PUMP-UP

Open Educational Resources

Learning Unit 1

Essentials of Heat Pump Technologies

Upskilling HVAC technicians on heat pump

technologies for green energy transition

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1 Contents

1 INTRODUCTION

1.1 Lesson 1. Introduction to Heat Pumps and types.

Heat pump technologies represent a highly efficient and versatile solution for heating and cooling buildings. These systems work by transferring heat from one location to another, rather than generating heat directly, making them significantly more energy-efficient than traditional heating methods. Heat pumps can extract thermal energy from various sources, including the air, ground, or water, and can be used for both space heating and cooling, as well as water heating. The technology behind heat pumps is based on the second law of thermodynamics and utilizes a refrigeration cycle to move heat against its natural flow from cold to hot areas. With their ability to provide both heating and cooling, heat pumps are a key technology in the transition to more sustainable and energy-efficient solutions for residential, commercial, and industrial applications.

1.2 Lesson 2. Fundamental Working Principles of HP systems (the HP cycle)

Heat pumps operate on several fundamental principles based on thermodynamics and heat transfer. At their core, heat pumps utilize the vapor-compression refrigeration cycle to move thermal energy from a low-temperature source to a high-temperature sink. This process relies on the behavior of a refrigerant as it changes phases between liquid and gas states. The cycle consists of four main components: an evaporator, a compressor, a condenser, and an expansion valve. As the refrigerant circulates through these components, it absorbs heat from the source, is compressed to raise its temperature, releases heat to the sink, and then expands to lower its pressure and temperature. The efficiency of a heat pump is measured by its coefficient of performance (COP), which is the ratio of heat transferred to work input. Importantly, heat pumps can operate in reverse mode, allowing them to provide both heating and cooling functions. This versatility, combined with their ability to extract heat from various sources such as air, ground, or water, makes heat pumps a highly efficient and flexible technology for thermal management in buildings and industrial processes.

1.3 Lesson 3. Principles of HP selection and System Design

Heat pump selection and design principles are essential to ensure optimum performance, energy efficiency and long-term comfort. The process begins with an accurate calculation of the heating and cooling loads of the space, considering factors such as size, insulation levels, local climate and heat sources. Unproper sizing with undersized units will struggle to meet demand, while oversized units will lead to inefficiency. Selection should consider the available heat source (air, ground or water) and climate considerations. Energy efficiency ratings such as *Seasonal Energy Efficiency Ratio (SEER)* for cooling and *Heating Seasonal Performance Factor (HSPF)* for heating should be analysed. In addition, the design should consider the characteristics of the building, the heat distribution system and the potential for zoning.

2 LECTURE NOTES

2.1 Lesson 1. Introduction to Heat Pumps and types.

Heat pump technologies encompass a range of systems that transfer heat from one location to another for heating, cooling, and water heating purposes. Here are the main types of heat pump technologies:

2.1.1 Air-Source Heat Pumps (ASHPs)

Most common type of heat pumps, Air-Source Heat Pumps (ASHPs) are highly efficient heating and cooling systems that extract heat from the outside air and transfer it indoors, or vice versa for cooling. These versatile devices operate on the principle of vapor compression, using a refrigerant to absorb and release heat as it cycles through the system. ASHPs typically achieve a Coefficient of Performance (COP) between 3 and 4, meaning they can produce 3 to 4 units of heat for every unit of electricity consumed. This high efficiency makes them an attractive option for reducing energy costs and carbon emissions in residential and commercial buildings. ASHPs are particularly effective in moderate climates but can also function in colder temperatures, with some models designed specifically for cold climates. As of 2023, ASHPs account for about 10% of building heating worldwide and are considered a key technology in phasing out gas boilers to reduce greenhouse gas emissions.

Two main subtypes:

- Air-to-air: Transfer heat between indoor and outdoor air.
- Air-to-water: Heat water for radiators or underfloor heating.

Figure 1. Air-Source Heat Pumps (ASHPs)

2.1.2 Ground-Source Heat Pumps (GSHPs)

Ground-Source Heat Pumps (GSHPs), also known as geothermal heat pumps, are highly efficient heating and cooling systems that utilize the relatively constant temperature of the earth to transfer heat. These systems consist of a heat pump unit connected to a series of underground pipes filled with a heat-transfer fluid. GSHPs can achieve higher efficiency ratings compared to air-source heat pumps, with coefficients of performance (COP) typically ranging from 3 to 6. This means they can produce 3 to 6 units of heat for every unit of electricity consumed. GSHPs are versatile, providing both heating and cooling for buildings, and can be used in various applications, from residential homes to large commercial structures. While they have higher upfront installation costs due to the need for ground excavation or drilling, GSHPs offer significant long-term energy savings and reduced carbon emissions, making them an attractive option for sustainable building design.

2.1.3 Water-Source Heat Pumps

Water-Source Heat Pumps (WSHPs) are highly efficient heating and cooling systems that extract thermal energy from water bodies such as lakes, rivers, or groundwater aquifers. These systems typically consist of a heat pump unit connected to a network of submerged pipes or a direct water intake. WSHPs can achieve higher efficiency ratings compared to air-source heat pumps, with coefficients of performance (COP) often ranging from 3 to 5, meaning they can produce 3 to 5 units of heat for every unit of electricity consumed. The relatively stable temperature of water sources throughout the year allows for consistent performance in both heating and cooling modes. WSHPs can be designed as either closed-loop systems, where a heat transfer fluid circulates through submerged pipes, or open-loop systems, which directly use the water source. While installation costs can be higher due to the need for water access and specialized equipment, WSHPs offer significant long-term energy savings and reduced carbon emissions, making them an attractive option for buildings located near suitable water sources.

