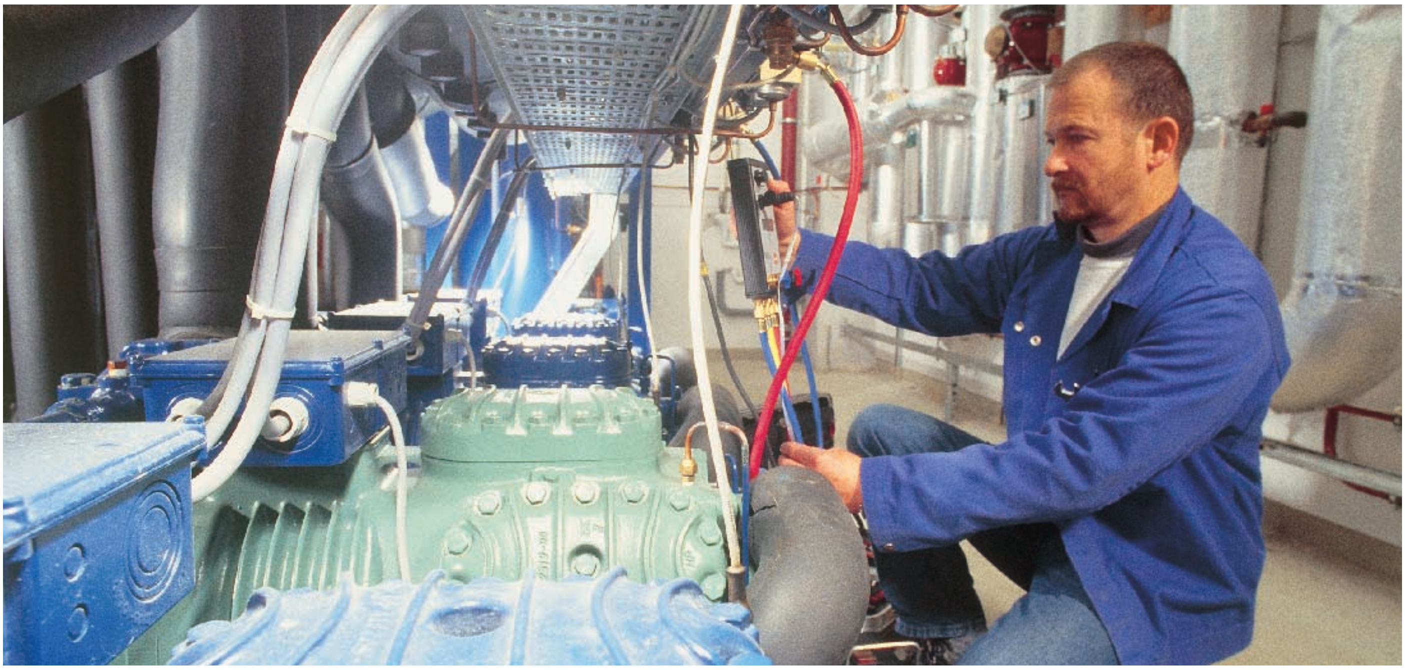
Practical measurement of pressures and temperatures in refrigeration systems

