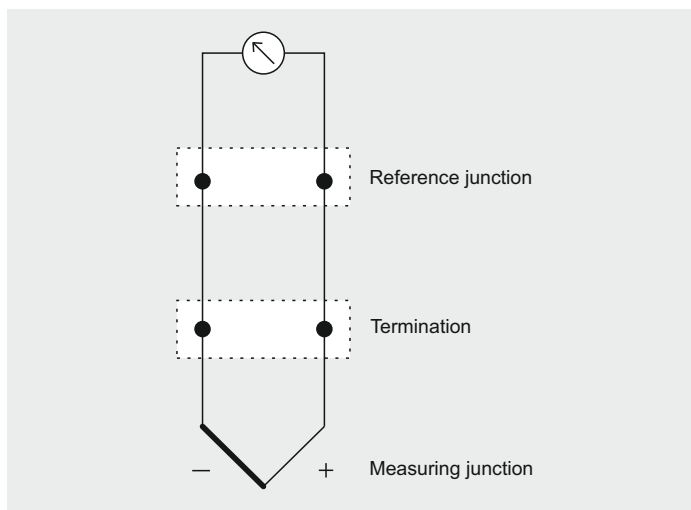


# Thermocouples - Functional principle and application

## The thermoelectric effect

The effect responsible for the action of thermocouples is the Seebeck effect. If a temperature difference exists along a wire, this will cause a displacement of electrical charge. The amount of the charge displacement depends on the electrical characteristics of the chosen material. If two wires of different materials are joined at one point and then subjected to a temperature, then a voltage difference will be generated between the open ends of the two wires. This voltage depends on the temperature difference along the two wires. In order to be able to measure the temperature at the junction, the temperature at the open end must be known. If the temperature of the open end is not known, then it must be extended (by a compensating cable) into the zone of known temperature (reference junction, usually referred to as the "cold junction").



**Fig. 1: Measuring circuit (schematic)**

The temperature of the reference junction must be known and constant. If no constant reference junction temperature is available, the reference junction has to be arranged as a thermostat, or its temperature has to be determined by means of a second sensor.

## Thermocouples to EN 60 584 and DIN 43 710

From the variety of possible metal combinations, certain ones have been selected (Tables 1 and 2) and their voltage tables and permitted tolerances incorporated in standard specifications (Fig. 2 and Tables 3 and 4).

Note that two Fe-Con thermocouples (Type J and L) and two Cu-Con thermocouples (Type T and U) have been standardized in both EN 60 584 and DIN 43 710.

The "old" thermocouples L and U are now being used less frequently than the thermocouples J and T to EN 60 584.

Thermocouple	Maximum Temperature	Defined up to	Positive limb	Negative limb	
FE-Con	J	750°C	1200°C	black	white
Cu-Con	T	350°C	400°C	brown	white
NiCr-Ni	K	1200°C	1370°C	green	white
NiCr-Con	E	900°C	1000°C	violet	white
NiCrSi-NiSi	N	1200°C	1300°C	mauve	white
Pt10Rh-Pt	S	1600°C	1540°C	orange	white
Pt13Rh-Pt	R	1600°C	1760°C	orange	white
Pt30Rh-PtRh	B	1700°C	1820°C	no data	white

**Table 1: Thermocouples to EN 60 584**

Thermocouple	Maximum Temperature	Defined up to	Positive limb	Negative limb	
FE-Con	L	700°C	900°C	red	blue
Cu-Con	U	400°C	600°C	red	brown

**Table 2: Thermocouples to DIN 43 710**

The individual thermocouples are not compatible, because of their differing alloy compositions. If a Fe-Con thermocouple Type L is connected to an instrument linearized for Type J, the difference in the thermal voltages leads to errors of up to several °C. The same applies to thermocouples Type U and T.