2.1.4 Absorption Heat Pumps

Absorption Heat Pumps are thermally-driven systems that use heat as their primary energy source instead of electricity. These pumps typically employ a refrigerant-absorbent pair, such as ammonia-water or lithium bromide-water, to facilitate the heat transfer process. Unlike conventional electric heat pumps, absorption heat pumps use thermal energy to drive the refrigeration cycle, making them particularly suitable in applications where waste heat or low-cost thermal energy is available. They operate on a principle similar to vapor compression systems but replace the mechanical compressor with a thermal compressor consisting of an absorber, generator, and solution pump. Absorption heat pumps can achieve coefficients of performance (COP) ranging from 0,8 to 1,6 for cooling and 1,2 to 2,5 for heating. While they typically have lower efficiency compared to electric heat pumps, absorption systems can be advantageous in situations where electricity is expensive or unavailable, or where there's an abundance of waste heat that can be utilized.

Can be powered by natural gas, solar-heated water, or geothermal-heated water.

Less common but useful in areas with limited electricity.

2.1.5 Advanced Technologies

Recent innovations are significantly improving heat pump performance and efficiency. variable-speed compressors allow heat pumps to adjust their output to match heating or cooling demands more precisely, reducing energy waste. Advanced scroll compressors offer quieter operation and improved durability. The development of more environmentally friendly refrigerants, such as R-32, is enhancing efficiency while reducing environmental impact. Smart controls and Wi-Fi connectivity enable better system management and optimization based on usage patterns and weather forecasts. Some heat pumps now incorporate desuperheaters to recover waste heat for water heating. Cold climate heat pumps with enhanced vapor injection technology can maintain high efficiency even in sub-zero temperatures. These advancements are collectively pushing the boundaries of heat pump performance, with some systems achieving coefficients of performance (COP) above 5, meaning they produce more than five units of heat for every unit of electricity consumed.

As a summary, several innovations are improving heat pump performance:

- Variable-speed compressors: Allow for more efficient operation.
- Scroll compressors: Quieter and more durable than traditional piston compressors.
- Desuperheaters: Recover waste heat for water heating.
- Improved refrigerants: Better performance and lower environmental impact.

Heat pumps are considered a key technology for reducing carbon emissions from heating and cooling, due to their high efficiency and ability to use electricity from renewable sources.

2.2 Lesson 2. Fundamental Working Principles of HP systems (the HP cycle).

Heat pumps operate on the principle of heat transfer, utilizing a refrigerant to absorb heat from one location and release it in another. In heating mode, they extract heat from the outside air, even in cold conditions, and transfer it indoors. For cooling, the process is reversed, with heat being absorbed from inside the home and released outdoors.

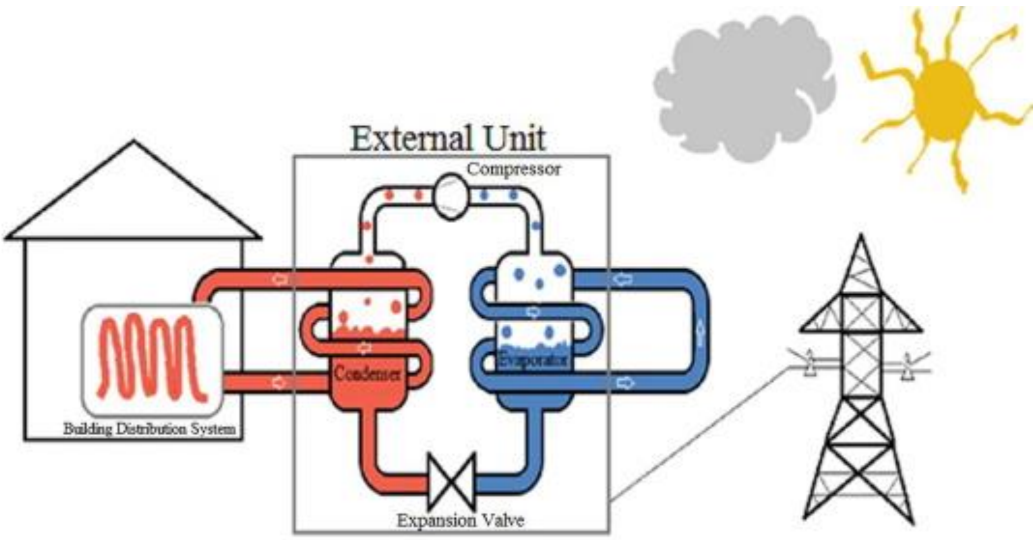

Figure 2. Heat Pump working principle

2.2.1 Components of Heat Pumps

Heat pumps are complex systems composed of several key components working in tandem to provide efficient heating and cooling. The main components include:

- Compressor: The core of the heat pump, pressurizing and circulating the refrigerant to facilitate heat transfer.
- Evaporator: Absorbs heat from the environment, either from outside air (in heating mode) or indoor air (in cooling mode).

- Condenser: Releases heat, expelling it outdoors in cooling mode or indoors in heating mode.
- Expansion Valve: Regulates refrigerant flow and pressure, preparing it for heat absorption in the evaporator coil.
- Reversing Valve: Enables switching between heating and cooling modes by reversing refrigerant flow.
- Refrigerant: The substance circulating through the system, changing states to absorb and release heat.
- Fans: Present in both indoor and outdoor units, moving air over coils to facilitate heat exchange.
- Indoor Unit (Air Handler): Houses the indoor coil and fan for distributing conditioned air.
- Outdoor Unit: Contains the compressor, outdoor coil, and fans for heat exchange with the surrounding air.
- Control Board: Manages overall system operations and ensures efficient performance.

