Knowledge
Refrigeration technology

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Testo Refrigeration Knowledge in 3 Modules.

Understanding refrigeration systems. Principles and main components of refrigeration technology. Correct measurement on refrigeration systems.

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Module 1: Understanding refrigeration systems

Refrigeration systems have become indispensable in various areas of our daily life. They ensure optimum air conditioning of buildings, cool industrial processes and enable longer storage and freezing of food. However, the advantages of refrigeration systems are accompanied by a significant consumption of resources which is constantly growing all over the world and affecting the climate. This makes it all the more important to plan systems for refrigeration and air conditioning technology professionally and operate them efficiently.
A refrigeration system is a closed, and ideally hermetically sealed, pipework system in which refrigerants circulate.
A refrigerant is an operating medium which takes up heat at a low temperature and low pressure and gives off heat at a higher temperature and higher pressure. These so-called compression refrigerant circuits comprise at least four main components which will be briefly described in greater detail below. The refrigeration system's operating media are the refrigerant and the oil in the compressor. Their selection is based on the respective application in conjunction with environmental impacts.

In this respect, the following must be incorporated into the evaluation and selection:
- the manufacture of the components,
- the potential risk of the operating media in the event of a leak or accident,
- the operating power needed to provide the refrigeration and
- the disposal of the system technology after its operating life.

1.1 Parameters for the efficiency of refrigeration systems

A good comparative value for heat pumps is the COP (**C**oefficient **O**f **P**erformance) or the **EER** (**E**nergy **E**fficiency **R**atio) for refrigeration systems. These performance figures reflect the **benefit-cost** ratio at a special operating point of the system at a defined point in time.

If you wish to consider the efficiency of the refrigeration system over a whole year, the **SEER** (**S**easonal **E**nergy **E**fficiency **R**atio) is of greater significance. In this case, the evaluation also includes the partial load operation of the refrigeration system in addition to the full load operation and design point. The very different ambient conditions which occur in the course of a year mean consideration of the partial load is particularly important.

Efficient performance regulation of the refrigeration supply (frequency converter for performance regulation of the compressor and speed regulation of the condenser or heat exchanger fans) is a must! Additional and complementary use of thermal storage media (e.g. ice storage units) can compensate for partial loads or extreme peak loads and ensure higher operational reliability and better system availability.

1.2 Criteria for practicable refrigerants

In theory, a very large number of substances can be used as refrigerants. However, not everything which is possible is also permitted and sensible: various safety requirements, the available system technology and environmental aspects restrict this choice. Only those operating media (here refrigerants) which meet specific criteria in a closed refrigerant circuit during operation are practicable.

Criteria for the selection of refrigerants

- The **vapour pressure** is above atmospheric pressure at the required evaporation temperatures.
- The **level of the condensation pressure** does not make any above-average demands in terms of the pressure resistance of the components and pipelines (e.g. maximum p_{ec} = 25 bar at +35°C outside temperature). Exceptions are the so-called high-pressure refrigerants, such as R-410A or R-744.
- The superheated vapour drawn in from the compressor has **small volumes under the intake conditions**, so as to be able to keep the compressor size (stroke volume) small.
- **Material compatibility** with the materials commonly used in refrigeration technology.
- **Lowest possible environmental pollution** during production and disposal of the refrigerant.
- **Safe handling as a matter of principle** for the fitter or service personnel.

However, this list only covers a selection of the important features. There is currently no refrigerant available which is ideal for all applications. This means that it is always necessary to make compromises.

Natural refrigerants have greatly increased in importance over recent years – not only since stronger regulations came into force globally (such as the EU F-Gas Regulation 2014). In addition to carbon dioxide (R-744), these above all include hydrocarbon gases, such as isobutane (R-600A) and propane (R-290). The use of ammonia (R-717) has been extremely widespread for many years, in particular in industrial refrigeration.

Both in terms of thermodynamics and of climate footprint, natural refrigerants are characterized as long-term and climate-friendly working media.
These positive features enable use in areas which in some cases make significantly higher demands in terms of system technology and lubricants. Thus CO_2 and propane are for example used in the area of supermarket refrigeration.