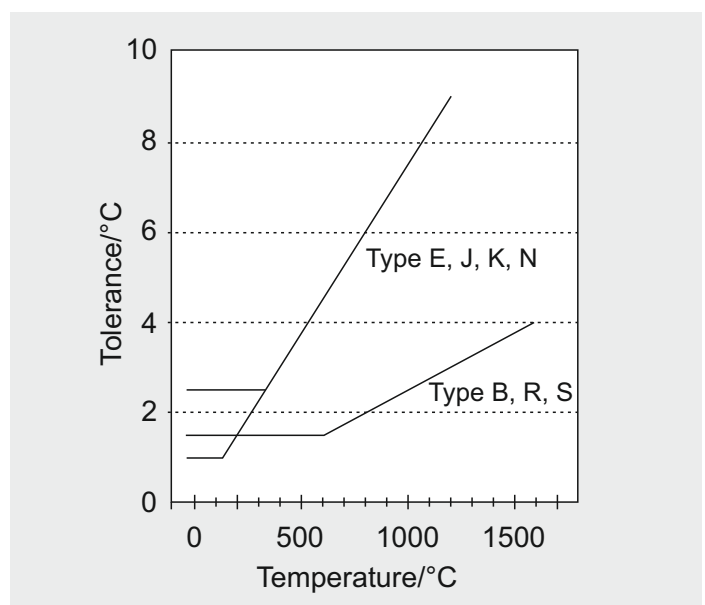
The maximum temperature represents the limit to which a tolerance is specified. The value under "defined to" is the temperature limit to which the thermal voltage is covered by standard specifications. In the thermocouples listed above, the first limb is always the positive one. The color codes apply both to the thermocouple itself and to the compensating cables. If the thermocouple wires are not color coded, the following differences may help to identify them.

- Fe-Con: positive limb is magnetic
- Cu-Con: positive limb is copper colored
- NiCr-Ni: negative limb is magnetic
- PtRh-Pt: negative limb is softer

These distinctions do not apply to the compensating cables. The thermocouples are insulated inside the fittings using ceramic materials. PVC, silicone, PTFE or glass fiber are used in the cables.

## Tolerances

EN 60 584 defines three tolerance classes for thermocouples. They normally apply to thermowires between 0.25 to 3mm diameter and to the condition as supplied. The standard cannot cover any possible subsequent ageing, since this largely depends on the conditions of use. The temperature limits specified for the tolerance classes are not necessarily the recommended operating temperature limits (see Tables 3 and 4). The larger value applies in each case.



**Fig. 2: Tolerances**

## Resistance thermometer - Functional principle and application

Thermocouple		Tolerance classes				
Fe-Con	J	Class 1	-40 ... +750°C	$\pm 0.004 \times t$	or	$\pm 1.5^\circ\text{C}$
		Class 2	-40 ... +750°C	$\pm 0.0075 \times t$	or	$\pm 2.5^\circ\text{C}$
		Class 3				
Cu-Con	T	Class 1	-40 ... +350°C	$\pm 0.004 \times t$	or	$\pm 0.5^\circ\text{C}$
		Class 2	-40 ... +350°C	$\pm 0.0075 \times t$	or	$\pm 1.0^\circ\text{C}$
		Class 3	-200 ... +40°C	$\pm 0.0015 \times t$	or	$\pm 1.0^\circ\text{C}$
Ni-CrNi and NiCrSi-NiSi	K	Class 1	-40 ... +1000°C	$\pm 0.004 \times t$	or	$\pm 1.5^\circ\text{C}$
	N	Class 2	-40 ... +1200°C	$\pm 0.0075 \times t$	or	$\pm 2.5^\circ\text{C}$
NiCr-Con	E	Class 3	-200 ... +40°C	$\pm 0.015 \times t$	or	$\pm 2.5^\circ\text{C}$
		Class 1	-40 ... +800°C	$\pm 0.004 \times t$	or	$\pm 1.5^\circ\text{C}$
		Class 2	-40 ... +900°C	$\pm 0.0075 \times t$	or	$\pm 2.5^\circ\text{C}$
Pt10Rh-Pt and Pt13Rh-Pt	S	Class 3	-200 ... +40°C	$\pm 0.015 \times t$	or	$\pm 2.5^\circ\text{C}$
	R	Class 1	-0 ... +1600°C	$\pm [1+(t-100) \times 0.003]$	or	$\pm 1.0^\circ\text{C}$
Pt30Rh-Pt6Rh	B	Class 2	-40 ... +1600°C	$\pm 0.0025 \times t$	or	$\pm 1.5^\circ\text{C}$
		Class 1				
		Class 3	+600 ... +1700°C	$\pm 0.0025 \times t$	or	$\pm 1.5^\circ\text{C}$
		Class 2	+600 ... +1700°C	$\pm 0.005 \times t$	or	$\pm 4.0^\circ\text{C}$

