Thermocouples ：

A thermocouple is a device consisting of two different conductors (usually metal alloys) that produce a voltage proportional to a temperature difference between either end of the pair of conductors. Thermocouples are a widely used type of temperature sensor for measurement and control and can also be used to convert a temperature gradient intoelectricity. They are inexpensive, interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures. In contrast to most other methods of temperature measurement, thermocouples are self powered and require no external form of excitation. The main limitation with thermocouples is accuracy and system errors of less than one degree Celsius (C) can be difficult to achieve.

Any junction of dissimilar metals will produce an electric potential related to temperature. Thermocouples for practical measurement of temperature are junctions of specific alloys which have a predictable and repeatable relationship between temperature and voltage. Different alloys are used for different temperature ranges. Properties such as resistance to corrosion may also be important when choosing a type of thermocouple. Where the measurement point is far from the measuring instrument, the intermediate connection can be made by extension wires which are less costly than the materials used to make the sensor. Thermocouples are usually standardized against a reference temperature of 0 degrees Celsius; practical instruments use electronic methods of cold-junction compensation to adjust for varying temperature at the instrument terminals. Electronic instruments can also compensate for the varying characteristics of the thermocouple, and so improve the precision and accuracy of measurements.

Thermocouples are widely used in science and industry; applications include temperature measurement for kilns, gas turbine exhaust, diesel engines, and other industrial processes.

Advantages ：

- Temperature range :
  Most practical temperature ranges, from cryogenics to jet-engine exhaust, can be served using thermocouples. Depending on the metal wires used, a thermocouple is capable of measuring temperature in the range － 200°C to + 2500°C.
- Robust :
  Thermocouples are rugged devices that are immune to shock and vibration and are suitable for use in hazardous environments.
- Rapid response :
  Because they are small and have low thermal capacity, thermocouples respond rapidly to temperature changes, especially if the sensing junction is exposed. They can respond to rapidly changing temperatures within a few hundred milliseconds.
- No self heating :
  Because thermocouples require no excitation power, they are not prone to self heating and are intrinsically safe.

一、Construction of Thermocouple ：

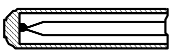
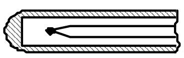
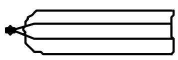
The effect responsible for the action of thermocouple is the "Seebeck effect". If a temperature difference exists along a wire, this will causes a displacement of electrical charge. The amount of the charge displacement depends on the electrical characteristics of the chosen material.
If two wires of 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. 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").

The temperature of the reference junction must be known and constant. The exact temperature is equal joined

Thermocouple Junction Types ：

Basically, they are 3 junction types, grounded, ungrounded and exposed. For grounded thermocouples it has a metal sheath and the thermocouple wires are welded to the casing.
Usually, it is done with a tig welding machine, but it can be done by soldering the wires. However, it may cause contamination to the thermocouple wires.

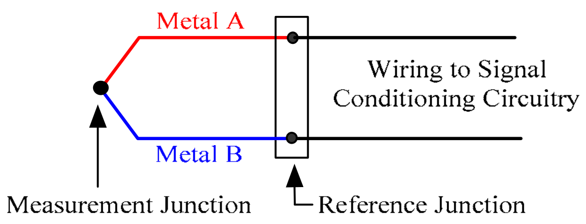
Usually, grounded thermocouples are not filled with MgO powder unless it is intended for higher temperature applications. Alternatively, to mineral insulated thermocouples, the wires can be insulated with ceramic insulators for

