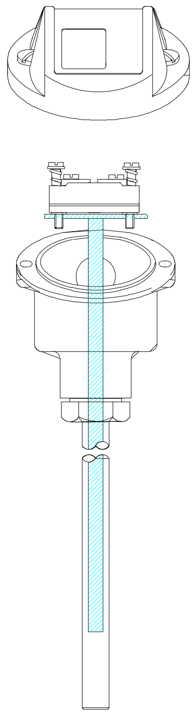
Technical
Information
TI 090T/02/e

Thermocouple Thermometers *omnigrad TSC*

with interchangeable mineral insulated insets



Thermocouples are used for temperature measurements in the range from -250 °C to +2200°C
They offer :
- high temperature ranges
- small dimensions
- fast response time

General
A thermocouple consists of two dissimilar metal wires joined at one end (hot junction) producing an electromotive force (emf) when the hot junction and the other ends (cold junction or reference junction) are put at different temperature. The hot junction is that part of the thermocouple which is subjected to the temperature to be measured. The cold, or reference junction, is that end of the thermocouple which is at lower temperature (normally the ambient one) for which the measure must be compensated. The intensity of the emf depends on the temperature difference between the two junctions and on the composition of the two metals.
Normal the thermocouple element terminates in a connection head. However, the reference junction is normally transferred to the instrument by use of thermocouple extension wire.

Insets
In general, the sensor assembly, or thermometer, includes three elements:
- protective thermowell,
- terminal housing,
- thermocouple inset

The inset, which is used for installation in the final assembly has the big advantage to be interchangeable. Since the inset itself is not suitable for heavy duty applications, it is a common practice to install it in appropriate thermowells. The inset consist of a mineral insulated stem of 3 mm (TEC 105) or 6 mm TEC 100) diameter, including one or two thermocouple junctions embedded in a MgO ceramic material which provides for the isolation of the wires each other, surrounded by a very thin sheath in stainless steel, in Inconel or in other heat resistant metals. The thermocouple hot junction is placed in a side which is normally isolated from the sheath, while on the other side a ceramic block is mounted on a metal plate. Alternatively a version with free wires for 2 wire head mounting transmitters is available.

Extension Wires
Extension wires are connected to the cold junction of the thermocouple. Extension wire extend the reference junction close to the measuring instrument and have approximately the same thermoelectric properties as the thermocouple wires. Extension cables are normally available as single or duplex, solid or stranded insulated wires in a wide range of sizes. A variety of insulation's and protective coverings is available in several combinations to suit the many types of environments encountered in industrial service.

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Thermowells

Thermowells containing thermocouple insets can be mounted by threaded, flanged or welded connections. They offer adequate mechanical protection for base metal thermocouples at temperatures to 1150℃. Since the thermowell is the component that comes into contact with the process, exact specification is most important, as it determines the life of the assembly.
Selection of the thermowell depends upon the chosen method of mounting, the space available, the pressure, the temperature, the flow speed and the nature of the product.
DIN 43763 defines a series of standard thermowell design, this includes :

- threaded thermowells type B or C;
- flanged thermowells type F;
- weld - in thermowells type D;

If fast response time is required , tapered thermowells are available.

Common application data

Thermocouples

Type T

These thermocouples are resistant to corrosion in moist atmospheres and are suitable for sub zero temperature measurements. They have an upper temperature limit of 380 ℃ and can be used in a vacuum and in oxidizing, reducing, or inert atmospheres.
This is the only thermocouple type for which error limits are established in the sub zero temperature range.

Type J

These thermocouple are suitable for use in vacuum and in oxidizing, reducing, or inert atmospheres, at temperature up to 760 ℃. The rate of oxidation of the iron thermoelement is rapid above 550 ℃, however the use of heavy-gauge wires is recommended when long life is required at these higher temperatures.

