

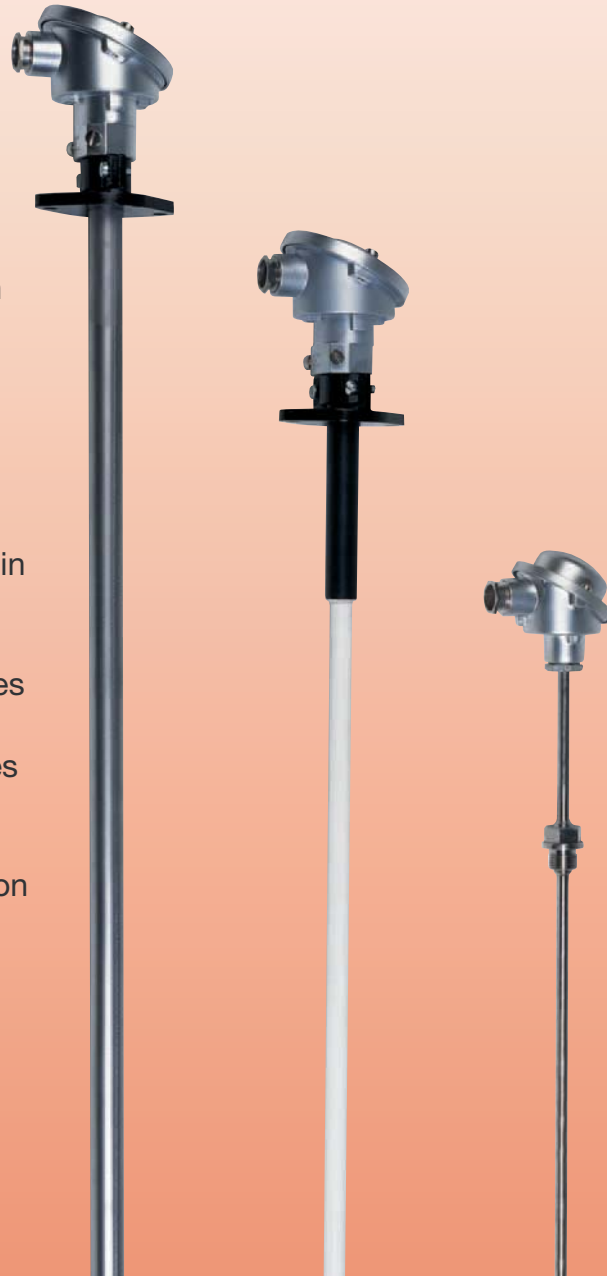


Basic Principles Design and Application of Thermocouples



measuring
•
monitoring
•
analysing

- Screw-in and plug-in thermocouples according to DIN
- Screw-in thermocouples with compensating lead
- Immersion and plug-in thermocouples with compensating lead
- Plug-in thermocouples with bayonet lock
- Jacket thermocouples
- Special probes according to customer specification



T2



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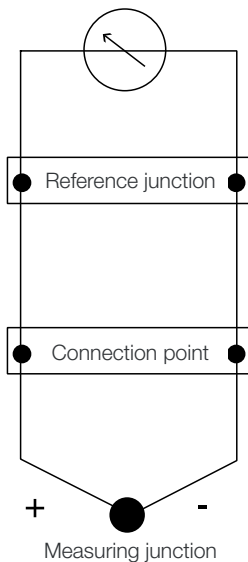
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Basic Principles:
Thermo-
couples

Seebeck effect

Thermocouples use the Seebeck effect: the Seebeck effect states that a voltage is generated at the point of contact of two different metals.



Electrical conductors of different metals or metal alloys are connected by punctiform welding.

A thermal e.m.f. is generated at the free ends (point of connection) by heating this junction (measuring junction).

The free ends are extended to a point with known temperature (reference junction) by means of compensating leads.

The temperature difference between measuring junction and reference junction is measured with thermocouples. The size of the thermal voltage depends on the materials used as well as the temperature difference.

A variety of metals and alloys that assure a smooth thermal e.m.f. characteristic without inflection point are used nowadays for industrial measurements.