Linde exploits the advantages of the electronic manifold

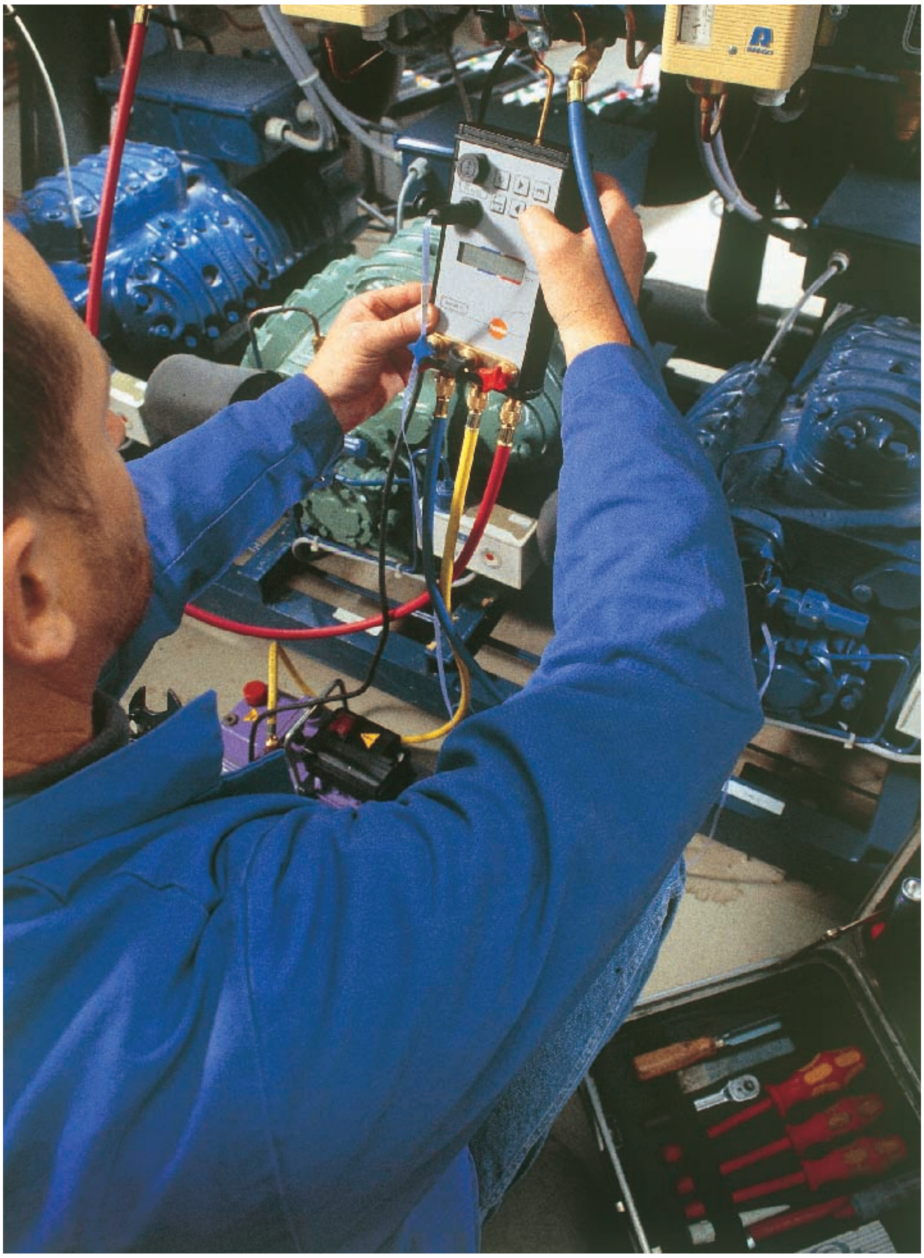
The new manifolds from Testo permit the measurement, recording and regulation of refrigeration systems and heat pumps in one easy-to-use device.

Some of the most important tools of the trade for refrigeration technicians and refrigeration system installation engineers are equipment for measuring pressure levels and temperatures. Generally speaking, this equipment primarily consists of banks of mechanical manometers. In practice, the wide variety of standard refrigerants means that multiple devices of this type with the corresponding scales or separate conversion tables or sliders are required. Further equipment includes temperature sensors and, if necessary separate vacuum and absolute pressure meters. In the refrigeration technology division at Linde AG, a leading manufacturer of refrigerated and non-refrigerated equipment for the grocery trade, modern testo 560 electronic manifolds are used for measuring, recording and regulating refrigeration systems. These devices form a unit of high quality sensors for measuring pressure, vacuum and temperature with integrated three-way valve banks to temporarily change the flow paths in systems. The pressure level and condensation temperature are displayed digitally. The measuring instrument's software can support 35 different refrigerant types. This means that it is suitable for virtually any refrigeration system. Additional devices and conversion tables or sliders are no longer necessary. The update option can be used to add new refrigerants at any time. The three-way valve banks make it possible to carry out the necessary system regulation operations right through to vacuum generation and filling, all with the device connected. The integrated vacuum measuring cell has optimum protection against positive pressure, thanks