Type K

This thermocouple is recommended for continuous use in oxidizing or inert atmospheres at temperatures up to 1250 ℃. Because their oxidation resistance characteristics are better than those of other base metal thermocouples, they are widely used at temperatures above 550 ℃.
Type K thermocouples can be used in hydrogen or cracked ammonia atmospheres if the dew point is below -40℃, e.g.. at a very low humidity. They should not be used, however, in:

- atmospheres that are reducing or alternately oxidizing and reducing unless suitably protected with protection tubes;
- sulphurous atmospheres unless properly protected;
- vacuum except for short time periods: preferential vaporisation of chromium from the positive element will alter calibration;
- atmospheres that promote "green-rot" corrosion of the positive thermoelement.
  This corrosion results from the preferential oxidation of chromium when the oxygen content of the atmosphere surrounding the sensor is low. It can cause large negative errors in calibration. The most serious temperature range is 800 - 1050℃

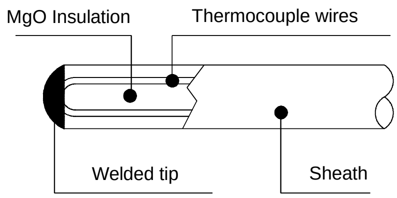


Fig 1 - Grounded junction

Types of hot junction

Two types of junction are available: grounded and isolated.
Figure 1 shows the grounded junction where the hot junction is welded to the sheath. It combines the advantage of excellent response time with the protection of a sealed sheath by allowing the thermocouple junction to touch the tip of the sheath itself.

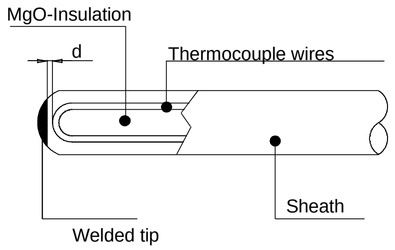


Fig 2 - Isolated junction

It may however cause some problems when connected to an electronic unit without galvanic isolated input.
In figure 2 the hot junction is isolated from the protective sheath. This means a low impedance path for electrical noise, keeping the measurement stable and accurate.

Response time

All sensors have a finite response time which has to be recognised when temperature of the medium is changing with time. The inherent response time of a sensor is a function of its construction and depends on type and diameter of both inset and thermowell, on process media conditions such as velocity, pressure and on the location of the thermowell. Given data are average values only.
The thermal response time T is the time required for the thermometer to react to a step change of temperature with a resistance change corresponding to a specified percentage of the step change. The response time for 50% change and 90% change are recorded and indicated on the single thermometer Technical Information.

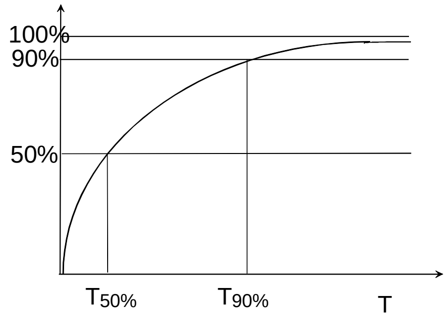


Fig 1 - Graphic representation of the response time inserted in the TSC thermometer Technical Information

Terminal heads

A thermometer terminal head is recommended to protect the connection between the thermocouple and the extension wire. In alternative a 2-wire transmitter can be mounted in the head. The head also permits easy replacement of the thermometer. The most widely used connection heads are constructed in light metal, usually aluminum, according DIN 43729 type B. All terminal heads are provided for connection to the thermowell and have a cable gland with gasket. The maximum ambient temperature for heads is 80℃ up to 130℃ with appropriate gaskets.
The curves in figure 3 are used to get an indication how big is the rise of temperature in the head, given the process temperature above local ambient temperature.