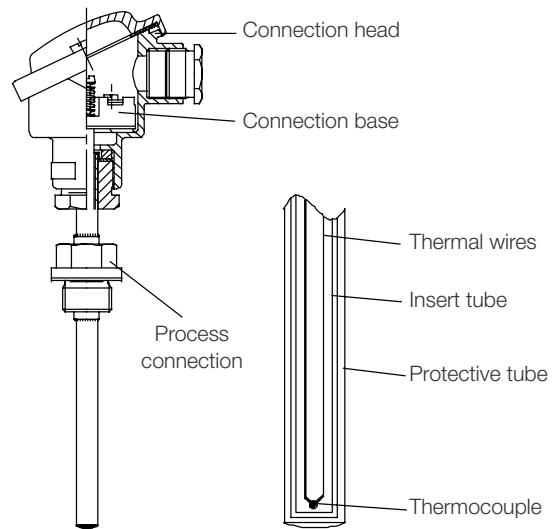
Some of these combinations have been standardized in IEC 584-1 and DIN 43 710.

Element	Temp. max.	Standardized to	Plus shank	Minus shank
FE-CuNi (J)	750°C	1200°C	black	white
Cu-CuNi (T)	350°C	400°C	brown	white
NiCr-Ni (K)	1200°C	1370°C	green	white
NiCr-CuNi (E)	900°C	1000°C	violet	white
Pt10Rh-Pt (S)	1600°C	1540°C	orange	white
Fe-CuNi (L)	600°C	900°C	red	blue
Cu-CuNi (U)	900°C	600°C	red	brown

The elements are not compatible due to different alloys. The maximum temperature is the temperature up to which a limit deviation is defined.

Design of thermocouples

In addition to a vast range of special versions, there are also versions whose component parts are fully described by standards.



Thermocouples with connection head

These thermocouples consist of measurement probe, protective tube, connection head which contains a connection base and possibly flanges or clamp process connection.

The measurement probe is a moulded unit comprising thermocouple in an insert tube and connection base.

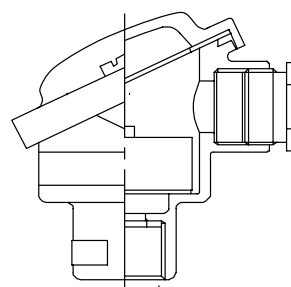
The measurement probes are manufactured as single or double versions. Their dimensions are defined in the standard DIN 43 735. Measurement probes with integrated two-wire transmitter are also manufactured. If a measurement probe is not used, the thermocouple with ceramic insulation is situated in the protective tube.

Protective tubes

In addition to the standard protective tubes, a large selection of protective materials is available, which are needed depending on the chemical and mechanical conditions.

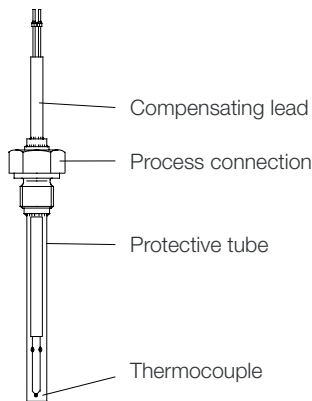
Connection heads

Connection heads models A and B are defined in DIN 43729. The smaller connection head form B, for which the two-wire transmitter has also been designed, is most commonly used.



Thermocouples with compensating lead

A measurement probe and connection head are not required for this version. The thermocouple is directly connected with the thermoelectric lead or compensating lead and inserted in the protective tube.



There are many very different designs for these thermometers. In addition to standard versions, customised versions are also available.

Jacket thermocouples

Jacket thermocouples are based on a mineral-insulated jacketed cable. The inner cable wires made of thermocouple material are embedded in pressed fireproof magnesium oxide in the thin-walled light jacketed cable made of stainless steel or Inconel.

Very good heat transfer between jacket and thermocouple allows short response times ($t_{0.5}$ from 0.1s) and high measuring accuracies.

The vibration-proof design assures long service life.

The flexible jacketed cable, minimum bend radius 5 x external diameter, allows temperature measurements at locations that are difficult to access.