to a valve. A connection for temperature sensors provides the option of calculating superheating and subcooling levels. For this purpose the probes are attached to the output of the evaporator or liquefier with a Velcro strip on the tube.
The most striking features include the recording and documentation of values measured on-site. These can be saved directly in the unit and then later transferred to a PC. The included software permits easy archiving and evaluation. The particular advantage of this option is the recording of all relevant parameters which are collected over individually adjustable periods and intervals. This greatly simplifies troubleshooting.
For example, a frequent cause of errors during operation of a refrigeration system is frozen moisture in the circuit. This reduces the size of the passages so that less refrigerant is flowing, which means that the refrigeration output drops. This problem can be identified very simply and reliably via the long-term recording of the evaporation and condensation pressure levels, without an installation engineer having to monitor the operation of the system for hours.
The electronic manifolds with high-pressure, low-pressure, vacuum and temperature measuring capabilities are convenient tools and measuring instruments all in one. They simplify practical work during the setting up and servicing of refrigeration systems and heat pumps.

Photos: Pressure level and temperature measurements in refrigeration systems



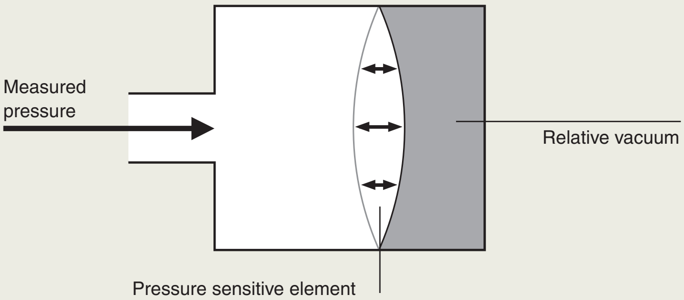
Calibration laboratory

Pressure

In the past few years the calibration laboratory for pressure measurements has been greatly expanded. For calibration work there are high precision pressure balances and electronic pressure calibration equipment available. Today the laboratory is accredited for relative and absolute pressure levels from 0 to 70 bar. Thus an exceptionally broad measurement range can be calibrated with maximum precision. The best possible measurement uncertainty in a range from 0.2 to 160 mbar is just 0.001 mbar.

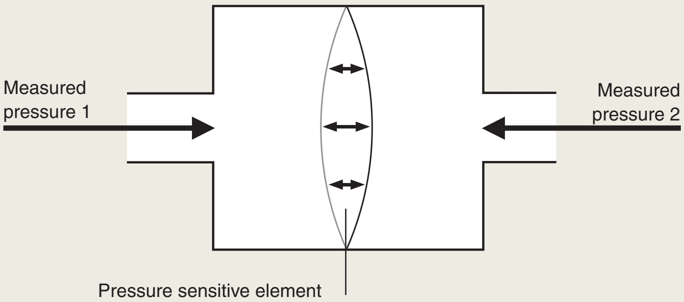
Absolute pressure (P_{abs})

The pressure which applies to the vacuum in the universe (zero pressure) is known as absolute pressure. Absolute pressure has "abs" as its index.



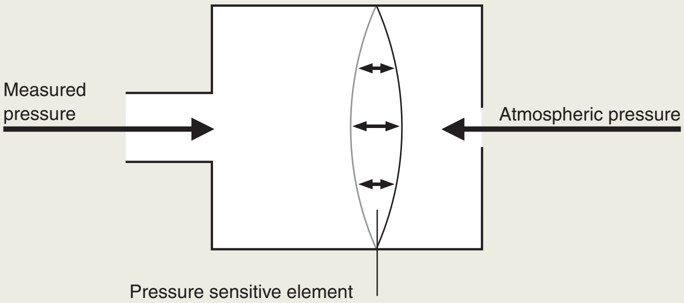
Differential pressure, pressure difference (Δp)

The difference between two pressures p_1 and p_2 is known as pressure difference ($\Delta p = p_1 - p_2$). If the difference between two pressures is a variable, this is referred to as differential pressure ($p_{1,2}$).



