DK DOOKWANG
MANUFACTURING COMPANY

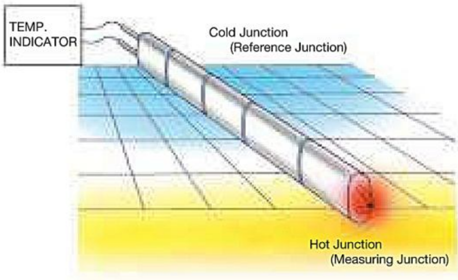
THERMOCOUPLE
WIRES, INSULATORS AND PROTECTION TUBES

SINCE 1993
DK

PRINCIPLE AND DESCRIPTIONS OF THERMOCOUPLE

When two dissimilar metal or alloy conductors are connected together to form a closed circuit and the two junctions are kept at different temperatures, thermal electromotive force (EMF) is generated at the temperature gradient zone along the conductors length in the circuit.Thus, when one end (cold or reference junction) is kept constant at a certain temperature, normally 0°C, and the other end (measuring junction) is exposed to unknown temperature, the temperature at the latter end can be determined by measuring EMF so generated. Such a combination of two dissimilar metal conductors is called "Thermocouple." As described, thermocouple is a "temperature difference sensor" to generate millivolt signal (EMF) only at the temperature gradient segment, which inevitably makes the thermocouple conductor heat treated in accordance with the temperature profile along the insertion depth. It is not correct, therefore, to use such a thermocouple as once heat treated and so stabilized, for measurement of the other location that has different temperature gradient. Particularly, when measurement is made in shorter insertion depth than previous measurement, it will result in large reading error, since already heat treated segment is exposed to non-temperature gradient zone thus exhibiting spurious EMF, therefore, avoid re-using one thermocouple for measurements at the different locations.

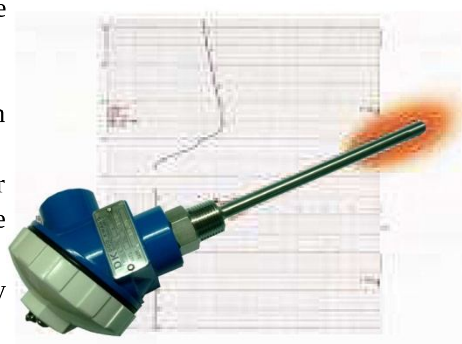
Generally, service life of the thermocouple can not be predicted nor be guaranteed, as the environments of temperature measurement are so various involving handling,installation, corrosion, vibration, thermal cycles and steep change in temperatures.



Features of Thermocouple

Industrial thermocouple, in comparison with other thermometers, has the following features:

1. Quick response and stable temperature measurement by direct contact with the measuring object.
2. If the selection of a quality thermocouple is properly made, wide range of temperature from −270 to 2,300°Ccan be measured.
3. Temperature of specific spot or small space can be measured.
4. Since temperature is detected by means of EMF generated, measurement, adjustment, amplification, control, conversion and other data processing are easy.
5. Less expensive and better interchangeability in comparison with other temperature sensors.
6. The most versatile and safe for measuring environments, if a suitable protection tube is employed.
7. Rugged construction and easy installation.



Structure and Measuring

Generally, industrial thermocouple is insulated with ceramic beads to prevent thermocouple conductors from short circuit and then inserted into a protection tube to avoid contacting directly to the measuring object or being exposed to the surrounding atmosphere. Our THERMIC Mineral Insulated Metal Sheathed Thermocouple has a pre-assembled construction composed of thermocouple wires, compacted ceramic powder insulation and protection sheath in one pliable, gas tight cable form. Reference junction should be kept or compensated at a constant temperature (ideally at 0°C) for measurement. The EMF generated can be measured with a simple moving coil type, electronic type, potentiometric and other indicators or converted to various data processing signals for computer control.

Precautions for Practical Applications

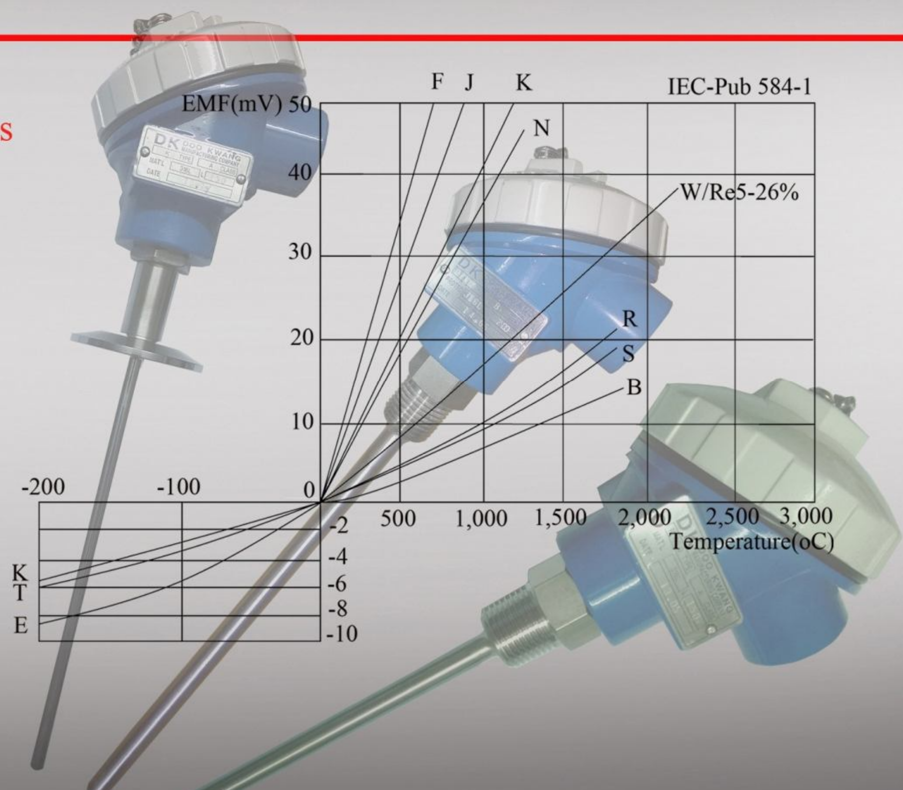
There are various types of thermocouple, so it is most important to carefully select an appropriate thermocouple for the specific application. In addition, care should be exercised when selecting protection tube, structure of the assembly and installation method in consideration of resistance to heat, pressure, thermal shock, corrosion and vibration. For the best of temperature measurement with thermocouple, overall measuring loop And components should be carefully designed. Although the importance of reference or cold junction is overlooked and often substituted by a simple electric resistor compensation inside the measuring instrument, stability of the reference junction actually controls measurement accuracy. It is therefore recommended that precision reference devices like our "Zeref V" (18 channels max., 0±0.01℃Accuracy) or industrial rack mount model "TRU 100"(100 channels, 0±0.03℃Accuracy per 15℃Ambient Span) should be used and Class 1 extension cables should be used for wiring rather than compensating cables. For guidance, various technical brochures, such as,"Instruction Manual

Combination of Standardized

Ref : IEC-Pub 584-2
ASTM E988-1996

Type	Alloy Composition of the conductors	
	Positive (+) Leg	Negative (-) Leg
B	BP(70%Platinum・30%Rhodium	BN(94%Platinum・6%Rhodium)
R	RP(87%Platinum・13%Rhodium)	RN(100%Platinum)
S	SP(90%Platinum・10%Rhodium)	SN(100%Platinum)
N	NP (84%Ni・14.2%Cr・1.45%Si)	NN (95%Ni・4.4%Si・0.15%Mg)
K	KP (90%Ni・10%Cr)	KN (95%Ni・2%Mn・2%Al)
E	EP (90%Ni・10%Cr)	EN Constantan (55%Cu・45%Ni)
J	JP (99.5% Iron)	JN Constantan (55%Cu・45%Ni)
T	TP (100% Copper)	TN Constantan (55%Cu・45%Ni)

EMF Curves of Standardized Thermocouples



The thermoelectric effect

The effect responsible for the action of thermocouples is the Seebeck effect. If a termperature 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 ofdifferent 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").

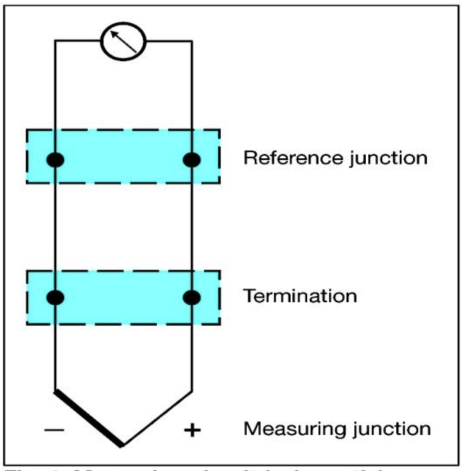


Fig. 1: Measuring circuit (schematic)

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 thermocouple

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-Pt6Rh	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

* Continuous temperature in pure air

Table 2: Thermocouples to DIN 43 710

J and T to EN 60 584. The individual thermocouples are not compatible, because of their differing alloy compositions. If a Fe-Co 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 firstlimb 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.

