compression and absorption systems can increase overall system efficiency.
9. Describe the concept of cascade condenser connection between mechanical and absorption systems.
10. What are the main benefits and challenges of hybrid refrigeration systems?



ASSESSMENT

4.1. District Cooling Systems and Heat Pumps

Quiz (0.8 minutes)

True or False: Heat pumps can operate for both heating and cooling at the same time.

What does SHC stand for in district energy systems?

Which of the following is not an advantage of SHC systems?

- a) Higher energy efficiency
- b) Increased fossil fuel use
- c) Lower carbon emissions
- d) Infrastructure sharing

Project Presentation (2 minutes)

Title: Simultaneous Heating and Cooling in Mixed-Use Buildings

Guidelines:

1. Analyze a hypothetical urban building block with offices and housing.
2. Design an SHC solution using heat pumps.

Final Evaluation Task (Technical Report + analysis) (2 minutes)

Task: Given demand curves for heating and cooling in a hospital, design a district SHC system:

Content:

1. Choose suitable heat pump configuration.
2. Analyze temperature levels and COP.

4.2. Cooling Technologies and Absorption Systems

Quiz (0.8 minutes)

What is the main difference between water-cooled and air-cooled chillers?

What type of chiller is better for large-scale industrial applications?

What does SEER measure?

Absorption systems use _____ instead of electricity for driving the cycle.

Project Presentation (2 minutes)

Title: Cooling Strategy for a Data Center

Guidelines:

1. Compare use of vapor compression chillers vs. absorption chillers.

Final Evaluation Task (Design task) (2 minutes)

Task: Design and compare two cooling systems of your choice for a university building:



4.3. Refrigerants

Quiz

What environmental metric combines direct and indirect emissions?

True or False: Zeotropic mixtures boil and condense at constant temperatures.

Project Presentation (2 minutes)

Title: Refrigerant Selection for a District Cooling System

Guidelines:

1. Analyze refrigerant options (HFCs, HFOs, naturals).
2. Compare environmental impacts (GWP, TEWI).
3. Address safety and regulations (ASHRAE classification).

Final Evaluation Task (Comparative assessment) (2 minutes)

Task: Create a comparative life cycle analysis (LCA) between an HFO-based chiller system and a natural refrigerant (e.g. CO₂) system.

4.4. Heat Pump Integration and Configurations

Quiz

What does COP stand for?

What happens to COP when the temperature gap between sink and source increases?

Name one renewable source that can be used to support a heat pump.

Project Presentation (2 minutes)

Title: Smart Integration of Heat Pumps in an Industrial Area

Guidelines:

- Propose a layout connecting heat pumps to DHN/DCN in a mixed industrial-residential area.

Final Evaluation Task (Analysis task) (2 minutes)

Task: Analyse energy performance of three heat pump configurations of your choice.

4.5. Thermal Energy Storage and Hybrid Systems

Quiz

What are the three types of TES systems?

What does latent heat storage rely on?

Which parameter does SEER consider that EER does not?

Project Presentation (2 minutes)

Title: Peak Load Management with TES in a District Cooling Plant

Guidelines:

1. Analyse cooling demand variation over a 24-hour cycle.



2. Design a TES strategy using chilled water and ice tanks.
3. Simulate peak shaving and tariff savings.
4. Evaluate environmental and economic impact.

Final Evaluation Task (Design and analysis) (2 minutes)

Task: Design and analyse a hybrid system combining vapor compression chillers and absorption refrigeration.



SOLUTIONS OF ASSESSMENT

4.1. District Cooling Systems and Heat Pumps

Quiz (0.8 minutes)

True or False: Heat pumps can operate for both heating and cooling at the same time. **True**

What does SHC stand for in district energy systems?

Simultaneous Heating and Cooling

Which of the following is not an advantage of SHC systems?

- a) Higher energy efficiency
- b) Increased fossil fuel use**
- c) Lower carbon emissions
- d) Infrastructure sharing

4.2. Cooling Technologies and Absorption Systems

Quiz (0.8 minutes)

What is the main difference between water-cooled and air-cooled chillers?

Water-cooled chillers reject heat through a water loop to a cooling tower or fluid cooler, achieving higher thermodynamic efficiency. Air-cooled chillers reject heat directly to the ambient air using mechanical fans, which makes them simpler to install but less efficient during high ambient temperatures.

What type of chiller is better for large-scale industrial applications?

Water-cooled centrifugal chillers, due to their massive cooling capacity and excellent efficiency at part-load conditions.

What does SEER measure?

Seasonal Energy Efficiency Ratio. It measures the cooling efficiency of a system over an entire season, accounting for realistic outdoor temperature fluctuations and part-load operations.

Absorption systems use **thermal energy** instead of electricity for driving the cycle.

4.3. Refrigerants

Quiz (0.8 minutes)

What environmental metric combines direct and indirect emissions?

TEWI

True or False: Zeotropic mixtures boil and condense at constant temperatures. **False**

4.4. Heat Pump Integration and Configurations

Quiz (0.8 minutes)

What does COP stand for?



Coefficient of Performance

What happens to COP when the temperature gap between sink and source increases?

It decreases. A wider temperature gap requires the compressor to perform more mechanical work to move the same amount of heat.

Name one renewable source that can be used to support a heat pump.

Geothermal energy (ground-source), aérothermal energy (ambient air), or solar thermal energy.

4.5. Thermal Energy Storage and Hybrid Systems

Quiz (0.8 minutes)

What are the three types of TES systems?

Sensible heat storage (e.g., water tanks, underground aquifers).

Latent heat storage (e.g., ice storage, phase-change materials).

Thermochemical heat storage (e.g., chemical bonds, adsorption processes).

What does latent heat storage rely on?

It relies on the phase change of a medium (Phase Change Materials - PCMs), such as the transition from solid to liquid (ice to water), which absorbs or releases large quantities of thermal energy at a constant temperature.

Which parameter does SEER consider that EER does not?

Seasonal variations in outdoor temperatures and the efficiency impacts of running at part-load conditions throughout the year (whereas EER is calculated at a single, fixed peak temperature and full load).