

Temperature Sensor Instruction Manual

OKAZAKI MANUFACTURING COMPANY



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Note : 1) All provisions are subject to change without any notice.
2) This manual is prepared with the greatest possible care, but if any problems,
please do not hesitate to contact us.

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CHAPTER 1 BEFORE TO USING

1.1 Attention to safety

Before using this product, carefully read both this "Attention to Safety" and the "Instruction Manual". Only use the product after having well understood the proper method of operation. The safety warnings shown below are to prevent harm or injury to yourself and the people near you when operating the temperature sensor. The two labels below describe what will happen in the unlikely event of mistake being made during handling or operation of the temperature.

	WARNING	CAUTION
	If this device is improperly used, people may be severely injured or killed.	If this device is improperly used, people may suffer light to medium injuries or material damage may occur.

Even items bearing a "Caution" label may, under certain conditions, lead to serious injury. Always observe safety procedures.

The terms "serious injury", "light injury", and "material damage" mentioned above have the following meanings.

Term	Meaning
Serious Injury	Long-term symptoms resulting as a result of loss of eyesight, injuries, burns (high & low temperature), electric shock, broken bones. Injuries will require a long period in hospital followed by repeated hospital visits.
Light Injury	Injuries, burns (high & low temperature) or injuries from electric shocks which do not require a long hospital stay or repeated hospital visit.
Material damage	Direct and indirect losses associated with inventory loss, and damage to plant and equipment.

INSTALLATION

WARNING	Do not connect lead cable of temperature sensors directly to power supply terminals.
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Lead cable (compensating lead cable or extension lead cable) of temperature sensors must be connected to terminal of receiving instruments. If connected by mistake to power supply, temperature becomes high that may cause a fire or an explosion.

WARNING	Do not handled temperature sensor roughly.
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There are heavy temperature sensors because of their constructions. If they drop from installation point, it might cause damage to person. Resistance thermometers which have very fine platinum wires are extremely delicate, therefore, temperature measurement error may be caused by damage. For temperature sensors with ceramic insulators or protection tubes, special attention of these sensors are required because of their brittleness.

WARNING	Do not use temperature sensors for hazardous locations in surrounding where temperature is over 60°C.
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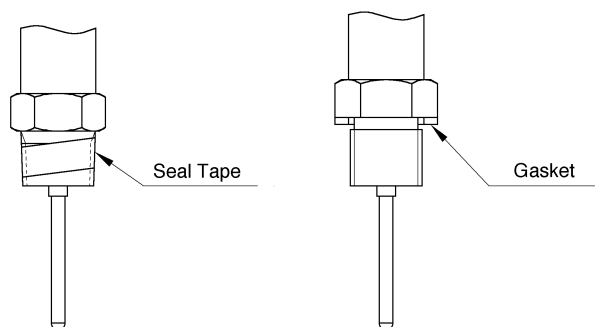
Temperature sensors for hazardous location are approved provided that they are used in surrounding where temperature is below 60°C. Please specify the surrounding temperature in location in order to make it safe.

WARNING**Make sure of closing a cover of terminal head after wiring.**

After wiring, if "O" ring is supplied, then make sure "O" ring is installed properly in cover of terminal head before installing the cover. This will prevent dust or rain entering terminal head. This is specially important for explosion proof terminal head, close the cover with a rated jig. For general type terminal head, use a screw driver shown below. For closing, turn the cover clockwise by hand and then tighten it 1/6~1/4 clockwise with jigs. The temperature sensors may not display correct temperature due to presence of dust or rain.

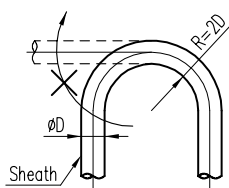
CAUTION**Make sure of mounting with screws or flanges.**

Installation of temperature sensors will be done with screws or flanges. In case of screwing, apply sealing tape or sealing agent for tapered thread, and O-ring gasket for parallel thread, and then tighten with spanner. For flange connection, use specified gasket and tighten all bolts equally. If air tightness is required, carry out the air tightness inspection after installation. For screwing sensor into thermowell, be sure to tighten at job site.

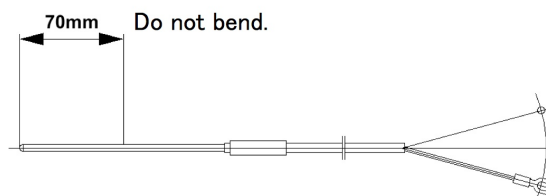
**CAUTION****Please note bending portion and bending radius of metal sheathed mineral insulated type temperature sensors.**

Material can be bent to a minimum radius of 2 times of sheath diameter, any bending tighter than that, will fracture the sheath. On bending at job site, bend to a radius of around 5 times of sheath diameter. However, do not bend near the sleeve. The conductor wire inside of the sheath is pulled by bend and it may be disconnected near the connecting part inside the sleeve.

For metal sheathed mineral insulated type resistance thermometers, do not bend 70mm length from the tip, where resistance element is installed.



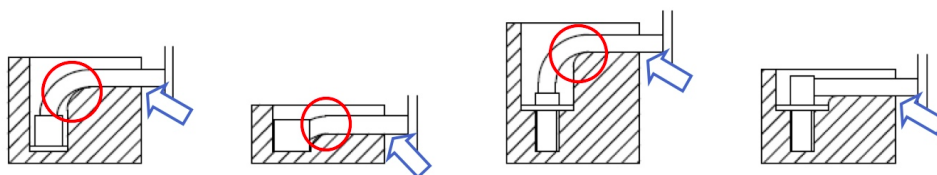
RESIOPAK



For metal sheathed mineral insulated type thermocouples, do not bend 5mm ($\phi D \leq 3.2$) length from the tip, where thermocouple wire is installed. And, do not apply any external force that may cause deformation such as dent on that surface. By thermal effect at the time of tip processing, the crack may occur, and also there is a possibility that the element wire is disconnected depending on the bending direction.

WARNING

Please consider carefully the bending position and bending radius for a lead wire type temperature sensor.



As for circular part above, when performing bending in the close vicinity of metal tip containing a temperature-sensitive element, do not perform any action while applying excessive force to the temperature sensor, such as pulling the lead wire. It may cause defects in measuring temperature. In cause defects in measuring temperature as well.

CAUTION

Do not expose terminals and connection portion with lead cables at temperature over 80°C.

In case of connection portion between temperature sensors and lead cables is exposed to high temperature, insulation resistance may become poor or measuring error may be caused. therefore, unless stated application for high-temperature, the surrounding temperature of both terminals and connection with lead cables should be below 80°C.

CAUTION

Make sure of polarity on connecting to terminals.

On connecting lead cables to terminals of temperature sensors, please make sure of the polarity. In case of wrong connection, it is impossible to measure the correct temperature due to big measuring error caused by wrong connection. Special attention to color of compensating cable is required because the color is different per applicable standard.

MAINTENANCE AND INSPECTION

WARNING

Do not open the cover of the terminal head in operation, located hazardous area.

It's possible to make ignition that is very dangerous.

WARNING

Do not use insulation resistance tester when plant operated.

When the plant is operated, it might be danger of leakage of explosive gases. Therefore, for checking the performance of temperature sensors, please do not use insulation resistance tester. There is a possibility in causing spark on using the insulation resistance tester which applies high-voltage. And it might be ignition factor of explosive gases.

WARNING

Do not disassemble or repair at site temperature sensors to be located hazardous area.

Flame proof temperature sensors which are located in hazardous area have approved construction by national institution. Therefore, it is not approved that the sensors are disassembled or repaired at other than approved factory because of its safety. Please be sure to send back to manufacturer to repair. Do not disassemble or repair at site.

WARNING

Please check shutdown, ordinary temperature and pressure on maintenance, inspection and replacement.

There are many cases of high temperature and pressure in the location where temperature sensors are installed. Therefore, it is very dangerous to start inspection in operating or just after shutdown. Please confirm the shutdown, and also confirm if the temperature and pressure become normally, and then start inspection and replacement works.

CAUTION

Do not touch sensing probe of temperature sensors.

Temperature sensors are used at high temperature and low temperature. Therefore, the sensor pulled out from installation point may be still hot or cold. Please note that in case touching with bare hand, it might be burnt or frostbitten. Do not touch until the temperature of sensors is close to room temperature.

CAUTION

Do not pull by force lead cable of lead cable type temperature sensors.

If pulled by force the lead cable of lead cable type temperature sensors, the wire might be broken at connection point. For the lead cable protected with flexible tube, the tube might get out of place at connection.

CAUTION

Do not use temperature sensors as footing.

Do not use the installed temperature sensors as footing when inspection works and so on. The temperature sensors have not any mechanical strength, therefore, they might be damaged or cause a wire break.

STORAGE

CAUTION

Store temperature sensors in dry and clean place.

Temperature sensors should be stored in a dry and in a clean place. The storage at in a high humidity place may cause low insulation resistance.

DISPOSAL

CAUTION

Scrap temperature sensors as industrial waste.

In case of disposal of temperature sensors, handle as industrial waste. If it is difficult to dispose off, ask industrial waste treatment traders approved by prefectural governor.

1.2 WHEN BREAK DOWN

Please contact the following post when trouble is caused in the equipment.

Manufacturing and sales : **OKAZAKI MANUFACTURING COMPANY**

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CHAPTER 2 INTRODUCTION

Thank you for purchasing our temperature sensor.

Okazaki temperature sensors are manufactured and tested by experienced technicians under an ISO 9001 quality control system. Following the recommendations in this manual can help obtain maximum life and dependability.