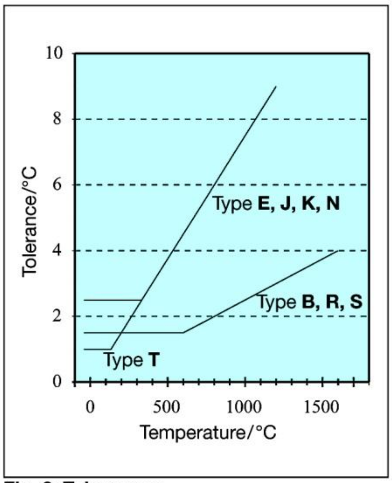


Fig. 2: Tolerances

Linearity

The voltage produced by a thermocouple is not linear with temperature and must therefore be liniearized 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 forcompensating 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

Thermocouple		Tolerance classes			
Fe-Con	J	Class 1	- 40 to + 750°C:	±0.004 x t	or ±1.5°C
		Class 2	- 40 to + 750°C:	±0.0075 x t	or ±2.5°C
		Class 3			
Cu-Con	T	Class 1	- 40 to + 350°C:	±0.004 x t	or ±0.5°C
		Class 2	- 40 to + 350°C:	±0.0075 x t	or ±1.0°C
		Class 3	-200 to + 40°C:	±0.0015 x t	or ±1.0°C
Ni-CrNi and NiCrSi-NiSi	K N	Class 1	- 40 to +1000°C:	±0.004 x t	or ±1.5°C
		Class 2	- 40 to +1200°C:	±0.0075 x t	or ±2.5°C
		Class 3	-200 to + 40°C:	±0.015 x t	or ±2.5°C
NiCr-Con	E	Class 1	- 40 to + 800°C:	±0.004 x t	or ±1.5°C
		Class 2	- 40 to + 900°C:	±0.0075 x t	or ±2.5°C
		Class 3	-200 to + 40°C:	±0.015 x t	or ±2.5°C
Pt10Rh-Pt	S	Class 1	0 to +1600°C:	±[1+(t-1100) x0.003]	or ±1.0°C
and		Class 2	- 40 to +1600°C:	±0.0025 x t	or ±1.5°C
Pt13Rh-Pt	R	Class 3			
Pt30RhPt6Rh	B	Class 1			
		Class 2	+600 to +1700°C:	±0.0025 x t	or ±1.5°C
		Class 3	+600 to +1700°C:	±0.005 x t	or ±4.0°C

Table 3: Tolerances to EN 60 584

Thermocouple		Tolerance classes
Cu-Con	U	+100 to +400 °C: ±3°C + 400 to +600 °C: ±0.0075 x t
Fe-Con	L	+100 to +400 °C: ±3°C +400 to +900 °C: ±0.0075 x t

Table 4: Tolerances to DIN 43 710 (1977)

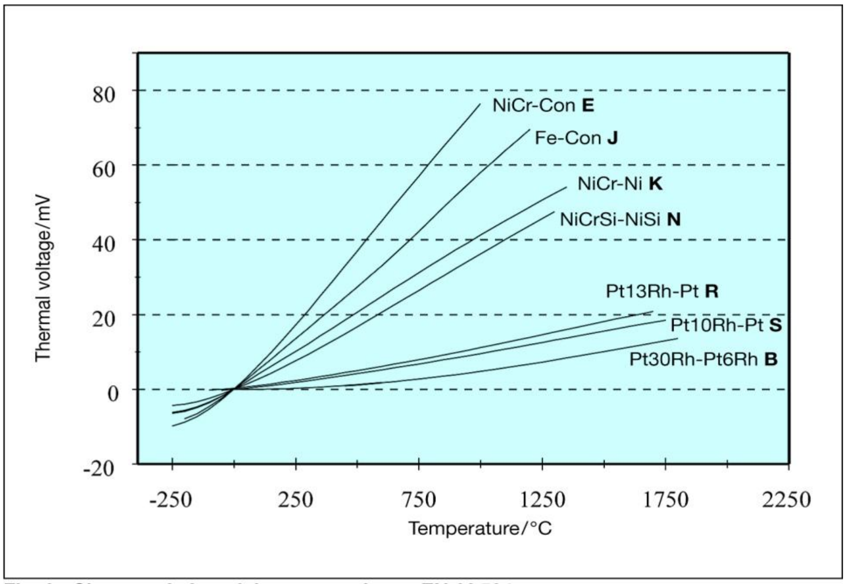


Fig. 3: Characteristics of thermocouples to EN 60 584

terminations, without exceeding the specified tolerances. Because of the non-linearity of the thermal voltage, the tolerances in mV or °C only apply tothe measured temperatures specified in the right column. This means, for example: A thermocouple Type J is connected to acompensating 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 ±2.5°C.

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.

Thermocouple and wire type	Tolerance classes 1	2	Operating temperature range [°C]	Measuring temperature [°C]
JX	± 85µV/±1.5°C	± 140µV/±2.5°C	-25 to +200	500
TX	± 30µV/±0.5°C	± 60µV/±1.0°C	-25 to +100	300
EX	± 120µV/±1.5°C	± 200µV/±2.5°C	-25 to +200	500
KX	± 60µV/±1.5°C	± 100µV/±2.5°C	-25 to +200	900
NX	± 60µV/±1.5°C	± 100µV/±2.5°C	-25 to +200	900
KCA	_	± 100µV/±2.5°C	0to+150	900
KCB	_	± 100µV/±2.5°C	0to+100	900
NC	_	± 100µV/±2.5°C	0to+150	900
RCA	_	± 30µV/±2.5°C	0to+100	1000
RCB	_	± 60µV/±5.0°C	0to+200	1000
SCA	_	± 30µV/±2.5°C	0to+100	1000
SCB	_	± 60µV/±5.0°C	0to+200	1000

Table 5: Tolerances for thermocables and compensating cables

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 coding 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 to DIN 43 714 (1979)

Construction of thermocouples

Apart from the virtually unlimited number of special models, there are also those whose components are completely defined by standard specifications.

Thermocouples with terminal head

These thermocouplesare of modular construction, consisting of the thermocouple proper, insert tube, terminal plate, protection tube and the terminal head. A flange or a screw fitting can be provided for mounting in position.

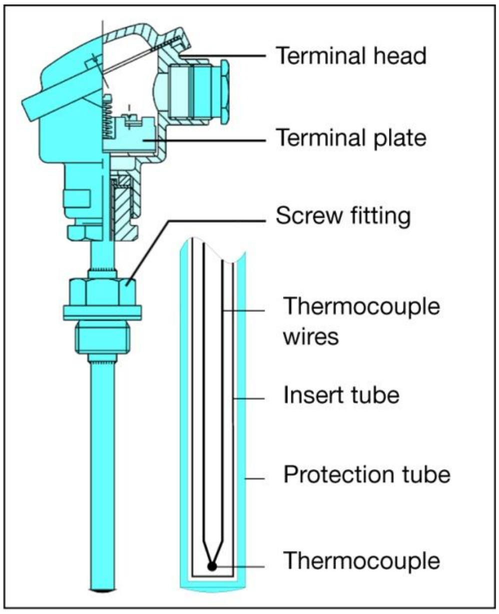


Fig. 4: Construction of a thermocouple

The measuring insertis a completely fabricated unit consisting ofthermocouple sensor and terminal plate, with the thermocouple contained in an insert tubeof 6 or 8 mm diameter made from bronze SnBz6 to DIN 17 681 (up to 300°C) or nickel. It is inserted into the actual protection tube, which is often made from stainless steel. The tip of the insert tube is in full contact with the inside of the protection tube end plate in order to ensure good heat transfer. The fixing screws of the insert are backed by springs, to maintain good contact even with differential expansion between insert tube and protection tube. This arrangement ensures that the insert can be readily replaced. The thermometers are available in single and twin versions. Their dimensions are laid down in DIN 43 735. If no measuring insert is used, the thermocouple is mounted directly in the protection tubeusing ceramic insulation. The choice of the protection tube material depends on the thermal, chemical and mechanical conditions on site. 43 720. These details are provided for general information only, and the user remains responsible for fully evaluating the protection tube material for its suitability to the operating conditions on site. The indicated temperature refers to the use without mechanical loads and (unless otherwise specified) in clean air. Ceramic protection tubesare employed where local conditions prevent the use of metal fittings, either for chemical reasons or because of high temperatures. Their main application is at temperatures between 1000 and 1650°C. They may be in direct contact with the medium, or may be used as a gastight inner tube to separate the thermocouplefrom the actual protection tube. Even hair cracks may lead to a poisoning and drifting of the thermocouple. The resistance of a ceramic to temperature shock increases with its thermal conductivity and the tensile strength, and is larger for a lower thermal expansion coefficient. The wall thickness of the material is also important; thin-walled tubes are preferable to those with larger wall thicknesses.

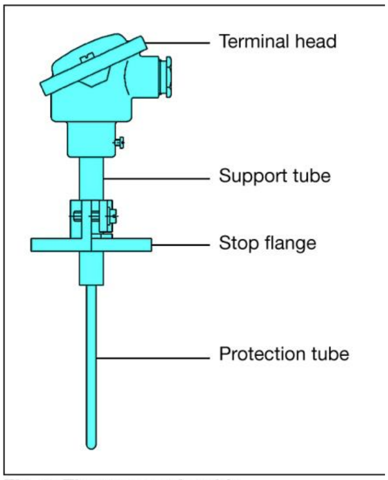


Fig. 5: Thermocouple with ceramic protection tube

In the case of noble thermocouples, the ceramic has to be of the highest purity. Platinum thermocouplesare very sensitive to poisoning by foreign chemical elements. These include especially silicon, arsenic, phosphorus, sulfur and boron. Special care must therefore be taken in high-temperature fittings to ensure that insulation and protection tube do not contain such elements, as far as this is possible. A particularly damaging material is SiO2. Poisoning takes place much more rapidly in a neutral or reducing atmosphere and is caused by the reduction of SiO2 to SiO, which reacts with platinum to form Pt5 Si2. As little as 0.2% SiO 2in the insulation of the protection tube material is sufficient in a reducing atmosphere to form such brittle silicides. Thermocouples with protection tubes that are permeable to gas can therefore not be used in a reducing atmosphere, such as in annealing furnaces, but are permitted in an oxidizing atmosphere or under a protective gas blanket. If an inner tube of gas-tight ceramic is used, the outer protection tube can be permeable to gas. In the high-temperature range, the insulation properties of the materials become important. Protection tubes in aluminium-oxide (KER610) and magnesium oxide exhibit appreciable conductivity above 1000°C. This produces a shunt effect which introduces errors into the thermocouple signal. The insulation of ceramics deteriorates with increasing alkali content. Pure aluminium oxide ceramics exhibit the best characteristics. KER 710 is therefore used for 4-bore insulators and protection tubes. Two gas-tight ceramicsare described below, whose characteristics are defined in DIN 43 724: KER 710is a pure oxide ceramic consisting of more than 99.7% AI2O3 , with traces of MgO, Si2O and Na2O, which is fire resistant up to 1900°C and has a melting point of 2050°C. It is the best ceramic material, with an insulation resistance of 107Ωx cm at 1000°C and good strength under alternating temperatures,thanks to its high thermal conductivity and relatively low thermal expansion. With platinum thermocouples, both the insulation rod and the protection tube must be in KER 710.

