Knowledge
Heating technology

Heat pump knowledge in 4 modules.

Understanding heat pumps.
Basic principles and main components.
Planning and measuring correctly. Sound.

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Module 1: Understanding heat pumps

Heat pumps are becoming increasingly important in everyday life. They heat buildings and tap water for sanitary use plus can provide cooling if required. The advantages of heat pumps over alternative or fossil heating systems shine through as long as they are ideally dimensioned, the entire system is optimally planned and the resident operates them correctly. If they are regularly maintained and run on green electricity – preferably from the customer's own PV system – heat pumps not only protect the environment, but also the customer's wallet.

Heat pumps are mainly used in residential buildings. Depending on the building's heat requirement, the heating output of a unit is between 5 and 20 kW. This practical guide deals with these types of applications. Heat pumps are the largest segment in the field of heating systems and the one with the highest growth rates. Larger systems for heat or for process cooling with a capacity in the megawatt range are used in trade and industry, shopping centres, hotels, office and administrative buildings or leisure facilities such as swimming pools or multi-purpose facilities. There are also pure hot-water heat pumps, which are used exclusively for sanitary purposes.

Heat pumps work according to the following principle: a hermetically sealed piping system, the refrigeration circuit, operates internally. In split systems, this is extended via copper pipes to the outdoor unit. A refrigerant circulates in the pipes. This is an operating fluid that absorbs heat at low temperature and low pressure and releases it again at higher temperature and higher pressure. These “compression refrigeration circuits” consist of four main components, which are briefly described in more detail below. The heat pump’s operating fluids are the refrigerant, the oil in the compressor and the brine or groundwater as the heat transfer medium. The choice of refrigerant depends on the available supply, ecological and safety aspects, subsidy options, but above all, the customer’s decision.


Outdoor unit for a heat pump

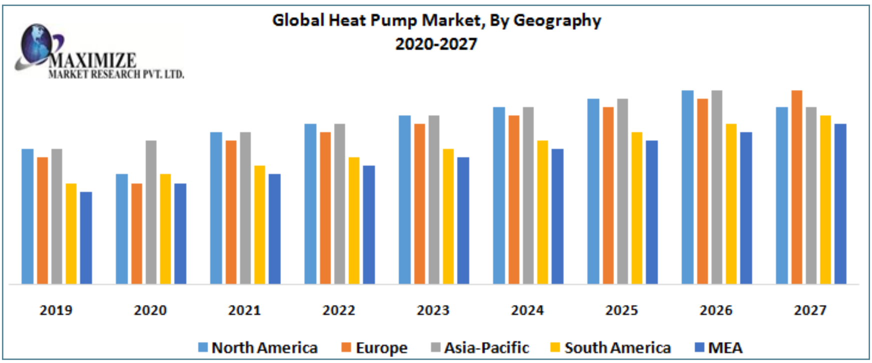
1. Heat source – heat sink – system boundary

Heat pumps take **heat** from different **sources** at a low temperature level and raise it to the required flow temperature. The following heat sources are used in private buildings:

- Air
- Ground (brine)
- Water

The most frequently used heat source with high rates of growth is air. Geothermal heat through the use of brine-filled probes, ground collectors or other techniques such as geothermal baskets is a distant second. Groundwater or well water is used very rarely.

Each heat source has its advantages and disadvantages, as described in the table below. However, air-to-water heat pumps seem to be gaining popularity in new-build single and multi-family homes, mainly because of their unlimited availability and lower investment costs. A similar trend is emerging for existing buildings. This is because air is the easiest heat source to exploit. What's more, new generations of modulating heat pumps now deliver acceptable seasonal performance factors for older buildings.



(Source: Maximize Market Research PVT. LTD.)

Heat source	Advantages	Disadvantages
Air	Available everywhere Easy to exploit Also suitable for renovations Low investment costs	Defrosting required Propagation of airborne sound Temperature fluctuations Excellent planning required
Ground/brine	High temperature (approx. 10°C) Constant temperature High yield (heat transfer) Excellent seasonal performance factors	Cumbersome to exploit High exploitation costs Space requirement for collectors Cooling of the soil
Water	Relatively constant temperature Relatively high temperature Possibility of passive cooling Good seasonal performance factors	High exploitation costs Not available everywhere Risk of well ageing Observe environmental regulations

(Source: ©NutzWort)

A **heat sink** is the point of transfer of thermal energy from the refrigeration circuit. In practice, this usually means a buffer storage tank. From this, the heat is transferred via a hydraulic system to radiators or underfloor, wall or ceiling heating systems in the rooms within the building. Alternatively, the indoor air can be heated using convectors, although this is rarely done in single and multi-family homes. Depending on the design, the hot water for use in the bathroom or kitchen can be connected to the same storage tank or a separate storage tank, or it can be produced by a pure hot-water heat pump.

The smaller the temperature difference between the heat source and the heat sink, and thus the lower the flow temperatures, the more efficiently a heat pump can work. Although this document does not examine heat sinks, the hydraulic supply of the building and heat exchangers (heat distribution and storage system) in further detail, these are all essential for the energy planning of a heat pump heating system. The system boundary is drawn around the heat pump and heat source system. The main focus is on air, as this is by far the most frequently used heat source.

2. Designs

There are two basic types of heat pumps:

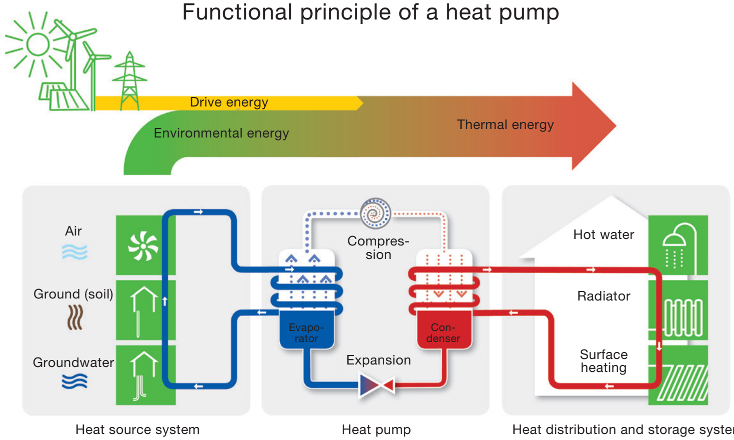
- Monobloc
- Split design

Monobloc

Monobloc means that the complete refrigerant circuit is located inside the heat pump. There are monobloc heat pumps for indoor and outdoor installation.