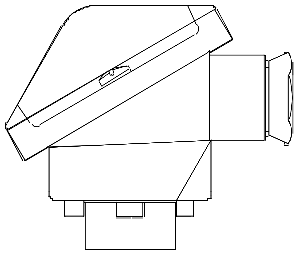


Fig 2 - Terminal head conform to DIN 43729 type B

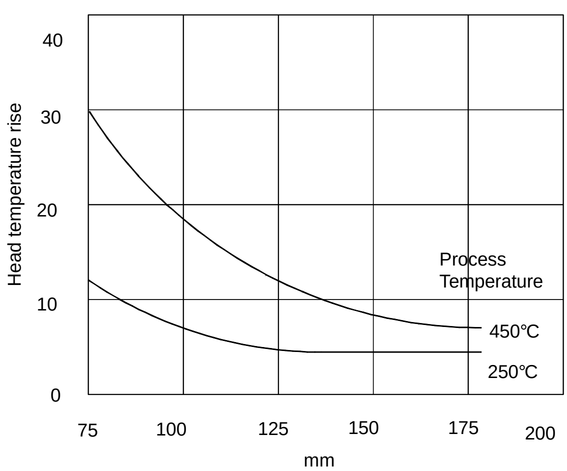
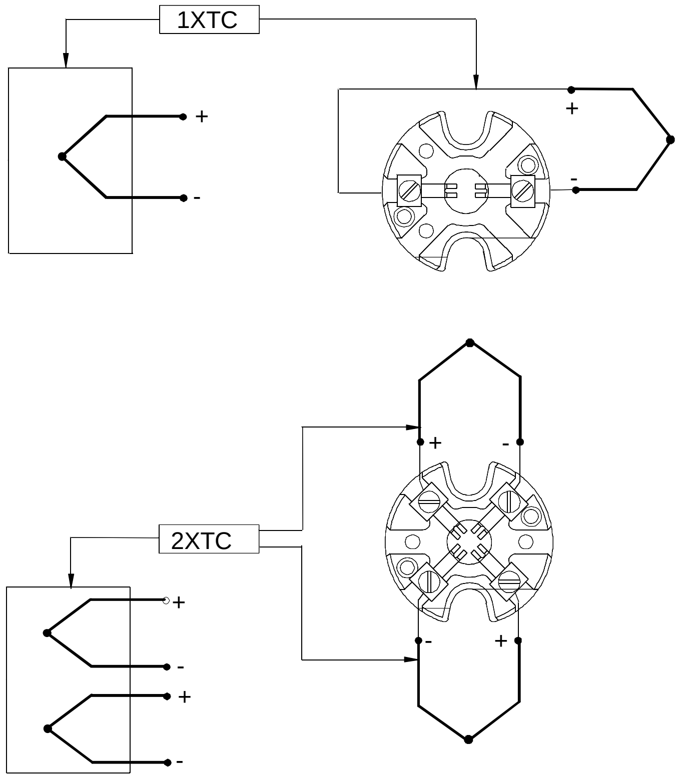


Fig. 3
The curves in figure 5 are used to get an indication how big is the rise of temperature in the head, given the process temperature, above local ambient temperature.

Internal Wirings

TEC 100 (6 mm in diameter) and TEC 105 (3 mm) are available in two versions. The connections of the first one with free wires for mounting of in-head transmitters, are shown in the left part of the figure, while the connections of the second one with ceramic terminal block, are shown in the right side of the figure.



Tolerances

Table 1 lists the tolerance class conform to the norm DIN IEC 584.2.
Standard thermocouples are delivered in tolerance class 2.
Thermocouples in other classes must be ordered specially.
Temperature-EMF tables are reported in appendix.

Tolerance Class	TC Type	Tolerance Values	Temperature range
1	T K	1.5 °C or 0.0075∗|t| 1.5 °C or 0.004∗|t|	-40 °C to +350 °C -40 °C to +800 °C
2	T J K	2.5 °C or 0.0075∗|t| 2.5 °C or 0.0075∗|t| 2.5 °C or 0.0075∗|t|	-40 °C to +400 °C -40 °C to +750 °C -40 °C to +1100 °C
3	T J K	2.5 °C or 0.0015∗|t| 2.5 °C or 0.0015∗|t| 1.5 °C or 0.0015∗|t|	-200 °C to +40 °C -200 °C to +40 °C -200 °C to +40 °C