Type	Shape	Feature	Remark
Grounded		1. This type can withstand 3500Kg/cm^2 or more. 2. It is not suitable for location with electromagnetic induction on radio frequency inter-ference.	Grounded thermocouples temperature sensors are widely used, because it offer faster respond time, more accurate reading at short distant. It is a preferred junction type for high temperature applications. Precaution for ground loop at long distances and at low temperature usage.
Ungrounded		1. This type has a slower reponse than the grounded type but is more commonly used since it is not restricted by the object to be measured. 2. The element is covered with an insulator thereby ensuring a long life span.	Ungrounded thermocouples are used primarily for isolating the control system from the sensor and to prevent ground loop. It ismore inaccurate and slow respond time.
Exposed		1. Since the element is exposed reposed reponse time is very fast. 2. This type is suitable for temperature measurement of gases such as automotive exhaust. 3. This type is mechanically werker than the other.	Exposed junction, offer the fastest respond time. It is not intended for pressurized or corrosive environments.

二、Thermocouple Theory ：

A thermocouple, shown in Figure 1, consists of two wires of dissimilar metals joined together at one end, called the measurement (“hot”) junction. The other end, where the wires are not joined, is connected to the signal conditioning circuitry traces, typically made of copper. This junction between the thermocouple metals and the copper traces is called the reference (“cold”) junction.*

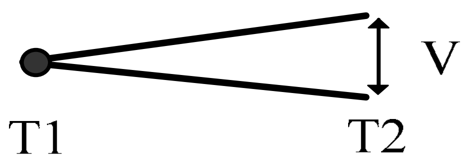
Thermocouple



The voltage produced at the reference junction depends on the temperatures at both the measurement junction and the reference junction. Since the thermocouple is a differential device rather than an absolute temperature measurement device, the reference junction temperature must be known to get an accurate absolute temperature reading. This process is known as reference junction compensation (cold junction compensation.)

Thermocouples have become the industry-standard method for cost-effective measurement of a wide range of temperatures with reasonable accuracy. They are used in a variety of applications up to approximately +2500 ˚C in boilers, water heaters, ovens, and aircraft engines—to name just a few. The most popular thermocouple is th e type K, consisting of Chromel and Alumel (trademarked nickel alloys containing chromium, and aluminum, manganese, and silicon, respectively), with a measurement rangeof －200˚C to +1250˚C.

The principal of operation is on the Seebeck effect. A temperature gradient along a conductor creates an EMF. If two conductors of different materials are joined at one point, an EMF is created between the open ends which is dependent upon the temperature of the junction. As T1 increases, so does V. The EMF also depends on the temperature of the open ends T2.



The junction is placed in the process, the other end (for the purposes of a standard output) is in iced water at 0C. This is called the reference junction. In the field the reference junction is usually at ambient temperature in the indicating unit and a cold junction compensation allowance is made. This is usually done through the indicator electronics.

Provided that set temperature limits are not exceeded, inexpensive compensating wires can replace thermocouple conductors for part of the circuit. They replicate the thermoelectric performance of the thermocouple wires up to a certain temperature.

Temperatures along the wires (between T1 and T2) will not affect output voltage, providing that the alloys are thermocouple wire or compensating cable. Alloy combinations are chosen which produce a high EMF, are stable at temperature and readily available.

Thermocouple output depends on the alloy mix of the conductors. No two mixes will be identical and sensor calibration is required if high accuracy is needed. The performance of an individual sensor will drift with high temperature exposure.

There are defined sensor combinations as shown in the thermocouple tables below. Lower temperature combinations are often called base metal. The most common one is type K NiCr v NiAl. These are limited to 1100C if any lifetime is expected. Above this temperature rare metals are used. Type R, Pt v PtRh(13%) is very common. These are much more expensive but can record up to 1700C (Type B) and remain stable for a reasonable lifetime.

The Seebeck effect describes the voltage or electromotive force (EMF) induced by the temperature gradient along the wire. The change in material EMF with respect to a change in temperature is called the Seebeck coefficient or thermoelectric sensitivity. This coefficient is usually a nonlinear function of temperature.