2.2.1.1 Compressor

The compressor has the function of raising the pressure of the refrigerant vapour from the suction pressure to the highest discharge pressure. In short, the compressor's mission is to suck in the gas that comes from the evaporator and transport it to the condenser by increasing its pressure and temperature.

Upon entering the compressor, the fluid is in a gaseous state with low temperature and pressure. In the compressor, the gas is compressed, decreasing its volume and increasing the pressure and temperature, so that at the exit, the fluid is in a gaseous state of high temperature and pressure, transporting the thermal load of the acclimatized medium and the compression energy.

Compressors can be classified into two large groups: volumetric or positive displacement compressors and centrifugal compressors. However, as for the motor-compressor coupling, these can be classified into:

- ✓ *Hermetic*: Both the motor and the compressor are within the same enclosure that is inaccessible, and they share a shaft, which allows greater recovery of the heat generated by the motor. This type of compressor is focused on small critical load equipment, as is the case of the system under study.

Figure 3. Hermetic compressor used in the Heat Pump studied

- ✓ *Semi-hermetic*: Like the hermetic, the motor and the compressor share a shaft, however in this case the compressor is accessible, which allows the repair of its parts. In addition, part of the heat generated in the engine is recovered in the coolant fluid, so the performance is higher than that of open engines.

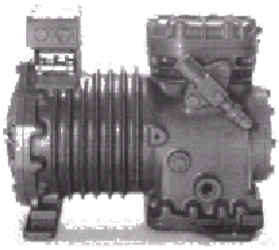

Figure 4. Example of a Semi-Hermetic Compressor

- ✓ *Open*: Motor and compressor are separate, they are independent. The axles are coupled in the assembly ensuring tightness in the passage of the axle.

Figure 5. Open Compressor Example

2.2.1.2 Heat Exchangers

Heat exchangers are important elements in the efficiency of heat pumps. Small temperature differences can be decisive in the energy efficiency of the system. The case of the heat pump analyzed is no exception. One of its main characteristics is that it is a reversible system, so the system's heat exchangers act both as a condenser and as an evaporator depending on the operating regime in which they operate. Thus, in the summer cycle, the internal exchanger will act as an evaporator and the external exchanger as a condenser, and vice versa during the winter cycle.

The *condenser* has the function of bringing the gases coming from the compressor into contact with a means to liquefy it. The air entering the condenser in a gaseous state of low temperature and pressure is heated and becomes a refrigerant in a liquid state, giving up all its energy to the condenser air, the sum of the energy it absorbed in the evaporator (thermal load of the medium) and that provided by the compressor. In the process, a fan is required to suck in the air from the outside, circulate it through the condenser and return it back to the outside, preventing its recirculation and sending the hot air into the atmosphere.

The *evaporator* is the place in the installation where the heat exchange between the refrigerant and the medium to be cooled takes place. The evaporator inlet air, a mixture of return air and ventilation, is cooled, dehumidified and transformed from liquid to gaseous. To do this, it is necessary to use a fan that sucks the air from the mixture, passes it through the evaporator and sends it to the medium to acclimatize, producing the effect of cooling the air.

Bearing in mind that the external exchanger is reversible, it should be noted that during the summer cycle, the evaporator sucks the air out of the fluid, cools it, dehumidifies it and releases it into the medium to be acclimatized. However, in winter, the evaporator breathes in the air from the outside, cools, dehumidifies, and returns it to the external environment.

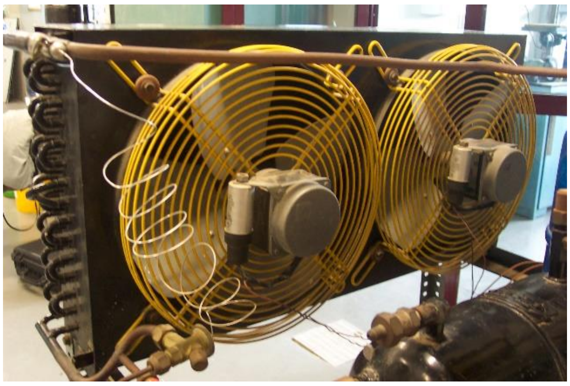

Figure 6. External Heat Exchanger

Figure 7. Internal heat exchanger

2.2.1.3 Expansion Devices

By means of this type of device, isoenthalpy pressure is reduced from condensation to evaporation pressure. Its function is to convert the refrigerant from high to low pressure, feeding the evaporator with the refrigerant fluid.

The system analysed has two expansion valves, which have a section that can be automatically varied so that superheating after evaporation remains constant and no liquid droplets enter the compressor.

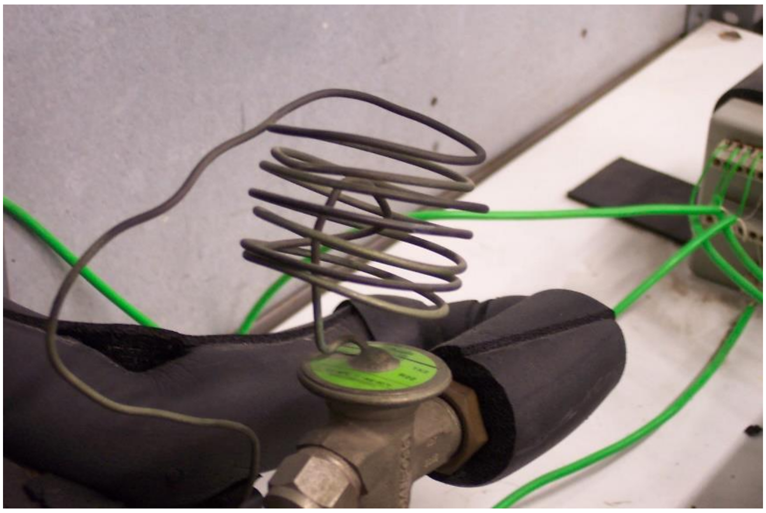

Figure 8. Expansion Valve

2.2.1.4 4-way valve

This type of valve has four connections connected to the suction and discharge of the compressor, the evaporator and the condenser, through which the circulation of the gas is modified according to the action of the coil. With the coil at rest, the compressor sucks the gases from the evaporator and compresses it to the condenser, and with the coil excited, the circuit is altered and the compressor draws in from the condenser and compresses onto the evaporator. Finally, disconnecting the coil returns the system to the normal circuit in its initial state.