Atmospheric pressure difference, positive pressure

Atmospheric pressure difference (p_e) is the difference between an absolute pressure (p_{abs}) and the respective atmospheric pressure ($p_e = p_{abs} - p_{amb}$). This is generally referred to as positive pressure.



Atmospheric air pressure (P_{amb})

This is the most important pressure for life on earth. Atmospheric pressure is created by the weight of the atmosphere surrounding the earth. The atmosphere reaches a height of up to approx. 500 km. Pressure decreases constantly up to this height (absolute pressure P_{abs} = zero). Atmospheric air pressure is also influenced by fluctuations in the weather. The average P_{amb} at sea level is 1013.25 Hectopascal (hPa) or millibar (mbar/ normal pressure in accordance with DIN 1343). Typically this value can fluctuate by ±5 % if there are low or high pressure weather areas.

Measuring principle

When designing pressure meters, the principle of the effect of pressure on a defined area is almost always used. This is then retraced to a measurement of force.

The following formula applies:

$$\textbf{Pressure (p)} = \frac{\textbf{Force (F)}}{\textbf{Area (A)}}$$

Pressure meters

Types of pressure meters

Liquid pressure meters
- U-tube manometer
- Inclined tube manometer
- Multi-liquid manometer
- Float manometer

Pressure balances with sealing liquid

Piston pressure meters
- Piston pressure meters with spring-loaded piston
- Piston pressure scales

Elastic pressure meters

Electric pressure sensors and pressure meters
- Sensor principles with strain meters
- Sensor principles with path measurement
- Compression meter
- Ionisation pressure meter
- Friction meter

Advantages of electrical pressure meters

There is a displacement of 1-3 mm in elastic pressure meters. The deformation in electrical pressure sensors is only a few µm. Due to this very low mechanical deformation, electrical pressure meters / sensors have an excellent dynamic performance and low material stress resulting in high endurance levels and long-term stability. Electrical pressure meters can also be manufactured in very small sizes.

An additional advantage is the easy-to-read display. Considering today's technology standards, accurate pressure measurement is becoming more and more important. Precision measuring meters have an accuracy of ±0.05 % of the full-scale value. In the case of mechanical manometers, such accuracies cannot be read on account of the parallax error and mechanical performance of the springs. Electrical precision meters with LCD display often have a resolution in the thousandth range of 0.001.

Conversion table for the most important pressure units

	Pa	hPa/mbar	kPa	MPa	bar	psi	mmH_2O	inH_2O	mmHg	inHg
Pa	1	100	1,000	1,000,000	100,000	6,895	9.807	249.1	133.3	3,386
hPa/mbar	0.01	1	10	10,000	1,000	68.948	0.09807	2.491	1.333	33.864
kPa	0.001	0.1	1	1,000	100	6.895	0.009807	0.2491	0.1333	3.386
MPa	0.000001	0.0001	0.001	1	0.1	0.006895	0.000009807	0.0002491	0.0001333	0.003386
bar	0.00001	0.001	0.01	10	1	0.0689	0.00009807	0.002491	0.001333	0.0339
psi	0.0001451	0.0145	0.14505	145.05	14.505	1	0.001422	0.0361	0.0193	0.4912
mmH_2O	0.102	10.2	102	102,000	10,200	704.3	1	25.4	13.62	345.9
inH_2O	0.004016	0.4016	4.016	4,016	401.6	27.73	0.0394	1	0.5362	13.62
mmHg	0.007501	0.7501	7.501	7,501	750.1	51.71	0.0734	1.865	1	25.4
inHg	0.0002953	0.0295	0.2953	295.3	29.53	2.036	0.002891	0.0734	0.0394	1

①
Leakage test in compliance with DIN EN 378 and DIN 8975

Refrigerating systems must be subjected to a leakage test before commissioning. Conscientious testing prevents refrigerant loss, reduces energy consumption and contributes to the protection of our environment.