Table 3: Tolerances to EN 60584

Thermocouple		Tolerances		
Cu-Con	U	+100 ... +400°C	$\pm 3.0^\circ\text{C}$	
		+400 ... +600°C	$\pm 0.0075 \times t$	
Fe-Con	L	+100 ... +400°C	$\pm 3.0^\circ\text{C}$	
		+400 ... +900°C	$\pm 0.0075 \times t$	

Table 4: Tolerances to DIN 43 710 (1977)

### Linearity

The voltage produced by a thermocouple is not linear with temperature and must therefore be linearized by the subsequent electronics. Digital instruments are programmed with linearization tables, or appropriate calibration values have to be entered by the user. Analog instruments are often provided with non-linear scales. The characteristics of thermocouples (Fig. 3) are defined by voltage tables to ensure full interchangeability.

This means, for example, that a Fe-Con thermocouple Type J can be replaced by any other thermocouple of this type irrespective of the manufacturer, without requiring any recalibration of the instrument to which it is connected.

### Compensating cables to EN and DIN

Compensating cables for thermocouples have their electric and mechanical properties defined in the EN 60 584 or DIN 43 714 standards. They are made either of the same material as the thermocouple itself (thermocables, extension cables) or from special materials with the same thermo-electric properties within restricted temperature ranges (compensating cables proper). The use of compensating cables saves the extra cost in the case of certain noble metals.

Compensating cables consist of twisted cores and are identified by a color code and code letters as follows:

Letter 1: code letter for the thermocouple  
Letter 2: X: same material as thermocouple  
C: special material

Letter 3: several types of compensating cable can be distinguished by a third letter.

Example:

KX: compensating cable for NiCr-Ni thermocouple Type K made from thermocouple material

RCA: compensating cable for PtRh-Pt thermocouple Type R, made from special material Type A

The tolerance classes 1 and 2 are defined for compensating cables. Class 1 has closer tolerances, which can only be met by extension cables made from the same material as the thermocouple, i.e. the X-type.

Compensating cables proper are normally supplied to Class 2. Table 5 shows the tolerances for the different compensating cable classes.

The operating temperature range in Table 5 covers the temperature to which the entire cable may be exposed, including the thermocouple terminations, without exceeding the specified tolerances. Because of the non-linearity of the thermal voltage, the tolerances in mV or °C only apply to the measured temperatures specified in the right column.

This means, for example:

A thermocouple Type J is connected to a compensating cable Type JX, Class 2. If the measured temperature remains constant at 500°C and the temperature of the terminals and/or the compensating cable varies from -25 to +200°C, then the indicated temperature varies by not more than  $\pm 2.5^\circ\text{C}$ .

Thermo- couple and wire type	Tolerance classes		Operating temperature range [°C]	Measuring temperature [°C]
	1	2		
JX	$\pm 85\mu\text{V}/\pm 1.5^\circ\text{C}$	$\pm 140\mu\text{V}/\pm 2.5^\circ\text{C}$	-25...+200	500
TX	$\pm 30\mu\text{V}/\pm 0.5^\circ\text{C}$	$\pm 60\mu\text{V}/\pm 1.0^\circ\text{C}$	-25...+100	300
EX	$\pm 120\mu\text{V}/\pm 1.5^\circ\text{C}$	$\pm 200\mu\text{V}/\pm 2.5^\circ\text{C}$	-25...+200	500
KX	$\pm 60\mu\text{V}/\pm 1.5^\circ\text{C}$	$\pm 100\mu\text{V}/\pm 2.5^\circ\text{C}$	-25...+200	900
NX	$\pm 60\mu\text{V}/\pm 1.5^\circ\text{C}$	$\pm 100\mu\text{V}/\pm 2.5^\circ\text{C}$	-25...+200	900
KCA	-	$\pm 100\mu\text{V}/\pm 2.5^\circ\text{C}$	0...+150	900
KCB	-	$\pm 100\mu\text{V}/\pm 2.5^\circ\text{C}$	0...+100	900
NC	-	$\pm 100\mu\text{V}/\pm 2.5^\circ\text{C}$	0...+150	900
RCA	-	$\pm 30\mu\text{V}/\pm 2.5^\circ\text{C}$	0...+100	1000
RCB	-	$\pm 60\mu\text{V}/\pm 5.0^\circ\text{C}$	0...+200	1000
SCA	-	$\pm 30\mu\text{V}/\pm 2.5^\circ\text{C}$	0...+100	1000
SCB	-	$\pm 60\mu\text{V}/\pm 5.0^\circ\text{C}$	0...+200	1000