Placement in the **building** is practised for all known heat sources. In the case of air, two ducts for supply and exhaust air connect the heat pump to the environment. Short-circuiting of the air flows must be prevented. Likewise, cold bridges must be prevented through the use of proper duct insulation. Heat is extracted from the ground using probes, ground collectors or baskets. Connection to the inside of the heat pump occurs via a brine circuit sealed off from the environment. However, if water

Functional principle of a heat pump



Heat pump system (Source: BWP)

is used, the system is open. The groundwater is directly delivered to the heat pump by the suction well and returned via the absorption well.

Monobloc systems are often installed outdoors in single and multi-family homes when using air as a heat source. Here, the recovered heat enters the building and the buffer storage tank via a well-insulated brine circuit. This is why various manufacturers also refer to this variant as split technology with a split refrigerant circuit. There are various points to consider for the unit installed outside. It should be placed as close as possible to the indoor unit in order to keep heat losses via the brine pipes low. In winter, the evaporator can ice up and will therefore be defrosted regularly. The thawed water must be able to drain off and must not result in any hazardous areas of black ice under the heat pump. In addition, the sound emissions of the compressor must not cause any noise nuisance.

<ins>Advantages:</ins>
- No intervention in the refrigerant circuit necessary
- Low refrigerant fill level
- No sound emissions from the compressor when installed indoors

<ins>Disadvantages:</ins>
- Loss of efficiency due to the additional heat exchanger for the brine circuit
- Sound decoupling from the building and distribution network required for indoor installation
- With outdoor installation, icing up and noise emissions to neighbouring buildings possible

Split design

The split design with a closed refrigerant circuit is a special type of air-to-water heat pump. The compressor, evaporator and expansion valve are located in the outdoor unit. The condenser is inside, often combined with the hydraulics and small buffer tank in one housing. You can also get units that have only the evaporator and fan in the outdoor unit, with the rest of the refrigerant circuit in the indoor section. In both cases, however, the outdoor and indoor units must be connected with refrigerant-carrying pipes, which together make up the refrigeration circuit. The outdoor unit should be placed as close as possible to the indoor unit to keep the refrigerant fill level low. With regard to icing up and noise emissions, the same requirements apply as for a monobloc installed outside.

An expert technician requires refrigeration expertise for installing sealed connecting pipes between the outdoor and indoor unit, for evacuation and for filling as well as for commissioning.

Advantages:

- Closed refrigeration circuit inside and outside
- Better coefficient of performance of the heat pump
- All sound-emitting components mostly outside the building

Disadvantages:

- Larger fill quantity of refrigerant
- Expert knowledge on refrigeration required
- Noise emissions and icing up of the outdoor unit

3. Modes of operation

If a heat pump supplies all the heat and hot water for a building, it is referred to as a **monovalent** system. In this case, the drive energy used is exclusively electricity. A variant of this is **mono-energetic** operation. This is when, for example, the integrated heating element, as direct heating, becomes part of the heat requirement planning. This can be useful so that a heat pump works with the optimum coefficient of performance during the main operating hours but is unable to handle the peak load at very low heat source temperatures. Nevertheless, the system achieves a better seasonal performance factor over a year than with monovalent operation. A second possibility can be the short-term heating of the hot water tank for hygiene reasons. Determining which of these two modes of operation a type of heat pump provides and which is the right choice for a customer under consideration of CO_2 emissions and operating costs requires planning experience and, in the event of doubt, consultation with the manufacturer.

Another possibility is **bivalent** operation of a heat pump. This is where, in addition to electricity, another primary energy source covers the heat requirement. Thus, when a building is renovated, the existing heating system can continue to be operated in parallel with the new heat pump, for example for hot water preparation only or to compensate for peak loads. Another variant is the coupling of environmental energy to cover the heat requirement. Examples are the use of a solar thermal system, a pellet or log stove, or where the building is supplied via a cold district heating network as a heat source. These are often referred to as **hybrid** heat pump systems. In addition, there are hybrid units that combine a heat pump and gas boiler in the same housing. They are primarily intended for the renovation market and can differ depending whether electricity or gas is the more environmentally friendly or economical mode of operation.

If home owners also want their heat pump to provide cooling, there are solutions for this on the market too. These are **reversible** systems, i.e. systems that can be switched over. These place additional demands on the expert technician with regard to planning, especially when it comes to heat absorption in the building and control aspects. For example, surfaces such as floors, walls and ceilings can also be used for room cooling if they are designed correctly from the outset. Alternatively, convectors are good solutions for heating and cooling. The flow temperature in each room must be closely monitored. If it is too low, condensate and moisture can form in the building fabric. Reversible systems are also more expensive to invest in than pure heat pumps.

4. Practicable refrigerants

Theoretically, a variety of refrigerants can be used for refrigeration circuits. However, not everything on the market is suitable for a heat pump: thermodynamics, various safety requirements in the building, available equipment, environmental aspects and customer preferences all limit the choice for heating. Currently, there is no refrigerant that covers all requirements. This means that compromise is always necessary.

In recent years, natural refrigerants for heating have greatly increased in significance – and not just since stricter regulations have come into force worldwide (such as the EU F-Gas Regulation 517/2014). For heat pumps, these not only include carbon dioxide (R 744) but also hydrocarbon gases such as propene (R 1270) and in particular propane (R 290). These natural refrigerants are long-term and climate-friendly working media in terms of both thermodynamics and their carbon footprint. Moreover, they are not halogenated gases and are therefore not regulated by the F-Gas Regulation.

Due to the highly flammable nature of halogenated hydrocarbon gases (safety class A3), particular emphasis must be placed on safety during planning, installation and operation. However, since heat pumps usually only require small quantities of refrigerant and with split systems the refrigeration circuit can even be installed outside, the potential risk is mitigated, although it must still not be disregarded. Refrigeration expertise is a prerequisite for handling refrigerants such as propane.