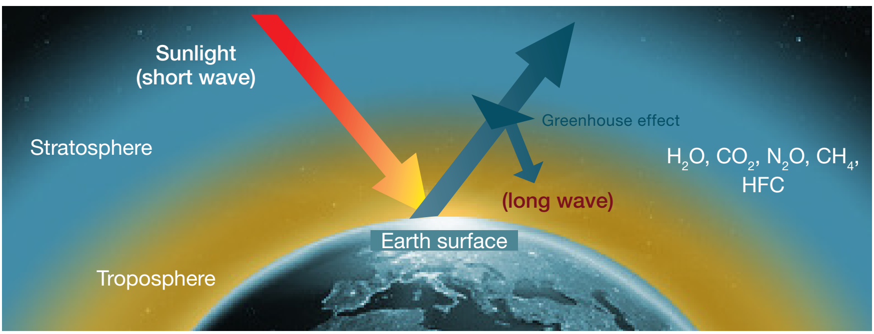
1.3 Evaluating refrigerants

a) The GWP value

The **G**lobal **W**arming **P**otential 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.

R-12, for example, has a 10,900-fold stronger effect than CO_2.

Refrigerant	GWP
R-12	10,900
R-502	4,657
R-507A	3,985
R-404A	3,922
R-407A	2,107
R-22	1,810
R-407C	1,774
R-134a	1,430
R-32	675
R-290 (propane)	3.3
R-600a (isobutane)	3
R-1270 (propylene)	1.8
R-774 (CO_2)	1
R-717 (ammonia)	0



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

a) The TEWI value

The **TEWI (T**otal **E**quivalent **W**arming **I**mpact) value also includes the ecological evaluation of a system.
This enables the description of the global environmental impact due to the operation of a refrigeration system, for example with different operating media (refrigerants).

The TEWI value takes into account the sum of the direct and indirect greenhouse gas emissions. The method is ideally suited for an instantaneous and comparative study. The above-mentioned ecological reasons give rise to an urgent need to ensure refrigeration technology applications are as far as possible without any harmful greenhouse gases. It is absolutely essential to make the hermetic sealing of refrigerant circuits as effective as possible, so that an emission of operating media into the environment can largely be avoided.
However, the TEWI value also describes the primary energy needed for refrigeration supply which, depending on the type of power generation, can also contribute to the global environmental impact.
This means it makes sense to plan and make energy-efficient systems which need the lowest possible amount of primary energy for the required cooling capacity.

$$\mathbf{TEWI} = \underbrace{\underbrace{(\mathbf{GWP} \times \mathbf{L} \times \mathbf{n})}_{\text{Leakage}} + \underbrace{(\mathbf{GWP} \times \mathbf{m}\,[1 - \alpha_{recovery}])}_{\text{Recovery losses}}}_{\text{Direct greenhouse effect}} + \underbrace{\underbrace{(\mathbf{n} \times \mathbf{E}_{annual} \times \beta)}_{\text{Energy requirement}}}_{\text{Indirect greenhouse effect}}$$

GWP:	Global Warming Potential	[-]
L:	Loss rate	[kg/a]
n:	Operating time	[a]
m:	Refrigerant fill level	[kg]
α_R:	Recovery ratio on disposal	[-]
E_a:	Annual energy consumption	[kWh/a]
ß:	CO_2 emission from energy consumption	[kg/kWh]

Calculation of the TEWI value

1.4 Planning and efficient operation of refrigeration systems

For good planning and efficient operation of refrigeration systems, it is necessary to carry out accurate measurements on the systems and to evaluate these correctly.
Each 1 K higher evaporation temperature or 1 K lower condensation temperature brings about a 2-3% improvement of the refrigeration system's performance figures. The evaporator superheating also has a major influence on the amount of heat being transferred from the items being cooled. Unnecessarily high superheating values (generally > 8 K) or unstable superheating signals lead to less than perfect filling of the evaporator and, linked to this, a poorer cooling capacity figure.

A variety of errors can occur during the evaluation, such as:

- Insufficient accuracy of the measuring instruments and their sensors
- Mathematical errors in the calculation of parameters
- Parallax error when reading off analog displays
- Distance of the measuring sensor from the required measuring point

Due to their mechanical qualities, analog pointer instruments for recording system pressures have only limited protection against vibrations and temperature changes when fitters are working. It is virtually impossible to avoid heavy stresses, especially in aeroplanes.
In addition, where there are significant changes of ambient pressure (e.g. due to changes of altitude), readjustments have to be made manually.
Electronic manifolds, such as the testo 550s, combine high-precision measurement of pressures and accurate display of the results in clear, digital format. This means that incorrect interpretations are virtually impossible.