If you are using a temperature sensor for the first time, we suggest you read Chapter 3

"TEMPERATURE SENSOR OVERVIEW". Chapter 3 briefly describes the functional principles of temperature sensors and provides basic usage information.

"CHAPTER 4 PRIOR TO INSTALLATION" and Chapter 5 "INSTALLATION" offer detailed technical instructions.

Temperature sensors are instruments and require careful handling until they have been installed.



CHAPTER 3 TEMPERATURE SENSOR OVERVIEW

3.1 Types of Temperature Sensors

Temperature sensors used for industrial purposes are generally classified into three groups; thermocouples, resistance thermometer sensors (RTS), and radiation thermometers.

We will discuss in detail thermocouples and resistance thermometer sensors which are our major products. Thermocouple and resistance thermometer outputs can be transmitted as electrical signals, unlike mercury thermometers or bi-metal type thermometers. Thermocouples can be used to measure temperatures over a wide range. Resistance thermometers can measure temperatures with high accuracy. Since the radiation thermometer is a non-contact measurement type, it is used for temperature control in applications where temperatures cannot be measured by contact: for example, surface temperature control of the steel plates in a continuous steel manufacturing line and temperature control of film-shaped products. The electrical signals from temperature sensors are used to control many different operations in a variety of industries. The steel, petrochemical and energy related industries are the largest users of temperature sensors. Many of these sensors are supplied with a temperature transmitter installed which converts the electrical output of a thermocouple or resistance thermometer sensor into a 4-20mA DC signal.

3.2 Measurement Principle of Thermocouple

Thermocouple theory is based on the circuit to the Fig.1. A current will flow if two dissimilar metals are joined at each end with T1 and T2 being two different temperatures. In actual use: A would be the measuring junction and connection B would go to a voltage measuring instrument. The output is a very small voltage, known as an electromotive force.

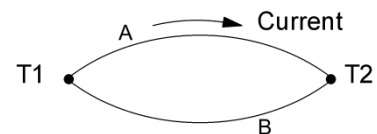


Fig. 1 Principle of Thermocouple

Chromel-Alumel is the most well-known combination of two kinds of alloy wires. It used to be called a CA thermocouple. It is now known as type "K". The contact on the temperature measuring side is called a measuring junction or a hot junction, and the other side a reference junction in the Fig.2. Generally, it measures the electromotive force caused by the temperature difference from the measuring side, while keeping the reference junction at 0°C. The table which represents the relationship between the temperature and electromotive force is called a standard electromotive force (EMF) table. This table is referenced by many internationally recognized standards such as JIS, IEC, ISA, etc. In the past, there were some differences in the standard EMF's recognized by the different countries. However, most countries are now using the same tables. Chapter 8 "REFERENCE MATERIAL" lists the tables of the standard EMF (JIS, IEC & ASTM).

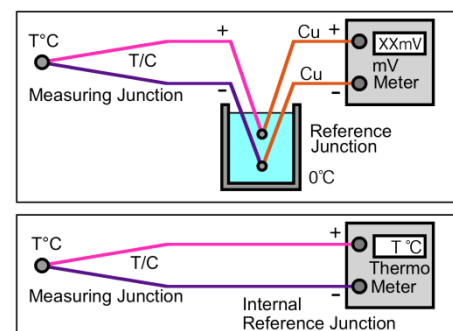


Fig. 2 Measuring Circuit

3.3 Types of Thermocouple

The thermocouples mainly used for industrial purposes have been standardized. In Japan, they have been stipulated in the JIS C 1602. Table 1 lists their types and features.

Table 1 Types of Thermocouples

Type	Composition		Major Feature
B	+	Pt-30Rh	Suitable for the use in oxidizing or inert gas atmosphere from 870 to 1700°C. Compensating cable not required because of small EMF at room temperature. Because the thermo-electromotive force at the normal temperature is small, copper can be used for the material of the compensating wire.
	-	Pt-6Rh	
R	+	Pt-13Rh	Suitable for the use in oxidizing or inert gas atmosphere from 0 to 1480°C. Platinum Thermocouple not to be directly inserted into a metallic protection tube. Therefore, longevity is extremely short at 1000°C or more though R thermo-couple of the NCF600 sheath type exists as a product.
	-	Pt	
S	+	Pt-10Rh	
	-	Pt	
C	+	W-5Re	Available until 2200°C in a vacuum, in an inert gas or in dry hydrogen. When it is in the high temperature air of $\geq 500^{\circ}\text{C}$, oxidize in short time. (Added to JIS C1602:2015, IEC 60584-1:2013)
	-	W-26Re	
N	+	Ni-14.2Cr-1.4Si	Developed to remove weak points of K Thermocouple. Si added to both the positive and negative wires and calibration drift is reduced. Cr added to positive wire. Oxidation resistance at high temperature improved and short range ordering features reduced.
	-	Ni-4.4Si-0.15Mg	
K	+	Ni-10Cr	Suitable for the use in oxidizing or inert gas atmosphere from -200 to 1260°C. Not suitable for the use in reducing gas atmosphere. Depending on the conditions, Green rot corrosion and extreme EMF drop caused in a very short time. Not suitable for the use in sulfuric atmosphere because of high Ni contents. When the insertion length changes when calibrating and using it again because there is an increase of EMF by SRO when using it in the temperature span from 250°C to 600°C, it is necessary to note it.
	-	Ni-2Al-2Mn-1Si	
E	+	Ni-10Cr	Suitable for the use in oxidizing or inert gas atmosphere from -200 to 900°C, not in reducing gas atmosphere. Can be used for lower temperature than 0°C.
	-	Cu-45Ni	
J	+	99.5Fe	Suitable for the use in vacuum and oxidizing, reducing and inert gas atmosphere. When used at higher temperature than 540°C, thick wire required to be used, because Fe oxidation of the positive occurs rapidly. Cannot be used at lower temperature than 0°C.
	-	Cu-45Ni	
T	+	Cu	Suitable for the use in oxidizing, reducing and inert gas atmosphere from -200 to 370°C. Can be used at lower temperature than 0°C. At the high limit temperature, Cu is oxidized.
	-	Cu-45Ni	

3.4 Measurement Principle of Resistance Thermometer sensor

Resistance thermometer sensors (RTS), make use of the characteristic that the electrical resistance values of the metals, semiconductors, etc. Change depending on the temperature. Some of the metals used include platinum, nickel, and copper. These metals all have the common characteristic that as the temperature rises, the resistance value increases.

The most widely used resistance thermometer sensors for industrial purposes are platinum resistance thermometer sensors which have a wide working temperature range and large resistance temperature coefficient. Thermistors use a semiconductor for resistance change as a function of

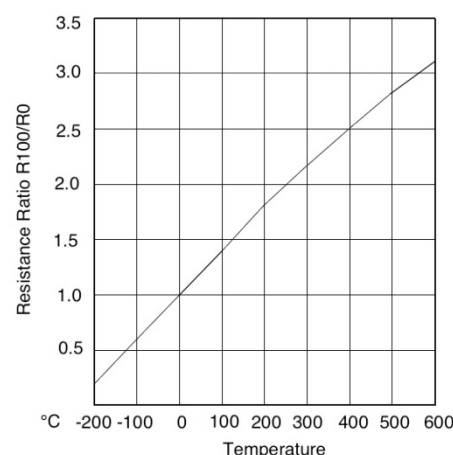


Fig. 3 Temperature Characteristic of Platinum Wire

temperature. There are usually used in electronic consumer products and normally not in industrial applications.

Resistance measurement requires either a bridge, or the potential method which replaces the resistance change with a voltage change, using a constant current source.

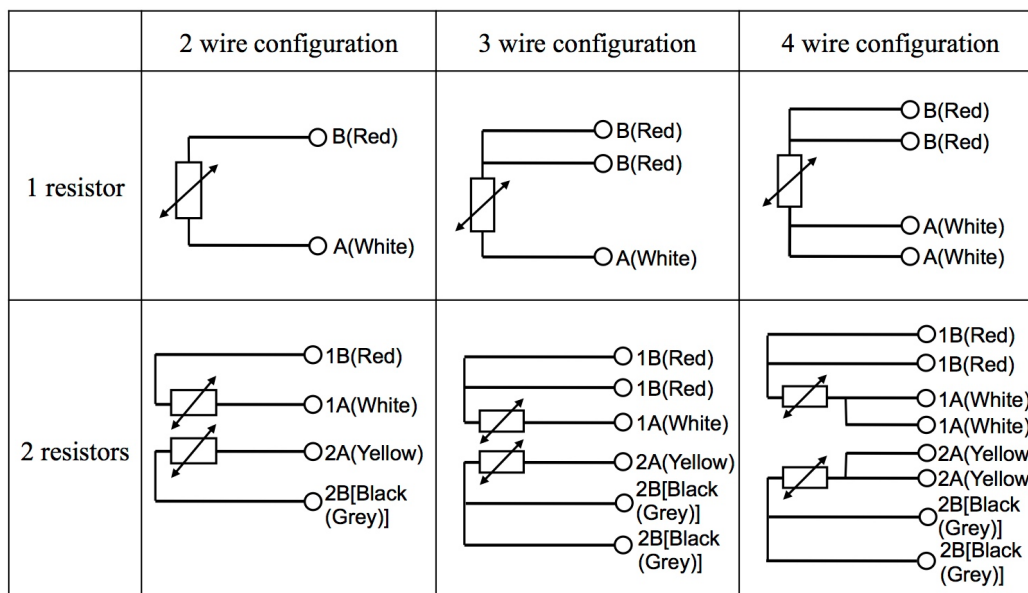


Fig.4 Connecting configuration

There are three common methods to connect the conductors for resistance measurement. As shown in the connection diagrams, they have the following features, sequentially from the top.