Notes:
|t| = module of calibration temperature (regardless the sign)
The tolerances value to be considered is the greater of the two values

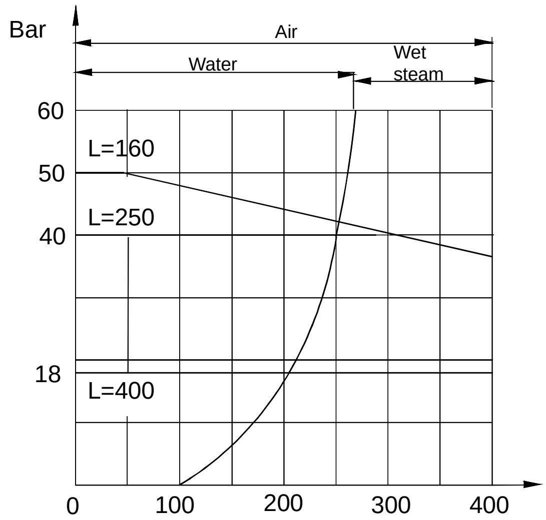
Loading capacity of protection tubes

The loading capacity of protection tubes depending on process media: its temperature, its velocity, its vibration frequency. Material characteristics such as wall thickness, insertion length, type of process connection must be considered. Basically it has to be said that those factors required to produce adequate well strength tend to reduce the accuracy and response of the temperature measurement.
The graphics in the following allow to find out the immersion length of the thermometer according to pressure and temperature noticed in the measurement place. The value inside the white squares are the immersion length in mm.

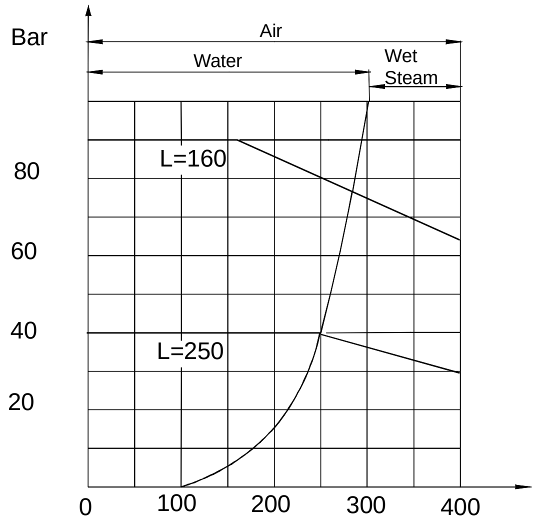
Each curve describes the limit of a particular immersion length.
For example if we have a thermometer with a DIN B thermowell in a place where temperature is 150 °C and pressure 30 bar proceed as following to to define the proper immersion length:

- draw a straight line perpendicular to the temperature axis starting from 150 °C
- draw a straight line perpendicular to the pressure axis starting from 30 bar
- find the intersection point of the two lines
- the immersion length just above this point correspond to the proper immersion length

Thermowell DIN Form B
Material : x6CrNiMoTi17122
Wnr. 1.4571
Permitted flow velocity:
in air: 25 m/s
in water: 3 m/s
L = Immersion length in mm

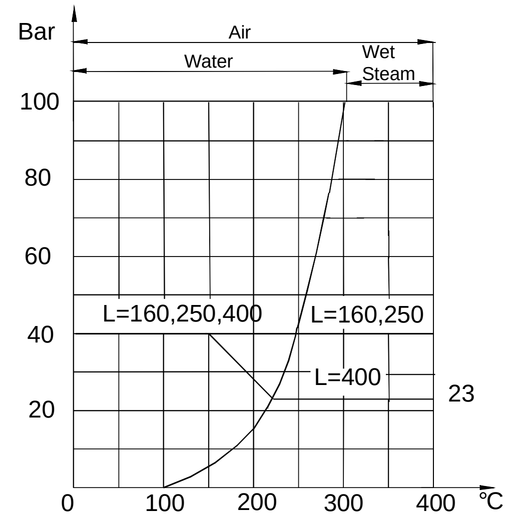


Thermowell DIN Form C
Material : x6CrNiMoTi17122
Wnr. 1.4571
Permitted flow velocity:
in air: 40 m/s
in water: 5 m/s
L = Immersion length in mm