The system should ideally be filled with dry oil-free air or nitrogen at permitted operating positive pressure for the leakage test. Filling is carried out directly using the electronic manifolds. The higher the test pressure that can be selected, the smaller the leakage volumes that can arise during practical operation.

Temperature fluctuations in the surrounding environment can have a significant influence on the results of measurements during the leakage test. This is why the assessment of the leakage resistance of a system by pressure measurement alone can lead to incorrect results. Changes in the ambient temperature are recorded by the internal or external temperature probe and taken into account by the electronic manifolds testo 556 and testo 560.

②
Evacuating the system in compliance with DIN 8975

Foreign gas must be removed from the system first before the system is filled with refrigerant, irrespective of the type of refrigerant. This can collect in the liquefier after starting up because it cannot be liquefied in the refrigerating system. The driving performance increases, the delivery rate of the compressor drops and the refrigerant mass flow rate and cooling capacity are reduced.

Water must be removed from fluorinated hydrocarbon systems because fluorinated hydrocarbon refrigerants react with water and form extremely corrosive acids. A reduction of the air pressure by vacuum pump lowers the boiling point of the water at the same time. The water evaporates at low pressure when heat is applied. It is sucked away by the vacuum pump and fed into the atmosphere. The heat causing the water to evaporate comes from the surrounding environment. The higher the ambient temperature, the faster the water evaporates.

Evacuating the system, i.e. connecting the vacuum pump to the refrigerating system, takes place directly through the valve bank of the electronic manifold, testo 560, or the vacuum measuring unit, testo 551. The vacuum sensor records the evacuating process within a measurement range of 0 to 200 hPa/mbar with maximum precision. The simultaneous display of the ambient and steam/sublimation temperature on the display makes it possible to see immediately if the achieved vacuum is sufficient for drying the circuit.

③
Filling the system with refrigerants

The circuit is connected to the refrigerant container via the valve bank of the electronic manifold and filled from the liquid or vapour phase. Venting the connecting lines and dosing the refrigerant volume is carried out with the help of the valves.

④
Choice of refrigerant

The purpose of a refrigerant is to remove heat from a medium at low temperature and to cool it or keep it cool and to transfer this warmth to the environment, i.e. to the air or water. Definition of refrigerants and their abbreviated designations are stipulated in DIN 8962. A wide variety of refrigerants is available for many different applications. Up to 38 standard manifolds can be called up in the electronic manifold menu. New refrigerants can be entered into the instrument using updates. The measured pressure on the suction and pressure side is shown on the display. The relevant condensation and evaporation temperatures are calculated and displayed simultaneously.

⑤
Commissioning

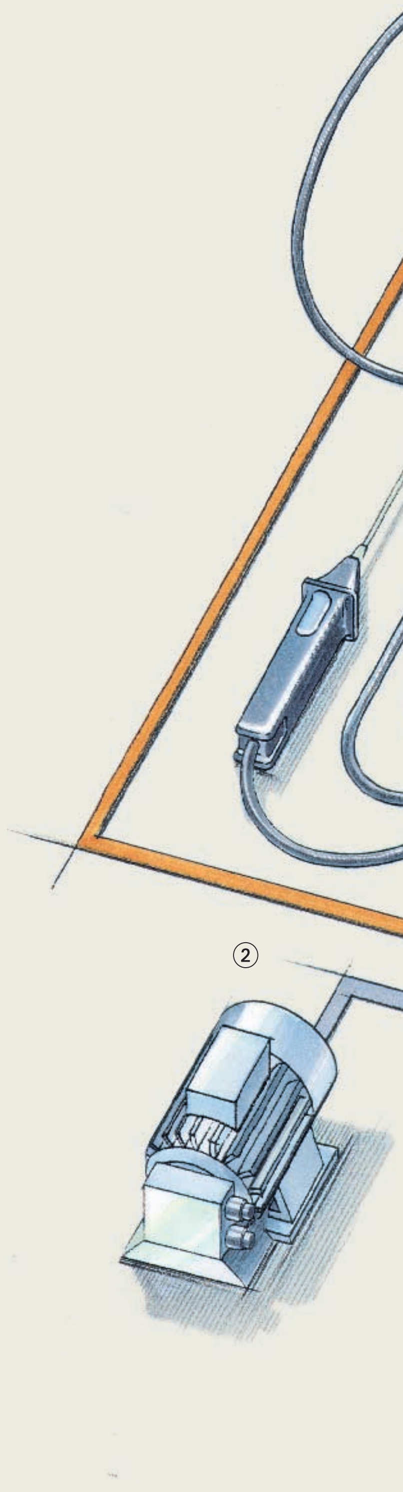
Condensation and evaporation temperatures, superheating, subcooling and other physical and electrical parameters are checked and adapted to requirements where necessary during commissioning. All electronic manifolds from Testo show both the measured pressures as well as respective calculated condensation and evaporation temperatures for the selected refrigerant.