Limit deviations

Thermocouples are defined in three tolerance categories according to IEC 584. This categorisation refers to the device status at delivery. It makes no reference to possible subsequent ageing, which greatly depends on the field service conditions. Fixed temperature limits for tolerance categories are not necessarily the recommended limits of the application temperature. The highest value applies in each case.

Element	Tolerance category
Fe-CuNi (J)	cl. 1: -40...+750°C: $\pm 0.004 \times t$ or ± 1.5 K
	cl. 2: -40...+750°C: $\pm 0.0075 \times t$ or ± 2.5 K
Cu-CuNi (T)	cl. 1: -40...+350°C: $\pm 0.004 \times t$ or ± 0.5 K
	cl. 2: -40...+350°C: $\pm 0.0075 \times t$ or ± 1.0 K
	cl. 3: -200...+40°C: $\pm 0.015 \times t$ or ± 1.0 K
NiCr-CrNi (K) and NiCrSi-NiSi (N)	cl. 1: -40...+1000°C: $\pm 0.004 \times t$ or ± 1.5 K
	cl. 2: -40...+1200°C: $\pm 0.0075 \times t$ or ± 2.5 K
	cl. 3: -200...+40°C: $\pm 0.015 \times t$ or ± 2.5 K
NiCr-CuNi (E)	cl. 1: -40...+800°C: $\pm 0.004 \times t$ or ± 1.5 K
	cl. 2: -40...+900°C: $\pm 0.0075 \times t$ or ± 2.5 K
	cl. 3: -200...+40°C: $\pm 0.015 \times t$ or ± 2.5 K
Pt10Rh-Pt (S) and Pt13Rh-Pt (R)	cl. 1: -0...+1600°C: $\pm [1 + (t-1100) \times 0.003]$ or ± 1.0 K
	cl. 2: -40...+1600°C: $\pm 0.0025 \times t$ or ± 1.5 K
Pt30Ph-Pt6Rh (B)	cl. 2: 600°C...1700°C: $\pm 0.0025 \times t$
	cl. 3: 600°C...1700°C: $\pm 0.005 \times t$

Thermal e.m.f. according to IEC 584-1

The Fe-Cu-Ni element model J is the most commonly used type. It is remarkable for its low price and high thermal voltage. Due to its good long-term stability, demand for the Ni-CrNi element model K is growing. Although it has a smaller thermal voltage, this is insignificant because of modern electronics.

Thermal e.m.f. in mV for temperatures in steps of 10°C (reference junction 0°C)

Fe-CuNi (J)

°C	0	10	20	30	40	50	60	70	80	90
0	0	0.507	1.019	1.536	2.058	2.585	3.115	3.649	4.186	4.725
100	5.268	5.812	6.359	6.907	7.457	8.008	8.560	9.113	9.667	10.222
200	10.777	11.332	11.887	12.442	12.998	13.553	14.108	14.663	15.217	15.771
300	16.325	16.879	17.432	17.984	18.537	19.089	19.640	20.192	20.743	21.295
400	21.846	22.397	22.949	23.501	24.054	24.607	25.161	25.716	26.272	26.829
500	27.388	27.949	28.511	29.075	29.642	30.210	30.782	31.356	31.933	32.513
600	33.096	33.683	34.273	34.867	35.464	36.066	36.671	37.280	37.893	38.510
700	39.130	39.754	40.382	41.013	41.647	42.283	42.922	43.563	44.207	44.852

NiCr-Ni (K)

°C	0	10	20	30	40	50	60	70	80	90
0	0	0.397	0.789	1.203	1.611	2.022	2.436	2.850	3.266	3.681
100	4.095	4.508	4.919	5.327	5.733	6.137	6.539	6.939	7.338	7.737
200	8.137	8.537	8.938	9.341	9.745	10.151	10.560	10.969	11.381	11.793
300	12.207	12.623	13.039	13.456	13.874	14.292	14.712	15.132	15.552	15.974
400	16.395	16.818	17.241	17.664	18.088	18.513	18.938	19.363	19.788	20.214
500	20.640	21.066	21.493	21.919	22.346	22.772	23.198	23.624	24.050	24.476
600	24.902	25.327	25.751	26.176	26.599	27.022	27.445	27.867	28.288	28.709
700	29.128	29.547	29.965	30.383	30.799	31.214	31.629	32.042	32.455	32.866
800	33.277	33.686	34.095	34.502	34.909	35.314	35.718	36.121	36.524	36.925
900	37.325	37.724	38.122	38.519	38.915	39.310	39.703	40.096	40.488	40.879
1000	41.269	41.657	42.045	42.432	42.817	43.202	43.585	43.966	44.349	44.729
1100	45.108	45.486	45.863	46.238	46.612	46.985	47.356	47.726	48.095	48.462