Thus far, the synthetic refrigerant R410A has been the most widely used in heat pumps. However, its high GWP value of 2088, expected price hikes and potential supply bottlenecks make it an increasingly unattractive option for new heat pumps. As bridging technologies with significantly lower GWP values, heat pump manufacturers offer various solutions using synthetic transitional refrigerants. The market is divided into two parts: firstly, there are suppliers of Asian origin that offer R32 as a solution. Secondly, many manufacturers have included different refrigerant mixtures in their product range. With reduced global warming potential, these are either still non-flammable (safety class A1) or have very low GWP values and therefore belong to safety class A2L “mildly flammable”. Therefore, the specified safety requirements must also be followed for these substances.

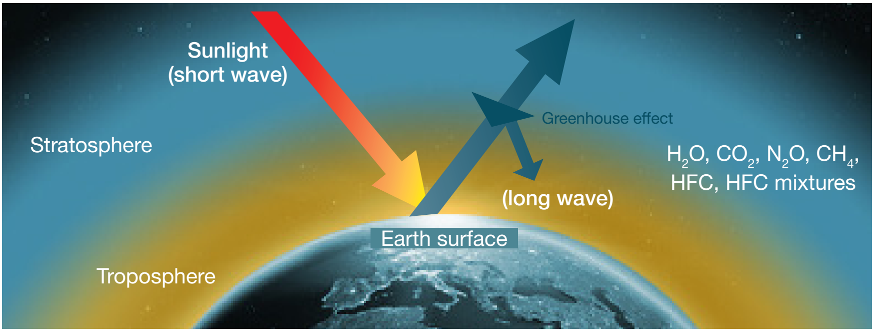
5. GWP value

The Global Warming Potential (GWP) is a numerical value which describes the impact of a substance on the atmosphere and thus its contribution to the greenhouse effect and to global warming. CO_2 with a numerical value of 1 is used as the baseline.

This value expresses how much 1 kg of a refrigerant in the atmosphere contributes to global warming in comparison to 1 kg of CO_2. This means the GWP value represents a CO_2 equivalent.

Refrigerant	GWP	Safety class
Synthetic		
R410A (50% R32 / 50% R125)*	2088	A1
R407C (23% R32 / 25% R125 / 52% R134a)	1774	A1
R466A (49%R32 / 11.5%R125 / 39.5% CF3I)*	733 (Low ODP value)	A1
R32 (pure substance)	675	A2L
R513A (44% R134a / 56% R1234yf)*	631	A1
R454B (68.9% R32 / 31.1% R1234yf)*	466	A2L
R454C (21.5% R32 / 78.5% R1234yf)*	148	A2L
R455A (21.5% R32 / 75.5% R1234yf / 3% CO_2)*	148	A2L
Natural		
R290 (propane)	3	A3
R1270 (propene)	3	A3
R744 (CO_2)	1	A1
* Mixture components; table not exhaustive		

(Table: ©NutzWort)



GWP values of well-known refrigerants and their effect on the atmosphere

6. Parameters for the efficiency of heat pumps

COP – Coefficient of Performance

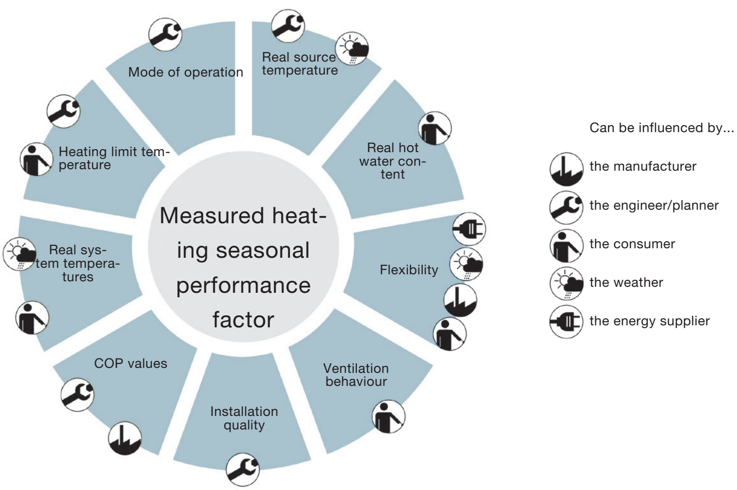
A good comparative value for heat pumps is the COP (Coefficient Of Performance). This value describes the heating output at the operating point in comparison to the electrical energy consumed. It is determined under laboratory conditions.

Important but often confused: the COP relates exclusively to the heat pump and not to the entire heating system. This becomes important in the case of the annual electricity bill, when the heating energy recorded by the heat meter is considered in relation to the electricity consumption. This is the heating seasonal performance factor.

Heating seasonal performance factor

The heating seasonal performance factor portrays the real operating scenario over a period of 12 months. It records the thermal energy emitted by the entire heating system – measured via the heat meter – and compares this to the real power consumption, including all auxiliary energy. This includes, for example, the circulation pumps in the brine or groundwater circuit coming from the heat source and also for distributing the heat in the building. The heating element for emergency operation or peak load coverage is also included. The graph shows all influencing factors that are crucial to the heating seasonal performance factor.

Factors influencing the efficiency of heat pumps



(Source: BWP)

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Module 2:
Basic principles and main components

Heat pumps use the functional principle of a compression refrigeration system. In this process, waste heat accumulates as a “waste product” in the refrigeration technology. Whenever possible, however, this should be recovered or, as in the case of heat pumps, put to intentional use. To understand the thermodynamic process behind this, here are a few simple basics.

1. Thermodynamics

In simplified terms, the **first law of thermodynamics** states that energy is not lost, but simply converted into a new form. This principle is particularly important when considering the energy flows in refrigeration, air conditioning and heating technology. The energy balance sheets must therefore be coherent.

Looking at this simply, it can be seen that the drive power from the compressor is added to the thermal energy absorbed in the evaporator from the heat source. With a COP of 4, this means 3 parts heat from the source and 1 part energy from the compressor, converted from electrical to thermal. The entire amount of energy is then released again on the high-pressure side of the refrigeration circuit at the condenser at a higher temperature level for heating or hot water.