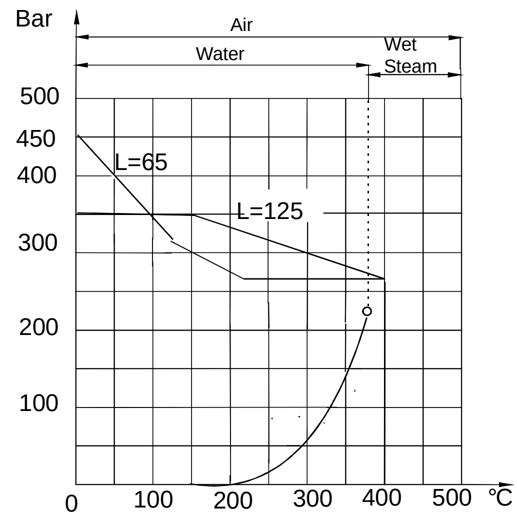


Loading capacity of protection tubes

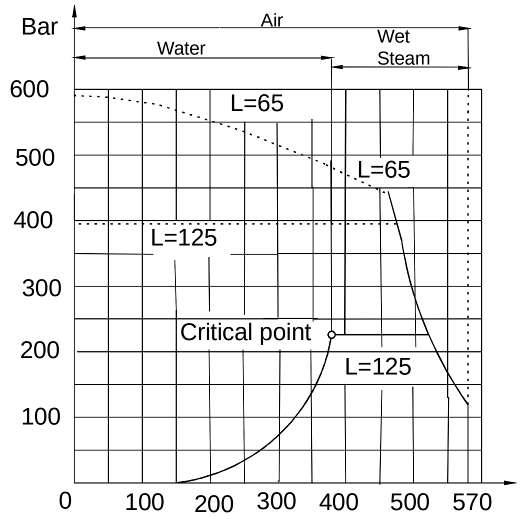
Thermowell DIN Form F
Material : x6CrNiMoTi17122
Wnr. 1.4571
Permitted flow velocity:
in air: 40 m/s
in water: 5 m/s
L = Immersion length in mm



Thermowell DIN Form D
Material : x6CrNiMoTi17122
Wnr. 1.4571
Permitted flow velocity:
in air: 60 m/s
in water: 30 m/s
L = Immersion length in mm

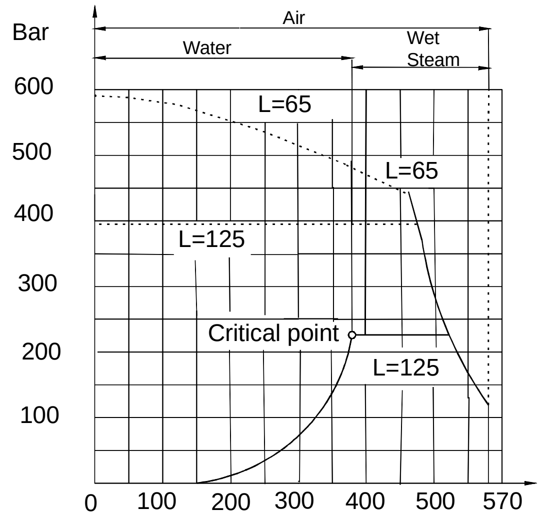


Thermowell DIN Form D
Material : 10CrMo910
Wnr. 1.7380
Permitted flow velocity:
in air: 60 m/s
Allowed pressure in water:
ax 450 bar and 5 m/s
in water: 3 m/s
L= Immersion length in mm



Loading capacity of protection tubes

Thermowell DIN Form D
Material : 10 CrMo44
Wnr. 1.7335
Permitted flow velocity:
in air: 60 m/s
Allowed pressure in water:
max 450 bar and 5 m/s
L = Immersion length in mm



Materials of protection tubes

Table 2
The atmosphere in which the protection tube has to work is of basic importance. The table 2 is a guide for the selection of the right material.