Table 5: Tolerances for thermocables and compensating cables

## Resistance thermometer - Functional principle and application

Thermocouple	Type	Sheath	Positive limb	Negative limb
Cu-Con	T	brown	brown	white
Fe-Con	J	black	black	white
NiCr-Ni	K	green	green	white
NiCrSi-NiSi	N	mauve	mauve	white
NiCr-Con	E	violet	violet	white
Pt10Rh-Pt	S	orange	orange	white
Pt13Rh-Pt	R	orange	orange	white

Table 6: Color coding for thermocouples to EN 60 584

Thermocouple	Type	Sheath	Positive limb	Negative limb
Fe-Con	L	blue	red	blue
Cu-Con	U	brown	red	brown

Table 7: Color ending for thermocouples to DIN 43 713

Thermocouple	Type	Sheath	Positive limb	Negative limb
NiCr-Ni	K	green	red	green
Pt10Rh-Pt	S	white	red	white
Pt13Rh-Pt	R	white	red	white

Table 8: Color coding for thermocouples DIN 43 714 (1979)

### Color coding of compensating cables

The color coding of compensating cables is laid down in EN 60 584 and DIN 43 713 (1990). For thermocouples to EN 60 584 (Table 6) this means:

The positive limb has the same color as the sheath, the negative limb is white. The "old" thermocouples Type L and U to DIN 43 713 (Table 7) are coded differently.

There are no details for the Pt30Rh-Pt6Rh thermocouple Type B. Ordinary copper connecting cables (plain copper) can be used as compensating cables in this case. According to DIN 43 714, the cable cores are twisted together for electromagnetic screening. Additional screening by foil or braiding can be provided. The insulation resistance between the cores and between cores and screening must not be less than  $10^7 \Omega \times m^{-1}$  at the maximum temperature; the breakdown voltage exceeds 500 VAC.

In addition to these color codes for compensating cables, there are also those according to DIN 43 714, 1979 (Table 8). They differ in certain respects from the ones mentioned above.

Where there are no color codes, it is not possible to identify cables by magnetism, color or hardness. Compensating cables Type KCA and KCB differ from the thermocable KX and the thermocouple Type K by having a magnetic positive limb.

## Voltage table for thermocouples to EN 60 584 - in mV

### Pt13Rh-Pt R

°C	0°C	+10°C	+20°C	+30°C	+40°C	+50°C	+60°C	+70°C	+80°C	+90°C
0	0	0.054	0.111	0.171	0.232	0.296	0.363	0.431	0.501	0.573
100	0.647	0.723	0.800	0.879	0.959	1.041	1.124	1.208	1.294	1.380
200	1.468	1.557	1.647	1.738	1.830	1.923	2.017	2.111	2.207	2.303
300	2.400	2.498	2.596	2.695	2.795	2.896	2.997	3.099	3.201	3.304
400	3.407	3.511	3.616	3.721	3.826	3.933	4.039	4.146	4.254	4.362
500	4.471	4.580	4.689	4.799	4.910	5.021	5.132	5.244	5.356	5.469
600	5.582	5.696	5.810	5.925	6.040	6.155	6.272	6.388	6.505	6.623
700	6.741	6.860	6.979	7.098	7.218	7.339	7.460	7.582	7.703	7.826
800	7.949	8.072	8.196	8.320	8.445	8.570	8.696	8.822	8.949	9.076
900	9.203	9.331	9.460	9.589	9.718	9.848	9.978	10.109	10.240	10.371
1000	10.503	10.636	10.768	10.902	11.035	11.170	11.304	11.439	11.574	11.710
1100	11.846	11.983	12.119	12.257	12.394	12.532	12.669	12.808	12.946	13.085
1200	13.224	13.363	13.502	13.642	13.782	13.922	14.062	14.202	14.343	14.483
1300	14.624	14.765	14.906	15.047	15.188	15.329	15.470	15.611	15.752	15.893
1400	16.035	16.176	16.317	16.458	16.599	16.741	16.882	17.022	17.163	17.304
1500	17.445	17.585	17.726	17.866	18.006	18.146	18.286	18.425	18.564	18.703
1600	18.842	18.981	19.119	19.257	19.395	19.533	19.670	19.807	19.944	20.080