The material **KER 610** has a higher alkali content (60% Al_2O_3, 37% SiO_2, 3% alkali) and, therefore, a low insulation resistance of about 104Ωx cm at 1000°C. Because of the high silicon dioxide content, it cannot be used in a reducing atmosphere. Compared with KER 710, it has only one-ninth the thermal conductivity; its mechanical stability is good. The advantage of KER 610 is its price, which is only about one-fifth that of KER 710. For the terminal heads, DIN 43 729 defines

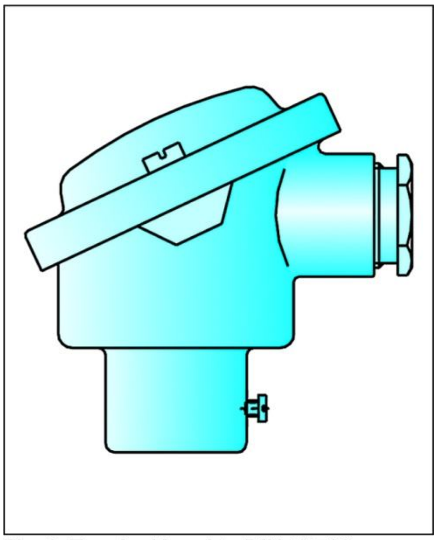


Fig. 6: Terminal head to DIN 43 729, Form B

The material used is aluminium.
Protection is not covered by a standard; it is usually splash-proof to IP54. The nominal diameter of the bore to take the protection tube is as follows:
Form A: 22, 24 or 32 mm.
Form B: 15 mm or thread M 24 x 1.5.

Thermocouples to DIN EN 14 597

Thermocouples for use with temperature controllers or temperature limiters for indirect heating systems must meet the requirements of DIN EN 14 597 and are subject to additional TUV approval. The thermocouples must withstand temperatures that are 15% above the upper temperature limit for at least one hour and have to meet certain response times in relation to the medium (e.g. air t0.63 = 120sec). The thermometers are designed to withstand mechanical loads caused by external pressure and the flow velocity of the medium at the operating temperature. No modifications to the thermometers arepermitted without obtaining a fresh TUV approval!

Thermocouples with compensating cable

Thermocouples with an attached compensating cable do not have a measuring insert or a terminal head. The thermocouple is directly connected to the thermocable or the compensating cable and enclosed in the protection tube. Strain relief is provided by crimping the protection tube at the entry of the compensating cable. The thermocouple is normally insulated; alternatively, it can be welded to the protection tube tip for improved thermal contact. The maximum temperature is determined mainly by the thermal stabilityof the cable sheath and insulation. Table 9 shows as examples some insulation materials and their upper temperature limit.

Material	Max. temperature °C
PVC	80
Silicone	180
PTFE	260
Glass fiber	350

Table 9: Temperature limits ofinsulation materials

There are many different thermometer designs, and they are often adapted to suit particular customer requirements. Some characteristic data are given below:
-diameter: 0.5–6mm
- protection tube length: 35 – 150mm
- protection tube material: stainless steel, heat-resistant steel or brass
- mounting: fixed or sliding flange, fixed thread or clamp

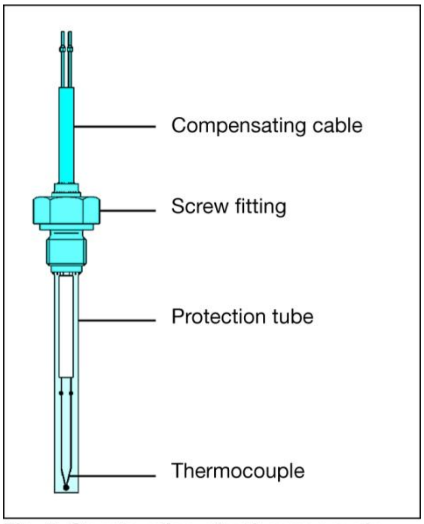


Fig. 7: Construction of a thermocouple with compensating cable

Thermocouples with bayonet fitting

Another version incorporates a bayonet fitting. The stainless steel pressure spring (Material Ref. 1.4310) also acts as a cable protector and ensures uniform pressure of the protection tube and sensing tip against the bottom of the bore. The fitting length can be varied by rotating the bayonet lock. Bayonet fittings and sockets are available in 12, 15 and 16 mm diameters.

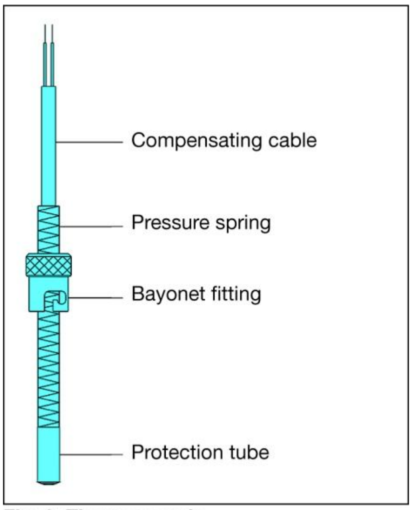


Fig. 8: Thermocouple with bayonet fitting

Thermocouples with a bayonet fitting are largely employed for measuring temperatures in solids, on bearings and moulding tools, e.g. in the plastics industry. Because of the special shape of the sensing tip, these thermocouples are suitable for both flat-bottom and cone-shaped bores

Mineral-insulated thermocouples

Mineral-insulated thermocouples consist of a thin-walled sheath of stainless or high-temperature steel (Inconel 600) in which thermocouple wires are embedded in compressed fire-resistant magnesium oxide.the two forms A and B, which differ in size and also slightly in style..

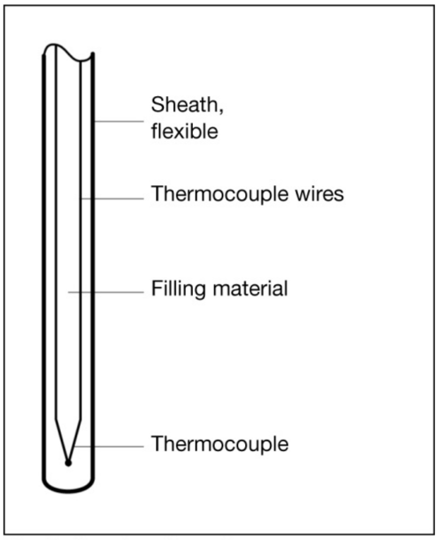


Fig. 9: Construction of a mineral-insulated thermocouple

Excellent heat transfer between sheath and thermocouple enables a fast response (t 0.5 from 0.1sec) and high accuracy. The shock-resistant construction ensures a long life.The flexiblesheath, minimum bending radius 5 times the external diameter of 0.5 – 6mm, permits temperature measurement in locations where access is difficult. Thanks to their special features, mineral-insulated thermocouples are used in chemical plant, power stations, pipelines, on test beds and wherever resistance to vibration, flexibility and easy installation are required.

Connection of thermocouples

The length of the compensating cable is of minor importance in view of the low internal resistance. With long distances and a small cross-section, the resistance of the compensating cable may, however, become relatively large. In order to avoid errors, the resistance of the input circuit of the instrument must be at least 1000 times the resistance of the thermocouple connected. It is essential to use only compensating cables of the same material as the thermocouple, or with the same thermoelectric characteristics, otherwise an additional thermocouple is formed at the connection point. The compensating cable has to be run up to the cold junction. The correct polarity must be observed when connecting up the thermocouple.

Effect on short-circuit and break

A thermocouple producesno voltage if the measured temperature is equal to the cold junction temperature. If a thermocouple or compensating cable is short-circuited, a new measuring point is produced at the location of the short-circuit. If it occurs in the terminal head, for example, the temperature measurement relates not to the actual measuring point,but to the terminal head. If there is a break in the measuring circuit, the instrument will show the cold junction temperature.

Measurement errors arising from the installation

A temperature probe can only indicate the temperature of its temperature-sensitive sensor. This temperature is not necessarily the same as that for the medium which is intended to be measured. The thermometer is not installed purely in the medium, but is also thermally linked to its surroundings. This results in a temperature shift (thermal conduction error). This error depends on a number of factors. These include: the temperature of the medium, ambient temperature, thermal characteristics of the medium, flow velocity and the immersion length ofthe thermometer. A lasting reduction of this error requires a suitable choice of installation site, whereby the immersion depth of the thermometer in the medium plays a particularly important role. As a rough guide for measurement in liquid media, the immersion depth should be at least 15 times the thermometer diameter. For critical applications, or to meet requirements for very high accuracy, the installation-induced error should be checked by a test measurement. To do this, the thermometer is pulled out of the normal installationposition by about 10 mm, and the temperature indication is noted.

Fault finding

One of the most frequent faults is the omission or the incorrect choice of the compensating cable. The thermocouple can be readily checked using a simple continuity tester or ohmmeter. The operation of the thermocouple and its correct polarity can be tested with a voltmeter (millivolt range), by heating its sensing tip

Possible connection errors and their effects:

- Indicator shows room temperature thermocouple or cable open-circuit.
- Indication has correct value but negative sign reversed polarity at the indicator.
- Indication cleary too high or too low
a) incorrect linearization of the indicator.
b) incorrect compensating cable or connections reversed.
- Indication too high or too low by a fixed amount incorrect cold junction temperature.
- Indication correct but drifting slowly in spite of constant measured temperature cold junction temperature not constant or not evaluated correctly.
- Temperature still indicated with one limb disconnected
a) electromagnetic interference picked up on the input cable.
b) parasitic voltages produced due to missing or faulty electrical isolation e.g. in furnaces.
- High reading when both thermocouple limbs are disconnected
a) electromagnetic interference picked up on the input cable
b) parasitic galvanic voltages, e.g. due to damp insulation in the compensating cable.

Safety notes

All welded joints on thermometers and pockets are monitored through a quality assurance system to DIN 8563, Part113. Special regulations apply to certain applications (e.g. pressure vessels) according to Section 24 of the German Trade Regulations. Where the user specifies such special requirements, the weld is monitored according to EN 287 and EN 288.