	Type of atmosphere				
Material of the sheath	**Oxidizing >0,5 % of O_2**	**Reducing CO,CO_2,H_2**	**Vacuum > 62 10^{-1} Torr**	**Inert He, Ar**	**Comments**
Stainless Steel	950°C	110°C	1000°C	1100°C	**Max 600°C** in presence of sulphur
Inconel 600	1100°C	1100°C	1000°C	1100°C	**Max. 600°C** in presence of sulphur + reducing atm. **Max. 800°C** in presence of sulphur + oxidising atm.

Table 3
Most common materials for protection tubes.
The table gives a guide for the selection of the correct material depending on the application.

Description	DIN W. Nr.	AISI/SAE	Application
x5CrNi1810	1.4301	AISI 304	acetone, asphalt, beer, carbonated beverage, cyanide, hydrogen, peroxide, sodium,steam, sulfur
x5CrNiMo1810	1.4401	AISI 316	food, fats, chloroform at room temperature and boiling, cleaning agents, soaps, petroleum processing and petrochemical industries
10CrMo910	1.7380		similar applications to 1.7335
x6CrNiMoTi1722	1.4571	AISI 316 Ti	food, fats, chloroform at room temperature and boiling, cleaning agents, soaps, petroleum processing and petrochemical industries
13CrMo44	1.7335		hot acid solutions and acid vapours, flu gases and sulphurs molten lead, zinc
Hastelloy C			low chloride water, steam, photographic solutions, diesel fumes, calcium bisulphite, chromic acids, ferric chloride, mercury chloride
Inconel 600	2.4816	NiCr15Fe	reducing atmosphere sodium, chlorine-free water sulphur-containing atmosphere carbon dioxide

Mounting of thermometer assemblies

In installing thermocouples it must be always borne in mind that the emf produced depends upon the difference in temperature between the measuring and reference junctions. With a fixed or known reference junction , the thermocouple thermometer is capable only of indicating the temperature attained by its measuring junction. It is thus necessary in a particular process to insure that the measuring junction is at the same temperature within the accuracy desired as the medium to be measured. Where thermowells are necessary in an installation, the problem is only aggravated. Among the many factors which influence the measuring junction temperature of a particular installation are:

- temperature of the surroundings
- velocity and properties of the fluid
- emissivity of the exposed surface
- thermal conductivity of thermocouple well materials
- ratio of heat-transfer areas.

Under installation conditions where the surrounding (duct wall) temperatures are appreciably different from the fluid temperatures in the case of gases, heat exchange will take place by the mechanism of radiation by the thermocouple and its surroundings. In addition, heat will flow from or to the thermocouple by the mechanism of conduction, and heat will be transferred by convection. Depending upon whether the surrounding temperature are higher or lower than the gas temperature, the thermocouple will indicate higher or lower temperature.
Both the thermocouple and the extension wire should be cleaned before fastening in a terminal block to assure good electrical contact.
The thermocouple should be installed where the temperature has to be measured at such a depth that the heat transfer from the medium along the thermowell is kept to the minimum to avoid thermal shunts errors. On the other side the surface in contact with the medium must be big enough to grant a good transfer of the temperature.

A good compromise is obtained with following measures :
in water and generally in liquids, the immersion length should be 5-6-times the pipe diameter of the thermowell
in steam, air and gases, the immersion length should be 20 times the pipe diameter of the thermowell.
Table 4 gives indications about the length of immersion in a pipe of given diameter. In pipes with small diameter the most suited immersion length can often be achieved only by installing the assembly at an angle to the pipe (see fig. 5) or in a bend . In this case mount the assembly always against the flow of the fluid.