### Pt10Rh-Pt S

°C	0°C	+10°C	+20°C	+30°C	+40°C	+50°C	+60°C	+70°C	+80°C	+90°C
0	0	0.055	0.113	0.173	0.235	0.299	0.365	0.432	0.502	0.573
100	0.645	0.719	0.795	0.872	0.950	1.029	1.109	1.190	1.273	1.356
200	1.440	1.525	1.611	1.698	1.785	1.873	1.962	2.051	2.141	2.232
300	2.323	2.414	2.506	2.599	2.692	2.786	2.880	2.974	3.069	3.164
400	3.260	3.356	3.452	3.549	3.645	3.743	3.840	3.938	4.036	4.135
500	4.234	4.333	4.432	4.532	4.632	4.732	4.832	4.933	5.034	5.136
600	5.237	5.339	5.442	5.544	5.648	5.751	5.855	5.960	6.064	6.169
700	6.274	6.380	6.486	6.592	6.699	6.805	6.913	7.020	7.128	7.236
800	7.345	7.454	7.563	7.672	7.782	7.892	8.003	8.114	8.225	8.336
900	8.448	8.560	8.673	8.786	8.899	9.012	9.126	9.240	9.355	9.470
1000	9.585	9.700	9.816	9.932	10.048	10.165	10.282	10.400	10.517	10.635
1100	10.754	10.872	10.991	11.110	11.229	11.348	11.467	11.587	11.707	11.827
1200	11.947	12.067	12.188	12.308	12.429	12.550	12.671	12.792	12.913	13.034
1300	13.155	13.276	13.397	13.519	13.640	13.761	13.883	14.004	14.125	14.247
1400	14.368	14.489	14.610	14.731	14.852	14.973	15.094	15.215	15.336	15.456
1500	15.576	15.697	15.817	15.937	16.057	16.176	16.296	16.415	16.534	16.653
1600	16.771	16.890	17.008	17.125	17.243	17.360	17.477	17.594	17.711	17.826

### Pt30Rh-Pt6Rh B

°C	0°C	+10°C	+20°C	+30°C	+40°C	+50°C	+60°C	+70°C	+80°C	+90°C
0	0	- 0.002	- 0.003	- 0.002	-0	0.002	0.006	0.011	0.017	0.025
100	0.033	0.043	0.053	0.065	0.078	0.092	0.107	0.123	0.140	0.159
200	0.178	0.199	0.220	0.243	0.266	0.291	0.317	0.344	0.372	0.401
300	0.431	0.462	0.494	0.527	0.561	0.596	0.632	0.669	0.707	0.746
400	0.786	0.827	0.870	0.913	0.957	1.002	1.048	1.095	1.143	1.192
500	1.241	1.292	1.344	1.397	1.450	1.505	1.560	1.617	1.674	1.732
600	1.791	1.851	1.912	1.974	2.036	2.100	2.164	2.230	2.296	2.363
700	2.430	2.499	2.569	2.639	2.710	2.782	2.855	2.928	3.003	3.078
800	3.154	3.231	3.308	3.387	3.466	3.546	3.626	3.708	3.790	3.873
900	3.957	4.041	4.126	4.212	4.298	4.386	4.474	4.562	4.652	4.742
1000	4.833	4.924	5.016	5.109	5.202	5.297	5.391	5.487	5.583	5.680
1100	5.777	5.875	5.973	6.073	6.172	6.273	6.374	6.475	6.577	6.680
1200	6.783	6.887	6.991	7.096	7.202	7.308	7.414	7.521	7.628	7.736
1300	7.845	7.953	8.063	8.172	8.283	8.393	8.504	8.616	8.727	8.839
1400	8.952	9.065	9.178	9.291	9.405	9.519	9.634	9.748	9.863	9.979
1500	10.094	10.210	10.325	10.441	10.558	10.674	10.790	10.907	11.024	11.141
1600	11.257	11.374	11.491	11.608	11.725	11.842	11.959	12.076	12.193	12.310
1700	12.426	12.543	12.659	12.776	12.892	13.008	13.124	13.239	13.354	13.470