Fundamentally, the following applies: superheating should be as high as necessary and as low as possible. Its main objective is to protect the compressor. That is why it should be defined and regulated both at the vaporiser output as well as directly before the suction intake of the compressor. Subcooling should be as high as possible taking into account financial aspects. A check at the vaporiser output as well as in front of the throttle device is also necessary. Fault-free and long-life operation is only guaranteed if saturated or subcooled refrigerant is in place directly in front of the throttle device.

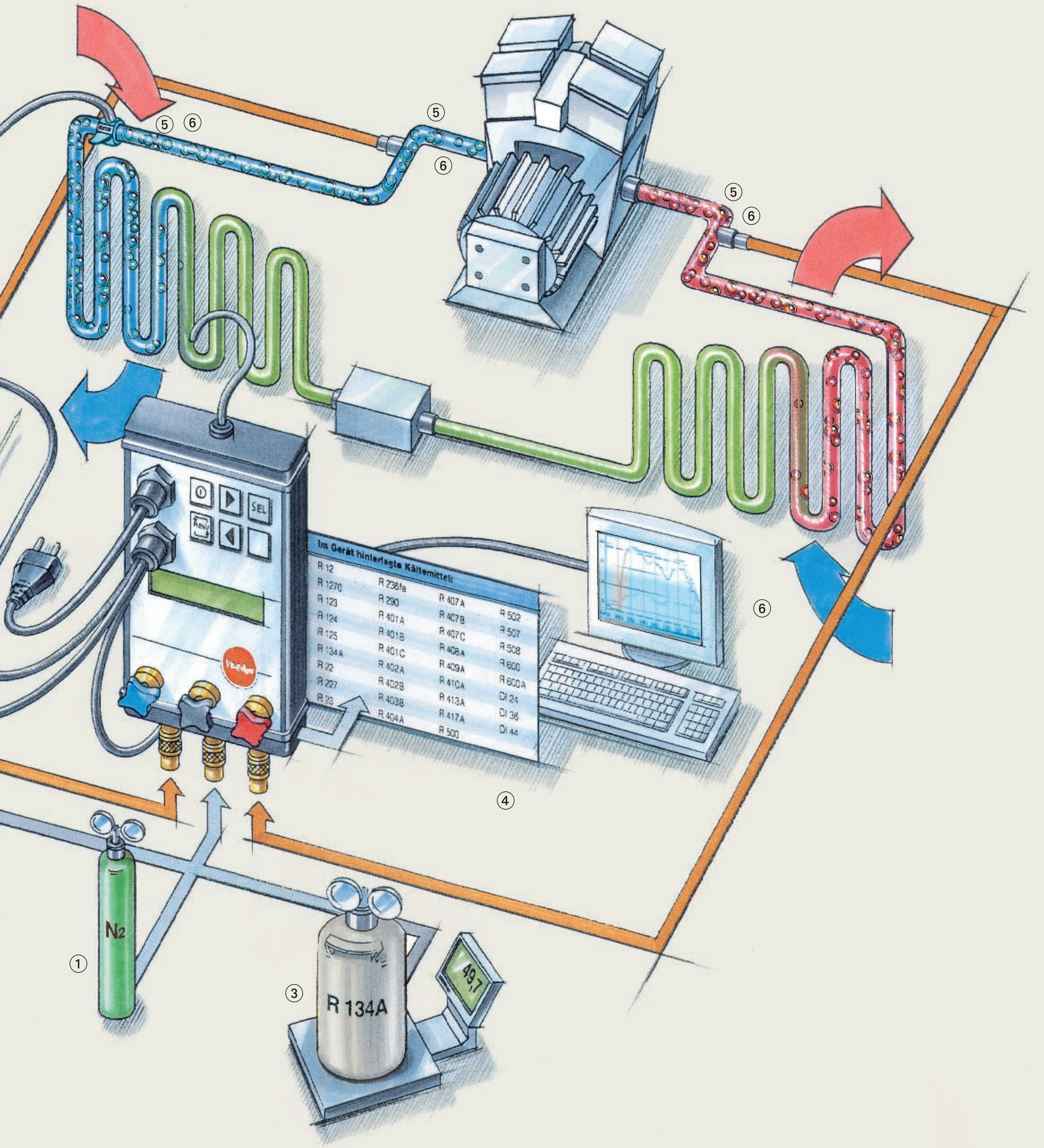
⑥
Inspections, maintenance, faults