The **second law of thermodynamics** is no less crucial when it comes to refrigeration technology. It states that (thermal) energy is only ever transferred naturally from a hotter body to a colder body. If additional energy (compressor) is used, this effect can also be used for heating. This is because the energy flow of a heat pump in winter is from the cold heat source to the even colder refrigerant in the evaporator. Thus, thermal energy can be extracted even from 10-degree soil or from very cold air outside. The transfer of energy still follows the principle: **“from warm to cold!”**

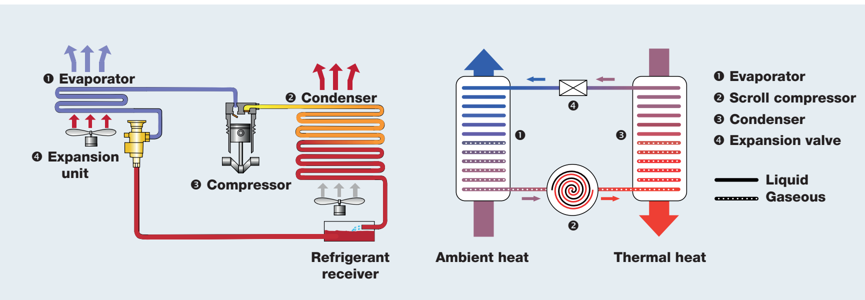
The **third law of thermodynamics** is derived from the second law. If heat always naturally "flows" from warm to cold, this means that absolute zero can never be achieved, at least via thermodynamic means. This is defined at 0 K or -273.15°C and describes a state where the particles are motionless.

2. The four main components of the compression refrigeration circuit

In general, the compression refrigeration circuit can be defined on the basis of four main components:

1) Evaporator
2) Condenser
3) Compressor
4) Expansion unit

The graphic shows these main components in the refrigerant circuit of a heat pump. A cycle is shown in which the refrigerant circulates in a closed circuit and in doing so undergoes two changes of state.



Refrigerant circuit of a heat pump

The evaporator

The evaporator is a very important component. It virtually forms the “interface” from the heat source side to the brine or refrigerant circuit.
There are two main types used in heat pumps:

- Finned heat exchanger, when heat is extracted from the medium air
- Plate heat exchanger for thermal transfer between two fluids

With both options, the heat flow is the same: from “hot” to “cold”. At low pressure (suction pressure), the refrigerant enters the evaporator still largely in liquid form from the expansion valve. There, it evaporates while absorbing heat from the heat source.
The aim is to inject so much refrigerant into the evaporator that the thermal energy absorbed is sufficient for the complete phase transition from liquid to vapour. In addition to sensible energy, latent energy is also absorbed. The smallest possible superheating of the vapour in the last part of the evaporator serves as a necessary control process for the injection unit. At the same time, this ensures that absolutely no liquid gets into the compressor, for instance in the event of load fluctuations. The evaporator and expansion unit components must therefore be very well coordinated.

This coordination has a significant influence on the efficiency and reliability of the system. The appropriate evaporation temperature and evaporator superheating serve as a measure of effective evaporation. Both values can be reliably determined with a testo 558s digital manifold.

The entire process is automatically monitored and controlled via the heating control. Under certain conditions (temperature, humidity), finned heat exchangers can ice up outdoors. The defrosting of the evaporator that is necessary when that happens represents an interruption of the thermal transfer. Defrosting is also carried out automatically by an icing sensor. Nevertheless, knowledge of the defrosting process is necessary because it affects the efficiency of the heat pump.

Knowledge about defrosting

- **Not too early:** because no build-up of frost or too little build-up of frost means unnecessary power consumption and interruption of the heat extraction coming from the source side.

- **Not too late:** because heavy frost on the evaporator significantly impairs the heat transfer.

- **No longer than necessary:** because too much heat from the defrosting process decreases the efficiency of the heating system.

- **As efficiently as possible:** the most common defrosting method for heat pumps is to use heat from the buffer tank. To do this, the circuit is briefly reversed and energy is extracted from the storage tank to defrost the fins in the outdoor unit. In some cases, defrosting is also carried out directly using heating water.

Another possibility is hot gas defrosting. Here, instead of reaching the condenser, the compressed and hot refrigerant reaches the evaporator via a bypass. The constructional work is more complex with this method but defrosting is very fast and efficient.

- **Controlled:** defrosting occurs automatically through the use of intelligent controllers; however, occasional checks are advisable, including of the probe position in the outdoor unit, in order to rule out any malfunctions that may have gone unnoticed. Intelligent heat pumps alert you to faults by means of remote monitoring.

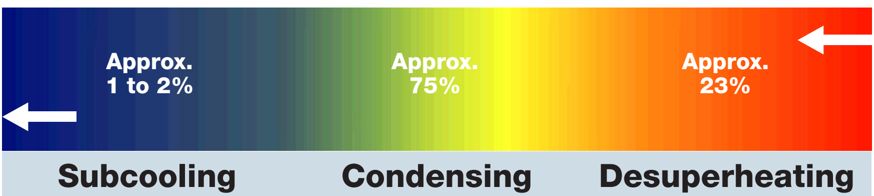
- **Well planned:** adjusting the defrosting requires some experience, but should be done conscientiously as the seasonal performance factor will otherwise be affected without this being noticed.

The condenser

The condenser inside a heat pump is a brazed or welded plate heat exchanger. This transfers thermal energy on the high-pressure side behind the compressor to the medium of the connected buffer tank. During this process, the refrigerant in the condenser liquefies, releasing both the sensible heat energy and the latent thermal energy absorbed during evaporation. If this all happens while flowing through the condenser and there is low desuperheating, optimum thermal transfer is achieved. In principle, a condenser has three sections:

- the desuperheating zone
- the condensing zone
- the subcooling zone

Condensing of the refrigerant takes up the greatest space. After compression, the first step involves the superheated refrigerant vapour being cooled down to the appropriate condensation temperature. At this point, the first drop of liquid refrigerant occurs in the condenser. As the heat dissipation to the surroundings continues, this drop gets larger and larger, until there is no longer any refrigerant vapour present. Subject to an appropriate condenser design, a slight subcooling of the refrigerant may now occur.



Process and proportions of the individual zones in the condenser

The compressor

The task of a compressor in the refrigerant circuit is to draw in the superheated vapour from the suction line (suction pressure) and to compress this vapour to the high-pressure level. This level results from the performance ratio of condenser and evaporator when there is a heat requirement in the building and the ambient conditions on the heat source side. Both are subject to seasonal fluctuations due to day/night or higher/lower annual temperatures. User behaviour also plays an important role.