2-wire configuration : This configurations allows no compensation of conductor resistance and can provide good accuracy only with short conductor leads. This type is not usually used except for high resistance RTS's.

3-wire configuration : This type of connection is used to eliminate the effect of conductor resistance. Care should be taken for long-distance transmission because variations in the resistance of conductors can have an effect on accuracy. This type of connection is most widely used in industrial applications.

4-wire configuration : This type of connection is used for high-accuracy measurement and standards because it is not affected by conductor resistance. Generally, a constant current is applied and the resistance value is measured by a potential difference.

In addition, in JIS C 1604 (1997 ed.), the symbol A specified as Red and symbol B specified as White. In JIS C 1604 (2013 ed.) and IEC standards, symbol A specified as White and symbol B specified as Red.

In order to reduce the uncertainty at the time of inspection in our company, it has decided to identify clearly the current terminal "b". In our standards, limited to 3-wire type, the symbols shall specify as "A, B, b", instead of "A, B, B"

3.5 Types of Resistance Thermometer sensor

The resistance thermometer sensors most widely used for industrial purposes are platinum resistance thermometer sensors. They are stipulated by the JIS C 1604 in Japan. There are currently two types; one is Pt100 which conforms to the international standard, and the other is JPt 100 which is the Japanese standard. They are not interchangeable because the ratio of resistance values at 100 °C and 0 °C (R_{100}/R_0) differ.

Platinum Thermometer	Type	R_{100}/R_0	Table 2 Types of Resistance sensors
	Pt100	1.3851	
	JPt100	1.3916	

Many of the resistance thermometer sensors in other countries conform to the IEC Standard. In Britain and Germany, their standards are exactly the same as the IEC Pub 60751 .

Abbreviations	:	
JIS	:	Japanese Industrial Standards
IEC	:	International Electrotechnical Commission
ASTM	:	American Society for Testing and Materials

CHAPTER 4 PRIOR TO INSTALLATION

4.1 To Check Items after Unpacking

Our temperature sensors have been produced under quality control procedure and shipped after in-house inspection.

The package shipped contains the following:

- (1) In the package : Temperature sensors
Accessories
Inspection report
- (2) Pasted outside the package : List of items (Packing List)

Check the package for its contents to be sure that they match the list of items. Also, check the quantity and appearance of each item for shortage and damage. Since the type of temperature sensor is indicated on the product name plate, confirm that the temperature sensor is the same as the one you have ordered.

4.2 Precautions for Storing the Temperature Sensor

When you do not immediately use the temperature sensor and want to store it for some time, observe the following:

- (1) Check for continuity and insulation resistance before storing. As for the checking method, follow the instruction for checking continuity (4.3) and that of insulation resistance (4.4). (This does not apply to grounded junction thermocouples, wire and insulator type temperature sensors without protection tube or bare wire elements).
- (2) Avoid any dusty or humid places where insulation resistance is likely to be reduced. Store the temperature sensor in an indoor dry area.
- (3) When storing temperature sensors for a long time, put into a terminal box a water-proof sealed polyethylene bag together with silica-gel. Silica gel should be replaced annually.
- (4) Do not apply mechanical vibration or shock.

4.3 Measurement of Continuity

With an ohmmeter, check resistance between the output terminals of the temperature sensor. Set the tester to the resistance (Ω) measurement range. The sensor is basically usable if it has continuity. If the tester indicates a reasonable resistance value whether it is analog or digital type, the temperature sensor is usually all right. If the tester indicates an infinite value or very high value (several 100k Ω), the temperature sensor is very likely to have an open circuit. Contact our dealer or office and send the product back. The terminals used for a temperature sensor continuity check are as follow :

- (1) For the thermocouple

With the compensation lead wires : Between red and white

With the terminal box : Between + and -

For more accurate judgment, compare with Table 3 and Table 4

Table 3 Resistance Values for Thermocouples

(Ω/m at Room Temperature)

Strand	Sheath Dia.	N	K	E	J	T	R
-	0.25	-	944.3	-	-	-	-
-	0.5	-	242.4	-	-	-	-
-	1.0	61	60.1	76.3	40.0	33	-
-	1.6	24.2	23.5	29.8	15.6	12.9	-
0.32	-	-	12.5	15	7.3	6.3	-
0.5	-	-	-	-	-	-	1.5
-	3.2	6.8	5.92	7.45	3.84	3.22	-
0.65	-	-	3.0	3.6	1.8	1.5	-
0.8	4.8	3.1	2.63	3.31	1.71	1.43	-
1.0	6.4	1.8	1.6	1.97	1.05	0.84	-
-	8.0-	1.0	1.03	1.26	0.67	0.54	-
1.6	-	-	0.5	0.6	0.3	0.25	-
2.3	-	-	0.24	0.29	0.14	0.12	-
3.2	-	-	0.12	0.15	0.07	0.06	-

Remarks : The data above are reference values for a comparison check only (not standard values).The compensation lead wires are omitted because there are too many types to describe.

(2) For the resistance thermometer sensors

With extension lead wires : Between white, and red and red and red.

With a terminal box : Between A and B(b), and B and B(b)

(4-wire type: Measured between A and A as well)

Table 4 Resistance Values for Resistance Thermometer sensor

(Pt 100 Ω) (Reference Values at Room Temperature)

Measuring Spot	Resistance Value
Between A-B or red-white	106~112Ω
*Between B-B or white-white	0.1~5Ω

Remarks : * Cannot apply to a sheath outer diameter of 2.3 mm or less.

4.4 Measurement of Insulation Resistance

With an insulation resistance tester (megger), check between the output pin of the temperature sensor and its main body or sheath. Depending on the type of temperature sensor and the sheath and protection tube outside diameters, the applied voltage of the insulation resistance tester must be varied. Applying a voltage higher than shown in table 5 and 6 may destroy insulation or cause a failure. The following table lists the rated voltage applicable to the temperature sensor size. It is recommended to use the lowest voltage available which results in a reading.

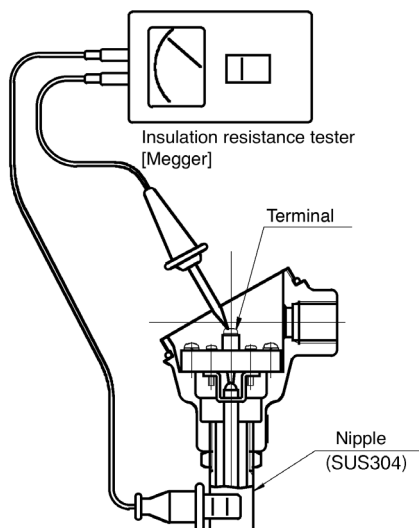
Table 5 Rated Voltages Applicable to Temperature Sensor for Routine Test

(JIS C 1602, C 1605-1995: * Company's standard)

Type of Thermocouple/Sheath O.D.		Insulation Resistance / Voltage Applicable
Thermocouple with Protection Tube		10MΩ/500VDC
Mineral Insulated Thermocouple	$\phi 0.1 \leq \text{O.D.} < \phi 0.15$ *	1MΩ/3VDC
	$\phi 0.15 \leq \text{O.D.} < \phi 0.5$ *	5MΩ/50VDC
	$\phi 0.5 \leq \text{O.D.} < \phi 2.0$	20MΩ/100VDC
	$\phi 2.0 \leq \text{O.D.}$	100MΩ/500VDC

Table 6 Rated Voltage and Insulation Resistance Values Applicable to Resistance Thermometer sensor for Routine Test (JIS C 1604-2013)

Type of Resistance Thermometer Sensors /Sheath O.D.	Insulation Resistance / Voltage Applicable
Resistance Thermometer Sensor with Protection Tube	100M Ω /100VDC or 125VDC
Sheath O.D. 0.8 ≤ O.D. ≤ 12.7	



The above mentioned values are given at time of shipment and should apply for receiving inspection. After delivery, insulation resistance values can decrease due to effects of installation, or decrease over a long period of time. In most cases, both thermocouples and resistance thermometer detectors with minimum insulation values in the hundreds of K Ω range would operate without any performance problems.

(Reference – <http://www.okazaki-mfg.com/faq/faq-j-tc.html>)

However, we would still recommend replacement since these sensors may be susceptible to electrical noise interference when resistance value measured is less than 1M Ω .

Fig.5 Measurement of insulation resistance

4.5 Precautions for Dielectric Strength Test

There is a provision of Dielectric Strength Test in JIS for both thermocouple and resistance thermometer sensor that is defined as type test or additional test. The test will not be performed in the delivery inspection unless otherwise requested. However, the Dielectric Strength Test can be performed by specified voltage upon request by particular customer. The maximum applied voltage to the both thermocouple and resistance thermometer sensor is AC500V. In the case of performing the test exceeding it, require caution; the design changes may be necessary.

CHAPTER 5 INSTALLATION

Temperature sensors used for industrial purposes are installed in places where temperature measurement is required for operation of various manufacturing plants. However, they should never be installed in the following places.

5.1 Installation Place

Temperature sensors used for industrial purposes are installed in places where temperature measurement is required for operation of various manufacturing plants. However, they should never be installed in the following places :

- (1) Where a high temperature heat source is located nearby and the terminal box or a joint (sleeve) has a temperature of 80°C or more. Note that measuring temperature with an explosion-proof temperature sensor requires the ambient temperature not to exceed 60°C.
- (2) Where a high-voltage power source is located and a high voltage is likely to be applied to the temperature sensor due to an electric leakage.
- (3) Where the joint (sleeve) is exposed to the rain, sprinkled water, or excessive moisture when the temperature sensor is used without a terminal box.
- (4) In an area where a worker may step on or mechanically shock the temperature sensor.