Module 2: Principles and main components of refrigeration technology

2.1 Thermodynamics

In simplified terms, the **first principle of thermodynamics** states that energy is not lost, but simply converted into a new form of energy. This principle is particularly important when considering the energy flows in refrigeration and air conditioning technology. The energy balance sheets must therefore be coherent. Looking at this more simply, it can be seen that the thermal energy absorbed in the evaporator has around a further ⅓ added as drive power from the compressor. This entire energy then has to be released again on the high-pressure side of the refrigeration system or ideally reused (waste heat utilization or heat recovery).

The **second principle of thermodynamics** is no less crucial when it comes to refrigeration technology. It states that (thermal) energy is only ever naturally transmitted from a warmer body to a colder body. If additional energy is used, this effect can however also be reversed, this is shown for example by the overall energy flow on a geothermal heat pump. This involves using energy from the cool ground for heating purposes. However, the individual energy transmissions always follow the principle: **"from warm to cold!"**

The **third principle of thermodynamics** is derived from the second principle. If heat always naturally "flows" from warm to cold, this means: 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.

2.2 The four main components of the compression refrigeration circuit

In general, the compression refrigerant circuit can be defined through 4 main components:

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

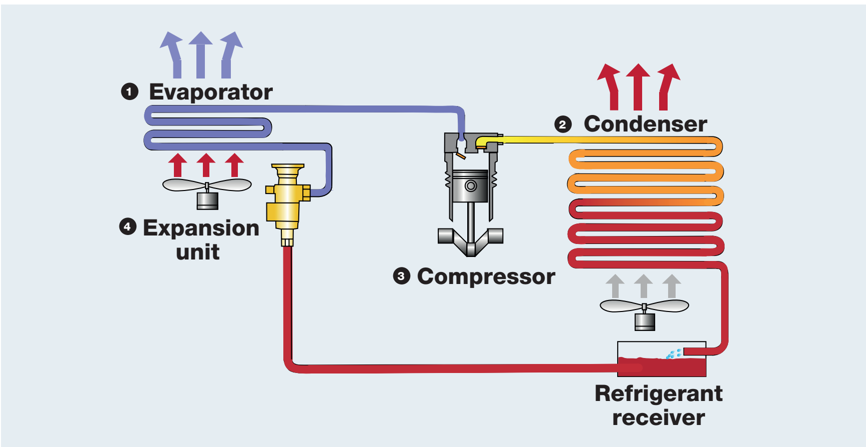
The graphic shows these main components in the refrigerant circuit. An anti-clockwise cycle is shown where the refrigerant circulates in a closed circuit and in doing so goes through two changes of aggregation state.

2.2.1 The evaporator

The evaporator is a very important component in the refrigerant circuit. It virtually forms the "interface" of the refrigeration system with the medium being cooled.
Various versions of evaporators are as follows:

- Laminated heat exchanger: the medium being cooled is for instance air.
- Plate or tube bundle heat exchanger: for cooling liquids.
- Contact evaporator: for thermal transfer of solids.

With all the possibilities mentioned, the heat flow is the same: it goes from **"warm" to "cold"**. At low pressure (suction pressure), most of the refrigerant comes into the evaporator still in a liquid state. There, it evaporates by absorbing heat which ideally comes entirely from the substance being cooled.



Simple, schematic refrigerant circuit

The objective is to inject the quantity of refrigerant into the evaporator which means that the energy from the material being cooled suffices for the complete phase transition from liquid to vapour. 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 no quantities of liquid get into the compressor, when there are for instance 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 digital manifold.

The cooling process is normally controlled via a thermostat which switches off the refrigeration point, or even the whole refrigeration system. When **defrosting** becomes necessary on the evaporator, this represents another interruption at the refrigeration point.