Pressure loading for temperature probes

The pressure resistance of protection fittings, such as are used for electric thermometers, depends largely on the different process parameters.

These include:

-temperature

-pressure

-flow velocity

-vibration In addition, physical properties, such as material, fitting length, diameter and type of process connection haveto be taken into account. The following diagrams are taken from DIN 43 763 and show the load limit for the different basic types in relation to the temperature and the fitting length, as wellas the flow velocity, temperature and medium

As explained in the standard, the values indicated are guide values, which have to be individually examined for the specific application. Slight differences in the measurement conditions may suffice to destroy the protection tube. If, when ordering an electric thermometer, the protection fitting needs to be checked, the load type and the limit values must be specified. Fig. 12 shows the load limits (guide values) for different tube dimensionson a variety of additional thermometer designs. The maximum pressure loading of cylindrical protection tubes is shown in relation to the wall thickness with different tube diameters. The data refer to protection tubes in stainless steel 1.4571, 100mm fitting length, 10m/sec flow velocity in air, or 4m/sec in water, and a temperature range from -20 to +100°C. A safety factor of 1.8 has been taken into account. For higher temperatures or different materials, the maximum pressure loading has to be reduced by the percentage values given in the table.

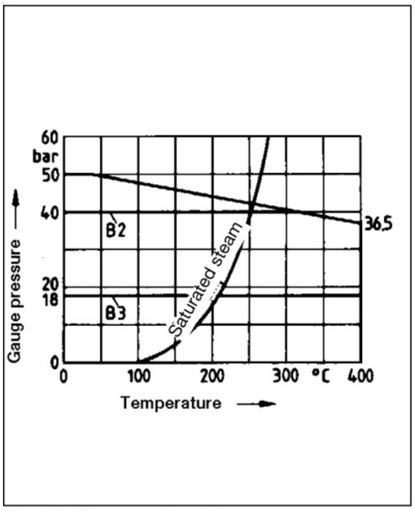


Fig. 10: Pressure loading for protection tube Form B

stainless steel 1.4571
velocity up to 25m/sec in air velocity up to 3m/sec in water

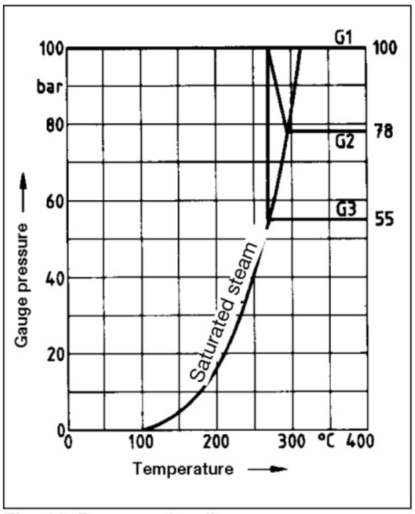


Fig. 11: Pressure loading for protection tube Form G

stainless steel 1.4571
velocity up to 40m/sec in air velocity up to 4m/sec in water

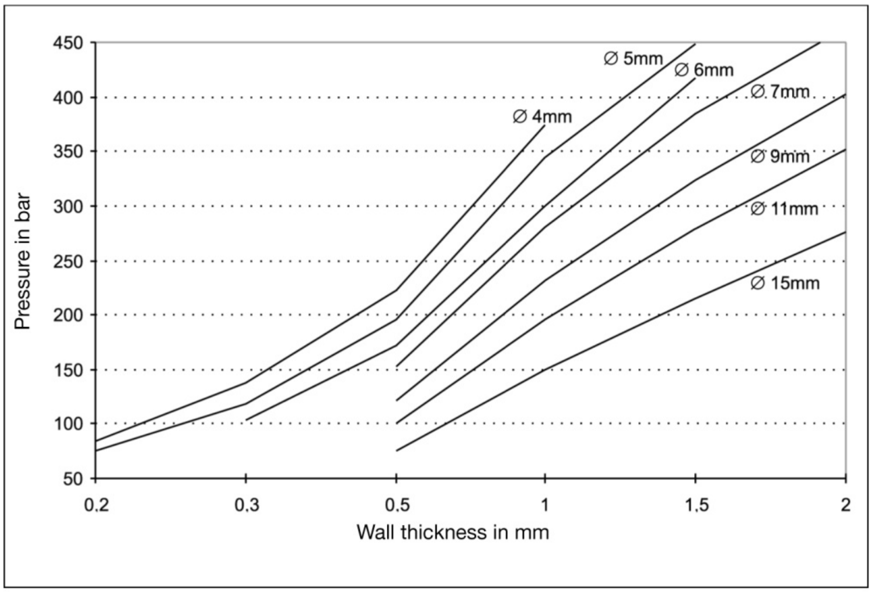


Fig. 12: Load limits on protection tubes for various tube dimensions

Material	Temperature	Reduction
CrNi 1.4571	up to +200°C	-10%
CrNi 1.4571	up to +300°C	-20%
CrNi 1.4571	up to +400°C	-25%
CrNi 1.4571	up to +500°C	-30%
CuZn 2.0401	up to +100°C	-15%
CuZn 2.0401	up to +175°C	-60%

Pressure test for thermometer protection fittings

The welded protection fittings of JUMO thermometers are subjected to a leakage test or a pressure test, depending on the construction of the protection fitting. Thermometers which are manufactured to DIN or to application-specific guidelines (chemical or petrochemical plant, pressure vessel regulation, steam boilers) require different pressure tests according to the specific application. If the thermometers are to be manufactured to such standards or guidelines, then the required tests or standards and/or guidelines have to be specified when ordering.

Scope of test

Tests can be carried out on each individual protection fitting and documented in a test report or acceptance certificate to EN 10 204 (at extra cost).

Type of test

Tests can be performed on protection fittings up to a fitting lengthof 1050mm with flange connection DN25 or screw connection up to 1" thread size

The following tests can be carried out:

Test type	Te s t medium	Pressure range	Te s t duration
Leakage test	helium	vacuum	10sec
Pressure test I	nitrogen	1 — 50bar	10sec
Pressure test I	water	50 — 300bar	10sec

Leakage test

A vacuum is produced inside the protection tube. From the outside, helium is applied to the protection fitting. If there is a leak in the protection tube, helium willpenetrate and will be recognized through analysis. A leakage rate is determined by the risein pressure (leakage rate > 1 x 10^{-6}l/bar).

Pressure test I

A positive pressure of nitrogen is applied to the protection tube from the outside. If there is a leak in the fitting, a volume flow will be produced inside the protection tube, which will be recognized.

Pressure test II

Water pressure is applied to the protection tube from the outside. The pressure must remain constant for a certain length of time. If this is not the case, the protection fitting has a leak.

Qualified welding processes for the production of protection tubes for thermometers

In addition to using perfect materials, it is the joining technique which ultimately determines the mechanical stability and quality of the protection fittings. This is why the welding techniques at JUMO comply with the European Standards EN 287 and EN 288. Manual welding is carried out by qualified welders according to EN 287. Automatic welding processes are qualified by a WPS (welding instruction) to EN 288.

The following table gives an overview of qualified welding processes:

Material	WIG welding	
	manual	manual
W11, W11 with W01 -W04 to EN 287	Tube diameter 2 — 30mm Wall thickness 0.75 — 5.6mm	Tube diameter 5 — 10mm Wall thickness 0.5 — 1.0mm

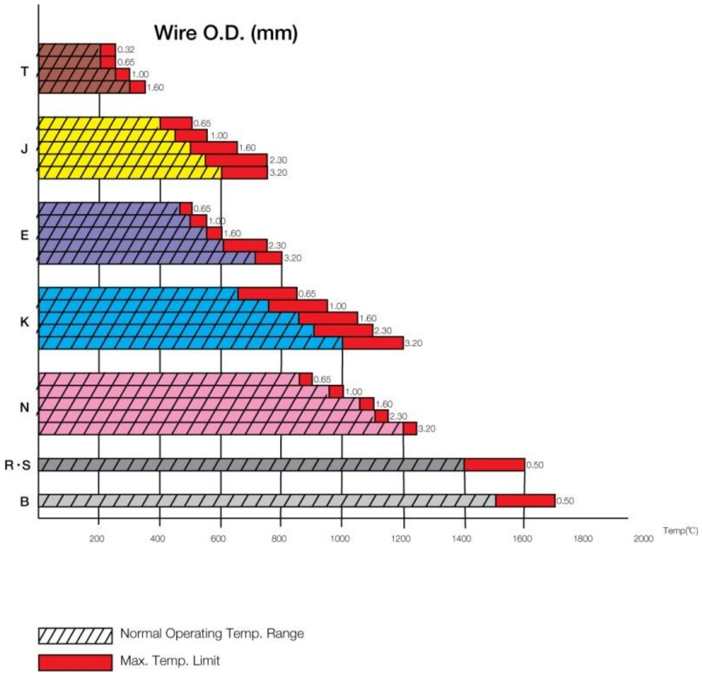
Based on these experiences, our welders can also join different materials and dimensions.

Laser beam welding is employed for wall thicknesses of less than 0.6mm, which is monitored by a laser beam specialist according to guideline DSV 1187.

On customer request, material test certificates can be issued at extra cost. Likewise, special tests and treatments can be carried out, which are calculated according to the extent of the work, as set out in various application guidelines. This includes X-ray examinations, crack test (dye penetration test), thermal treatment, special cleaning processes and markings.

Operating and Maximum Temperature Limits to Conductor Diameter (mm)

Note :
(1) Operating temperature limit means the upper temperature where thermocouple can be used continuously in air.
(2) Maximum limit means the upper temperature where thermocouple can be used temporarily for short period of time owing to unavoidable circumstances. This graph is given as a guide only, and not to be guaranteed.