Figure 9. 4-way valve

2.2.1.5 Deposits

The system analyzed also includes two tanks. One located after the condenser and before the compressor used to prevent the entry of impurities into it; and another located at the exit of the evaporator, used to accumulate the excess fluid.

Figure 10. Tank-Accumulator before the compressor

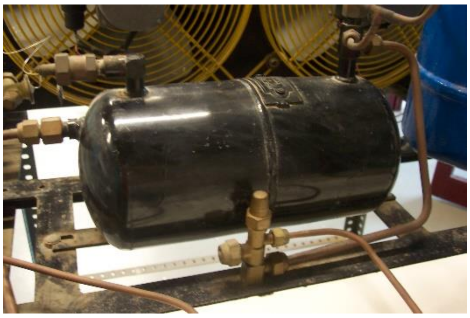

Figure 11. Reservoir for excess coolant

2.2.2 Working Modes

2.2.2.1 Winter Mode

In winter, the heat pump operates by circulating refrigerant to transfer heat from the outside air to the interior of the building. The process begins with very cold, low-pressure refrigerant absorbing heat from the outdoor air in the external heat exchanger, even when temperatures are below freezing. This refrigerant then flows to the air-source heat pump's compressor, where it is mechanically pressurized, causing it to heat up significantly. A reversing valve directs this hot refrigerant to an indoor heat exchanger, where it transfers its heat to the indoor air. As the refrigerant cools, it passes through an expansion device, which makes it very cold again. Now colder than the outdoor temperature, the refrigerant can once more absorb heat from the outside air, restarting the cycle. This continuous process efficiently extracts heat from the outdoor environment and transfers it indoors, providing warmth even in cold weather conditions.

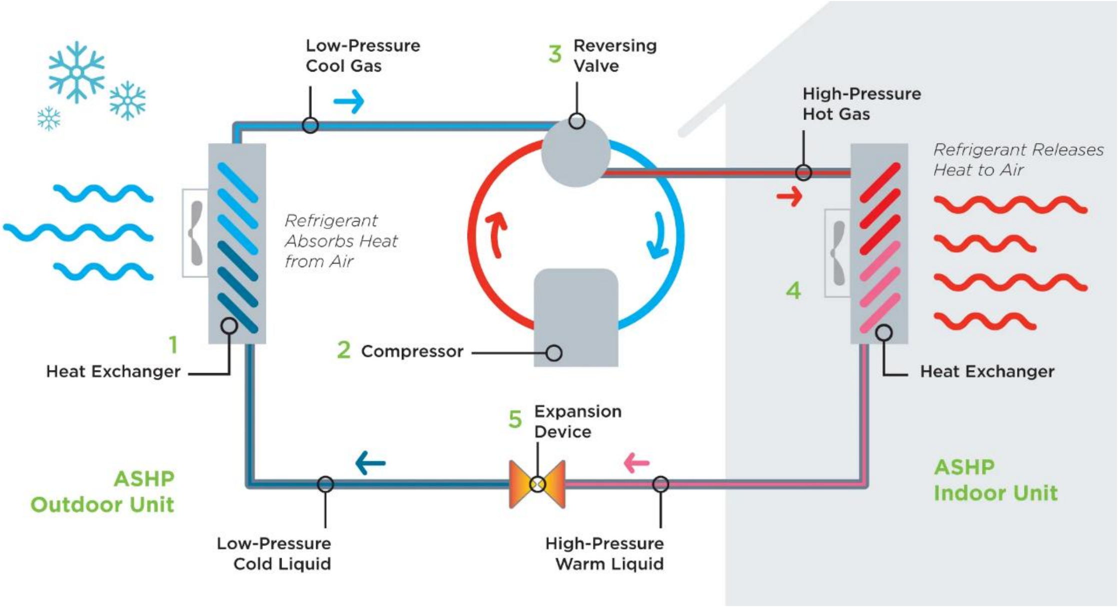

Figure 12. Principle of Operation in Cooling Mode of the Heat Pump

2.2.2.2 Heating Mode

In summer, the heat pump process is reversed for cooling. The refrigerant passes through an expansion device, becoming very cold. This cold refrigerant then absorbs heat from the indoor air as it flows through the indoor heat exchanger, effectively cooling the interior space. The now-warmed refrigerant is compressed, further increasing its temperature and pressure. A reversing valve then directs this hot refrigerant to the outdoor heat exchanger. Here, since the refrigerant is hotter than the outside air, it releases its heat to the environment. This cycle operates similarly to a conventional air conditioning system, efficiently transferring heat from inside the building to the outside, thereby cooling the indoor space.