Even the most perfect technical system requires servicing at regular intervals. Maintenance and repairs are necessary to various extents over the course of time. The purpose of all service work is the upkeep of the system. DIN 31051 Maintenance defines the general terminology and measures required for this.

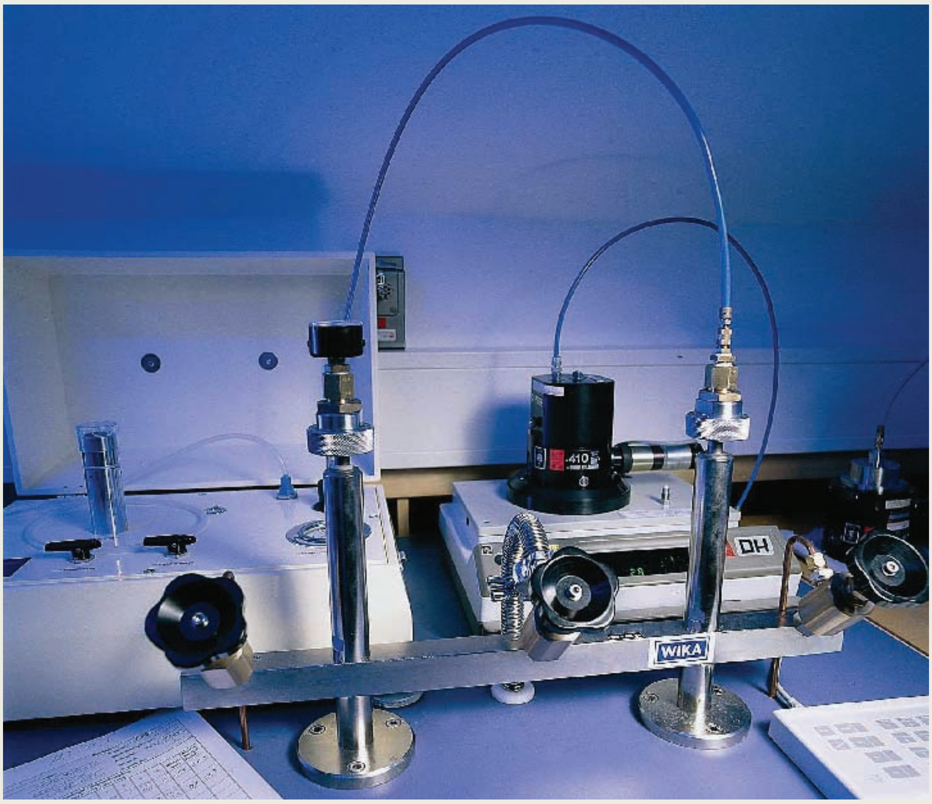
The electronic manifold is also the main tool and measuring instrument for the refrigeration system engineer. Along with main control measurements, the system's flow passages can also be changed temporarily using the three-way valve banks. Faults where the cause is not clear can be traced by means of long-term measurements. The electronic manifold testo 560 records the measurement data of the system at definable intervals. The stored values can be transferred to a PC and analysed and filed long-term with the help of easy-to-use software.



