

The temperature is one of the seven basic units of the international unit system. In general, it is the most familiar measuring unit and, in addition, the most important one for nearly all production processes.

Approximately one third of all measuring points in processing installations are temperature measurements.

### **1. Definition temperature**

For the unambiguous determination of a temperature, two fixed points and a linear scale are needed. The

Celsius scale with the unit symbol °C is the one generally known.

The origin of this unit is in the fixed temperature points of water. The freezing and boiling points of water were chosen, and this interval was divided into 100 parts.

The second most commonly used unit is

Kelvin with the unit symbol K.

Here the lower fixed point is chosen to be the lowest physically possible temperature, absolute zero, and the value 0 is allocated to it. The division was selected to be the same as that of water.

This defines the absolute zero as -273.15°C.

$$0^{\circ}\text{C} = 273.15\text{K}$$

In practice, temperature information is given in the unit °C. For temperature differences, usually the unit Kelvin K is used.

### **2. Measuring principles**

The temperature has many physical effects on materials. For example

- with solid and liquid materials it leads to changes in volume and length
- with gaseous materials in closed containers it leads to pressure changes
- with semi-conductors and metals it changes the electrical resistance.

This means that there are many options for measuring the temperature. For industrial applications, in practice the contact-making measuring methods have become the most commonly used. This includes

- mechanical contact thermometers
- electrical contact thermometers.

#### **2.1 Mechanical contact thermometers**

The mechanical contact thermometers include, besides the generally familiar glass thermometers where the length of a liquid column allows the temperature to be read, enclosed systems filled with liquid or gas where the internal pressure is a function of the temperature. The metal-expansion thermometers (bi-metal) also belong to this group.

Mechanical thermometers are of a simple, robust and reliable design. They do not require any external energy supply for their function. For thermometers with dials, bi-metal systems or gas pressure-spring systems are usually used.

LABOM thermometers with dials correspond to the requirements in EN 13190. Housing and movements are made from corrosion resistant materials, as are all connectors, capillaries and stems. The devices can be supplied with mechanical and inductive contact devices and in this way they can be used for temperature monitoring in plants. Scale ranges see data sheet T1-027. Available upon request.

##### **2.1.1 Liquid-in-glass thermometers**

For process measuring technology, liquid-in-glass thermometers are rather less important. They are very suitable for calibration and as a standard for other temperature measurements. They are also appreciated on account of their high accuracy and reliability for local temperature display in laboratories.

##### **2.1.2 Liquid-expansion thermometers**

Liquid-expansion thermometers work according to the same principle as glass thermometers. In principle, they consist of an immersed tube with a pressure vessel and display. Both parts are connected together via a capillary. The vessel is regarded as the active part of the immersed tube and is filled with a liquid as the expanding medium.

The expansion of the liquid will lead to a pressure increase in the enclosed system. The pressure change is displayed by means of a spring measuring system. The liquids used are generally industrial alcohols.

### 2.1.3 Gas expansion thermometers

Gas expansion thermometers hold a key position in process measurement technology. Just as with fluid thermometers, the thermal expansion of an enclosed volume is displayed by means of a Bourdon-tube system.

The gas filling usually consists of dry nitrogen with a system pressure of 40 to 130 bar. This allows temperatures from -80°C to 600 °C to be measured.

### 2.1.4 Bimetallic thermometers

The bimetallic thermometer essentially consists of an immersion tube with a welded-in bimetallic helix and a display unit with a dial and a pointer fixed onto them. The 270° rotation of the bimetallic helix is directly transmitted via a shaft to the pointer.

The bimetallic helix consists of two firmly connected metal strips with different temperature expansion rates. These strips are wound up helically. By choosing an appropriate winding length, diameter and material combination, the thermometer is tuned in such a way that the nominal temperature range corresponds to a rotation of 270°. By choosing different material combinations for the bimetallic strip, scale ranges between -100 °C and +600 °C can be chosen. Designs and dimensions are defined in EN 13190.

### 2.2 Electrical contact thermometers.

Electrical contact thermometers have become increasingly important. In contrast to mechanical thermometers, the output signals can be transmitted, displayed, recorded and processed. In addition, the design and size can be matched to the measuring task as desired. In this context thermo-couples and resistance thermometers are to be mentioned among others.