## Voltage table for thermocouples to EN 60 584 - in mV

### Cu-Con T

°C	0°C	-10°C	-20°C	-30°C	-40°C	-50°C	-60°C	-70°C	-80°C	-90°C
-200	-5.603	-	-	-	-	-	-	-	-	-
-100	-3.378	-3.656	-3.923	-4.177	-4.419	-4.648	-4.865	-5.069	-5.261	-5.439
0	0	-0.383	-0.757	-1.121	-1.475	-1.819	-2.152	-2.475	-2.788	-3.089

°C	0°C	+10°C	+20°C	+30°C	+40°C	+50°C	+60°C	+70°C	+80°C	+90°C
0	0	0.391	0.789	1.196	1.611	2.035	2.467	2.908	3.357	3.813
100	4.277	4.749	5.227	5.712	6.204	6.702	7.207	7.718	8.235	8.757
200	9.286	9.820	10.360	10.905	11.456	12.011	12.572	13.137 1	3.707	14.281
300	14.860	15.443	16.030	16.621	17.217	17.816	18.420	19.027	19.638	20.252

### Fe-Con J

°C	0°C	-10°C	-20°C	-30°C	-40°C	-50°C	-60°C	-70°C	-80°C	-90°C
-200	-7.890	-	-	-	-	-	-	-	-	-
-100	-4.632	-5.036	-5.426	-5.801	-6.159	-6.499	-6.821	-7.122	-7.402	-7.659
0	0	-0.501	-0.995	-1.481	-1.960	-2.431	-2.892	-3.344	-3.785	-4.215

°C	0°C	+10°C	+20°C	+30°C	+40°C	+50°C	+60°C	+70°C	+80°C	+90°C
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

## Voltage table for thermocouples to EN 60 584 - in mV

### NiCr-Ni K

°C	0°C	-10°C	-20°C	-30°C	-40°C	-50°C	-60°C	-70°C	-80°C	-90°C
-200	-5.891	-	-	-	-	-	-	-	-	-
-100	-3.554	-3.852	-4.138	-4.411	-4.669	-4.913	-5.141	-5.354	-5.550	-5.730
0	0	-0.392	-0.778	-1.156	-1.527	-1.889	-2.243	-2.587	-2.920	-3.243
°C	0°C	+10°C	+20°C	+30°C	+40°C	+50°C	+60°C	+70°C	+80°C	+90°C
0	0	0.397	0.798	1.203	1.612	2.023	2.436	2.851	3.267	3.682
100	4.096	4.509	4.920	5.328	5.735	6.138	6.540	6.941	7.340	7.739
200	8.138	8.539	8.940	9.343	9.747	10.153	10.561	10.971	11.382	11.795
300	12.209	12.624	13.040	13.457	13.874	14.293	14.713	15.133	15.554	15.975
400	16.397	16.820	17.243	17.667	18.091	18.516	18.941	19.366	19.792	20.218
500	20.644	21.071	21.497	21.924	22.350	22.776	23.203	23.629	24.055	24.480
600	24.905	25.330	25.755	26.179	26.602	27.025	27.447	27.869	28.289	28.710
700	29.129	29.548	29.965	30.382	30.798	31.213	31.628	32.041	32.453	32.865
800	33.275	33.685	34.093	34.501	34.908	35.313	35.718	36.121	36.524	36.925
900	37.326	37.725	38.124	38.522	38.918	39.314	39.708	40.101	40.494	40.885
1000	41.276	41.665	42.053	42.440	42.826	43.211	43.595	43.978	44.359	44.740
1100	45.119	45.497	45.873	46.249	46.623	46.995	47.367	47.737	48.105	48.473
1200	48.838	49.202	49.565	49.926	50.286	50.644	51.000	51.355	51.708	52.060
1300	52.410	52.759	53.106	53.451	53.795	54.138	54.479	54.819	-	-