The compressor is the component in the refrigerant circuit that requires the most electrical energy. Heat pumps almost exclusively use fully hermetic compressors. Semi-hermetic designs are also used for systems with a higher output in commercial or industrial applications.

Fully hermetic compressor:
These compressors are hermetically sealed. They are used in large quantities for smaller capacities. The electric motor and the inside of the compressor are not accessible from the outside. The electric motor is cooled via the cold suction vapour (suction vapour cooling) and/or the oil (oil cooling). Two compression principles are used in heat pumps:

Scroll: Two interlocking spirals compress the refrigerant as it flows through. To do this, one stands still, while the other rotates at high speed, creating increasingly narrow chambers. The pressure increases and the gas is compressed, heated and discharged at the end. Scroll compressors are the most common type of construction in classic heat pumps. They work quietly and efficiently. For the heat source air, speed-controlled operation with a frequency converter is preferred because it allows the fluctuating ambient conditions to be balanced in an energy-optimized manner. For temporarily higher flow temperatures, output control also pays off.

Twin rolling pistons: in this design, the pistons fully rotate. Another designation for this is therefore a rotary compressor. Rotary piston compressors are not quite as efficient, but they are somewhat cheaper. They can exploit this advantage particularly in the small output range below 5 kW heating output. As the heating requirements of highly insulated homes are becoming ever smaller, interest in this type of design is growing. For heating and hot water, but also, for example, for coupling houses with a high source temperature from cold district heating networks, or for domestic ventilation systems with a heat pump module.

Semi-hermetic compressor:
Semi-hermetic compressors are used for medium and very high capacities in chillers or heat pumps. The electric motor and compressor are securely connected to each other in the housing, and the motor is cooled via the cold suction vapour or an attached fan. In contrast to fully hermetic compressors, the electric motor can be replaced and the valve plates of the compressor are freely accessible for servicing. This mode of operation usually involves reciprocating compressors or screw units for very large capacities. However, neither of these plays a major role in heat pumps in the output range for single or multi-family homes. The reasons for this are the significantly higher costs or noise emissions.

The expansion unit

The expansion unit in a refrigerant circuit has the important task of injecting the right quantity of liquid refrigerant into the evaporator to enable as much refrigerant as possible to evaporate in its pipe contents. Evaporating refrigerant requires a lot of energy for this, which is extracted from the heat source. There are various designs:
- Capillary tube
- Automatic expansion valve
- Thermostatic expansion valve
- Electronic expansion valve

Only the last two types are really of relevance for heat pumps. **The thermostatic expansion valve** is currently the standard for refrigerant circuits. Its task is to keep the superheating section in the evaporator constant. To keep this as small as possible, the exact setting of the thermostatic expansion valve is particularly important.

The **electronic expansion valve** has the highest control quality of the aforementioned expansion elements. The aim is to keep the superheating ratio in the evaporator constant using the auxiliary energy (electrical actuation) and to adjust it quickly in the event of load fluctuations. Since the supplier market has been developing cost-effective variants for some years now, the electronic expansion valve is also becoming increasingly popular for heat pumps. Its precise controllability has a particularly positive effect on the COP of a heat pump and especially on the seasonal performance factor.

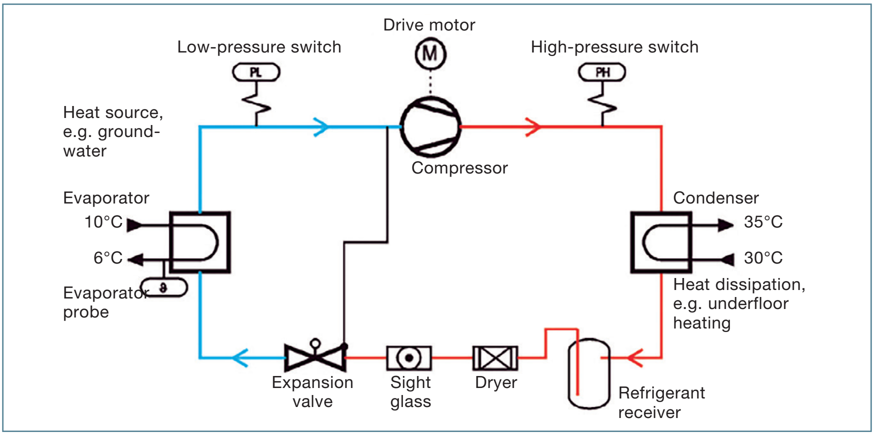
3. Other important components in the refrigerant circuit

In addition to providing sufficient liquid refrigerant to the expansion units, the **refrigerant receiver** also has the task of separating any vapour bubbles that may be present in the condensate pipe from the liquid. When selecting the design, the vertical receiver is preferable to the horizontal receiver. **Vertical receivers** have a higher liquid column and thus a better possibility of fill level monitoring as well as a subcooling gain.

The **refrigerant dryer** – built into the liquid line – is intended to bind the residual moisture from the system. In combination with refrigerant, oil and heat, the residual moisture that may be present can result in the production of acid, which can attack the compressor's enamelled copper wire, amongst other things. The acid content in the circuit can also be minimized using appropriate additives. An additional filter prevents foreign particles, such as chips or scale, from reaching the solenoid valve or expansion valve. This filter dryer must be replaced every time work is carried out on the refrigerant circuit.

The **sight glass** enables a “view” of the flowing refrigerant. If the sight glass is incorporated immediately before the expansion valve, pre-evaporation due to high pressure drops in the liquid line and too low a subcooling or a lack of refrigerant can easily be seen.

The **low-pressure switch** monitors the refrigerant pressure on the heat source side. If this drops too much, for example due to a leak, it switches off the heat pump for safety reasons. The task of the high-pressure switch is to protect the compressor. If the pressure becomes too high, it switches off the compressor. This happens when not enough heat is being absorbed by the condenser.



The components of the simple refrigerant circuit of a heat pump (source: DIN “Heat Pump Manual”; Jürgen Bonin; 3rd edition 2017, Beuth Verlag; Figure 3.5, page 11)

Module 3: Planning and measuring correctly

Heat pumps are industrially prefabricated in large quantities. The refrigerant circuit is then already pre-installed in a monobloc – whether for indoor or outdoor installation. In the case of split units, the expert technician must close the refrigerant circuit. The next task is to properly connect the heat pump to the thermal storage tanks or the distribution network in the building and to the heat source. No mistakes must be made here, because this will inevitably have a negative impact on the seasonal performance factor and thus the overall efficiency of the heating system. The final step is commissioning.