#### 2.2.1 Thermo-couples

Thermo-couples utilise the so-called Seebeck effect. They consist of two different metal wires which are connected at one end. A temperature change at the connection point results in an electro-motive force (EMF) at the other two open ends and therefore to a measurable change in the voltage.

Thermo-couples are suitable for temperatures of -200 to nearly +2000°C, and they are therefore also suitable for the measurement of very high temperatures.

#### 2.2.2 Resistance thermometers

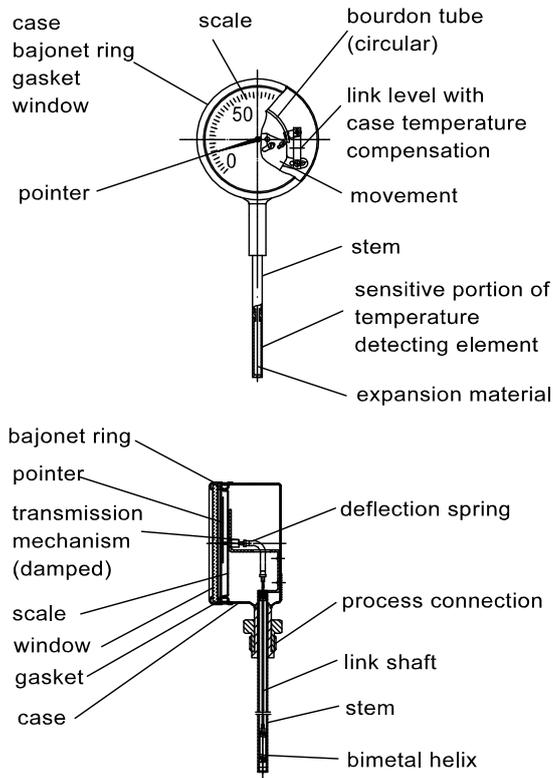
Resistance sensors use the effect that the electrical resistance of a material changes as a function of its temperature. This resistance change can be measured and then converted into a temperature. There are two different types of resistance sensors: metallic sensors, mainly platinum (Pt100, Pt1000) and semiconductor sensors (NTC, PTC). Everywhere where high precision and low drift are required, Pt100/ Pt1000 resistance thermometers are used. The Pt100/Pt1000 sensor is a resistor made from platinum, which at 0°C has a resistance of 100 Ohm or 1000 Ohm and whose resistance increases as the temperature rises.

Usually sensors of the accuracy classes A or B, according to DIN EN 60751, are used for temperature measuring devices.

The permissible deviations according to DIN EN are for all nominal resistances in

- class A:  $\pm (0,15 + 0,002 \times [t])$  °C
- class B:  $\pm (0,3 + 0,005 \times [t])$  °C

Class A requires platinum thermometers in the range between -200°C and +650°C; class B between -200°C and +850°C.



### 2.2.3 Temperature transmitters

Temperature transmitters are provided with an electrical signal for the relevant process measurement as the input signal. These resistance or voltage signals are transformed into standardised signals by the transmitter. This means that longer leads are possible without change to the signal, and that cable interference or potential drift are avoided.

The design of transmitters is so compact that they can be integrated into the connection head of the thermometer, either instead of the ceramics base on the measuring insert or in the cover of the head housing.

„Intelligent“ digital transmitters allow connection to all commercially available Pt-sensors and can be easily parameterised online via a local interface or HART or Profibus.



## 3. Definitions

For dial thermometers, i.e. all spring and bimetallic thermometers, the requirements and tests are defined in EN 13190.

For resistance thermometers, i.e. for the measuring inserts, all the relevant requirements are described in the standard DIN 43762.

An overview of the fundamental values and permissible limiting deviations of resistance thermometers of classes A and B and further information about tolerances are included in the standard DIN IEC 751.

### Measuring ranges / range of indication

The standard EN 13190 mentioned above distinguishes for dial thermometers the measuring range and the range of indication. The measuring range must always be 2/3 of the range of indication. Triangles on the edge of the scales are to be used to mark the start and end of the measuring range.