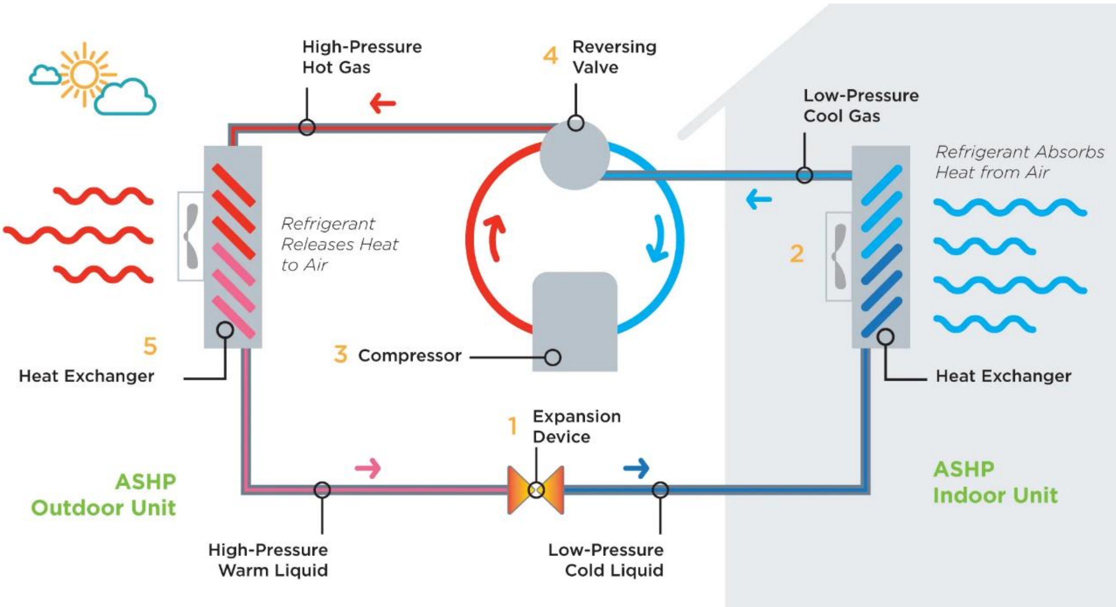

Figure 13. Principle of Operation in Heating Mode of the Heat Pump

2.3 Lesson 3. Principles of HP selection and System Design.

Heat pumps are versatile climate control systems that operate differently depending on the environmental conditions, adapting to provide efficient heating or cooling across various climatic zones. Their performance and efficiency are significantly influenced by the ambient temperature and humidity levels, leading to distinct operational characteristics in different climate types.

In moderate climates:

Heat pumps demonstrate superior efficiency, particularly when outdoor temperatures remain above 5-7°C (41-45°F).

They can achieve substantial energy savings, potentially reducing consumption by 30-40% compared to traditional heating and cooling systems.

The moderate temperature range allows for optimal heat exchange, maximizing the coefficient of performance (COP).

These climates often experience balanced heating and cooling needs, allowing year-round utilization of the heat pump's capabilities.

In warm climates:

Heat pumps primarily function as air conditioners during summer months, extracting heat from inside the home and releasing it outdoors.

They exhibit particularly high efficiency in regions characterized by mild winters and hot summers, where temperatures typically range between 0 and 35°C (32-95°F).

The cooling mode operation is highly effective, as the temperature differential between indoor and outdoor environments facilitates efficient heat transfer.

In these climates, heat pumps often provide an energy-efficient alternative to traditional air conditioning systems.

In cold climates:

The efficiency of heat pumps tends to decrease as outdoor temperatures drop below 0°C (32°F).

When temperatures plummet below -20°C (-4°F), maintaining efficient operation becomes increasingly challenging.

In very cold regions, heat pumps may require supplementary heating systems or the installation of more powerful, cold-climate-specific heat pump models.

Advanced cold-climate heat pumps utilize enhanced technology to maintain efficiency at lower temperatures, such as variable-speed compressors and improved defrost cycles.

General operation:

Heat pumps utilize a reversible refrigeration cycle to transfer heat between the interior and exterior of a building.

In heating mode, they extract heat from the outside air, ground, or water source, and transfer it indoors.

When cooling is required, the process is reversed, with heat being extracted from inside the building and released outside.

The system comprises key components such as the compressor, condenser, expansion valve, and evaporator, which work in tandem to facilitate the heat transfer process.

The efficiency of heat pumps is typically measured by the Coefficient of Performance (COP) for heating and the Energy Efficiency Ratio (EER) for cooling. These metrics are directly influenced by the ambient temperature, with performance generally improving as the temperature difference between the heat source and heat sink decreases.

Thus, while heat pumps demonstrate optimal efficiency in moderate climates, technological advancements have expanded their effective operational range. However, in extreme climates, particularly very cold regions, they may require adaptations or complementary systems to maintain efficiency and meet heating demands. The selection and design of a heat pump system should always consider the specific climatic conditions of the installation site to ensure optimal performance and energy efficiency.

Furthermore, Heat Pump selection and design is based on several key factors to ensure optimal performance, energy efficiency, and long-term comfort. The primary considerations include:

- Heating and cooling load calculation: Determine the required capacity in British Thermal Units (BTUs) based on the space size, insulation levels, local climate, and heat sources.
- Climate considerations: Select a heat pump suitable for the local climate, with higher Heating Seasonal Performance Factor (HSPF) ratings for colder regions.
- Energy efficiency ratings: Look for high Seasonal Energy Efficiency Ratio (SEER) for cooling and HSPF for heating.
- Heat source availability: Choose between air-source, ground-source (geothermal), or water-source heat pumps based on location, available space, and budget.
- Building characteristics: Consider the building's insulation, airtightness, and existing heating system.
- Heat distribution system: Design the distribution system (e.g., radiators, underfloor heating) to operate at low temperatures for increased efficiency.
- Proper sizing: Avoid oversizing or under sizing the heat pump, as both can lead to inefficiency and comfort issues.
- Zoning considerations: Evaluate the need for zoned heating and cooling for more precise temperature control.
- Brand and model selection: Research different brands and models, considering reliability, performance, and budget.