Tips for defrosting

- **Not too soon:** because no frosting, or too little, mean unnecessary heat input and an interruption of the cooling process.
- **Not too late:** because heavy frosting on the evaporator leads to a significant deterioration of heat transfer.
- **Not longer than necessary:** because the excess energy input by the defrost heating has to be removed from the refrigeration system again.
- **As efficient as possible:** do not defrost using separate heating elements in an air cooler, but use the system's "own" condensation heat from "inside to outside" (hot vapour or cold vapour defrosting, function switch) and enable the heat needed to melt the frost to be used for the items being cooled.
- **Controlled:** defrost via intelligent controllers or using remote monitoring; place defrost completion probe in the correct position in the evaporator.
- **Well planned**: carry out as on-demand defrosting.

With laminated evaporators, the routing of the air through the fans represents an important aspect in terms of evaluating the efficiency of the heat exchanger.
In addition, the throw distance of the fan and the air volume flow required by the respective items being cooled must be adjusted. Intelligently switching the fans on and off during the standstill phase enables the following, amongst other things:

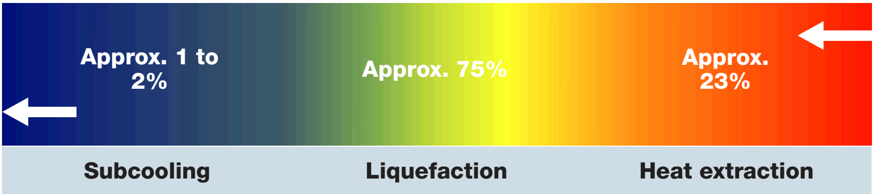
- Enhancing the quality of the items being cooled
- Delaying the need for defrosting
- Improving the energy balance sheet of the refrigeration system

2.2.2 The condenser

The role of a condenser in a refrigeration system is to dissipate the thermal energy absorbed from the items being cooled and the majority of the electrical power assimilated from the compressor during the compression process. The condenser output is around 1.3 times higher than the evaporator output (reference value). Just like the evaporator, the condenser can be laminated, liquid-cooled or its heat dissipated to a solid. Utilizing the heat for another process (waste heat utilization / heat recovery) is a key issue here when it comes to planning an energy-efficient system. This involves the vaporous, superheated refrigerant, which is under high pressure, being liquefied by giving off heat.

In principle, a condenser has three sections:

- the heat extraction zone
- the liquefaction zone
- the subcooling zone



Process and proportions of the individual zones in the condenser

Liquefaction 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. It is now possible for there to be a slight subcooling of the refrigerant, where the design of the condenser is appropriate.

This depends on the cleanliness of the heat exchange surfaces, particularly with air-cooled condensers. When there is soiling, the thermal transfer deteriorates, resulting in poorer efficiency of the heat exchanger as well. This in turn leads to falling performance figures, lower system availability or even to failures of the refrigeration system.

Utilization of the thermal energy is not only a must when planning any system, but also represents a sensible option when retrofitting existing systems. As a rule, heat for defrosting can be used (very efficiently and effectively) for room heating, drinking water heating or another technical process. Specifically when heating rooms and drinking water, it is efficient from an energy perspective only to use thermal energy which is currently available without any additional measures (e.g. increasing the pressure). When a refrigeration system is operated intermittently, the use of buffer storage units is also worthwhile. However, warm drinking water should not be stored for reasons of hygiene, but should only be heated as required by heating water in so-called instantaneous heaters.

2.2.3 The compressor

The compressor is the component in the refrigerant circuit which needs the most energy. The focus in system planning should therefore be on using this efficiently.
A distinction is generally made between three different housing designs:

- **Fully hermetic compressor:**
hermetically sealed compressor, smaller outputs, the electric motor and compressor are not accessible from the outside, the electric motor is cooled using cold suction vapour (suction vapour cooling) and/or using oil (oil cooling).

- **Semi-hermetic compressor:**
medium and larger outputs, electric motor and compressor are solidly connected together in the housing, the motor is cooled using cold suction vapour or a fitted fan, the electric motor can be replaced and the compressor's valve plates are freely accessible for servicing.

- **Open compressor:**
compressor and drive are generally connected together via a shaft or magnetically. The refrigerant does not flow through the electric motor, but is directly drawn in by the compressor, flange-mounting on a gear box is possible, the compressor's valve plates are also freely accessible for servicing. This involves the electric motor being actively or passively cooled by the ambient air.

The task of the 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 is based on the ratio of the condenser output under the appropriate ambient conditions and the current system load and is constantly changing. Load fluctuations and seasonal changes due to day/night or higher/lower annual temperatures are just some of the influencing factors.