TYPE	Wire Dia.(mm)	Normal Operating Temp. Range (℃)	(℃) Max. Temp. Limit
B	0.5	1,500	1,700
R・S	0.5	1,400	1,600
N	0.65	850	900
	1	950	1,000
	1.6	1,050	1,100
	2.3	1,100	1,150
	3.2	1,200	1,250
K	0.65	650	850
	1	750	950
	1.6	850	1,050
	2.3	900	1,100
	3.2	1,000	1,200
E	0.65	450	500
	1	500	550
	1.6	550	600
	2.3	600	750
	3.2	700	800
J	0.65	400	500
	1	450	550
	1.6	500	650
	2.3	550	750
	3.2	600	750
T	0.32	200	250
	0.65	200	250
	1	250	300
	1.6	300	350

Code	No.of Conductors
S	Single pair, 2 conductors
D	Dual pair, 4 conductors
T	Triple pair, 6 conductors

Standardized Types of Thermocouple

B

Type B (Pt・30%Rh/Pt・6%Rh)
Thermocouple 600℃∽1700℃

Type B thermocouple has higher melting point and mechanical strength than other Pt/Rh thermocouples because of its higher content of Rhodium in both legs. Type B thermocouple can be used continuously in oxidizing and neutral atmospheres up to 1600℃and intermittently up to 1700℃. Even in reducing atmosphere, Type B may be used for fairly longer period than other Pt/Rh thermocouples, but not generally recommended.Type B thermocouple is recommended especially for the applications requiring precision measurement and durability at high temperatures. This thermocouple has very small EMF up to 100℃, thus for less critical applications, copper leads can be used as a compensating wire. Precious metal thermocouples are generally sensitive to contaminants and easily be corroded at elevated temperatures. It is essential to keep the thermocouple wire clean and use dustfree high purity (>99.5%) Alumina insulators and protection tubes.

R

Type R (Pt・13%Rh/Pt)
Thermocouple 0℃∽1600℃

Type R thermocouple has superior mechanical properties to Type S and is recommended for continuous use in oxidizing and inert atmospheres around temperatures up to 1400℃and intermittently up to 1600℃. However, it should not be used in vacuum, reducing or metallic vapour atmospheres unless properly protected with clean high purity (>99.5%) Alumina insulators and protection tubes. Among precious metal thermocouples, Type R is most widely used.

S

Type R (Pt・13%Rh/Pt)
Thermocouple 0℃∽1600℃

Type S thermocouple is the first historic thermocouple originally developed by Le Chatelier in 1886. It had been widely used as a standard thermometer as an interpolation means to determine the temperature scale between the fixed (freezing) points ranging from 630.74℃ of Antimony to 1064.43℃of Gold as defined by the International Practical Temperature Scale (IPTS). Applications are similar to Type R, but it has less mechanical strength.

N

Type N (Nicrosil/Nisil)
Thermocouple -200℃∽1250℃

This new thermocouple combination of 84Ni-14.2Cr-1.4Si vs. 95.5Ni.-4.4Si-0.1Mg was first developed by Materials Research Laboratory of the Australian Department of Defense. Further research and evaluation have been extensively carried out by NIST (former NBS), ASTM and other research organizations to standardize and establish the present EMF table. Type N thermocouple exhibits superior long-term stability and oxidation resistance over type K when used at high temperatures ranging from 600 to 1250℃. By virtue of fine adjustment of chromium content with additions of Si and Mg, it has less EMF shift in the region of "short range ordering" and also resistant to "Green Rot" corrosion. In comparison with type K, rate of EMF drift is reported to be half or one third over the range of 1000℃and therefore recommended for use in oxidizing atmosphere of 1000-1200℃continuous.

K

Type B (Pt・30%Rh/Pt・6%Rh)
Thermocouple 600℃∽1700℃

Type K thermocouple was originally developed by Mr. A. L. Marsh of Hoskins Co., U.S.A. in 1906 and, since then, has undergone many improvements. It has linear EMF characteristics and most widely used as industrial thermocouple with high reliability because of its versatile characteristics. It can be used in oxidizing to 1250℃.Type K thermocouple may be used in hydrogen or cracked ammonia atmospheres if the dewpoint is below-42℃. However, it should not be used in reducing, alternatively oxidizing and reducing, sulfurous or "green-rot" corrosive atmospheres unless properly protected. "Green-rot" can be minimized by increasing oxygen supply through the use of large diameter protection tube or ventilated protection tube. It can also be minimized by inserting a "getter" to absorb the oxygen in a sealed protection tube. For such a special application, consult our factory.

E

Type R (Pt・13%Rh/Pt)
Thermocouple 0℃∽1600℃

Type E thermocouple has the highest EMF characteristics among industrial thermocouples which allows the best resolution to temperature change. Since it was adopted by ANSI in 1964 and JIS in 1974, type E thermocouple has met rapidly increasing demands and has been widely used even in large scale thermal and nuclear power stations. It can be used up to 750℃continuously.For practical use, precautions similar to those for type K are required. Careful attention is also needed in selection of the indicator to be connected because type E thermocouple has the highest resistivity among the base metal thermocouples.

J

Type R (Pt・13%Rh/Pt)
Thermocouple 0℃∽1600℃

Type J thermocouple has the second highest EMF characteristics and is recommended for use in reducing, inert, oxidizing or vacuum atmospheres up to 750℃. Because of comparatively less expensive price, type J has been easily accepted for use in various applications. However, it should not be used in sulphurous atmospheres above 538℃due to formation of the sulfides that leads conductors to embrittlement. The iron element is often rusted under high humidity environment, therefore, type J is less desirable than type T for low temperature measurements.

T

Type N (Nicrosil/Nisil)
Thermocouple -200℃∽1250℃

Type T thermocouple has good resistance to corrosion in moist atmospheres and is suitable for sub-zero temperature measurements. It can be used in vacuum and in oxidizing, reducing or inert atmospheres up to 400℃. At higher temperatures, it is susceptible to rapid oxidation by water vapour. Because of its stable and precise EMF characteristics, type T is widely used in laboratories.Type T is the first thermocouple for which tolerance in the sub-zero temperature range has been established. Due to high thermal conductivity of the conductors, care must be exercised to eliminate heat conduction error that often occur on short stem length type T thermocouple unit.

Note : Types E, J and T have the same negative (-) legs composing of Cu-Ni with an alloy name of "Constantan," but the alloying ratio of Cu-Ni is adjusted to their respective matching positive (+) legs.Therefore, the negative legs of constantan have no Interchangeability between types.

Special Thermocouple Wires

Platinel 0~1300℃Oxidizing, Inert Pt40Rh/Pt20Rh 0~1800℃Oxidizing, Inert Ni18Mo/Ni0.8Co 0~1200℃Reducing, Inert W3Re/W25Re 0-2200℃Reducing, Inert, Vacuum Mo5Re/Mo41Re 0-1700℃Reducing, Inert, Vacuum

INSULATORS AND PROTECTION TUBES

Thermocouples are widely used for temperature measurements of various gases and liquids. If bare thermoelement wires are exposed directly to detrimental atmospheres and fluid, they are often physically and chemically affected resulting in reducing service life with severe deterioration and corrosion.
Thermocouples are, therefore, usually protected with insulators and protection tubes.In selection of suitable insulators and protection tubes, consideration should be given to the materials especially of heat resistance, mechanical strength, chemical stability, etc. depending on the respective operating conditions. This is the most important point in thermometric practice.

INSULATORS

Characteristics

Type	Code	Operating Temp. (℃)	Maximum Temp. (℃)	Features
Aluminous Ceramic Grade 2	PS2	1,400	1,500	Silimanite Grade. Less porosity with reasonable heat load softening and good resistance to thermal shock.
Aluminous Ceramic Grade 1	PS1	1,500	1,600	Mullite Grade. Gas tight structure with less heat load softening. Better than PS2.
Recrystallized Alumina 99.7%	PS0	1,600	1,800	Gas tight structure with excellent resistance to corrosion. Highest purity among alumina ceramics. Very low Alkalis.
Magnesia Ceramic	MG	1,800	2,200	Porous structure but excellent resistance to corrosion. Only suitable for Basic environment.

Note : Operating and maximum temperatures vary depending on the atmospheres and mode of temperature changes

Dimensions

Model	Code	Nom.O.D.	Nom.I.D.	Length	T/C Wire	Material
Round 1 bore	SH-1	1	0.4	100	3.2	PS1
	SH-2	2	1	100	0.5 0.65	PS1 PS0
	SH-3	3	2	100	1.0 1.6	PS1
	SH-5	5	3	100	2.3	PS1
	SH-6	6	4	100	3.2	PS1
Round 2 bores	DH-3	3	0.8	100	0.5	PS1 PS0
	DH-4	4	1	100	0.5 0.65	PS1 PS0
	DH-4A	4	0.8	2000	0.5	PS0
	DH-4B	4	1.2	2000	0.5 0.65	PS0
	DH-6	6	1.5	100	0.65 1.0	PS2
	DH-8	8	2	100	0.65 1.0 1.6	PS2
Round 3 bores	TH-4	4	1	100	0.5 0.65	PS1 PS0
	TH-6	6	1.5	100	0.65 1.0	PS1
Round 4 bores	QH-3	3	0.8	100	0.5	PS1
	QH-8	8	2	100	0.65 1.0 1.6	PS1
	QH-12	12	3	50	1.0 1.6 2.3	PS2
	QH-14	14	4	50	2.3 3.2	PS2
Round 6 bores	HH-6	6	1	100	0.5 0.65	PS2
Oval 2 bores	DE-10	10×7.5	3	34	1.0 1.6 2.3	PS1 PS0
	DE-12	12×7.5	4	34	2.3 3.2	PS1

Note : Insulators are available in longer length up to 3,000 mm. Consult factory

INSULATORS AND PROTECTION TUBES

Metal Protection Tubes

Caution : Due to high thermal conductivity of the metal tubes, minimum insertion length should be more than twenty five times of its overall diameter to eliminate heat conduction error.