Considering these factors, it can be selected and designed a heat pump system that provides efficient heating and cooling while minimizing energy consumption and environmental impact.

3 QUESTIONS & ANSWERS

3.1 What is a heat pump?

A heat pump is a versatile and sustainable energy solution capable of providing heating, cooling, and hot water across residential, commercial, and industrial applications. By extracting thermal energy from diverse sources such as air, ground, and water, heat pumps efficiently transform this ambient energy into usable heating or cooling for buildings. Unlike traditional heating systems that generate heat through combustion, heat pumps transfer existing heat, making them exceptionally energy-efficient. This innovative technology enables significant energy savings and reduces carbon emissions, positioning heat pumps as a key component in sustainable building climate control strategies. Their ability to operate in multiple modes and extract renewable energy from natural sources makes them an environmentally friendly alternative to conventional heating and cooling systems, offering both economic and ecological advantages.

3.2 Is a Heat Pump cost-effective?

The cost-effectiveness of heat pumps is influenced by various factors including climate, local fuel types, and electricity costs. They are most economical in moderate climates with balanced heating and cooling needs, offering up to three times more heat energy output than electrical energy input. Their efficiency makes them particularly attractive in areas with lower electricity costs compared to gas. However, the overall cost-effectiveness should be evaluated by considering installation and operational costs alongside potential long-term savings. Climate plays a crucial role; in extreme climates, the efficiency of heat pumps may decrease, potentially reducing their cost-effectiveness.

3.3 Are heat pumps reliable in comparison to a gas boiler?

Heat pumps have proven to be highly reliable and remarkably efficient heating solutions. According to the International Energy Agency, they are three to five times more efficient than traditional gas boilers. This superior efficiency is due to their ability to extract heat from air, water, or ground sources, rather than generating heat through combustion. Currently, about 20 million heat pumps are in use across Europe, with this number expected to grow significantly as countries strive to achieve carbon neutrality by 2050. Heat pumps operate on a refrigerant cycle that allows for continuous energy capture and transfer, providing heating, cooling, and hot water for various applications, from small residential units to large industrial installations. While the technology may seem cutting-edge, the underlying principle dates back to the 1850s, and heat pumps have been in operation in various forms for decades, demonstrating their long-standing reliability and effectiveness.

3.4 How long does a Heat Pump last?

The lifespan of a heat pump typically ranges from 10 to 20 years, influenced by factors such as unit quality, maintenance practices, and operational climate. Regular upkeep, including annual servicing and timely repairs, can significantly extend a heat pump's longevity. While the main unit may function for up to two decades, it's important to note that individual components like the compressor or fan might require replacement earlier. The durability of a heat pump is thus a combination of its overall robustness and the ongoing care it receives, with proper maintenance playing a crucial role in maximizing its operational life and efficiency.

3.5 Do Heat Pumps work in cold weather?

Heat pumps can indeed function in cold weather, though their efficiency tends to decline as outdoor temperatures drop. This decrease in performance is due to the reduced amount of heat available in colder air for the heat pump to extract. In extremely cold climates, a supplementary heat source may be necessary to maintain comfort. However, certain types of heat pumps, such as geothermal systems, maintain better efficiency in cold weather by extracting heat from the ground, which maintains a more stable temperature than air. Despite these challenges, advancements in heat pump technology have improved their cold weather performance, making them viable options for heating in many colder regions, albeit with potential adjustments or supplementary systems in place for extreme conditions.

3.6 How environmentally friendly are heat pumps?

Heat pumps harness most of their energy directly from surrounding natural sources like air, water, and ground, making them an inherently clean and renewable technology. By utilizing a small amount of electricity as driving energy, these systems efficiently transform ambient thermal energy into heating, cooling, and hot water. This unique operational mechanism allows heat pumps to achieve remarkable energy efficiency, typically generating three to five times more energy than they consume. The synergy between heat pumps and solar panels represents an ideal renewable energy combination, as solar-generated electricity can power the heat pump's electrical components while the heat pump extracts renewable thermal energy from the environment. This integrated approach not only reduces carbon emissions but also maximizes sustainable energy utilization, offering an environmentally friendly alternative to traditional heating and cooling systems.

3.7 Are heat pumps expensive?

Heat pumps currently present a higher initial investment compared to fossil-based heating solutions, with average upfront costs ranging from two to four times that of gas boilers. However, this cost differential is mitigated over the heat pump's lifespan due to its superior energy efficiency, which is three to five times greater than gas boilers. According to a recent International Energy Agency (IEA) analysis, this efficiency could translate to annual energy bill savings exceeding 800 Eur. To further incentivize heat pump adoption, the European Heat Pump Association (EHPA) advocates for electricity prices to be no more than double that of gas and supports the implementation of a carbon price. Additionally, EHPA emphasizes the need for policy instruments to protect consumers from electricity price volatility, thereby encouraging the transition from fossil fuels to clean heating solutions. For a comprehensive overview of strategies to accelerate heat pump deployment, EHPA recommends referring to their EU Heat Pump Accelerator document, which outlines key measures deemed essential for expediting the widespread adoption of this technology.