In a petrochemical or gas manufacturing plant, the temperature sensor may be installed in the hazardous location.

In that case, use an explosion-proof temperature sensor whose grade is suitable for that area. There are two types of explosion-proof temperature sensors; flame-proof type and intrinsic safety explosion-proof type. As for explosion-proof temperature sensors, refer to Section 8-3.

5.2 Accurate Temperature Measurement

In order to measure the temperature accurately, the temperature sensor should be thermally balanced against the object measured. To that end, it must be installed so that it is not affected by heat transfer or heat conduction from its surroundings. Observe the following points, depending on the object measured.

- (1) Temperature measurement of fluid in a pipe or tank.

If the actual insertion length of the protection tube is short, the temperature sensor will be thermally affected from the surrounding area and cause an error. The required insertion length will differ depending on the fluid type, specific gravity, and flow speed. Install the temperature sensor so that the insertion length will be longer than the values shown in table 4-2. Assume them as the minimum required values. When installing with an angle tube to compensate for small diameter piping, place the tube toward the upstream direction of flow, place it in an elbow area or use a bigger piping size for the measuring area.

LA : Insertion Length (Actual Insertion)

L : Insertion Length (Total length)

And furthermore, there are cases where the insertion length to be shortened depending on the calculation results with fluid conditions (temperature, pressure and velocity, etc.) and the protection tube specifications (material, insertion length, outside diameter and thickness, etc.).

In that case, the protection tube may be used by length less than insertion length described in Table-7.

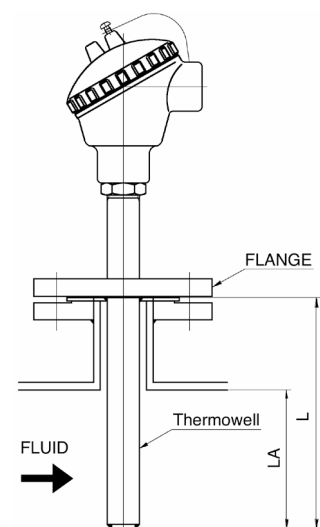


Fig.6 Actual insertion length

Please note that the error by lack of insertion length differ depending on the fluid type or the velocity.

Table-7 Insertion length to recommend

Type of Fluid	Thermocouple	Resistance Thermometer
Liquid	5 times or longer than the thermowell's outer diameter	5 times or longer than the thermowell's outer diameter + resistor length
Gas	10 times or longer than the thermowell's outer diameter	10 times or longer than the thermowell's outer diameter + resistor length

(2)

Surface temperature

measurement of a solid

Apply the temperature sensor tightly to the surface of the solid you want to measure. To do this, place the temperature sensor parallel to the object measured for as long as possible to avoid a thermal effect from the surroundings. When the ambient temperature is higher than the surface, this can help avoid the effects of radiant heat. An ideal approach would be to lay the temperature sensor inside a slot or hole in the surface of the solid being measured.

(3) Temperature measurement inside a furnace

To accurately measure the temperature of a high-temperature gas, a sufficient insertion length is required. Since the wires tend to deteriorate due to atmospheric gases, it is necessary to select a proper material for the protection tube or to use a purging gas.

The required insertion length is about 10 to 15 times or longer than the outer diameter of the protection tube.

5.3 Precautions for Connecting the External Wiring

After installing the temperature sensor in the desired measuring location connect external conductors to send its signal to a receiver. In this case, note that the type of the conductors used for thermocouple and resistance thermometer sensors are different.

(1) Mineral Insulated Thermocouple

For the external conductors, use the standard compensation lead wires recommended for each thermocouple type. Be particularly aware that use of the wrong type of compensation lead wires can cause a large error. The color coding of compensation lead wires differ depending on the type of the wire and the color regulations specified in various standard such as JIS, ANSI, IEC, etc. An erroneous connection of +/- may also cause a large error. Make sure that the temperature at the joint is 80°C or less. Since the normal compensation temperature range of the compensation lead wires is about 100°C, a connection to a high-temperature section causes an unexpected error. Also, make sure that the insulation coating material is sufficient to withstand the working conditions and environment. For normal vinyl coating, the upper limit of the allowable temperature is about 90°C. When the external wiring may be exposed to the rain, etc., do not use the conductors with fiber glass insulation coating. If used, moisture or humidity will reduce insulation resistance and cause an error.

The discernment color of the standard of each country is shown in table 8.

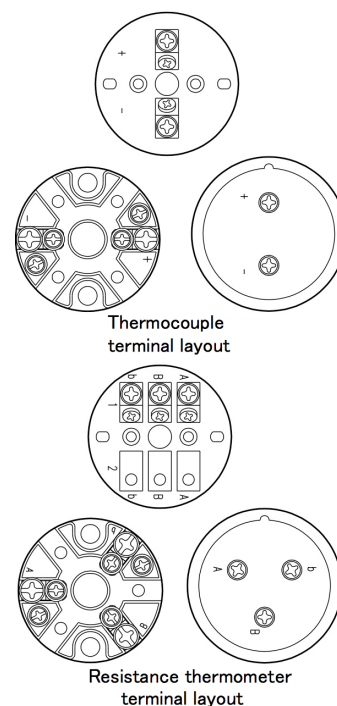
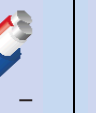
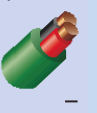
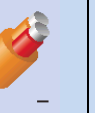
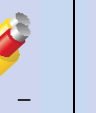
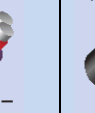


Fig.7 Terminal layout

Table 8 Compensating cable color code

Thermocouple type	B	R/S	N	K	E	J	T
IEC 60584-3:2007 JIS C 1610:2012							
JIS C 1610-1995 Class 2			-				
ASTM E-230-2008							

(2) Resistance thermometer sensor

Control cables are generally used as the external conductors. For example, if a measurement is done with a 3-wire connection, each sensor requires 3 wires. In JIS C1604: 2013 edition, the terminal symbol identifies as White-Red-Red or A-B-B. However, the company since April 2015 regards the identification color as the main object, it specifies as A-B-b limited to 3-wire type in order to clarify the current terminal “b” at the time of measurement. (For lead wire type, indicating “b” only at the Red side, but it may differ depending on the conditions.) In case of the sheath length exceeding 700 mm, please check the current terminal of measurement device and connect to the “b” terminal of our device. As with the thermocouple compensation lead wires, select the insulation coating material suitable for the installation environment. When the external wiring may be exposed to rain, etc., do not use the conductors with fiber glass insulation

(3) Grounding method

When you install a temperature sensor and connect it to its receiver with external conductors, a grounded shield wire may be used to avoid noise pick up on the conductors. Generally, one-point grounding is recommended. When the thermocouple is not grounded, ground the instrument. When shielded conductors are supplied with our product, the sheath section will be grounded due to mounting conditions. Therefore, the following two methods are available:(A similar method is recommended when connecting the temperature sensor and the shielded external lead wires on site.)

- When a grounding conductor is not available at the end of the lead wire, make attachment between the sheath and shield, and ground the sheath.
 - When a grounding conductor is available at the end of the lead wires the sheath and shield are insulated to avoid 2-point grounding since grounding is normally done on the part of the instrument.
- As shown in the figure of the grounding type of Fig. 8, a shield recommends you the method of grounding in the same part as grounding of a thermocouple.

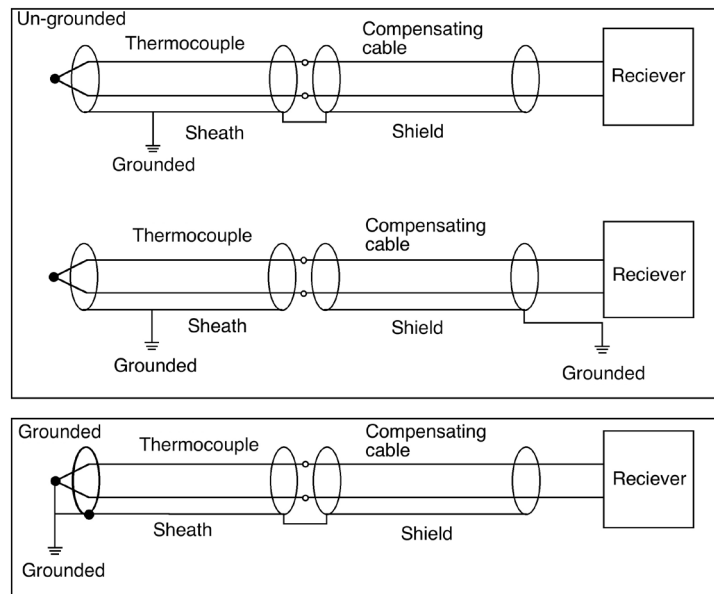


Fig.8 Grounding of Shield

(4) Caution after wiring

After the external conductors are connected, take care not to leave any dust or wire strips inside the terminal head. If wire strips are left, it will cause a short circuit or insulation deterioration. After connecting, tightly close the cover to prevent any permeation of rain water, etc. If an adaptor or the like is attached to the wiring port, confirm that the threads are screwed tight.

CHAPTER 6 SAFETY USE

6.1 Maintenance

Maintenance is important for safe and sure temperature measurement and control. Although maintenance methods differ depending on the operation, we recommend the following:

- (1) Systematization of maintenance work
- (2) Education and training to maintenance workers
- (3) Security of maintenance workers
- (4) Standardization of maintenance
- (5) Accuracy control of the inspection equipment (Recalibration)
- (6) Preparation and management of the maintenance data

6.2 Maintenance and Inspection

Since the maintenance and inspection of installed temperature sensors vary depending on the installation place and purpose, they cannot be handled identically. General methods are listed below for your reference.