This means the so-called pressure stroke on the compressor, and thus also the stress and efficiency, are variable. There is the risk, especially at lower outside temperatures, that the output of the air-cooled condenser will become considerably too great due to the lower outside temperatures. Appropriate output control is needed here. The simplest option is frequency-led speed control of the fans. For refrigeration systems which may be switched off over a long period of time in a cold environment, receiver pressure control must also be installed. In this way, cycling of the compressor or a low pressure fault during start-up can be avoided.
During compression of the superheated refrigerant which is drawn in, the latter undergoes considerably more superheating. Depending on the refrigerant, this may mean temperatures of more than +100°C occurring at the pressure socket of the compressor. These temperatures thus also require special oils in the compressor, because these must not lose their lubricating qualities even at low evaporation temperatures.

2.2.4 The expansion unit

The expansion unit in a refrigeration or air conditioning system has the important task of injecting the right quantity of liquid refrigerant into the evaporator to enable the greatest possible amount of refrigerant to evaporate in its pipe contents. Evaporating refrigerant requires a lot of energy for this and it is taken from the items being cooled. The following models are widespread

- Capillary tube
- Automatic expansion valve
- Thermostatic expansion valve
- Electrically actuated expansion valve

The **capillary tube** is the simplest throttle device. This is precisely calculated beforehand by the manufacturer of the system; as a rule, the flow rate is also checked. The length and the internal diameter are variable, enabling the required back pressure to be achieved. This is a very low-cost solution, but it only operates ideally at the design point. As a result, this type of expansion unit is for example often to be found in refrigerators.

The **automatic expansion valve** (better: constant pressure expansion valve) is used more rarely, because it solely tries to keep the evaporation pressure constant. These valves should only be used on systems with low load fluctuations.

The **thermostatic expansion valve** is currently still the standard in commercial refrigeration systems. In contrast to the constant pressure expansion valve, this solely enables the superheating section in the evaporator to be kept constant. The exact setting of the thermostatic expansion valve is particularly important to ensure the fewest possible failures here.
When the load fluctuates, the superheating section in the evaporator changes and thus the temperature of the superheated vapour at the evaporator outlet as well. This is the control variable and the valve now varies the quantity of refrigerant injected. Changing the inlet pressure (high pressure) before the thermostatic expansion valve and changing the temperature of the refrigerant liquid (subcooling) can however result in the valve output changing significantly. This must be taken into account right from the system planning stage!

The **electrically actuated expansion valve** (often also called electronic expansion valve) has the highest control quality of the expansion units mentioned. The objective is firstly much more precise adjustment of the superheating ratio in the evaporator and secondly its optimum adjustment even when there are load fluctuations using the auxiliary energy (electrical actuation).
In principle, a distinction is made between two types of actuation: pulse width modulation and continuous drive via a step motor. Pulse width modulation involves the pulsing actuation of a type of solenoid valve. The pulse width is generally 6 seconds. The higher-level injection regulator decides how long the valve remains open during this time, using the information which it receives from a variety of probes on and around the evaporator.

Due to the intermittent mass flow, these valves are more suitable for so-called **multi-circuit systems** (several refrigeration points on one refrigerant circuit). In this respect, the dimensioning of the liquid line is an important point in terms of preventing pressure surges. Electrically actuated expansion valves which are driven and controlled via a step motor are often the best choice for demanding refrigeration systems. They continuously inject the liquid refrigerant into the evaporator. Because the associated electronic controller constantly checks the optimum fill level of the evaporator and if necessary readjusts it, these valves are the best choice, especially when there are varying load conditions.

2.5 Other important components in the refrigerant circuit

In addition to providing sufficient liquid refrigerant to the expansion unit, the **refrigerant receiver** also has the task of separating any vapour bubbles that may be present in the condensate pipe from the liquid. When choosing the design, the **vertical receiver** is to be preferred to the horizontal one. Vertical receivers have a higher liquid column and thus a better possibility of fill level monitoring and also 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 may give rise to an acid which can attack the compressor's enamelled copper wire, amongst other things. Furthermore, it is possible to minimize the acid content in the circuit with appropriate additives. An additional filter prevents foreign particles, such as chips or scale, from reaching the solenoid valve or expansion valve. If any procedure is carried out on the refrigerant circuit, this filter dryer must be replaced.