All about the refrigerating system



Industrial calibration process: pressure



Pressure balances as a reference standard

One of the most accurate industrial methods is pressure calibration using a pressure balance. This is why pressure balances with different designs are used as reference standards in DKD/ÖKD laboratories.

With piston pressure balances, the pressure is exerted on a specific area of a piston, which is compared to the weight force of calibrated weights or a spring element. The design challenge for this type of equipment is the seal on the piston. It must be adjusted to fit in a cylinder with a perfect pressure seal and minimal friction.

Testo CAL uses various pressure balances in the accredited laboratories. The calibration range is between -1 bar and 70 bar.

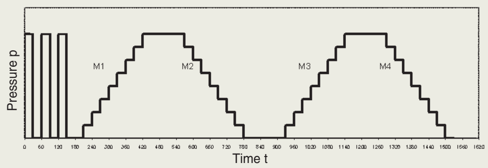
For DKD calibration there are three different procedures (identified using A, B and C) which depend on the precision class of the test specimens (see table). First of all, the object to be calibrated is preloaded at the full-scale value. Next, 11 or 6 measurement points (depending on the procedure) are distributed evenly across the measuring range.

Extract from the accreditation range from DKD laboratory 11204

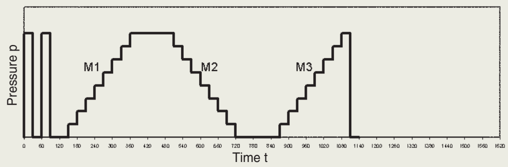
Parameter/ object to be calibrated	Measuring range	Meas. conditions	Measurement uncertainty
Negative and positive pressure p_e	-1 bar to 0 bar	Pressure medium: gas DIN EN 837 DKD-R 6-1	$1 \cdot 10^{-4}$ p_e; but not less than 20 µbar
	0.2 mbar to 160 mbar		$2 \cdot 10^{-4}$ p_e; but not less than 1.0 µbar
	< 160 mbar to 20 bar		$7 \cdot 10^{-5}$ p_e; but not less than 0.012 mbar
	< 20 bar to 70 bar		$8 \cdot 10^{-5}$ p_e
Absolute pressure p_{abs}	0.03 bar to 20 bar		$7 \cdot 10^{-5}$ p_{abs}; but not less than 0.0012 mbar
	< 20 bar to 70 bar		$8 \cdot 10^{-5}$ p_{abs}
Positive pressure p_e	0 bar to 70 bar	Pressure medium: gas DIN EN 837 DKD-R 6-1	$2 \cdot 10^{-3}$ p_e
	< 0.02 bar to 70 bar		$5 \cdot 10^{-4}$ p_e
Absolute pressure p_{abs}	1 bar to 21 bar		$5 \cdot 10^{-4}$ p_{abs}

Measuring instrument Accuracy	Calibration process
< cl. 0.1 (< 0.1% of full-scale value, but not less than ±0.2 Pa)	Calibration using procedure A: 11 measuring points evenly distributed across the measuring range for the instrument. Additional repeated measurement with second setup.
< cl. 0.1 to 0.6 (< 0.1 to 0.6 % of full-scale value, but not less than ±10 Pa)	Calibration using procedure B: 11 measuring points evenly distributed across the measuring range for the instrument.
< cl. 0.6 (< 0.6% of full-scale value, but not less than ±1 mbar)	Calibration using procedure C: 6 measuring points evenly distributed across the measuring range for the instrument.

Procedure A



Procedure B



Procedure C