(1) Daily maintenance and inspection

The temperature sensor cannot inform you of a temperature until it is connected to its receiver. An abnormality, if any, can be detected in an early stage by confirming that the temperature indicated by the receiver is within a normally expected temperature range. When there is another temperature sensor near the measuring point, you can compare the reading between the two temperature sensors.

In case of the sensor with a terminal box, an O-ring may be deteriorated by the ambient environment (light, ozone, etc.). Recommend the operation check and part replacement at the time of regular inspection every year, although there may be no problem for more than a few years depending on the ambient environment.

(2) Confirmation of the working conditions

The type and shape of the temperature sensor depends on its installation place and temperature.

Particularly, conditions such as atmosphere, temperature, pressure, flow speed, etc. have a great effect on determining what materials are used to build the temperature sensor as well as the size and configuration. Make sure that the working conditions have not changed. If they have changed, it is necessary to confirm that the current temperature sensor will still be suitable. If it is not suitable, replace the temperature sensor with one that will meet the working conditions.

(3) Confirmation of the insertion length

If the insertion length of the temperature sensor into the object being measured changes, heat conduction from the outside also changes and an error may occur. In the case of thermocouple, an error may occur if there is deterioration of the wires creating a non-uniformity. Confirm that the initial condition of the wires upon installation have remained unchanged.

(4) Confirmation of the measuring current value

The resistance thermometer sensor has a current flowing to the element for measurement of its resistance value. This "measuring current" value should be maintained in order to provide a continuing level of accuracy. If the normal current changes, there will be a change in self heating that can cause an error in measurement. Make sure that the normal current is maintained.

(5) Cleaning and inspection of the protection tube

Soot, dust, sludge, etc., when accumulated onto the protection tube during use may worsen heat conductivity to the temperature sensor inside and result in a measurement error. Clean them periodically.

The protection tube is attached to protect the temperature sensor against the measurement atmosphere. Make sure that it has not been corroded or oxidized and that it is free from mechanical damage. When removing the temperature sensor for inspection, see that no foreign substance has entered the protection tube. Clean the inside if necessary. Make sure that water does not get inside the protection tube as it can cause various problems.

(6) Inspection of the installation area and its operating conditions

The temperature sensors are sometimes installed with screws and flanges. Depending on the type of installation, some sensors may be subjected to mechanical vibrations from pumps, power sources or forcible surges of the fluid. These external forces may loosen the clamped parts. When conditions are severe, welded or brazed sections could be damaged, and allow air to enter or the fluid measured to leak out. Pay attention to the condition of temperature sensors, which can be checked visually.

(7) Inspection of insulation resistance

Check the measuring circuit for insulation resistance including the temperature sensor. A decrease of insulation resistance can cause an indication error or induction problems. When the grounded type thermocouple is used, remove the thermocouple terminals and check the receivers circuit for insulation resistance. (For checking insulation resistance of the temperature sensor, refer to Section 3.4. The criterion for replacement is resistance value of 1M Ω minimum.

(8) Inspection of the connections

Check each connection in the measuring circuit for its condition and polarity. In the case of a thermocouple, reversed polarity results in a large error.

(9) Inspection of the external conductors

The temperature sensor and receiver are wired to each other with external conductors. If the external conductors are damaged or the wrong type of compensation lead wires are connected, a measurement error can occur. Check for continuity, insulation resistance, reverse polarity, type and appearance of the compensating lead wires.

(10) Periodic Inspection

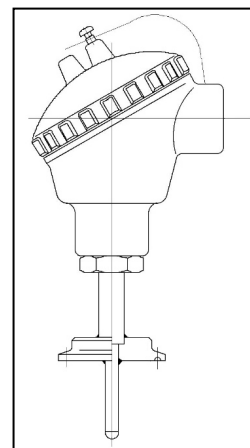
Even if the temperature sensor is operating properly, it is recommended that the sensor be removed from the measurement point and calibrated in comparison with a standard thermometer once or twice a year. However, as for Type K thermocouples used at 250°C or higher, temperature reading may indicate a higher value due to the effect of SRO if the immersion length at the time of periodic inspection is shorter than the immersion length in use at site. Additionally, if Type K thermocouples are used in a high-temperature furnace with a deep immersion length, temperature reading may indicate beyond the limit of error due to SRO at the time of periodic inspection with shorter immersion length. These phenomena are attributed to the heterogeneity of the thermocouple wires due to the influence of the ambient temperature during use. When the temperature gradient is added to the inhomogeneous part, an error in temperature reading will appear more notably. (Refer to Table 1 in Section 3.3.)

In addition, as specified in the next page, in the case of a temperature sensor mounted with a ferrule and a flange, etc. for food-grade sanitary standards, there is a very short insertion length of the product from the limitations of the mounting portion. In particular, in the case of resistance thermometer sensor which attaches the resistance element at the tip, there is a possibility that insufficient insertion error occurs at the time of product installation when the insertion length is 60mm or less. And furthermore, in the case of performing the re-inspection, it does not reach the actual temperature of the temperature bath unless it is immersed in the test temperature bath until the ferrule and the flange portion, shows a large error.

Here is an example of the temperature sensor having extremely short insertion length with a ferrule. In

fact, based on the re-inspection performed by customer, the insertion length of the sensor that error occurred was 30 mm or less.

In the case of performing the re-inspection of the sensor having the short insertion length, the correct temperature may not be measured when only the sensor below the ferrule immersed into the test bath because the heat dissipation by ferrule is large.



6.3 Periodic inspection of Temperature Sensor

Long term stability of temperature sensors depend on the type of installation, the measuring temperature and its environment. The frequency of replacement will depend on the working conditions and can be determined by temperature inspection at constant intervals along with daily maintenance and inspection. Stable temperature control for most processes can be obtained by carrying out the above-mentioned accuracy control. There are various inspection methods available, depending on the type of the temperature sensor used and the inspection temperature available. The following describes a general inspection method for your reference.

(1) Fixed point inspection

This method uses a standard fixed point as a temperature reference. It is effective for calibrating a specific temperature with high accuracy and mainly used for the calibration of primary standards.

Table 9 ITS-90 Defined Fixed Points

Material and Its State	K	°C
Triple point of equilibrium hydrogen	13.8033	-259.3467
Triple point of neon	24.5561	-248.5939
Triple point of oxygen	54.3584	-218.7916
Triple point of argon	83.8058	-189.3442
Triple point of mercury	234.3156	-38.8344
Triple point of water	273.16	0.01
Melting point of gallium	302.9146	29.7646
Freezing point of indium	429.7485	156.5985
Freezing point of tin	505.078	231.928
Freezing point of zinc	692.677	419.527
Freezing point of aluminum	933.473	660.323
Freezing point of silver	1234.93	961.78
Freezing point of copper	1357.77	1084.62

Nonetheless, the defined fixed points are specified as Table 9, ITS-90 (International Temperature Scale 1990), the other test temperature is usually used for general temperature sensors. Please note that there is a restriction on the length and the outer diameter of the temperature sensor in the case of using these fixed-point devices.

In general, the test cannot perform with insufficient insertion length. Our temperature sensor calibration section has performed the JCSS calibration and can perform the calibration in the part of the defined fixed point. When testing a resistance thermometer or a thermocouple, the boiling point of nitrogen, oxygen or water and the freezing point of water are used, and the Comparative inspection is used for these tests instead of the above Fixed point inspection.

(2) Comparative inspection

This is the method most frequently used. In general, this method uses a laboratory calibrated temperature sensor as a standard. The inspection is performed by comparing the readings of the standard probe against the readings of the test probe.

Unlike fixed calibration, this method enables the use of a wide range of inspection temperatures.

The typical test devices and testable temperature range are specified in Table 10.

Please note that the test devices are depending on the test temperature and there is a restriction on the length and the outer diameter of the temperature sensor.

The temperature sensor especially for food-grade sanitary standards, the insertion length is short due to the restriction of size at the installing part. In that case, our company can manufacture the sensor with longer length, and then adjust it to the requested length before delivery. Accordingly, the error may become bigger due to lack of insertion length at the time of re-inspection or in the installed state of the product. In the case of a resistance thermometer sensor, care is required for the insertion length 60 mm or less because the resistance element is attached to the tip.

Table10 Inspection Temperatures

Bath or furnace	Inspection Temperature Range
Liquefied helium	-269°C
Liquefied nitrogen	-196°C
Liquefied oxygen	-183°C
Low-temperature dry well	-100°C ~ -40°C
Low-temperature bath	-80°C ~ R.T.
Water bath	R.T. ~ 80°C
Oil bath	80°C ~ 200°C
Niter bath	200°C ~ 500°C
Electric furnace	400°C ~ 1050°C

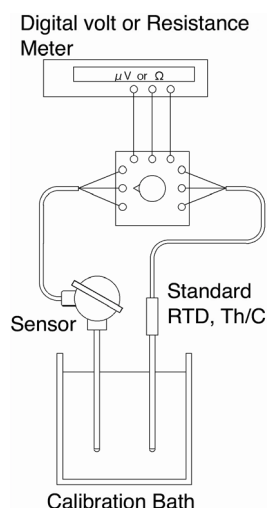


Fig.9 Comparison method

(3) Deviation method

This method is similar to comparative inspection and convenient for inspection of a large amount of thermocouples. The inspection setup is almost the same as mentioned in (2). This method is done by taking a thermocouple identical to the test thermocouples and calibrating it at a standard temperature. It can then be insert into the calibration bath together with the thermocouples to be tested and the difference between their electromotive forces can be measured. This method does not required a reference junction. Our thermocouples are tested in this method.