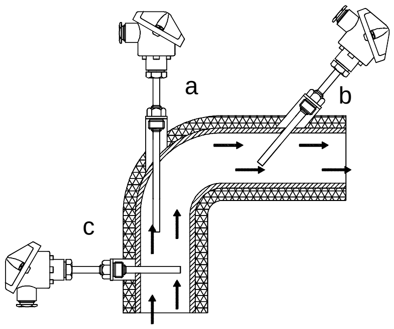


Fig. 5
Suggestions for mounting as-semblies in small pipes.
a - at elbows, against the flow;
b - lanted, against the flow;
c - perpendicular to the flow

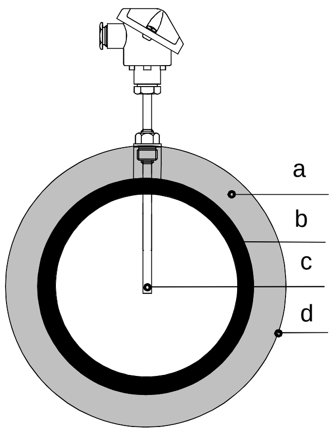


Fig.6
Typical set-up for reducing thermal flow leakages:
a - insulation material
b - pipe
c - thermometer assembly
d - external plate

Table 4
Recommended immersion length in pipes.
For general guidance only.

Nominal diameter of piping (mm)						
50	75	100	150	200	300	400
30	40	50	60	80	100	120
Recommended immersion length (mm)						

Appendix Temperature to EMF Tables

The Temperature EMF reference tables give the generated EMF (electro motive force) for every type of thermocouple depending on the temperature difference between the two junctions. When the reference junction is maintained at 0 ℃, or when its temperature is properly compensated by the electronic circuit, the actual temperature can be read directly from the tables.

The tables are very useful for adjusting thermocouple simulators when they are not provided with an output calibrated directly in temperature.
These tables give values of EMF with three decimal point (0.001 mV) in intervals of ten degrees Celsius.

Temperature-EMF table for thermocouple type T: mV vs.℃ (IEC 584)

℃	0	10	20	30	40	50	60	70	80	90
-200	-5.603	-5.753	-5.889	-6.007	-6.105	-6.181	-6.232	-6.258		
-100	-3.378	-3.656	-3.923	-4.177	-4.419	-4.648	-4.865	-5.069	-5.261	-5.439
-0	0.000	-0.383	-0.757	-1.121	-1.475	-1.819	-2.152	-2.475	-2.788	-3.089
+0	0.000	0.391	0.789	1.196	1.611	2.035	2.467	2.908	3.357	3.813
100	4.277	4.749	5.277	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	13.707	14.281
300	14.860	15.443	16.030	16.612	17.217	17.816	18.420	19.027	19.638	20.252

Temperature-EMF table for thermocouple type J: mV vs. ℃ (IEC 584)

℃	0	10	20	30	40	50	60	70	80	90
-200	-7.890	-8.096								
-100	-4.632	-5.036	-5.426	-5.801	-6.159	-6.499	-6.821	-7.122	-7.402	-7.659
-0	0.000	-0.501	-0.995	-1.481	-1.960	-2.431	-2.892	-3.334	-3.785	-4.215
+0	0.000	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	25.16	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	34.967	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
800	45.498	46.144	46.790	47.434	48.076	48.716	49.354	49.989	50.62	51.249

Appendix Temperature to EMF Tables

Temperature-EMF table for thermocouple type K: mV vs.°C (IEC 584)

°C	0	10	20	30	40	50	60	70	80	90
-200	-5.891	-6.035	-6.158	-6.262	-6.344	-6.404	-6.441	-6.458		
-100	-3.553	-3.852	-4.138	-4.410	-4.669	-4.912	-5.141	-5.354	-5.550	-5.730
-0	0.000	-0.392	-0.777	-1.156	-1.527	-1.889	-2.243	-2.586	-2.920	-3.242
+0	0.000	0.397	0.798	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	43.968	44.349	44.729

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