However, for small changes in temperature over the length of a conductor, the voltage is approximately linear, which is represented by the following equation where △V is the change in voltage, S is the Seebeck coefficient, and △T is the change in temperature:

$$\triangle V = S * \triangle V$$

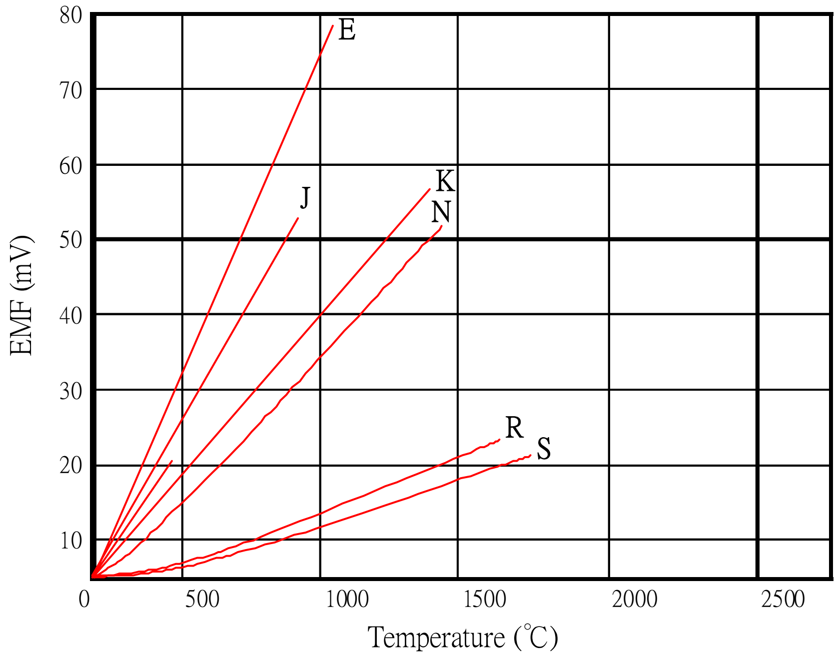
A thermocouple is created whenever two dissimilar metals touch at one end and are measured at the other, creating a small open-circuit voltage as a function of the temperature difference between the contact point and the measurement point of the metals. The measured voltage from the thermocouple is the difference between the Seebeck voltage across each conductor, represented by the above equation. S varies with changes in temperature, which causes the output voltage of thermocouples to be nonlinear over their operating ranges.

Calibration Types：

Thermocouples are classified by calibration type because they have varying electromotive force (EMF) versus temperature curves. Some generate considerably more voltage at lower temperatures, while others do not begin to develop a significant voltage until subjected to high temperatures. Also, calibration types are designed to deliver as close to a straight line voltage curve inside their temperature application range as possible. This makes it easier for an instrument or temperature controller to correctly correlate the received voltage to a particular temperature.

Additionally, thermocouple calibration types have different levels of compatibility with different atmospheres. Chemical reaction between certain thermocouple alloys and the application atmosphere could cause metallurgy degradation, making another calibration type more suitable for sensor life and accuracy requirements.

Thermocouple Millivolts / Temperature Curves



2-1 . Thermocouple Voltage-Temperature Relationship :

For typical metals used in thermocouples, the output voltage increases almost linearly with the temperature difference (△T) over a bounded range of temperatures. For precise measurements or measurements outside of the linear temperature range, non-linearity must be corrected. The nonlinear relationship between the temperature difference (△T) and the output voltage (mV) of a thermocouple can be approximated by a polynomial:

$$\triangle T = \sum_{n=0}^{N} a_n v^n$$

The coefficients an are given for n from 0 to between 5 and 13 depending upon the metals. In some cases better accuracy is obtained with additional non-polynomial terms. A database of voltage as a function of temperature, and coefficients for computation of temperature from voltage and vice-versa for many types of thermocouple is available online.

In modern equipment the equation is usually implemented in a digital controller or stored in a look-up table; older devices use analog circuits. Piece-wise linear approximations are an alternative to polynomial corrections.