(4) Field inspection

This method is used for calibration in the field where the temperature sensors are actually used. As this is a simpler method, calibration accuracy is inferior to the methods mentioned above. This method generally does not require special equipment. Accumulation of calibration data periodically is a practical method to judge whether the temperature sensor in use is still functioning or should be replaced.

a) Replacement method

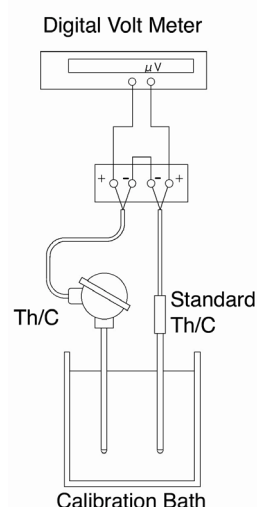


Fig. 10 Deviation method

Replace the temperature sensors are in use with a calibrated temperature sensor and compare their indicated temperature values. When using this method, the temperature of the object measured must be stable for a long period of time. When taking the measurement, it is necessary to allow sufficient time for any delay in response when protection tube is installed. It may also be necessary to adjust the insertion length.

b) Parallel insertion method

Install a calibrated temperature as close as possible to the temperature sensor in use and compare their indicated temperature values. This method requires an insertion hole or protection tube to be installed in advance that is parallel to the temperature sensor in use. Both sensors must be measured at the same insertion depth. It is also necessary to have thermocouple junction area or RTS sensing area of the two in direct contact.

CHAPTER 7 TROUBLESHOOTING

7.1 Identifying Problems

A problem with a temperature sensor is normally detected through an error in temperature indication. Since all of temperature indication errors are not caused by the temperature sensor, it is necessary to accurately grasp what is causing the problem. The most frequent problem causes would be breakage or defects in the insulation of the thermocouple or resistance thermometer bulb.

7.2 Troubleshooting for Thermocouples

Table 11 Troubleshooting for Thermocouples

Trouble	Occurrence Timing		Possible Cause	Remedy
	Upon Start-up	During Operation		
A temperature indication scales out to the minus side	O	O	• The polarity of the sensor at either the receiver or thermocouple is reversed	• Check and connect correctly.
	O	O	• Burn out setting of the receiver is at the lower limit and the thermocouple or compensation lead wires are open circuited or the terminal block has no power continuity. • Trouble of the receiver.	• Check for snapping and continuity with a tester, and replace or reconnect the terminals. • Check and repair or replace
A temperature indication scales out to the plus side	O	O	• Burn out setting of the receiver is at the upper limit, and the thermocouple or compensating lead wires are snapped or the terminal block has no power continuity. • Trouble of the receiver.	• Check for snapping and continuity with a tester, and replace or reconnect the terminals. • Check and repair or replace
The temperature sensor indicates close to a room temperature	O	O	• The input connection terminal or compensating junction of the receiver is short-circuited.	• Check the connection terminals and remove the cause of short-circuit.
		O	• Internal short-circuit of the compensating lead wires. • Trouble of the receiver.	• Check for continuity with a tester, and repair or replace.
A temperature indication remains unchanged if the temperature changes.	O	O	• Open circuit in thermocouple. • Open or short circuit of the compensating lead wires. • Trouble at the receiver. (No burnout circuit)	• Check the circuit of the thermocouple & v compensating lead wires and instrument. • Repair or replace.
Unstable indication.	O	O	• Intermittent open circuit of the thermocouple or compensating lead wires. • Contact failure at the terminal block. • Trouble at the receiver	• Check for continuity with an ohmmeter and replace or reconnect the terminals. • Check and repair or replace.
	O		• Electric noise interference. • Effect of fluctuation of the fluid temperature to be measured.	• After a check, change the grounding method or shield. • Change to the slower response thermocouple.
An indication value is abnormal.	O		• Mismatch of thermocouple or compensating lead wires. • Different polarity of the compensating lead wires. • Faulty installation of the thermocouple • Type of the receiver or range setting is wrong.	• Check and set again or change the connection • Check installation position, insertion length, and installation method, and reinstall. • Check and set again.
		O	• Deterioration of the thermocouple's thermoelectromotive force • Deterioration of insulation of the thermocouple or compensating lead wires. • Change of thermocouple installation. • Trouble in the receiver.	• Replace • Replace • Check, and repair or replace. • Check, and repair or replace.

7.3 Troubleshooting for Resistance Thermometer Sensors

Table 11 Troubleshooting for Resistance Thermometer

Trouble	Occurrence Timing		Possible Cause	Remedy
	Upon Start-up	During Operation		
Negative temperature indication	O	O	Faulty 3 -wire type connection	Check and connect correctly.
	O	O	- Short -circuit at the resistance element block.. - Burnout setting of the receiver is at the lower limit, and the resistance element or extension conductors are open or the terminal block has no continuity	Check for short circuit with an ohmmeter or reconnect the terminals
Excessive positive temperature indication	O	O	- The resistance element is open circuit. - Burnout setting of the receiver is at the lower limit, and the resistance element or extension conductors are open or the terminal block has no continuity	Check for open circuit with an ohmmeter, and replace or reconnect the terminals.
Temperature indication remains unchanged if a temperature changes.	O	O	Trouble in the receiver.	Check, and repair or replace.
An indication value is unstable.	O	O	The input connection terminal or compensation junction of the receiver is short-circuited	- Check for open circuit with an ohmmeter, and replace or reconnect the terminals. - Check and repair or replace.
	O		- Internal short-circuit of the compensation lead wires. - Trouble in the receiver.	After a check, change the grounding method or shield.
An indication value is abnormal.	O		- Faulty resistance value of the resistance element. - Faulty installation of the resistance thermometer sensors. - Type of the receiver or setting of the range is wrong.	- Replace - Check for an installation position, insertion length, and installation method, and reinstall.
		O	- Deterioration of insulation of the resistance thermometer sensor or extension conductors. - Change of installation of the resistance thermometer sensor. - Trouble of the receiver.	- Check the insulation resistance, and replace. - Check the insulation, and repair or replace. - Check the receiver , and repair or replace.
An indication value is several percent higher.	O		A "JPt" type resistance thermometer sensor is connected to a "Pt" type instrument.	Replace with an adequate one which meets the standard
An indication value is several percent lower.	O		A "Pt" type resistance thermometer sensor is connected to a "JPt" type instrument	Replace with an adequate one which meets the standard.

CHAPTER 8 BASIC SPECIFICATIONS AND STRUCTURE OF TEMPERATURE SENSORS

8.1 Protection Tube Type Temperature Sensors

This is a type of temperature sensor that has been used for many years. It is constructed with a solid insulator type thermocouple or mica insulated/fin type resistance thermometer sensor inserted into the protection tube. The protection tube is used to protect the thermocouple or resistance thermometer sensor against ambient environments. Stainless steel is the most often used material. A flange or screw is welded to the protection tube for installation. It is an inexpensive sensor due to its simple structure and widely used.

(1) Insulator type thermocouple

The insulator type thermocouple consists of thermocouple wires, insulators, terminal box, and protection tube. The tip of the thermocouple is welded to create a measuring junction. For high-temperature measurement, platinum thermocouple wires (B, R, S) are used with a ceramic protection tube.

(2) Fin type resistance thermometer sensor

The fin type resistance thermometer sensor is also called a general resistance thermometer sensor. Its basic structure is exactly the same as that of the insulator type thermocouple, except a temperature sensing element is used. Originally supplied with a mica type resistance element, it currently uses a CERACOIL element (refer to Remarks below) to enhance strength and insulation of the element block.

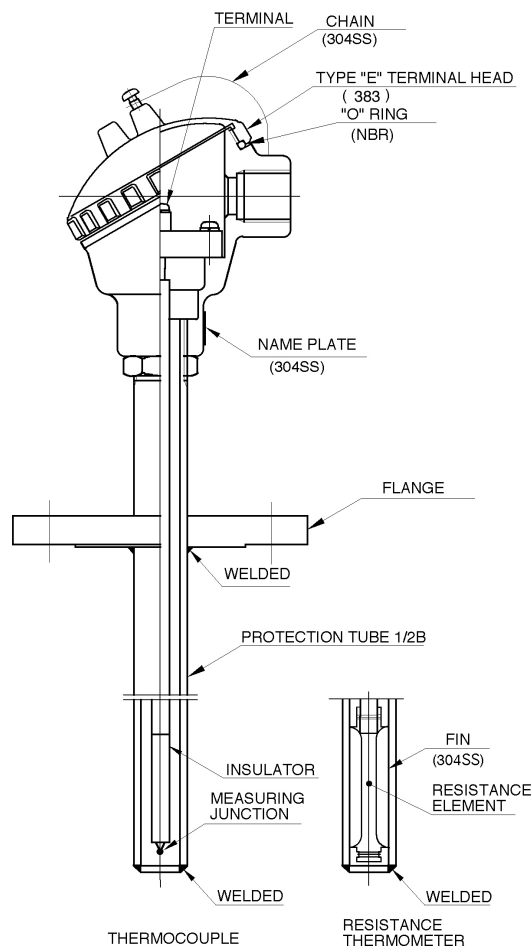


Fig. 11 Structure of Protection Tube Type Temperature Sensor

(Remarks)

CERACOIL : Okazaki product name for the ceramic insulated very fine platinum wire coil. It is used as the element of the sheathed resistance thermometer sensor.