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.

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Module 3: Correct measurement on refrigeration systems

3.1 Recording and evaluating important parameters

Exact measuring values and expert knowledge are the basis of comprehensive system evaluation and correct adjustment of a refrigeration and air conditioning system. This is the only way to record and evaluate crucial operating conditions or parameters.

Important parameters that need to be checked include:

- The **evaporator superheating:** for optimum evaporator filling and for checking the current superheating of the expansion valve.
- The **suction vapour superheating:** for operation of the compressor within the framework of its operating diagram, in order for instance to guarantee the compressor's suction vapour cooling and thus prevent any possible oil coking.
- The **way an internal liquid/suction vapour heat exchanger works:** in order to check how great the additional subcooling and superheating are as a result of using a heat exchanger of this kind.
- The so-called **acting** temperature difference on the heat exchanger: in order to improve the heat exchanger's efficiency or reassess it.

Important when commissioning refrigeration systems:

If refrigeration systems are commissioned, the settings made in the course of commissioning often remain unchanged over a long period of time. An incorrect or inaccurate superheating setting could therefore damage the compressor.

- **Superheating values that are too low** lead to bearing washout and can lead to a winding short circuit or oil foaming.
- **Superheating values that are too high** lead to issues including performance losses, heavier icing on the evaporator and thus defrosting times being too long.

The system efficiency and the ecological balance sheet become significantly worse, the customer is dissatisfied and the consequence is unnecessary servicing work.

Important in the case of servicing:
In the case of servicing, it is often particularly crucial that the fitter gets the **most important system parameters quickly**. The so-called manifold is the most important measuring instrument for the fitter. However, this indispensable measuring instrument is often exposed to mechanical and thermal stresses in vehicles and at building sites.
The analog model, that is a manometer with mechanical pointers, is particularly prone to providing inaccurate measuring values due to stresses. In addition, the direct readout of crucial values such as **superheating** (see section 3.2) and **subcooling** (see section 3.3) is not possible. When the above values are calculated manually, there is always the risk of mathematical errors occurring, as well as the parallax error.
This is different with the digital manifold. Here, the pressures of the system and the associated temperatures can be recorded in **parallel** and **very accurately** to enable the superheating and subcooling to be determined. It is virtually impossible to make either a parallax error or a mathematical one.
The display illumination, ambient pressure adjustment and also measurement data storage are useful additions, allowing servicing work to be carried out quickly and efficiently. It would therefore be impossible nowadays to imagine the toolbox of any refrigeration/air conditioning engineer not containing electronic refrigeration measuring instruments, like the testo 550s digital manifold.

3.2 Subcooling

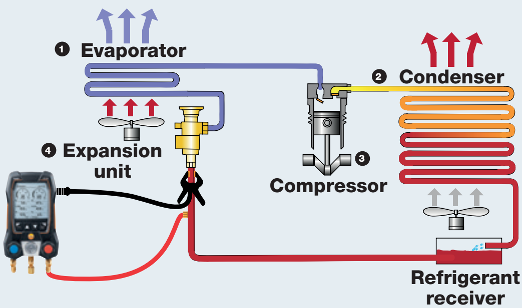
In principle, it is best to determine the subcooling of the liquid refrigerant before the expansion unit. Subcooling calculations after the condenser or after the (vertical) receiver are only relevant for the consideration of subsections. However, what state the refrigerant is in before the expansion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

Subcooling is a very important evaluation parameter for the efficiency of the refrigeration system. If there is additional subcooling (e.g. via an external subcooler) later in the refrigerant circuit, all pipework components in the liquid line must be checked or readjusted.

On the one hand, subcooling leads to an enthalpy gain, thus increasing the amount of heat which can be absorbed by the evaporator. On the other hand, it is required in order to be able to overcome the pressure drops in the liquid line without pre-evaporation.