2-2. Thermocouple Power Production :

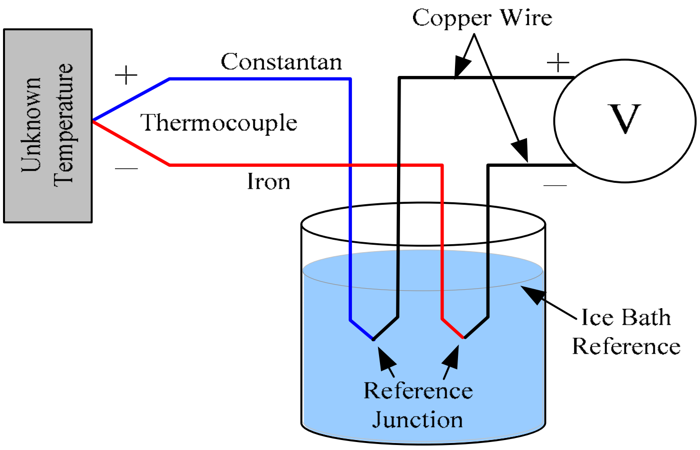
A thermocouple can produce current, which means it can be used to drive some processes directly, without the need for extra circuitry and power sources. For example, the power from a thermocouple can activate a valve when a temperature difference arises. The electrical energy generated by a thermocouple is converted from the heat which must be supplied to the hot side to maintain the electric potential. A continuous flow of heat is necessary because the current flowing through the thermocouple tends to cause the hot side to cool down and the cold side to heat up (the Peltier effect).

Thermocouples can be connected in series to form a thermopile, where all the hot junctions are exposed to a higher and all the cold junctions to a lower temperature. The output is the sum of the voltages across the individual junctions, giving larger voltage and power output. Using the radioactive decay of transuranic elements as a heat source, this

2-3. Reference Junction Compensation ：

The temperature of the thermocouple’ s reference junction must be known to get an accurate absolute-temperature reading. When thermocouples were first used, this was done by keeping the reference junction in an ice bath. Figure 2 depicts a thermocouple circuit with one end at an unknown temperature and the other end in an ice bath (0 ˚C).

This method was used to exhaustively characterize the various thermocouple types, thus almost all th ermocouple tables use 0˚C as the reference temperature.



Basic iron-constantan thermocouple circuit

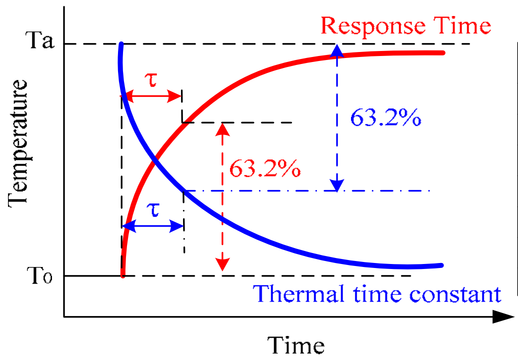
2-4. Response Time / Thermal Time Constant ：

The smaller the diameter, the faster the thermocouple responds. Grounding the junction also improves response time by approximately 50 percent based on the sensor achieving 63.2 percent of the final reading or to the first time constant. It takes approximately five time constants to obtain steady state readings. Temperature accuracy of the surrounding medium depends on the capability of the sensor to conduct heat from its outer sheath to the element wire.

Several factors come into play. Most commonly noted is “time constant” (thermal time constant). Time constant, or thermal response time, is an expression of how quickly a sensor respond s to temperature changes. As expressed here, time response is defined as the length of time it takes a sensor to reach 63.2 percent of a step temperature change.

Response is a function of the mass of the sensor and its efficiency in transferring heat from its outer surfaces to the wire sensing element. A rapid time response is essential for accuracy in a system with sharp temperature changes. Time response varies with the probe’ s physical size and design.

Response times indicated represent standard industrial probes.