8.2 Sheathed Temperature Sensor

The most popular type of temperature sensors are made with metal sheath mineral insulated cable. Known as MI cable, it is supplied with thermocouple wire or resistance thermometer conductors. The insulation in the tube is highly compacted magnesium oxide (MgO) powder. Various outer diameters can be manufactured, ranging from 0.08 mm to 12.7 mm O.D. Very long sheaths can be also manufactured. The sheathed temperature sensor uses the tip of the cable as a temperature sensing area. By carefully selecting a proper sheath material, these temperature sensors can be used under extreme environments without using the protection tubes. Fig.12 shows sectional views of the sheath, and Fig.13 a structural view of the most popular types of sheathed temperature sensors.

Normally, the sheathed thermocouple has a measuring junction inside the sheath to create the temperature sensing area. The sheathed resistance thermometer sensor has a resistance element (CERACOIL) embedded at the tip of the sheath as the temperature sensing area.

Note that the front end of about 70 mm can not be bent because it contains the sensing element.

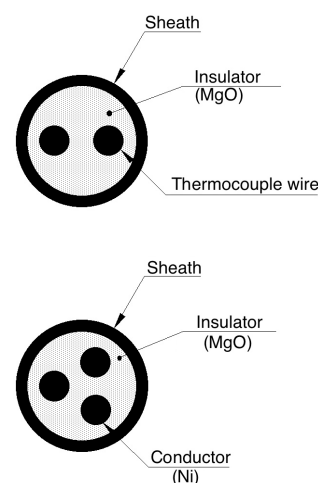


Fig. 12 Section of Sheath

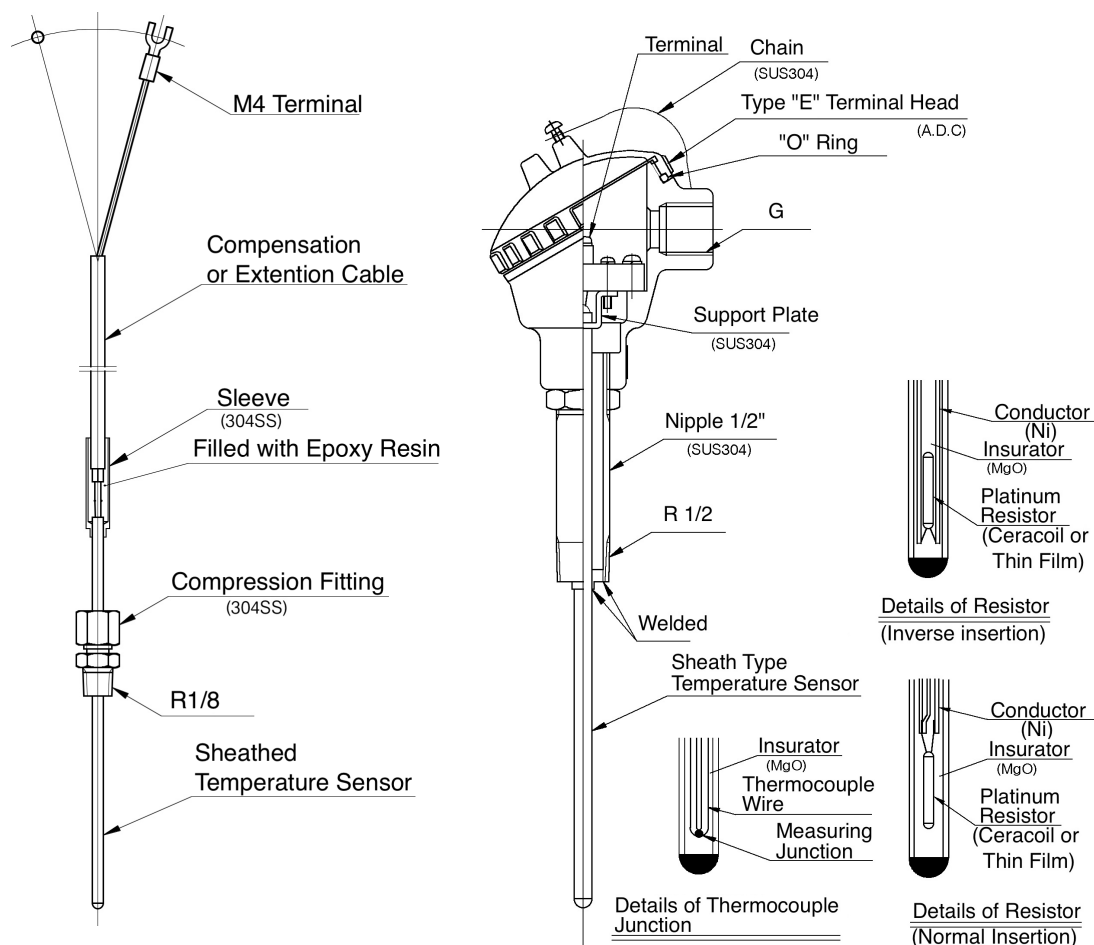


Fig. 13 Structure of Sheathed Temperature Sensor

sheathed thermocouple is referred to as AEROPAK, and the sheathed resistance thermometer sensor is RESIOPAK. A typical sheath outer diameter is 3.2 mm to 8.0 mm O.D. The sheathed temperature

sensors with a thin outer diameter of 4.8 mm O.D. or less are installed in various places because they can be easily bent by hand. ***The recommended minimum bending radius is twice the sheath outside diameter. Bending or straightening a temperature sensor with a smaller diameter will break the conductors. However, in case of bending at local by customer, we recommend that the bending radius is 5 times or over of the sheath outside diameter.***

The connection head type of temperature sensor shown in Fig.13 is often combined with the protection tube and is used for process control in various types of plants. The measuring junction, which is the temperature sensing area of the thermocouple, has several types of configurations as shown in Fig.14. Proper selection depends on the applications. Extra care should be taken when using the pressure-tight explosion proof temperature sensor. In this case, the measuring junction is limited to the un-grounded type only in Japan

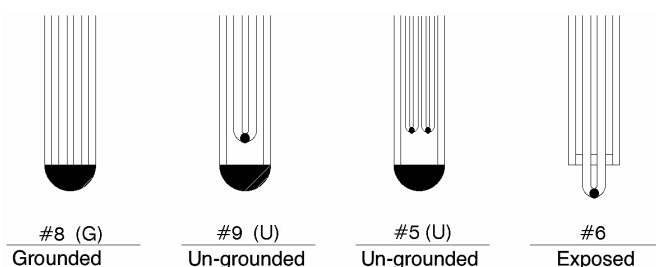


Fig. 14 Measuring junction types

8.3 Explosion-proof Temperature sensor

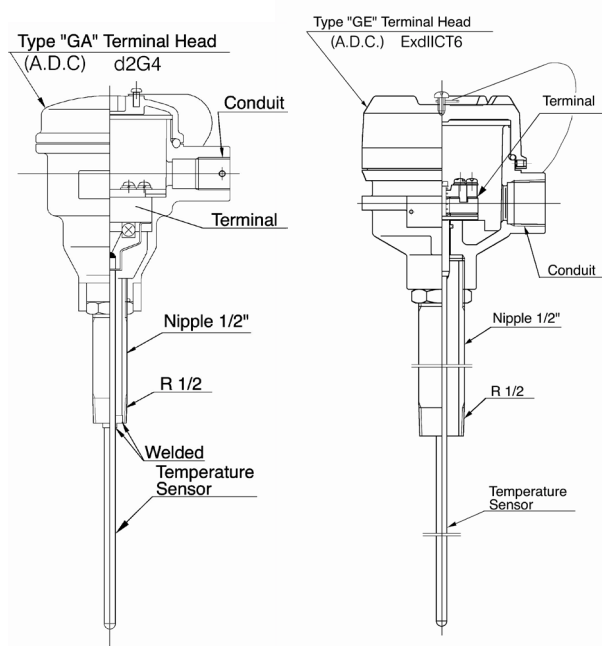
In oil refining plants, gas manufacturing plants, and chemical plants, many areas are designated as hazardous. These areas where a combustible gas or inflammable steam is mixed with the air and can generate an atmosphere, which is likely to explode if there are any sparks. When using electric appliances in the hazardous areas, there are various restrictions set up for their enclosures to insure that explosions will not occur due to the sparks produced by the electric appliances. Those restrictions are the "Explosion-proof Structural Standards for Electric Machines and Appliances (Notification N0.16 of Ministry of Labor, 1969)". These standards apply to temperature sensors (thermocouples and resistance thermometer sensors) because they are also classified therein as measuring instruments.

Since our explosion-proof temperature sensors have been designed following those standards and passed the verification by an official authorization organization, they can be safely used in the hazardous area.

There are five types of explosion-proof structures. Of them, only the following two types are applied to temperature sensors.

(1) Flame-proof structure

This is a fully enclosed structure. It can be defined that when gas or steam finds its way into a container and causes an explosion, the said structure contains the explosion pressure, and a flame caused by the explosion does not ignite the gas or steam outside the said container.



Currently, our products have passed the verification of the Flame-proof grade d2G4 or Exd II BT4. When wiring the external conductors through the wiring port, it is necessary to employ either pressure-tight packing type adapter or conduit tube screw coupling system at the wiring port (conduit). External wiring of the sensor is the user's responsibility and should be installed based on applicable explosion proof guidelines. Note that, especially, Exd type Flame-proof product require the use of pressure-proof packing type adaptors.

Based on the recent increase demand for products complying with explosion-proof standards for each country, we have started manufacturing products in compliance with respective standards in EU countries, the United States, China and South Korea. These products are adapted to the standards of each country, but are not for use in Japan.

(2) Intrinsic safety explosion-proof structure

In this structure, the sparks and heat produced in the electric circuits of the electric machines and appliances cannot become an ignition source for the explosive atmosphere.