### NiCr-Con E

°C	0°C	-10°C	-20°C	-30°C	-40°C	-50°C	-60°C	-70°C	-80°C	-90°C
-200	-8.824	-9.063	-9.274	-9.455	-9.604	-9.719	-9.797	-9.835	-	-
-100	-5.237	-5.680	-6.107	-6.516	-6.907	-7.279	-7.631	-7.963	-8.273	-8.561
0	0	-0.581	-1.151	-1.709	-2.254	-2.787	-3.306	-3.811	-4.301	-4.771
°C	0°C	+10°C	+20°C	+30°C	+40°C	+50°C	+60°C	+70°C	+80°C	+90°C
0	0	0.591	1.192	1.801	2.419	3.047	3.683	4.329	4.983	5.646
100	6.317	6.996	7.683	8.377	9.078	9.787	10.501	11.222	11.949	12.681
200	13.419	14.161	14.909	15.661	16.417	17.178	17.942	18.710	19.481	20.256
300	21.033	21.814	22.597	23.383	24.171	24.961	25.754	26.549	27.345	28.143
400	28.943	29.744	30.546	31.350	32.155	32.960	33.767	34.574	35.382	36.190
500	36.999	37.808	38.617	39.426	40.236	41.045	41.853	42.662	43.470	44.278
600	45.085	45.891	46.697	47.502	48.306	49.109	49.911	50.713	51.513	52.312
700	53.110	53.907	54.703	55.498	56.291	57.083	57.873	58.663	59.451	60.237
800	61.022	61.806	62.588	63.368	64.147	64.924	65.700	66.473	67.245	68.015
900	68.783	69.549	70.313	71.075	71.835	72.593	73.350	74.104	74.857	75.608

## Voltage table for thermocouples to DIN 43710 - in mV

### Cu-Con U

°C	0°C	-10°C	-20°C	-30°C	-40°C	-50°C	-60°C	-70°C	-80°C	-90°C
-200	-5.70	-	-	-	-	-	-	-	-	-
-100	-3.40	-3.68	-3.95	-4.21	-4.46	-4.69	-4.91	-5.12	-5.32	-5.51
0	0	-0.39	-0.77	-1.14	-1.50	-1.85	-2.18	-2.50	-2.81	-3.11

°C	0°C	+10°C	+20°C	+30°C	+40°C	+50°C	+60°C	+70°C	+80°C	+90°C
0	0	0.40	0.80	1.21	1.63	2.05	2.48	2.91	3.35	3.80
100	4.25	4.71	5.18	5.65	6.13	6.62	7.12	7.63	8.15	8.67
200	9.20	9.74	10.29	10.85	11.41	11.98	12.55	13.13	13.71	14.30
300	14.90	15.50	16.10	16.70	17.31	17.92	18.53	19.14	19.76	20.38
400	21.00	21.62	22.25	22.88	23.51	24.15	24.79	25.44	26.09	26.75
500	27.41	28.08	28.75	29.43	30.11	30.80	31.49	32.19	32.89	33.60

### Fe-Con L

°C	0°C	-10°C	-20°C	-30°C	-40°C	-50°C	-60°C	-70°C	-80°C	-90°C
-200	-8.15	-	-	-	-	-	-	-	-	-
-100	-4.75	-5.15	-5.53	-5.90	-6.26	-6.60	-6.93	-7.25	-7.56	-7.86
0	0	-0.51	-1.02	-1.53	-2.03	-2.51	-2.98	-3.44	-3.89	-4.33

°C	0°C	+10°C	+20°C	+30°C	+40°C	+50°C	+60°C	+70°C	+80°C	+90°C
0	0	0.52	1.05	1.58	2.11	2.65	3.19	3.73	4.27	4.82
100	5.37	5.92	6.47	7.03	7.59	8.15	8.71	9.27	9.83	10.39
200	10.95	11.51	12.07	12.63	13.19	13.75	14.31	14.88	15.44	16.00
300	16.56	17.12	17.68	18.24	18.80	19.36	19.92	20.48	21.04	21.60
400	22.16	22.72	23.29	23.86	24.43	25.00	25.57	26.14	26.71	27.28
500	27.85	28.43	29.01	29.59	30.17	30.75	31.33	31.91	32.49	33.08
600	33.67	34.26	34.85	35.44	36.04	36.64	37.25	37.85	38.47	39.09
700	39.72	40.35	40.98	41.62	42.27	42.92	43.57	44.23	44.89	45.55
800	46.22	46.89	47.57	48.25	48.94	49.63	50.32	51.02	51.72	52.43