Code	Rate of change(%) for To-Ta
τ	63.2
2τ	86.5
3τ	95.0
4τ	98.2
5τ	99.4
6τ	99.8
7τ	99.9

三、Thermocouple Types ：

Calibration types have been established by the American Society for Testing and Materials (ASTM) according to their temperature versus EMF characteristics in accordance with ITS-90, in standard or special tolerances.

Additionally, there are non-ASTM calibration types. These thermocouples are made from tungsten and tungsten-rhenium alloys. Generally used for measuring higher temperatures, they are a more economical alternative to the platinum and platinum alloy based noble metal thermocouples, but limited to use in inert and non-oxidizing atmospheres.

Thermocouple Type	Conductors	
	Positive	Negative
B	Platinum-30%Rhodium	Platinum-6%Rhodium
E	Nickel-Chromium alloy	Copper-Nickel alloy
J	Iron	Copper-Nickel alloy
K	Nickel-Chromium alloy	Nickel-Aluminum alloy
N	Nickel-Chromium-Silicon alloy	Nickel-Silicon-Magnesium alloy
R	Platinum-13%Rhodium	Platinum
S	Platinum-10%Rhodium	Platinum
T	Copper	Copper-Nickel alloy

Thermocouple Tolerance and Applicable Standard

Type	Composition	JIS C 1602-1995 DIN / IEC 584-2-1982 BS / EN 60584-2-1993			ASTM E230-1996 ANSI MC96.1		
		Temp. Range	Class	Tolerance (℃)	Temp. Range	Class	Tolerance (℃)
B	(+) Pt-30%Rh (−) Pt-6%Rh	600 ~ 1700 ℃	2	± 0.0025 | t |	870 ~ 1700 ℃	Standard	±0.5%
		600 ~ 800 ℃	3	± 4.0		Special	±0.25%
		800 ~ 1700 ℃		± 0.005 | t |			
R & S	(+) Pt-13%Rh (−) Pt-10%Rh	0 ~ 1100 ℃	1	± 1.0	0 ~ 1450 ℃	Standard	±0.5 or ±0.25%
		0 ~ 600 ℃	2	± 1.5		Special	±0.6 or ±0.10%
		600 ~ 1600 ℃		± 0.0025 | t |			
N & K	N : (+) Ni-Cr-Si (−) Ni-Si K : (+) Ni-Cr (−) Ni-Al	-40 ~ 375 ℃	1	± 1.5	0 ~ 1260 ℃	Standard	±2.2 or ±0.75%
		375 ~ 1000 ℃		± 0.004 | t |			
		-40 ~ 333 ℃	2	± 2.5		Special	±1.1 or ±0.40%
		333 ~ 1200 ℃		± 0.0075 | t |			
		-167 ~ 40 ℃	3	± 2.5	-200 ~ 0 ℃	Standard	±2.2 or ±2.00%
		-200 ~ 167 ℃		± 0.015 | t |			
E	(+) Ni-Cr (−) Cu-Ni	-40 ~ 375 ℃	1	± 1.5	0 ~ 870 ℃	Standard	±1.7 or ±0.50%
		375 ~ 800 ℃		± 0.004 | t |			
		-40 ~ 333 ℃	2	± 2.5		Special	±1.0 or ±0.40%
		333 ~ 900 ℃		± 0.0075 | t |			
		-167 ~ 40 ℃	3	± 2.5	-200 ~ 0 ℃	Standard	±1.7 or ±1.00%
		-200 ~ 167 ℃		± 0.015 | t |			
J	(+) Fe (−) Cu-Ni	-40 ~ 375 ℃	1	± 1.5	0 ~ 760 ℃	Standard	±2.2 or ±0.75%
		375 ~ 750 ℃		± 0.004 | t |			
		-40 ~ 333 ℃	2	± 2.5		Special	±1.1 or ±0.40%
		333 ~ 750 ℃		± 0.0075 | t |			
T	(+) Cu (−) Cu-Ni	-40 ~ 125 ℃	1	± 0.5	0 ~ 370 ℃	Standard	±1.0 or ±0.75%
		125 ~ 350 ℃		± 0.004 | t |			
		-40 ~ 133 ℃	2	± 1.0		Special	±0.5 or ±0.40%
		133 ~ 350 ℃		± 0.0075 | t |			
		-67 ~ 40 ℃	3	± 1.0	-200 ~ 0 ℃	Standard	±1.0 or ±1.50%
		-200 ~ -67 ℃		± 0.015 | t |			