Please note:

- The subcooling on the surface of the liquid in the receiver is **always 0 K.**
- Additional subcooling must always be generated **immediately after the receiver**.
- The subcooling possibilities are rather limited in an **air-cooled condenser**.
- The **performance improvements that run in parallel** to the subcooling on the expansion unit, on the solenoid valve and in the evaporator must be taken into account right from the design stage.
- **Very extensive subcooling** may lead to lack of damping when the solenoid valves are opened and thus to hydraulic shocks in the liquid line.
- Only very low values are possible for physical reasons immediately after the refrigerant receiver. These are dependent on the **ambient temperature**, the **design** of the receiver (vertical/horizontal), the **inlet subcooling** of the refrigerant in the receiver that may be present and the **current fill level** in the refrigerant receiver (geodetic height).



Determination of subcooling before the expansion valve

3.3 Superheating

Just like subcooling, superheating is one of the most important parameters for evaluating the current efficiency of the system. In principle, a distinction has to be made here as to the point in the refrigerant circuit where the superheating should be calculated:

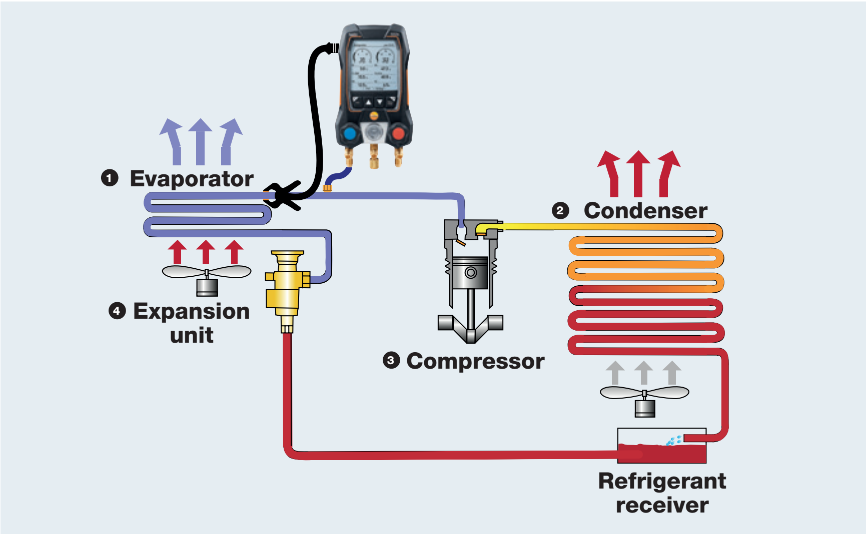
1) Evaporator superheating
2) Superheating in the suction line
3) Intake superheating
4) Superheating in the compressor

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.

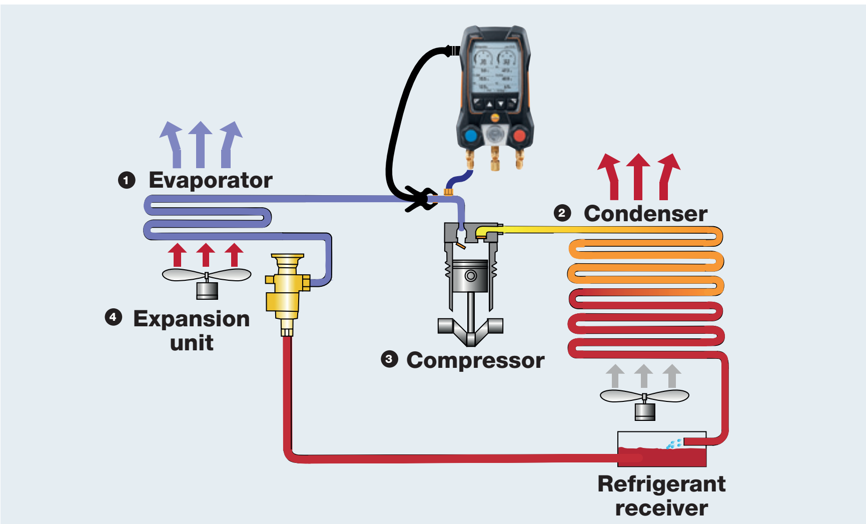
Regarding 2)
Superheating in the suction line generally occurs due to the heat impact of the environment through the insulation on the suction line. This heat impact is normally not desired with systems that have optimum planning and implementation, because this heat also has to be transported by the refrigeration circuit. However, if additional heat exchangers are incorporated into the suction line, which for example ensure a thermal connection of the suction and liquid lines as so-called "internal heat exchangers", this is a very positive and performance-enhancing effect in overall terms (except with R-717 and R-22).

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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