1. Planning heat pump systems

However, everyday practice often demands even more from a specialist company. In contrast to combustion technology with energy sources such as oil, gas, wood or pellets, each degree Celsius higher or lower in the thermodynamic cycle of a heat pump plays a major role in the use of electrical energy. For example, a 1 K increase in evaporation temperature on the heat source side or a 1 K decrease in condensation temperature at the heat sink brings about a 2 to 3 percent improvement in the heat pump's COP. Expert knowledge is therefore required.

Planning a heat pump system includes the preliminary investigation, conceptual development and detailed planning. Thought must also be given to the hydraulic circuits, dimensioning of system components, documentation, system commissioning, operator training and cost considerations.

2. Practical knowledge for work in the field

Exact measuring values and expert knowledge form the basis for a comprehensive system evaluation and the correct adjustment of the refrigerant circuit of a closed split heat pump. This is the only way to record and evaluate crucial operating conditions or parameters.

Preparation

For commissioning and, primarily, in the event of servicing, it is crucial that the expert technician **quickly obtains the most important system parameters** of a refrigerant circuit. It is true that, to some extent, pressures and temperatures can be read out on modern heat pumps. However, it is only possible to be certain that the displayed values are correct after a check. A manifold and a temperature measuring instrument are therefore indispensable tools when it comes to commissioning. However, measuring instruments are often exposed to mechanical and thermal stress in vehicles and on construction sites. The analog version, i.e. a manometer with mechanical pointers, has the disadvantage that crucial values such as **subcooling** and **superheating** cannot be read off directly. When calculating these values manually, there is always the risk of mathematical errors. In addition, so-called parallax errors, i.e. pressure value readout errors, can occur when interpreting the pointer position.

This is not the case with a digital manifold. Here, the system pressures and associated temperatures can be recorded **in parallel and with great accuracy** to enable the superheating and subcooling to be determined. It is impossible to make either a parallax error or a mathematical error.

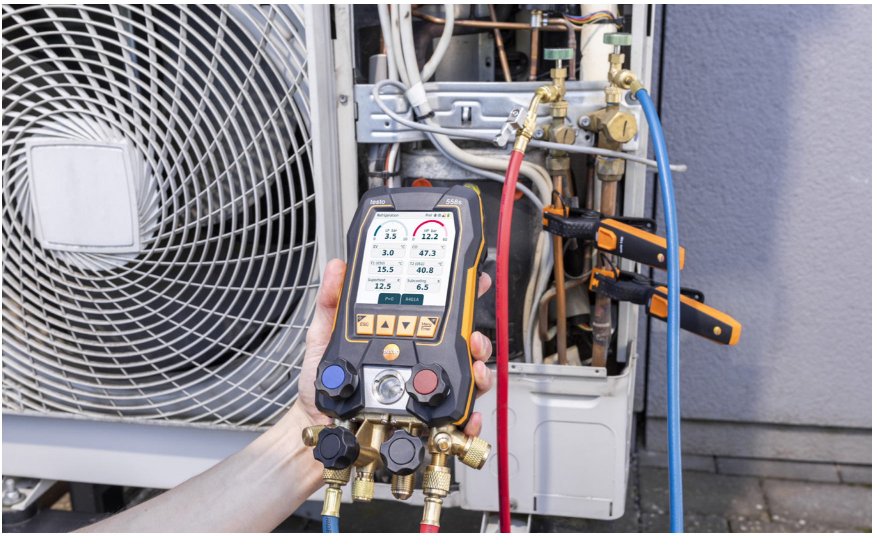
The display illumination, ambient pressure adjustment and also measurement data storage are useful additions, allowing servicing work to be carried out quickly and efficiently. Electronic refrigeration measuring instruments like the testo 558s digital manifold have therefore become an indispensable part of the toolbox of any heat pump technician.

Initial commissioning

Once the heat pump has arrived and been installed, the cooling circuit of split systems must be completed. The correct choice of pipes to be used is taken from the current standards. This is because the material, wall thickness, toughness, corrosion and pressure resistance must be selected to match the refrigerant used. All soldered joints are connected leak-tight by brazing under inert gas (nitrogen) with copper or silver solder.

Next, the refrigerant circuit is commissioned. The expert technician connects a digital manifold to the corresponding high-pressure and low-pressure connections on the heat pump. The red and blue hoses help the expert technician to keep track of where the pressure measurement is being taken. The third hose, which is usually yellow, is connected to the manifold’s service port. It is used initially to introduce dried nitrogen for the pressure or leakage test. It is also perfectly legitimate to remove the existing air from the pipelines and the heat exchanger beforehand using a vacuum pump and then introduce the dried nitrogen into the evacuated system. It is now important to gradually raise the test pressure to the calculated permissible overpressure. This makes it possible to detect leaks due to pores or fine cracks in materials, weld seams and soldered joints and eliminate them in good time during subsequent operation. Other weak points susceptible to leaks are screw connections, valve stuffing boxes, measuring and monitoring devices and, paradoxically, seals of all kinds.

Digital manifolds from Testo have their own measurement program for the leakage test, whereby checks are carried out over a certain period of time to ascertain whether the applied pressure in the system remains constant. The leakage test is also carried out along the system using foaming agent or a Testo leak detector from the 316 series. Once the tests have been completed and documented successfully, the nitrogen can be drained from the system. Here again, the digital manifold helps the expert technician to release the nitrogen only to the extent that a slight overpressure remains in the system. A vacuum pump is then connected to the yellow hose and the system is evacuated. In turn, a digital manifold or vacuum probe such as the testo 552i, which is attached to the system and transmits the measurement results to the manifold or app, can be used to obtain even more accurate vacuum measurements. Once the final vacuum has been reached and the vacuum testing has been successfully documented again, the heat pump valves can be opened and the refrigerant, already pre-filled by the manufacturer, can be introduced into the system. If the pre-filled refrigerant quantity is not sufficient, top this up via the yellow service hose.



testo 558s digital manifold in use

The heat pump is now ready for use, so series of measurements can follow for commissioning purposes. For this, high and low pressures can be read directly from the manifold. If a temperature probe is connected for this, subcooling and superheating can be easily determined in real time. The flow and return temperatures to the building as well as the intake and output temperatures at the evaporator can be determined using another temperature measuring instrument.