Material	Code	Operating Temp. (℃)	Features
Plain Steel	41	800	Good resistance to reducing atmosphere but less resistant to oxidation and acids attacks. Thick walled tubes are used in molten aluminium
304 S.S.	304	900	Widely used as a common protection tube against heat and corrosion but not recommended for use in the presence of sulphur or reducing flame. Subject to stress and "pit" corrosion.
304L S.S.	304L	980	Less carbon content (C=0.03%) than 304 S.S. and better resistance to grain boundary corrosion. Subject to stress and "pit" corrosion.
321 S.S.	321	980	Higher corrosion resistance than 304 S.S. because of its Ti content to prevent carbon preticipation. Excellent resistance to grain boundary corrosion after welding due to less carbon preticipation.
316 S.S.	316	980	Contains Mo and has excellent resistance to corrosives, heat, acids and alkalis.
316L S.S.	316L	980	Less carbon content than 316 S.S. and has better resistance to grain boundary corrosion. Resistant to "pit" corrosion.
310S S.S.	310S	1,000	High Ni-Cr content and good high temperature strength with resistance to oxidation at high temperatures. High mechanical strength.
347 S.S.	347	980	Because of its Nb-Ta content, prevents carbon preticipation. Higher corrosion resistance than 304 S.S. and excellent resistance to grain boundary corrosion
446 S.S.	446	980	Excellent resistance to oxidizing and reducing flames containing sulphur. Suitable for use in non-ferrous molten metals and other high temperature applications, but less mechanical strength
253 MA	253	1,000	Superior oxidation resistance to 310 S.S. at high temperatures due to formation of dense and tight oxide layer by silicon and cerium additions. Can be used under sulphurous atmospheres.
HCF	HCF	1,100	One of the best oxidation and corrosion resistant alloys at high temperatures, particularly durable under carburizing and crude oil burning furnaces. Better resistance to sulphur and vanadium-pentoxide than ordinary Cr-Al-Fe alloys. No embrittlement but less mechanical strength at high temperature
Carpenter 20 Cb-3	C2CB	1,000	Improved Carpenter 20 Alloy. Cu is newly added to form solid solution with Ni, and Mo content provides enhanced corrosion resistance to nonoxidizing acids, such as Nitric, Fluoric Acid. Virtually immune to pit corrosion.
50Co-30Cr	50	Oxi. 1,150 Red. 1,200	Excellent resistance to heat, corrosion and abrasion. One of the best alloy against high temperature sulphur bearing atmospheres.
Inconel 600	600	1,050	Excellent resistance to oxidizing and reducing atmospheres at high temperatures. But sulphurous atmospheres should be avoided. Immune to stress and "pit" corrosion.
Inconel 601	601	1,050	Superior oxidation resistance at high temperatures to Inconel-600, by virture of strong bonding of metal oxide film.
Inconel 625	625	1,050	Improved strength and stress rupture properties up to 980℃by Mo and Cb additions, and immune to chloride stress corrosion cracking.
Incoloy 800	800	70	Excellent to high temperature oxidizing atmospheres and thermal shock. About 10 times longer service life than 304 S.S. against high temperature corrosion.

PROTECTION TUBES

Material	Code	Operating Temp. (℃)	Features
Incoloy 825	825	1,000	An improved version of Incoloy 800. All round superior alloy for high temperature applications, particularly in oil refineries against organic sulfides, hydrogen-sulfide and sulphur combustion products
Kanthal A1	KA	1100	Good resistance to high temperature oxidation but becomes brittle due to recrystallization. Poor mechanical strength above 850℃
80Ni・20Cr	NC	1100	Good mechanical strength and corrosion resistance at high temperature oxidizing atmospheres but not recommended for use in sulphurizing atmospheres.
Kurimax	KU	1,200	Excellent resistance to molten chemicals and combustion gases. Also good resistance to corrosion by liquid copper.
Hastelloy B	HB	Oxi. 500 Red. 760	Excellent resistance to heat and corrosion, especially to HCl and H2SO4.
Hastelloy C-276	HC	1,000	Excellent resistance to high temperature oxidizing and reducing atmospheres and also to Cℓ2gases.
Hastelloy X	HX	1,100	Excellent resistance to oxidizing and carburizing atmospheres at high temperatures. Better machinability and weldability than other Hastelloy alloys.
Haynes Alloy 25	HY	Oxi. 810 Red. 980	High resistance to oxidizing and carburizing atmospheres at high temperatures.
Titanium	TI	Oxi. 250 Red. 1,000	Superior corrosion resistance in cryogenic temperatures but at high temperatures, easily oxidized and becomes brittle.
Monel	MN	Oxi. 500 Red. 600	Excellent resistance to water vapor and sea water at high pressure and corrosion.
Tantalum	TA	Oxi. 300 Red. 2,200	Excellent heat-resistant material with high resistance to all acids but apt to severe oxidation and embrittlement in air at high temperatures.
Molybdnum	Mo	Oxi. 400 Red. 2,000	Excellent mechanical strength up to 1500℃for applications under inert, reducing and vacuum atmospheres. Resistant to metal vapours at high temperatures but reacts with carbon or graphite. Should not be used in air or oxygen containing gases.

Note:
Operating and maximum temperatures of the above tubes vary depending on the measuring environments.
Special protection tubes such as Inconel-X750, Nimonic 75∽80, other alloy tubes, etc.
are also available upon request

NOMINAL ANALYSIS OF METAL PROTECTION TUBES

Material	Code	Chemical Composition(%wt)								
		C	Si	Mn	P	S	Ni	Cr	Fe	orthers
STPG370	370	<0.25	<0.35	0.30~0.90	<0.040	<0.040	_	_	Bal	_
SS400	400	_	_	_	<0.050	<0.050	_	_	Bal	_
304 SS	304	<0.80	<1.00	<2.00	<0.045	<0.030	8.00~10.50	18.00~20.00	Bal	_
304L SS	304L	<0.030	<1.00	<2.00	<0.045	<0.030	9.00~13.00	18.00~20.00	Bal	_
321 SS	321	<0.08	<1.00	<2.00	<0.045	<0.030	9.00~13.00	17.00~19.00	Bal	Ti:5×C%
316 SS	316	<0.08	<1.00	<2.00	<0.045	<0.030	10.00~14.00	16.00~18.00	Bal	Mo:2.00~3.00
316L SS	316L	<0.030	<1.00	<2.00	<0.045	<0.030	12.00~15.00	16.00~18.00	Bal	Mo:2.00~3.00
310S SS	310S	<0.08	<1.50	<2.00	<0.045	<0.030	19.00~22.00	24.00~26.00	Bal	
347 SS	347	<0.8	<1.00	<2.00	<0.045	<0.030	9.00~13.00	17.00~19.00	Bal	Nb:10×C%
446 SS Equiv. *1 SANDVIK P-4	446	<0.20	<1.00	<1.50	<0.040	<0.030		23.00~27.00	Bal	<N:0.25 _ _
253 MA *4	253		1.7	0.6	_		_	21	Bal	Ce 0.04 N 0.17
●HCF	HCF	<0.02	- Trace -		_		_	20	Bal	Al 3.0 Trace Zr+Ti
●Carpenter 20 Cb-3	C2Cb	<0.02	0.4	<1.0	–	_	33	20	Bal	Mo 2.2 Cb+Ta 8×C
●Haynes Alloy 25	HS25	0.1	<1.0	1.5	_	_	32	20	1.5	Co Bal W 15
Kantal A1	KA	_	_	_	_	_		22	Bal	Al 5.8
80Ni・20Cr	NC	_	_	_	_	_	75~80	15~20		Trace Ti
Inconel 600	600	<0.15	<0.50	<1.00	<0.030	<0.015	>72.00	14.00~17.00	6~10	Trace Co <Cu:0.50
Inconel 625	625	<0.10	<0.50	<0.50	<0.030	<0.015	Bal	21.5	<5.0	Mo9 Nb+Ta:3.7
Incoloy 825	825	<0.05	<0.50	<1.0	<0.030	<0.03	38-46	19.5~23.5	Bal	Al:<0.2 Ti:0.6-1.2 Mo:2.5~3.5
Incoloy 800	800	<0.10	<1.00	<1.50	<0.030	<0.015	30.00~35.00	19.00~23.00	Bal	Trace Cu, Trace Co, Al, Ti
50Co-30Cr (UMCo-50) *2	50	0.05~0.15	<1.00	0.30~1.00	<0.020	<0.020	<3.00	26.00~30.00	–	Co 50 Trace Mo
●Kurimax *3	KU	_	_	_	_	_	_	_	_	W4, Trace Nb, Ti
●Hastelloy B	HB	<0.05	1	<1.0	0.04	<0.03	Bal	_	<5.0	Mo:28 Co:2.5 V:0.6
●Hastelloy C-276	HC	<0.02	<0.08	<1.0	<0.04	<0.03	Bal	14.5~16.5	6	Mo:15.0~17.0 Trace W, Co, V
Hastelloy X	HX	<0.05	<1.00	<1.00	<0.040	<0.030	Bal	20.50~23.0	18.5	Mo:8.00~10.00 W0.6, Co1.5 Trace B
●Monel 400	MN	<0.3	<0.5	<2.0		<0.024	>63.0		2.5	Cu:28.0~34.0 Trace Co

●Only available in the form of solid bar stock.

*1: SANDVIK P4 is Sandvik AB's Trade Mark.

*2: UMCo-50 is Mitsubishi Material Co's Trade Mark.

*3: Kurimax is Kurimoto Iron Works Co's Trade Mark..

*4: 253MA is Avesta A.B.'s Trade Mark.

*5: Haynes 25 is Haynes International Corp.'s Trade Mark.

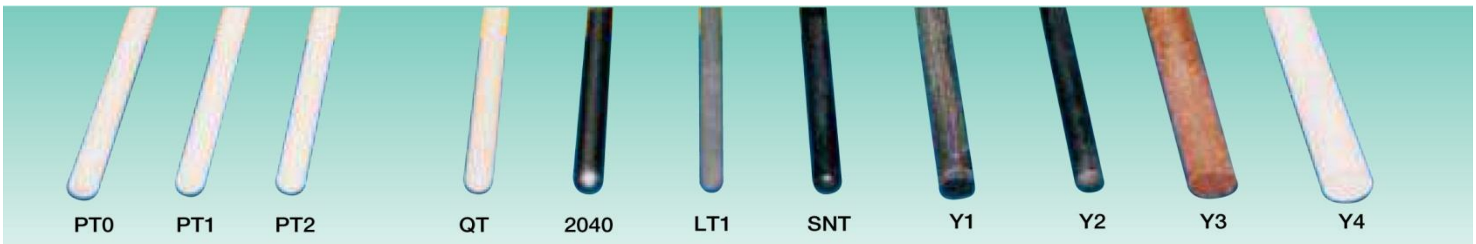
*6: Carpenter 20 Cb-3 is Carpenter Technology Corp.'s Trade Mark.