Characteristics of Thermocouple's Electromotive F

Type / Temperature (℃)	B	R	S	N	K	E	J	T
-100	-	-	-	-2.407	-3.554	-5.237	-4.633	-3.379
0	0.033	0	0	0	0	0	0	0
100	0.178	0.647	0.646	2.774	4.096	6.319	5.269	4.279
200	0.431	1.469	1.441	5.913	8.138	13.421	10.799	9.228
300	0.787	2.401	2.323	9.341	12.209	21.036	16.327	14.862
400	1.242	3.408	3.259	12.974	16.397	28.946	21.848	20.872
500	1.792	4.471	4.233	16.748	20.644	37.005	27.393	
600	2.431	5.583	5.239	20.613	24.905	45.093	33.102	
700	3.154	6.743	6.275	24.527	29.129		39.132	
800	3.957	7.950	7.345	28.455	33.275		45.494	
900	4.834	9.208	8.449	32.371	37.326			
1000	5.780	10.506	9.587	36.256	41.276			
1100	6.786	11.85	10.757	40.087	45.119			
1200	7.311	13.228	11.951	43.846	48.838			
1300	7.848	13.926	12.554	45.694	50.644			
1400	8.956	14.629	13.159	47.513	52.410			
1500	10.099	16.040	14.373					
1600	11.263	27.451	15.582					
1700	12.433							

Thermocouple Sensors Coding

□□ - □□□□□□ -□□□□-□□□

TC: Thermocouples

Standard:
J: JIS (Red: (+); White(-))
A: ANSI/ ASTM (Red:(-))

Thermocouples Type
K / B / C / E / N / J / R / S / T

Junction Type
G: Grounded
U: Ungrounded
E : Exposed

Class
1 / 2 / 3
4 : Standard
5 : Special

Element No.
S: Single M : Multiple
D: Dual
T: Triple

Encapsulation:
1 : Type I
2 : Type II
3 : Type III

Serial Number

Terminal (Box):
H: Head Type
T : T Type
Y : Y type
P : Plug
N : Non
O : Other

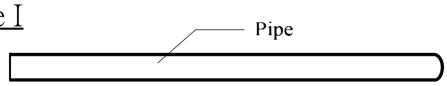
Extension Wire:
Y : Yes
N : No

Insulation:
G : Glass-fiber
T : Teflon
N : Non

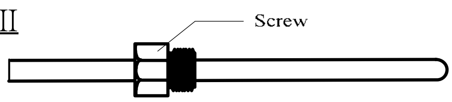
Material:
1 : Stainless
2 : Ceramic
3 : Other

Encapsulation

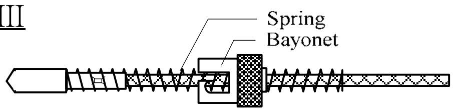
Type I



Type II

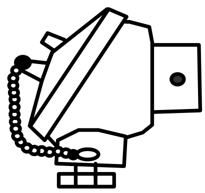


Type III



Terminal (Box):