### Accuracy classes

Dial thermometers are divided into two accuracy classes: class 1 and class 2. Information about the error classes with reference to the scale range and the measuring range are defined in EN 13190. The information is given in °C.

For electrical resistance thermometers, the tolerance classes A and B are defined in accordance with the standard DIN IEC 751. The accuracy, or rather the measuring error of a temperature measurement, depends not only on the fundamental precision of the measuring device and the calibration, but decisively on the execution and selection of the measuring method. The better the heat transfer from the process to the temperature sensor, the smaller the uncertainty in the measurement and the faster a stable end temperature is reached.

Temperature measuring devices are especially always adjusted and calibrated in containers of thermo-stabilised liquids or dry calibrators.

### Measuring stability

The measuring stability of all temperature measuring devices used in the process can be impaired. In particular in the case of bimetallic thermometers vibrations or impacts can lead to faulty measurements.

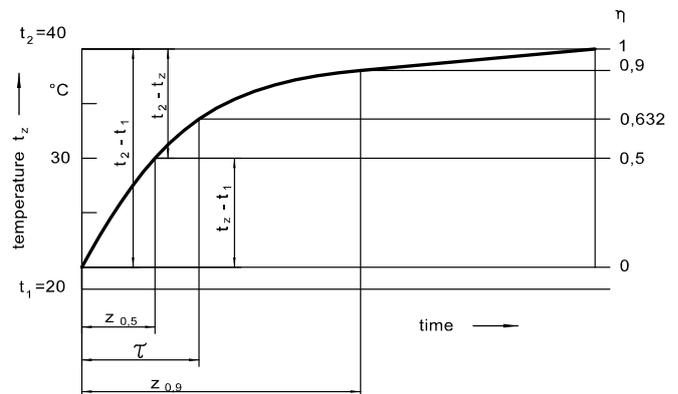
Gas expansion thermometers are more suitable under such environmental conditions because of their more stable measuring systems.

### Transition or time response

In the case of temperature changes the time response is important. An accurate temperature measurement always requires some time during which the heat exchange between the process temperature and the contact thermometer takes place. This adaptation time depends on:

- type and design of the temperature sensor
- type of material to be measured
- flow rate of the medium to be measured

If the temperature value is abruptly changed by immersing the thermometer, it will only react gradually with a transition function.



### Temperature influence

By immersing a contact thermometer into a hot medium, heat is withdrawn from the medium to be measured. This results in a measuring error which is the larger, the larger the heat transfer is from the product to the measuring device.

In the case of large, thick-walled flanged thermowells, or an insufficient immersion depth of the measuring sensor into the product to be measured, the heat energy is conducted to the measuring point through the material.

The heat exchange between the thermometer and the surrounding pipe wall and the parts exposed to the environmental air also influences the measuring result by conducting away or radiating off heat. Thermometers should be selected and arranged in such a manner that the measuring error arising in this way be kept as small as possible.

### Temperature measurements on surfaces

The measuring of surface temperatures is generally regarded as rather difficult. Several requirements have to be fulfilled:

- a good and uniform heat transfer between the product and e.g. the surrounding pipe surface
- the heat transfer from the surface of the pipe to the sensor must be as good as possible
- the heat dissipation by the thermometer must be as low as possible.

The first requirement must be satisfied by the product, the process or the processing technology.

For fulfilling the second requirement, a form-fit metallic clamping system is necessary, and for the third requirement an insulation sleeve must prevent heat dissipation.

The temperature sensor in clamp-on technology excellently fulfils all requirements on devices for optimum surface temperature monitoring, particularly for sterile processing.

For mounting on pipes with external diameters from 4 up to 104 mm the resistance thermometer in clamp-on technology is available as a pipe collar. On pipes with external diameters from 57 up to 200 mm you can mount it with tightening straps.

The resistance thermometer for measuring surface temperature measures temperatures at tanks and pipes. The temperature is sensed by a modified, rapid response Pt 100 measuring element. Device accuracy has been maximized by designing for thermal isolation. Heat transfer has been optimized by spring loading the measuring insert.

The use of a weld-on or weld-in socket makes mounting very straightforward.



Resistance thermometer clamp-on-technology



Resistance thermometer Clamp-on for tightening strap installation



Resistance thermometer for measuring surface temperature