E 13 Internal/external cold junction compensation in thermocouples

Thermocouples measure temperature in the range of -200 °C to 1600 °C, different types (K, J, ...) having different temperature ranges. They are based on the principle of thermoelectric voltage, which results from the different coefficients of expansion (temperature dependent) of the metals. A charge separation according to the Seebeck effect takes place. This creates a direct voltage source (thermoelectric voltage) above -273 °C. This voltage is used for measuring temperature.

A thermocouple does not allow the measurement of an “absolute” temperature, only the difference of the temperatures between the measurement point (e.g. 100 or 0 °C) and the cold junction (for standardized range at 0 °C). A thermoelectric voltage is also created at 0 °C. A voltage given in the standardized voltage series of different thermocouples always means: "reference 0°C" and can be calculated according to the following formula.

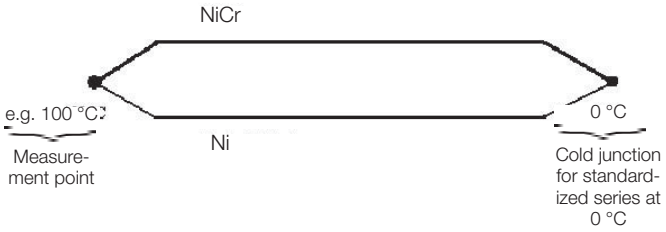
$$U_{(100°C)} = U_{(th\ at\ 100°C)} - U_{(th\ at\ 0°C)}$$

In technical application, the **thermocouple conductors are only directly connected to each other at the measurement point,** whereas the ends of the thermal wire are connected to the cold junction. At the cold junction, the measuring instrument is connected via measurement lines (thermocouple lines or compensation lines or another material e.g. copper). In order to now measure the temperature correctly, the temperature of the cold junction must be known according to the formula above. The two measurement lines, from the cold junction to the measuring instrument, should furthermore be made from the same material, in order to hinder the generation of additional thermoelectric voltages.

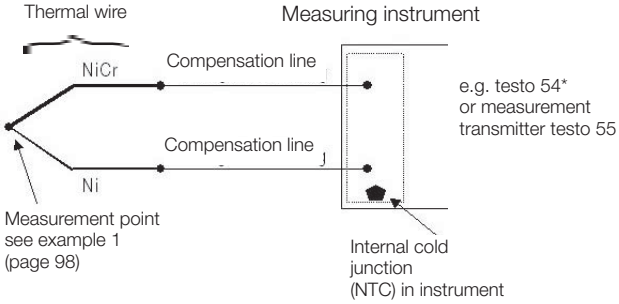
New thermoelectric voltages also occur at the transition point to the copper wire. This means that only the voltage difference (temperature difference) between the measurement point and the transition point (external/internal cold junction) can be measured.

At the transition points from the thermocouple to another material (e.g. copper wire), thermoelectric voltages occur which falsify the measurement result. For this reason, an external or internal cold junction temperature for error compensation must be entered, in order to obtain accurate measurements.

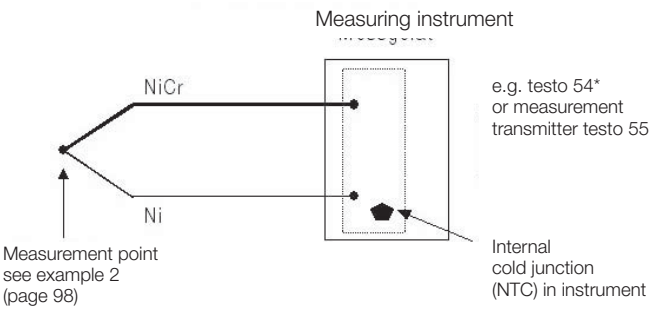
In **internal cold juntion measurement,** the transition from the thermocouple (e.g. NiCr-Ni or compensation line) to a different material (e.g. the copper conductors of the electronic bard) is located within the measuring instrument. For this reason, the cold junction temperature measurement (e.g. by NTC) takes place in the instrument. For the use of compensation lines, cf. chap. E 9 above.



Internal cold junction with compensation line (same thermoelectric properties as thermocouple)



Internal cold junction with thermocouple line

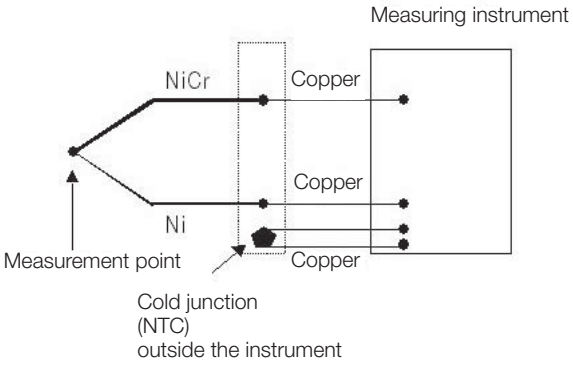


* In testo 54 (external process display), the cold junction temperature can be read when the TC input is shorted.

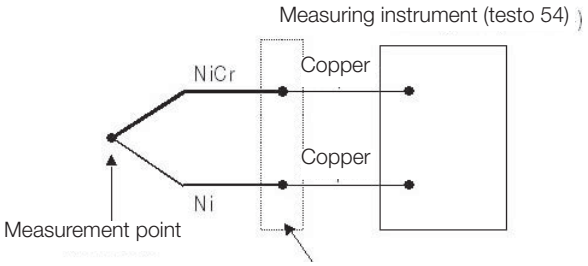
E 13 Internal/external cold junction compensation in thermocouples

In **external cold junction measurement,** the transition from the thermocouple (e.g. NiCr-Ni) to a different material (e.g. copper wire) is located outside the measuring instrument. For this reason, the cold junction temperature measurement (e.g. by NTC) takes place externally. (see illustration below).

External cold junction with any material (e.g. copper)



External cold junction in testo 54 with any material (e.g. copper)



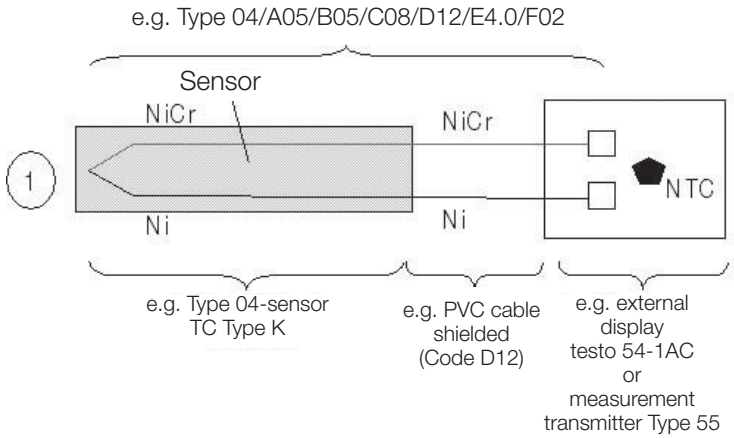
Correction of standard basic values (cf. chap. C 15), when the cold junction temperature deviates from 0 °C (examples):

TC Type	Reduction in mV at 20 °C	50 °C
Cu-CuNi (Type T)	0.80	2.05
Fe-CuNi (Type J)	1.05	2.65
NiCr-Ni (Type K)	0.80	2.02

In testo 54 (cf. brochure “Stationary Measurement Technology, Process Displays/Online Monitoring/General Information, testo 54 ”), the correction values are stored for all common TC types, the cold junction temperature is entered via the operating menu.

Examples:

1) Internal cold junction with thermocouple



2) Internal cold junction with compensation line