Once the heat pump has been running in trial operation for some time, the expert technician uses an electronic leak detector to re-check the refrigerant circuit during the precision check. This ensures that even the smallest leaks are detected. The measurements are rounded off during commissioning by measuring the electrical values such as supply voltage and current consumption (e.g. with the testo 770-3). The system can be handed over to its owner.

Service and maintenance

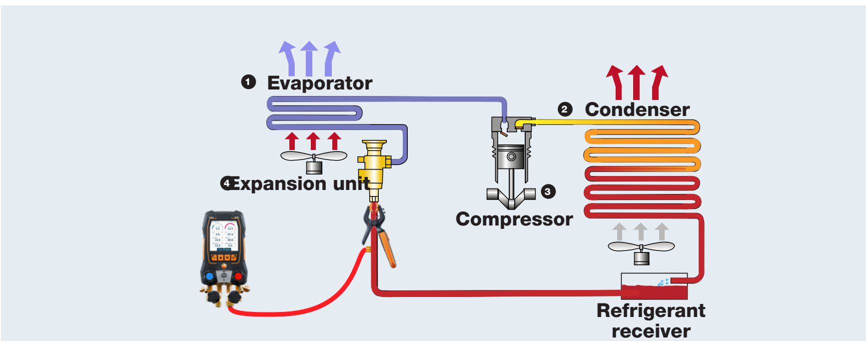
Depending on the refrigerant, heat pumps are subject to mandatory maintenance. In order to avoid creeping refrigerant losses or malfunctions, for example due to dirty heat exchanger surfaces, it also makes sense to have a maintenance contract between the operator and the expert technician. Testo also offers the right measuring instruments for the refrigerant circuit. To prevent refrigerant escaping when connecting measuring instruments, the testo 549i pressure transmitters can be used. This is because, for pure check measurements, no hoses are required for connection. The pressure is displayed on a smartphone or tablet. The same applies to temperature measurements with the clamp thermometer testo 115i. Another essential instrument for servicing and maintenance is the electronic leak detector. This helps the expert technician to detect even the smallest refrigerant losses, so heat pump failures due to a lack of refrigerant can be prevented in good time.

3. Recording and evaluating important parameters

Subcooling

In principle, it is best to determine the subcooling of the liquid refrigerant before the expansion unit. Subcooling calculations after the condenser or after the (vertical) receiver are only relevant when looking at specific subsections. However, what state the refrigerant is in before the expansion unit is crucial.

Subcooling is a very important evaluation parameter when it comes to the efficiency of the refrigerant circuit. Firstly, subcooling leads to an enthalpy gain, thus increasing the amount of heat which can be absorbed by the evaporator. Secondly, it is needed to overcome the pressure drops in the liquid line without pre-evaporation.



Determination of subcooling before the expansion valve

Superheating
Just like subcooling, superheating is one of the most important parameters for assessing the current efficiency of the heat pump. In principle, a distinction has to be made here as to the point in the refrigerant circuit where the superheating should be calculated:
1) Evaporator superheating
2) Superheating in the suction line
3) Intake superheating
4) Superheating in the compressor

Regarding 1)
Evaporator superheating is determined immediately after the evaporator and at the start of the suction line. The probe element of the thermostatic expansion valve or the superheating sensor of electrically actuated expansion valves is located in the same place.

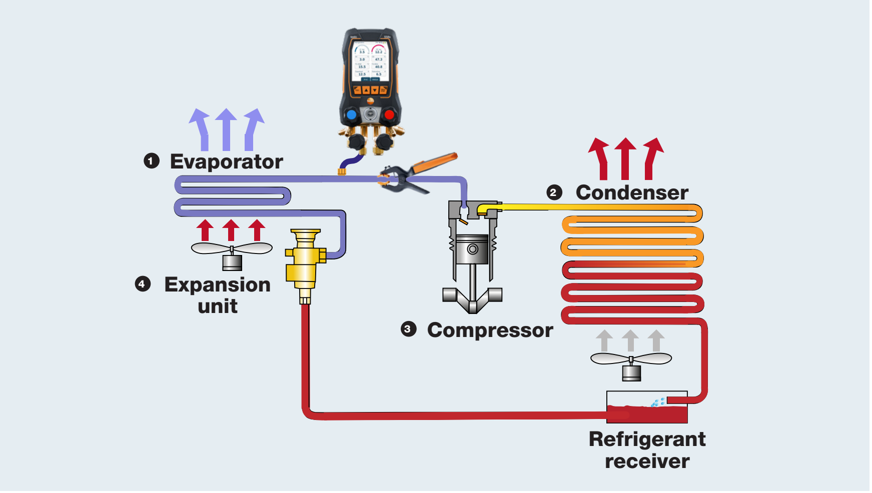
Regarding 2)
Superheating in the suction line generally occurs due to the heat impact of the environment through the insulation on the suction line. This heat impact is normally not desired in systems that are optimally planned and designed because the heat has to be additionally absorbed by the refrigerant circuit.

Regarding 3)

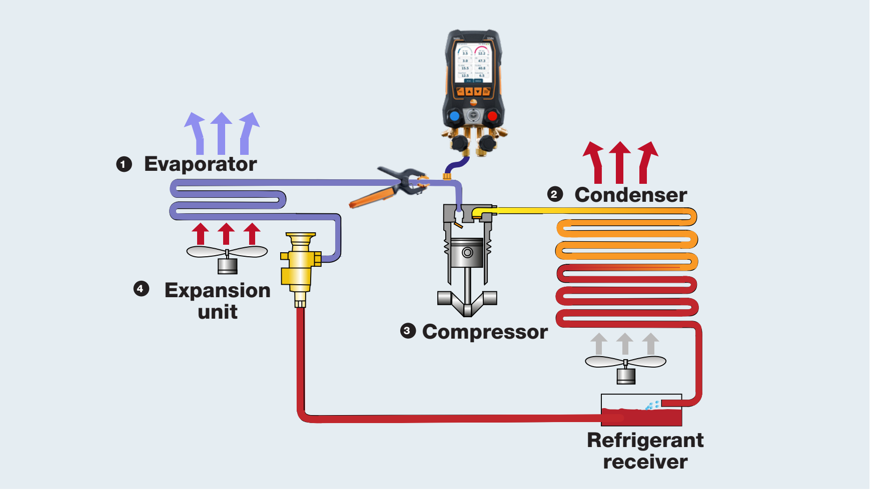
Intake superheating, determined immediately before the intake of the superheated suction vapour into the compressor, is based on the sum of the evaporator and suction line superheating, including any internal heat exchanger that may be present.