Non-Metallic Protection Tubes

Caution :

1. Operating and maximum temperatures vary depending on the heat pattern and atmosphere. For low thermal conductivity ceramic tubes, preheating and slow insertion into the furnace are recommended. Generally, insertion speed of 100 to 150 mm per minute after preheating around 80∽100℃will be adequate. 2. Minimum insertion length of the Nonmetallic tube should be more than fifteen times of its overall diameter, excepting those of higher heat conductivity materials like SiC and Cermet which need twenty five times or more.

Materia	Code	Operating Temp. (℃)	Features
Translucent Quartz Transparent Quartz	QT	1,000	99.99%Quartz Excellent to thermal shock but fragile. Poor resistance to alkalis but good to acids. Less gas-tightness in hydrogen and reducing gases. High thermal conductivity
Silimanite	PT2	1,400	High alumina ceramic. Good resistance to thermal shock. Recommended for use in coal or oil burning and electric furnaces. Slightly porous
Mullite	PT1	1,500	60%Alumina-40%Silica Sintered alumina. Better than PT2 but slightly less thermal shock resistance. Recommended for use in heating furnace and regenerator, impervious
Recrystallized Alumina	PT0	1,600	99.5%Alumina Superior chemical stability and better than PT1. Recommended for use in molten steel, slag and molten glass, impervious.
Cermet (Chrome-Alumina	LT1	1,300	77%Alumina-23%Chrome Excellent resistance to heat and abrasion. Recommended for temperature measurements of molten copper and other nonferrous metals.
Cermet (Cermotherm)	2040	1,600	60%Mo-40%Zr O2 High heat conductivity, good thermal shock resistance and corrosion resistance in molten metals. Recommended for continuous use in molten steel but not suitable for use in oxidizing atmosphere at high temperatures.
Static Press Sintered Alpha-SiC	Y0	1,650	Pure fine grain Alpha SiC, 99.9% Highest Grade among SiC material. Gas Tight. Low friction, high hardness. Five times as higher thermal conductivity of Alumina. Suitable for all the dry atmospheres but attacked by water vapour.
Recrystallized Silicon Carbide	Y1 (GK	1,400	99% SiC Porous but good resistance to acids and alkalis. Recommended for use in air neutral atmospheres up to 1,400℃and also in high temperature stagnant furnace atmosphere as an outer protection tube, etc. Attacked by water vapour.
Self-bonded Silicon Carbide	Y2 (KT)	1,650	99% SiC Very low porosity. Excellent resistance to thermal shock, corrosion and abrasion at high temperatures. Recommended for use in oxidizing and reducing atmospheres up to 1,650℃. but attacked by water vapour.
Clay-bonded Silicon Carbide	Y3 (NF)	1,500	89%SiC+8.5%SiO2+0.7%Al2O3+0.7%Fe2O3 Good heat conductivity. Better resistance to thermal shock than oxide ceramic tubes. Like Other SiC types, use under water vapour must be avoided.
Nitride Bonded Silicon Carbide	Y4 (RF	1,550	78%SiC+3%SiO2+18%Si3N4(Si2ON2) Excellent performance superior to Y3 SiC but contains Si3N4. Most suitable for use in molten aluminum, reheating. Attacked by water vapour.
Silicon Nitride (Si3N4)	SNT	1,350	Excellent thermal shock resistance. Less corrosion to acids and alkalis. High hardness. Fairly good resistance against most of molten metals.
Sialon	SLN	1,250	Good oxidation and thermal shock resistance. Better corrosion resistance to molten metals, especially good for molten Aluminum bath than Silicon-Nitride. Durable to iron and steel up to 1,600℃.
Zirconia	ZR 1706	1800	MgO Stabilized Zr O2 Gas-tight and exceptionally good thermal shock resistance. Chemically stable against molten metals other than alkalis. Recommended for use in molten special metals, slag and glass up to 1,800℃. Suitable for use in high temp. protection tube up to 1,900℃where PT0 Alumina softens



Code order | DK-XXXX | - | 1 | - | 2 | - | 3 | - | 4 | - | 5 |

MODEL

1. ELEMENT TYPE

☐ **K**

2. PROTECTION TUBE DIA. (mm)

☐ **3.2** ☐ **4** ☐ **4.8** ☐ **6.4**

☐ **4.8** ☐ **6.4** ☐ **8** ☐ **Others**

3. LENGTH (mm)

☐ **20** ☐ **30** ☐ **40** ☐ **50**

☐ **100** ☐ **150** ☐ **200** ☐ **Others**

4. THREAD

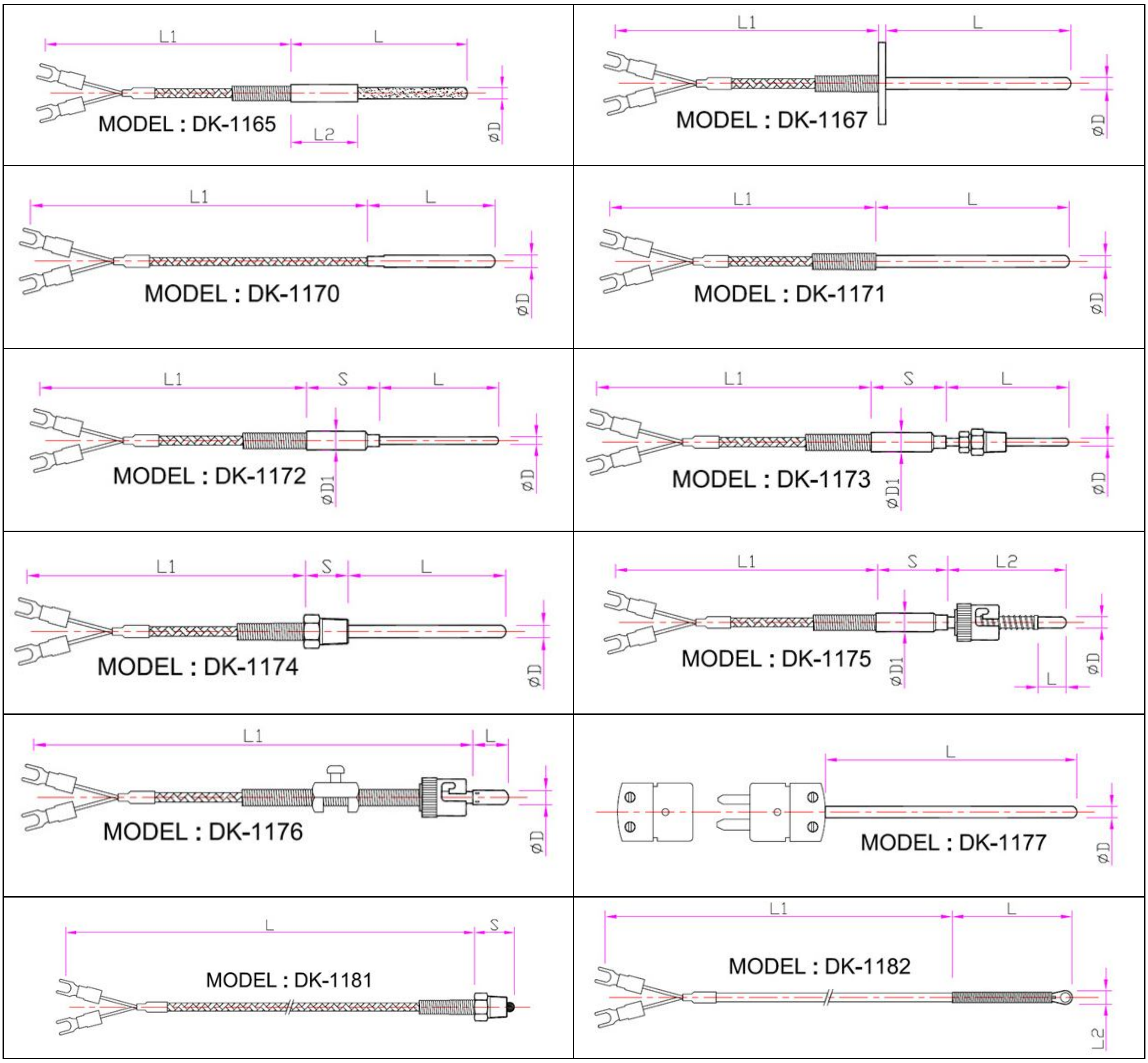
☐ **1/4** ☐ **1/8** ☐ **__**

☐ **3/8** ☐ **1/2** ☐ **Others**

5. CABLE (mm)

☐ **2000**

MODEL:



Order code | DK-XXXX | - | BDM | - | 1 | - | 2 | - | 3 | - | 4 | - | 5 |

MODEL

1. ELEMENT TYPE

☐ K ☐ J

☐ T ☐ Others

2. PROTECTION TUBE DIA. (mm)

☐ 3.2 ☐ 4 ☐ 6.4 ☐ 8

☐ 10 ☐ 12 ☐ 15.8 ☐ Others

3. LENGTH (mm)

☐ 100 ☐ 150 ☐ 200 ☐ 300

☐ 700 ☐ 1200 ☐ 1600 ☐ Others

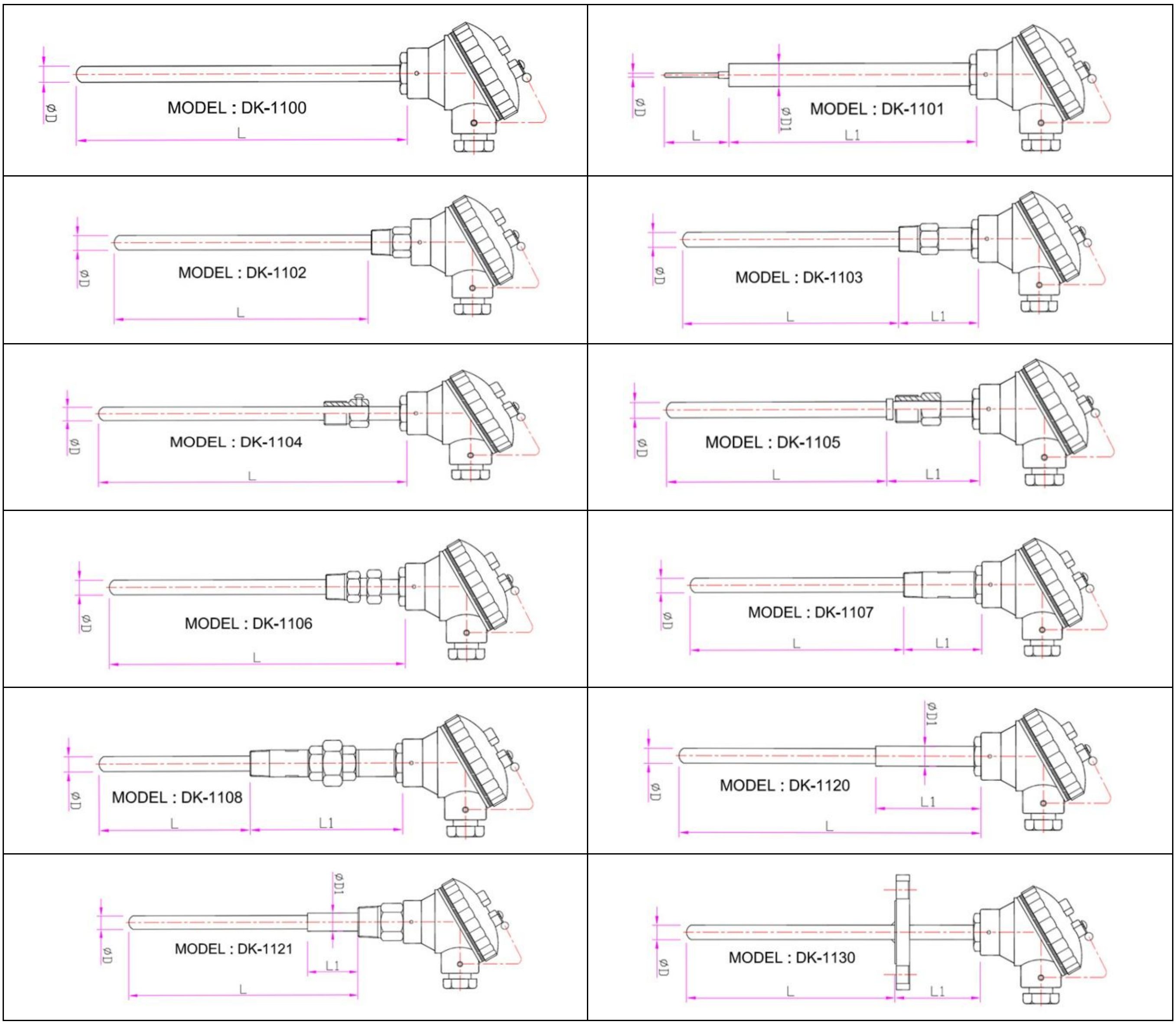
4. THREAD

☐ 3/8 ☐ 1/2 ☐ Others

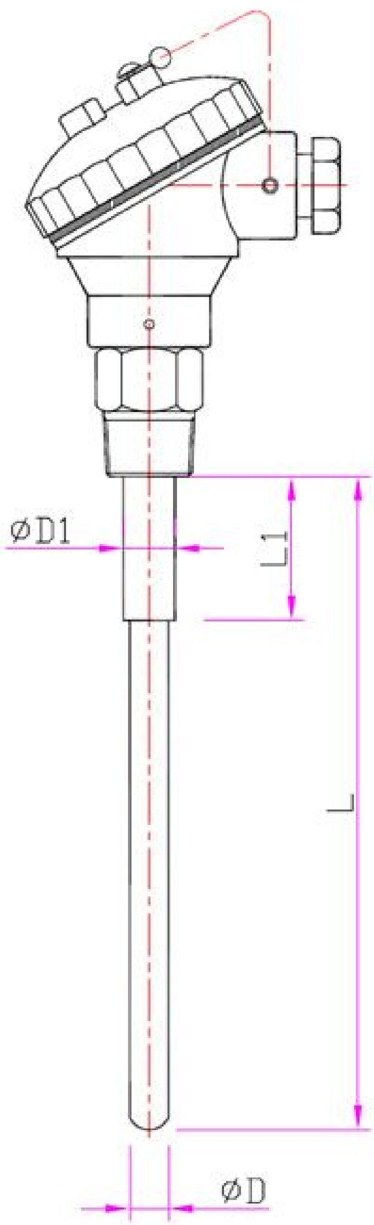
5. PROTECTION TUBE MAT'L

☐ 304 (default) ☐ 316S ☐ 316L ☐ CERAMIC ☐ Others

MODEL:



MODEL : DK-1121



1. HEAD

☐ Mini ☐ Standard ☐ Large
☐ Explosion Resistant ☐ ______

2. ELEMENT TYPE

☐ K ☐ J ☐ T ☐ E
☐ R ☐ B ☐ S ☐ Others_____

3. ELEMENT GRADE

☐ 0.75
☐ 0.25 ☐ 0.5

4. ELEMENT PAIR

☐ Single ☐ Double

5. ELEMENT DIAMETER

☐ 0.32 ☐ 0.65 ☐ 1.0 ☐ 1.6
☐ 2.3 ☐ 3.2 ☐ Others ______
☐ 0.3 ☐ 0.4 ☐ 0.5

6. PROTECTION TUBE MAT'L

☐ PT-1 ☐ PT-0 ☐ GK-SIC
☐ RED-SIC ☐ SI-SIC ☐ ________

7. PROTECTION TUBE DIA. (m/m) (øD)

☐ 6 ☐ 8 ☐ 10 ☐ 13 ☐ 15
☐ 17 ☐ 20 ☐ Others ______

8. SUPPORT TUBE MAT'L

☐ SUS304 ☐ SUS316 ☐ SUS316L
☐ SUS310 ☐ SUS446 ☐ INC.600
☐ Others ________

9. SUPPORT TUBE DIA. (m/m) (øD1)

☐ 12.7 ☐ 15.8 ☐ 21.7 ☐ 22.3
☐ 27.2 ☐ 34.0 ☐ Others ______

10. LENGTH (m/m)

L : ________ L1 : ________

11. THREAD

1)TYPE ☐ PT ☐ NPT ☐ PF
2)SIZE ☐ 3/8 ☐ 1/2 ☐ 3/4 ☐ 1
☐ Others ______

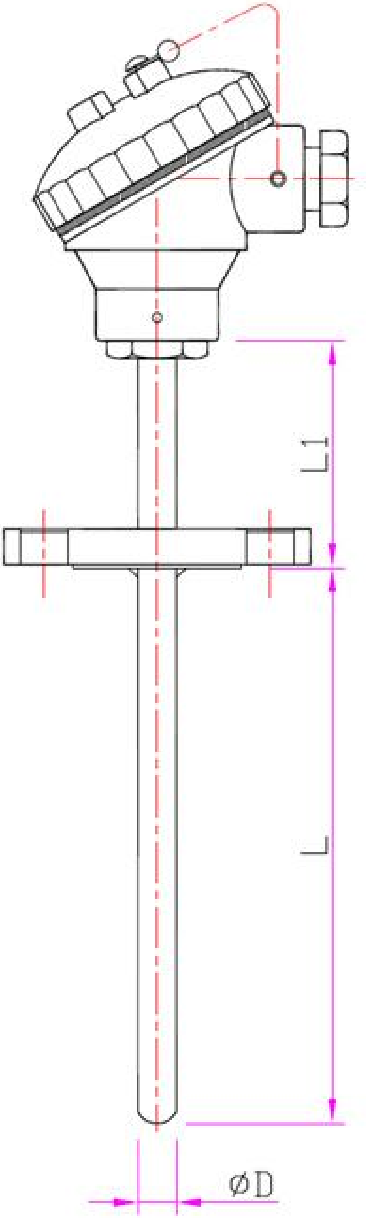
12. CABLE GLAND

1)TYPE ☐ PT ☐ NPT ☐ PF
2)SIZE ☐ 1/2 ☐ 3/4 ☐ Others _____
3)PAIR ☐ Single ☐ Double(One Side)
☐ Double(Two Side)

THERMOCOUPLE

DK DOOKWANG MANUFACTURING COMPANY

MODEL : DK-1130	



12. FLANGE

- ☐ JIS ______ K ______ A
- ☐ ANSI ______ # ______ "
- ☐ RF ☐ FF

1. HEAD
☐ Mini ☐ Standard ☐ Large
☐ Explosion Resistant ☐ ________

2. ELEMENT TYPE
☐ K ☐ J ☐ T ☐ E
☐ R ☐ B ☐ S

3. ELEMENT GRADE
☐ 0.75
☐ 0.25 ☐ 0.5

4. ELEMENT PAIR
☐ Single ☐ Double

5. ELEMENT DIAMETER
☐ 0.32 ☐ 0.65 ☐ 1.0 ☐ 1.6
☐ 2.3 ☐ 3.2 ☐ Others ________
☐ 0.3 ☐ 0.4 ☐ 0.5

6. PROTECTION TUBE MAT'L
☐ SUS304 ☐ SUS316 ☐ SUS316L
☐ SUS310 ☐ SUS446 ☐ INC.600
☐ Others ________

7. PROTECTION TUBE DIA. (m/m) (ØD)
☐ 6.4 ☐ 8.0 ☐ 10.0 ☐ 12.7
☐ 15.0 ☐ 17.3 ☐ 21.7
☐ Others ________

8. LENGTH (m/m)
L : ________ L1 : ________

9. THREAD
1)TYPE ☐ PT ☐ NPT ☐ PF
2)SIZE ☐ 3/8 ☐ 1/2 ☐ 3/4 ☐ 1
☐ Others ________

10. TIP SHAPE
☐ GROUND ☐ UNGROUND ☐ EXPOSED

11. CABLE GLAND
1)TYPE ☐ PT ☐ NPT ☐ PF
2)SIZE ☐ 1/2 ☐ 3/4 ☐ Others ______
3)PAIR ☐ Single ☐ Double(One Side)
☐ Double(Two Side)

THERMOCOUPLE	DK DOOKWANG MANUFACTURING COMPANY

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