Head Type



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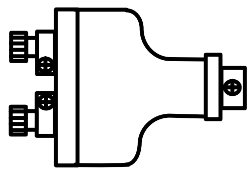
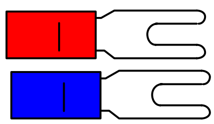
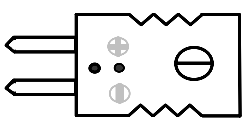
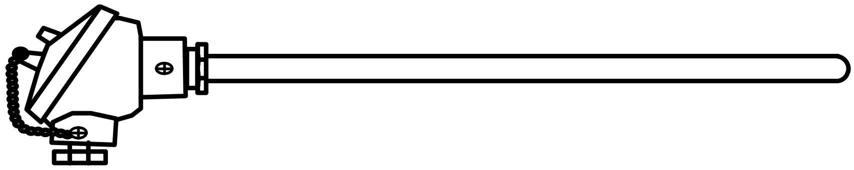
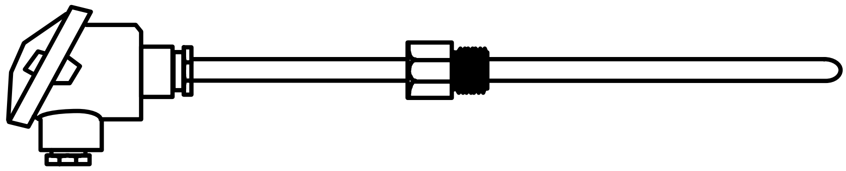
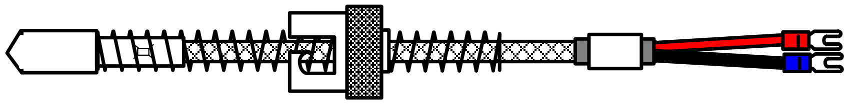
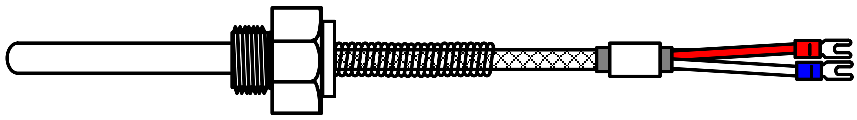
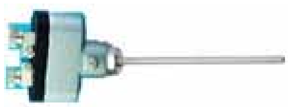
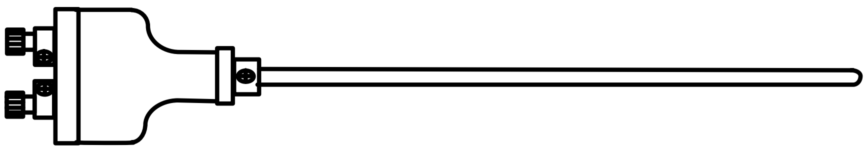
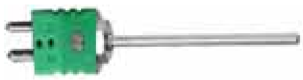
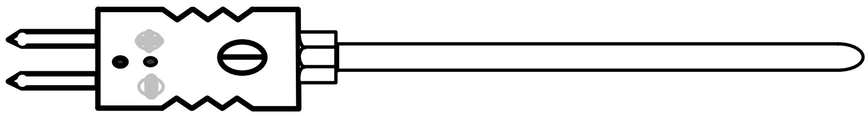
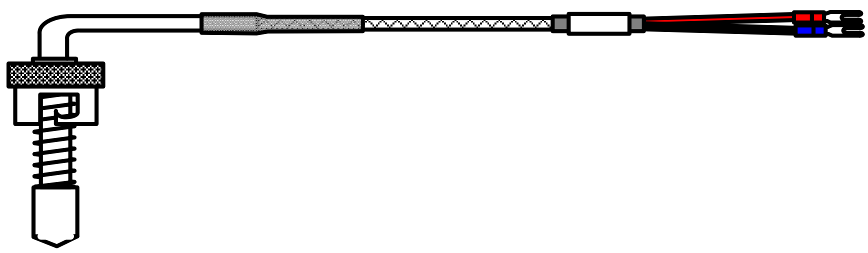


Y Type



Plug Type



* Besides , the above standard characteristic product , we have some special types and can provide the flexible design according to your needs as well .