Connection head according to DIN 43729, form A

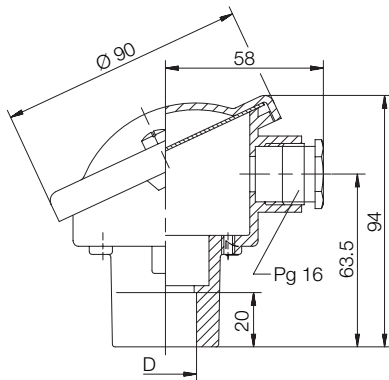
Standard **model A**

Material: aluminium-die casting

Protection: IP 54

Temperature range: -20 ... +80 °C

d in mm
22.5
26.5
32.5



Connection head in special design

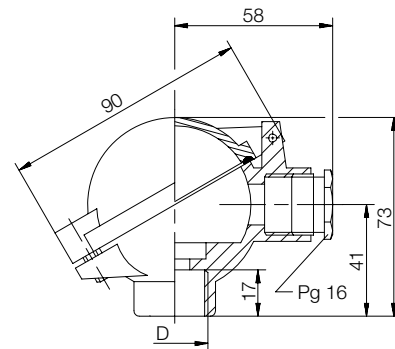
with hinged lid **model HABL**

Material: aluminium-die casting

Protection: IP 54 (Option: IP 65 or 67)

Temperature range: -20 ... +80 °C

d in mm
15.5
M24x1.5
22.0
32.0



Connection head according to DIN 43729, form B

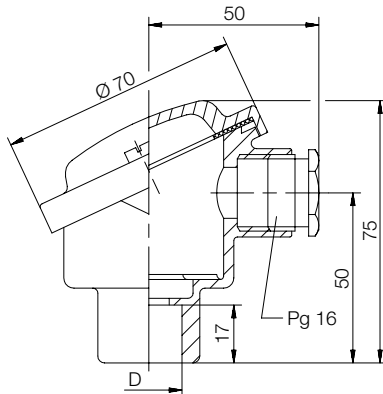
Standard **model B**

Material: aluminium-die casting

Protection: IP 54

Temperature range: -20 ... +80 °C

d in mm
15.5
M24x1.5



Connection head in special design

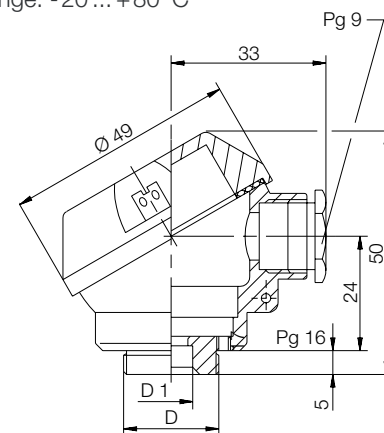
Small and compact **model MA**

Material: aluminium-die casting

Protection: IP 54

Temperature range: -20 ... +80 °C

d in mm
M10x1



Connection head according to DIN 43729 form B

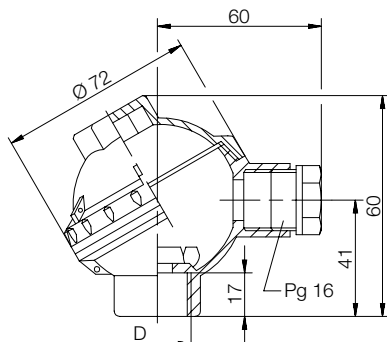
Plastic threaded cover **model SBK**

Material: plastic black (cover also in other colours)

Protection: IP 54

Temperature range: -20 ... +80 °C

d in mm
15.5
M24x1.5



T2