3.8 Do heat pumps work when it's freezing outside?

Heat pumps demonstrate remarkable efficiency even in sub-zero temperatures, leveraging the substantial energy present in air or water that may feel cold to human touch. A recent study confirms their viability in regions with minimum temperatures above -10°C, encompassing all European countries. Air-source heat pumps transfer energy from outdoor air to indoor spaces for heating, reversing this process for cooling in summer. Ground-source heat pumps, alternatively, exchange heat between homes and the ground, benefiting from the earth's consistent temperature year-round. The technology's effectiveness in cold climates is evidenced by its widespread adoption in Scandinavia, where heat pumps satisfy 60% of

Norway's total building heating needs and over 40% in Finland and Sweden. These three nations lead globally in heat pump installations per capita, underscoring the technology's suitability and efficiency in even the most challenging cold-weather environments.

3.9 Do heat pumps also provide cooling?

Heat pumps offer dual functionality for both heating and cooling. Operating on a reversible principle, these systems absorb heat from the cold external air and transfer it indoors during winter months, while in summer, they extract heat from warm indoor air and expel it outside, effectively cooling the interior. This mechanism mirrors that of refrigerators, which employ the same heat pump principle to maintain cool temperatures. The versatility of heat pumps provides significant advantages for home and business owners, eliminating the need for separate heating and cooling equipment. This consolidation of functions not only results in space savings but also offers considerable benefits in terms of time, energy efficiency, and cost-effectiveness, making heat pumps an increasingly popular choice for year-round climate control in various settings.

3.10 I live in an apartment, can I still install a heat pump?

Heat pump installation in apartments is indeed possible, though it requires careful consideration of several factors. For air source heat pumps, options include installation on balconies, gardens, or external walls, with portable units serving as an alternative for single-room heating and cooling. Ground source heat pumps are feasible if the building has sufficient outdoor space for a shared system, allowing individual indoor units in each apartment connected to a common ground loop. Ductless heat pumps are often more suitable for apartments due to their easier installation. However, it's crucial to obtain permission from building management or owners before proceeding. The feasibility of installation depends on the apartment's specific layout, available outdoor space, and existing infrastructure. To ensure the most appropriate solution, it's advisable to consult with multiple contractors and compare quotes, taking into account the unique characteristics of your apartment and building.

3.11 Do I need to do renovation and/or installation work before installing a heat pump in my building?

The installation process for a heat pump depends on various factors, including the building's energy efficiency and the specific type and size of the heat pump chosen. Improving your home's insulation and sealing air leaks is an essential first step to enhance overall heating system efficiency and reduce energy costs. Typically, heat pumps require connection to the home's electrical system for power and, if necessary, to the existing air duct system for air distribution. Air source heat pumps are generally easier to install, while ground source (geothermal) heat pumps involve the additional step of installing underground pipes. Selecting an appropriately sized heat pump is crucial for optimal performance and efficiency. To ensure the best solution for your specific needs and building type, it's recommended to consult with specialized engineers and technicians who can provide expert guidance and tailored recommendations.

3.12 Can heat pumps be installed in buildings of historical interest?

Heat pumps are versatile solutions suitable for various building types, provided they are compatible with existing heating or cooling systems. However, their installation in listed or historically significant buildings may be subject to specific visual and structural regulations. Implementing a heat pump should always be a well-considered process, adhering to local rules and guidelines. Despite potential restrictions, heat pumps offer significant benefits in cost savings and energy efficiency, making them an attractive option for improving the environmental performance of historically and culturally important buildings. For those seeking real-world examples, the successful replacement of gas heating with heat pumps in the historic Bath Abbey in the UK demonstrates their potential in heritage settings. Additionally, a recent study by Historic England provides valuable insights into the application of heat pumps in heritage buildings, offering further evidence of their suitability and benefits in preserving culturally significant structures while enhancing their environmental sustainability.

3.13 Can I have a heat pump if drilling is not possible where I live?

Heat pump installation is indeed feasible with multiple flexible options that do not necessarily require invasive structural modifications. Several heat pump types can be installed without drilling holes into walls or floors, offering versatile placement alternatives such as exterior mounting or garden installation. These systems can be seamlessly connected to existing ductwork, provided there is sufficient air supply for optimal performance. The key consideration is ensuring proper air circulation and selecting a heat pump model compatible with your home's current infrastructure. This approach allows homeowners to upgrade their heating and cooling systems with minimal disruption to the existing building structure, making heat pump adoption more accessible and convenient.

3.14 Can heat pumps be used in industrial and manufacturing processes?

In the industrial sector, heat accounts for over 60% of energy consumption, making industrial heat pumps a crucial technology for producing renewable energy and recovering waste heat, aligning with the EU's climate and energy objectives. With 37% of industrial processes requiring temperatures below 200°C, heat pumps are well-suited for these applications. The recent surge in natural gas prices has prompted more European businesses to adopt heat pumps, enabling them to reduce their carbon footprint in compliance with EU directives while maintaining energy-efficient production. Electrification of manufacturing processes is already a reality in several industries, particularly in the paper, chemical, and food sectors. A notable example is Mars Wrigley Confectionery, the world's leading chocolate manufacturer, which has implemented heat pumps in its Dutch factory in Veghel, resulting in energy savings and reduced emissions in the production of its famous candies and chocolate bars. For more information on heat pump applications in the food and beverage industry, interested parties can explore the Heat Pump Stories and Resource Hub.

3.15 How many heat pumps are there in Europe today?

Around 24 million heat pumps are installed in Europe. Heat pump sales have been steadily increasing over the past decade, but started declining in 2023 – when they dropped by 6.5% in comparison to 2022.

This is due to sudden policy changes, including stop-and-go subsidies and support schemes for buying a heat pump, and high electricity prices combined with inflation and increased cost of living. This is why, EHPA advocates for more policy clarity in setting out measures to address barriers to heat pump growth.

These include correcting the electricity-to-gas price ratio, curbing subsidies to fossil fuel heating, providing clear information on the benefits of clean energy technologies to consumers as well as training more installers and specialised workers.