Regarding 4)

In practice, it is virtually impossible to determine the **additional superheating** present in the compressor, so this has hardly any role to play in terms of servicing. This superheating is predominantly caused by the compressor's suction vapour cooling and is specific to the manufacturer.



Determination of evaporator superheating



Determination of intake superheating

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Module 4: Sound level

When planning the installation site of a heat pump, its sound emissions must be taken into account as early as possible. This applies both to monoblocs installed indoors and to units with integrated compressors installed outdoors.

1. The installation site

Inside

If the heat pump is installed indoors, the complete refrigerant circuit and thus also the compressor are located within the building. The units are usually well insulated. However, sound transmission cannot be ruled out. Reverberant floors or empty rooms can make this even worse. This should be taken into account when planning the installation site. Effective insulation

Air-to-water heat pump installed outside can be achieved, for example, with a concrete foundation slab and rubber mat. In the case of an air-to-water heat pump, the air ducts to the outside must be both thermally insulated and soundproofed. Moreover, when connecting each heat pump to pipes and electrical cables, care must be taken to ensure acoustic decoupling from the domestic installations, for example via compensators.

Outside

Air-to-water heat pumps installed outdoors should be placed at a sufficient distance from and facing away from neighbouring properties. The air flow must not be obstructed from any side. When placed on a foundation or base, condensate can flow off unhindered, even in the case of snow. In this case, the housing must be installed professionally. Buffers or plastic elements, which are usually included, decouple the outdoor unit from the ground. This prevents sound transmission. Correct installation then prevents unwanted noise transmission. Sound-absorbing surrounding surfaces or greenery are also helpful.

The outdoor installation location must also not impair the efficiency of the heat pump. For example, a ground depression is not a good place because cold outside air can accumulate in it, affecting the COP. Since heat pump designs vary widely, it is advisable to consult the manufacturer if in doubt.

2. Structure-borne sound

In buildings, sound is usually propagated due to structure-borne sound through the floor and walls. It is then transmitted to the ambient air. This enables noise to spread from the basement to the entire building, or even to the surrounding area.

3. Sound measurement

If necessary, an approved test measurement can be carried out for heat pumps. Minimum requirements for the sound measurement of heat pumps can be found in the Ecodesign Regulation (EU) 813/2013/EC, for example. The sound level can be accurately determined using precise measuring instruments such as the testo 816-1. For a sound measurement, it is advisable to differentiate between some technical terms.

Sound power

Sound power is a theoretical calculated value. It describes the total sound energy emitted by a sound source. The greater the distance, the greater the area over which the sound power can spread.

Sound pressure

Sound pressure occurs where a noise source causes air to vibrate. The greater the change in air pressure, the louder the perception of a sound.

Sound radiation

The radiation of sound or noises is expressed in decibels, or dB for short. In the case of airborne sound, the unit is given the additional abbreviation dB(B). In the case of structure-borne or liquid-borne sound, the unit is dB(A).

Sound emission

Sound emission is the term used to describe the sound emitted by a source. It is expressed as a sound power level with the indication dB.

Sound immission

The sound impact on a location is called sound immission, measured as a sound pressure level in dB.

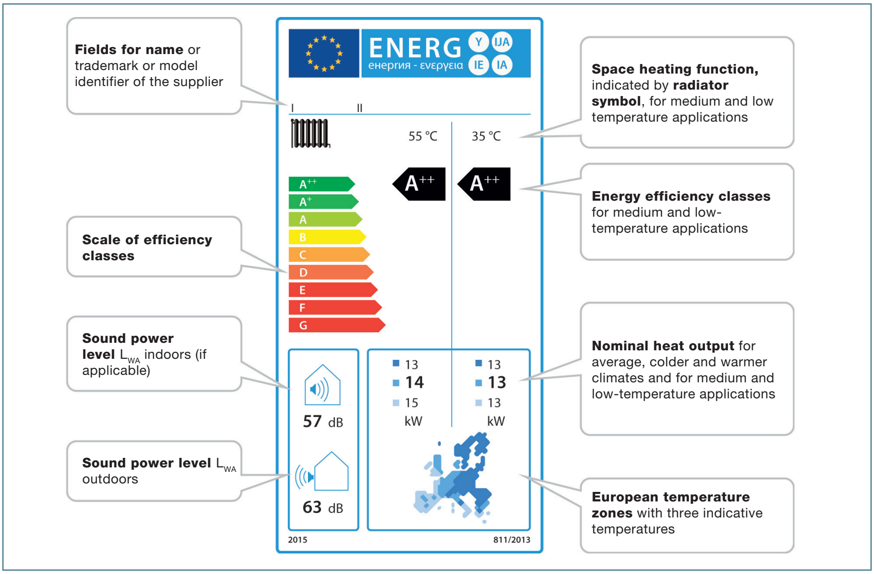
4. Optical sound

The growing number of air-to-water heat pumps installed outside is increasingly resulting in a curious problem: optical sound. This is when neighbours feel annoyed by noise because they see the fan blade turning. In reality, there is no noise at all because the heat pump is not running – the wind is driving the fan. The issue can be remedied by using a heat pump design that hides the fan. Choosing a location away from the neighbouring property or facing the street has the same effect. In case of any doubt, a sound level measurement conducted by an expert technician using the testo 816 measuring instrument and in the presence of the neighbour can help to eliminate the problem of optical noise.

Example of a design that prevents optical noise and makes the heat pump almost invisible.

Tips on sound

- Take the heat pump manufacturer's noise emission data on the energy label into account
- Carefully decouple the heat pump installed indoors from the building, supply lines and air ducts
- The Technical Instructions on Noise Abatement (TA-Lärm) list guideline values for noise immissions. Important to know: the system operator is responsible for compliance
- It is advisable to ensure sufficient distance from neighbouring buildings in the case of outdoor units
- Out of sight, out of mind – a privacy screen can help and act as a preventive measure



The energy label for heat pumps (source: BWP)

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