Heat pumps can be used efficiently to provide 100% of a building's heating, cooling and hot water demand. From the smallest units that power nearly zero-emissions homes to large industrial installations, heat pumps are fit for purpose in new and renovated buildings as well as in industrial applications and district heating systems.

4 PRACTICAL EXERCISES

4.1 Exercise 1. Calculating the Coefficient of Performance (COP) and Heat Transfer

A heat pump operates between an outdoor temperature of 7°C and an indoor temperature of 27°C. The system receives 2 kWh of electrical energy input. Calculate:

a) the theoretical COP for Heating
b) the Total Heat Delivered to the Hot Side

1. Convert Temperatures to Kelvin:

- T_{cold}=7∘C=280.15 K$T_{cold}=7\circ C=280.15K$
- T_{hot}=27∘C=300.15 K$T_{hot}=27^{\circ}C=300.15K$

2. Calculate the Theoretical COP for Heating:

$$COP_{heating} = \frac{T_{hot}}{T_{hot} - T_{cold}}$$

$$COP_{heating} = \frac{T_{hot}}{T_{hot} - T_{cold}} = \frac{300.15}{300.15 - 280.15} = 15.0$$

3. Determine the Total Heat Delivered to the Hot Side:

$$Q_{out} = COP_{heating} \; x \; Input \; Energy \; (W)$$

$$Q_{out} = 15.0 \; x \; 2 \; kWh = 30 \; kWh$$

4. Interpretation:

The heat pump can theoretically deliver **30 kWh of heat** to the indoor environment for every 2 kWh of electrical energy consumed under ideal (reversible) conditions.

4.2 Exercise 2. Calculate the EER of the heat pump

A heat pump in cooling mode removes 12,000 BTU/h of heat from a building and consumes 1,200 Watts of electrical power. Calculate the EER of the heat pump.

$$EER = \frac{Cooling \; Output \; (\frac{Btu}{h})}{Electrical \; Input \; (Watts)}$$

$$EER = \frac{12000 \; (\frac{Btu}{h})}{1200 \; (Watts)} = 10$$

This means the unit delivers 10 BTUs of cooling for every watt of electrical energy consumed.

5 MULTIPLE CHOICE QUESTIONS

5.1 What is the most common type of heat pump?

A) Geothermal heat pump

B) Water-source heat pump

C) Solar heat pump

D) Air-source heat pump (ASHP)

5.2 What is the function of the accumulator tank before the compressor?

A) Store refrigerant

B) Increase refrigerant pressure

C) Prevent impurities from entering the compressor

D) Cool the refrigerant

5.3 In winter mode, what does the heat pump do?

A) Extracts heat from the interior and sends it outside

B) Extracts heat from the outside air and transfers it indoors

C) Only cools the indoor air

D) Does not operate

5.4 What is the principle of operation of heat pumps?

A) Vapor compression

B) Thermal conduction

C) Thermal radiation

D) Convection

5.5 What type of valve is used to change the direction of refrigerant flow?

A) Expansion valve

B) Check valve

C) 4-way valve

D) Gate valve

5.6 What is used to reduce the pressure of the refrigerant in the system?

A) Compressor

B) Expansion valve

C) Condenser

D) Evaporator

5.7 What is the typical range of the Coefficient of Performance (COP) for air-source heat pumps?

A) 1 to 2

B) 5 to 6

C) 7 to 8

D) 3 to 4

5.8 What does the evaporator do in the heat pump cycle during winter?

A) Heats the indoor air

B) Absorbs heat from the outside air

C) Releases heat to the outside

D) Has no function in winter

5.9 What type of heat pump transfers heat between indoor and outdoor air?

A) Air-to-air heat pump

B) Water-to-water heat pump

C) Geothermal heat pump

D) Solar heat pump

5.10 What should be considered when designing a heat pump system?

A) Only the initial cost

B) The brand of the compressor

C) The specific climatic conditions of the installation site

D) The aesthetics of the system

5.11 What is the function of the condenser in the heat pump cycle?

A) Absorb heat

B) Release heat to the environment

C) Reduce pressure

D) Increase the temperature of the refrigerant

5.12 What type of heat pump is most suitable for cold climates?

A) Air-to-water heat pump

B) Solar heat pump

C) Air-source heat pump with high HSPF rating

D) Geothermal heat pump

5.13 What is used to dehumidify the air in the summer cycle?

A) Compressor

B) Condenser

C) Evaporator

D) Expansion valve

5.14 What should be avoided when selecting a heat pump?

A) Oversizing or undersizing the heat pump

B) Considering energy efficiency

C) Evaluating building characteristics

D) Researching different brands

5.15 What type of refrigerant is used in heat pumps?

A) Water

B) Specific vapor refrigerants

C) Oil

D) Air

5.16 What is the purpose of the 4-way valve?

A) Regulate pressure

B) Increase temperature

C) Change the direction of refrigerant flow

D) Cool the refrigerant

5.17 What is needed to calculate heating and cooling load?

A) Only the size of the space

B) Only the local climate

C) Only the type of heat pump

D) Size of the space, insulation levels, and local climate

5.18 What happens to the refrigerant as it passes through the expansion device?

A) Increases its pressure

B) Decreases its pressure

C) Heats up

D) Evaporates completely

5.19 What type of heat pump heats water for radiators?

A) Air-to-water heat pump

B) Air-to-air heat pump

C) Geothermal heat pump

D) Solar heat pump

5.20 What is a key benefit of heat pumps?

A) Only effective in warm climates

B) Reduce energy costs and carbon emissions

C) Noisy compared to other systems

D) Require more maintenance than traditional systems

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