For the temperature sensor, a safety isolator (Zener barrier) is installed in a safe place to prevent electric energy from flowing into the hazardous area and becoming an ignition source when there is a problem with the instrument. When combining the temperature sensor with the safety isolator, it is necessary to select the safety isolator which is suitable for the electrical characteristics (inductance and capacitance) of the temperature sensor. Currently, a combination of our temperature sensors with Yokogawa Electric-made safety barriers (BARD series), Nakamura Electric Manufacturing Company's (NZB series) and MTL Instruments' (MTL series) are authorized by a government department. There are few restrictions for thermometer sensor combinations. Please refer to the Table 13.

However, in European countries and USA, temperature sensors (thermocouple and resistance thermometer) do not need to be certified because of small amount of energy reservation. Therefore, these sensors can be used without being certified under permissible range of safety barriers.

Table 13 Possible combination of Thermometers and Safety Barriers

*1 : BecCause of separately certification, it can be used with safety barriers which have allowed value (). BARD 600 is acceptable.

Type	Element	Model	Class	Certificate	Internal Resistance	Allowable L	Allowable C	Manufacturer
Thermocouple	Single	*1	i3a G 5	T34599	-	(1.6Mh+LW)	(0.5μF+CW)	Yokogawa Electric Corporation
	Double	BARD600x2		T34600	235±15Ω	0.8mH	0.1μF	
Resistance	Single	BARD700		T34601	130±15Ω	0.45mH	0.1μF	
Thermocouple	Single	NZB2-1R52	Exia	TC14292	52Ω	0.51mH	1.7μF	Nakamura Electric Mfg. Co., Ltd.
Resistance	Single	NZB3-1R75	IICT5	TC14293	75Ω	0.51mH	1.7μF	
*2 Resistance	Double	MTL5082	Exia IICT3	TC17865	Insulated	48.5mH	21μF	Cooper Industries Japan K.K.

*2 : Resistance thermometer has double elements with single safety barrier, therefore, one circuit of resistance thermometer is used as an extra. (sensor limited type)

LW : Inductance of outside lead wire

CW : Capacitance of outside lead wire

Note 1 : For NZB series made by Nakamura Electric Mfg. Co., Ltd., label of certification shall be supplied

Note 2: There is an option other than above of insulating barriers made by Cooper Industries Japan K.K. and P+F can use for a thermocouple (single). Please contact us if you need further information.

8.4 Lead Wire Type Temperature sensor (Thermocouple type, Resistance thermometer sensor type)

The lead wire type temperature sensor that enables the temperature measurement where are difficult to mount the sheath type temperature sensor, and it is generally consisted by insulated with glass fiber or resin-coated insulated wire. The resistance element shall be incorporated in the temperature sensing part for a resistance thermometer sensor.

For example, in case of installing a temperature sensor into a bearing, the sheath type temperature sensor may be difficult to install. Since the temperature-sensitive element (or temperature measuring junction) is incorporated in the inside of a metal tip that applied to the tip of the lead wire type temperature sensor, and it can be bent at the close part of the temperature sensing part, the lead wire type temperature sensor is enabled to install in a narrow place. However, extreme bending is strictly prohibited.

CHAPTER 9 REFERENCE MATERIAL

9.1 Thermocouple Reference Thermo-electromotive Force Table

Table 14 Reference Thermo-electromotive Force Table

B Thermocouple										μV	ITS-90
°C	0	10	20	30	40	50	60	70	80	90	100
0	0	-2	-3	-2	0	2	6	11	17	25	33
100	33	43	53	65	78	92	107	123	141	159	178
200	178	199	220	243	267	291	317	344	372	401	431
300	431	462	494	527	561	596	632	669	707	746	787
400	787	828	870	913	957	1 002	1 048	1 095	1 143	1 192	1 242
500	1 242	1 293	1 344	1 397	1 451	1 505	1 561	1 617	1 675	1 733	1 792
600	1 792	1 852	1 913	1 975	2 037	2 101	2 165	2 230	2 296	2 363	2 431
700	2 431	2 499	2 569	2 639	2 710	2 782	2 854	2 928	3 002	3 078	3 154
800	3 154	3 230	3 308	3 386	3 466	3 546	3 626	3 708	3 790	3 873	3 957
900	3 957	4 041	4 127	4 213	4 299	4 387	4 475	4 564	4 653	4 743	4 834
1000	4 834	4 926	5 018	5 111	5 205	5 299	5 394	5 489	5 585	5 682	5 780
1100	5 780	5 878	5 976	6 075	6 175	6 276	6 377	6 478	6 580	6 683	6 786
1200	6 786	6 890	6 995	7 100	7 205	7 311	7 417	7 524	7 632	7 740	7 848
1300	7 848	7 957	8 066	8 176	8 286	8 397	8 508	8 620	8 731	8 844	8 956
1400	8 956	9 069	9 182	9 296	9 410	9 524	9 639	9 753	9 868	9 984	10 099
1500	10 099	10 215	10 331	10 447	10 563	10 679	10 796	10 913	11 029	11 146	11 263
1600	11 263	11 380	11 497	11 614	11 731	11 848	11 965	12 082	12 199	12 316	12 433
1700	12 433	12 549	12 666	12 782	12 898	13 014	13 130	13 246	13 361	13 476	13 591
1800	13 591	13 706	13 820								

R Thermocouple										μV	ITS-90
°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
0	0	-51	-100	-145	-188	-226					
°C	0	10	20	30	40	50	60	70	80	90	100
0	0	54	111	171	232	296	363	431	501	573	647
100	647	723	800	879	959	1 041	1 124	1 208	1 294	1 381	1 469
200	1 469	1 558	1 648	1 739	1 831	1 923	2 017	2 112	2 207	2 304	2 401
300	2 401	2 498	2 597	2 696	2 796	2 896	2 997	3 099	3 201	3 304	3 408
400	3 408	3 512	3 616	3 721	3 827	3 933	4 040	4 147	4 255	4 363	4 471
500	4 471	4 580	4 690	4 800	4 910	5 021	5 133	5 245	5 357	5 470	5 583
600	5 583	5 697	5 812	5 926	6 041	6 157	6 273	6 390	6 507	6 625	6 743
700	6 743	6 861	6 980	7 100	7 220	7 340	7 461	7 583	7 705	7 827	7 950
800	7 950	8 073	8 197	8 321	8 446	8 571	8 697	8 823	8 950	9 077	9 205
900	9 205	9 333	9 461	9 590	9 720	9 850	9 980	10 111	10 242	10 374	10 506
1000	10 506	10 638	10 771	10 905	11 039	11 173	11 307	11 442	11 578	11 714	11 850
1100	11 850	11 986	12 123	12 260	12 397	12 535	12 673	12 812	12 950	13 089	13 228
1200	13 228	13 367	13 507	13 646	13 786	13 926	14 066	14 207	14 347	14 488	14 629
1300	14 629	14 770	14 911	15 052	15 193	15 334	15 475	15 616	15 758	15 899	16 040
1400	16 040	16 181	16 323	16 464	16 605	16 746	16 887	17 028	17 169	17 310	17 451
1500	17 451	17 591	17 732	17 872	18 012	18 152	18 292	18 431	18 571	18 710	18 849
1600	18 849	18 988	19 126	19 264	19 402	19 540	19 677	19 814	19 951	20 087	20 222
1700	20 222	20 356	20 488	20 620	20 749	20 877	21 003				

S Thermocouple										μV	ITS-90
°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
0	0	-53	-103	-150	-194	-236					
°C	0	10	20	30	40	50	60	70	80	90	100
0	0	55	113	173	235	299	365	433	502	573	646
100	646	720	795	872	950	1 029	1 110	1 191	1 273	1 357	1 441
200	1 441	1 526	1 612	1 698	1 786	1 874	1 962	2 052	2 141	2 232	2 323
300	2 323	2 415	2 507	2 599	2 692	2 786	2 880	2 974	3 069	3 164	3 259
400	3 259	3 355	3 451	3 548	3 645	3 742	3 840	3 938	4 036	4 134	4 233
500	4 233	4 332	4 432	4 532	4 632	4 732	4 833	4 934	5 035	5 137	5 239
600	5 239	5 341	5 443	5 546	5 649	5 753	5 857	5 961	6 065	6 170	6 275
700	6 275	6 381	6 486	6 593	6 699	6 806	6 913	7 020	7 128	7 236	7 345
800	7 345	7 454	7 563	7 673	7 783	7 893	8 003	8 114	8 226	8 337	8 449
900	8 449	8 562	8 674	8 787	8 900	9 014	9 128	9 242	9 357	9 472	9 587
1000	9 587	9 703	9 819	9 935	10 051	10 168	10 285	10 403	10 520	10 638	10 757
1100	10 757	10 875	10 994	11 113	11 232	11 351	11 471	11 590	11 710	11 830	11 951
1200	11 951	12 071	12 191	12 312	12 433	12 554	12 675	12 796	12 917	13 038	13 159
1300	13 159	13 280	13 402	13 523	13 644	13 766	13 887	14 009	14 130	14 251	14 373
1400	14 373	14 494	14 615	14 736	14 857	14 978	15 099	15 220	15 341	15 461	15 582
1500	15 582	15 702	15 822	15 942	16 062	16 182	16 301	16 420	16 539	16 658	16 777
1600	16 777	16 895	17 013	17 131	17 249	17 366	17 483	17 600	17 717	17 832	17 947
1700	17 947	18 061	18 174	18 285	18 395	18 503	18 609				

K Thermocouple										μV	ITS-90
°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
-200	-5 891	-6 035	-6 158	-6 262	-6 344	-6 404	-6 441	-6 458			
-100	-3 554	-3 852	-4 138	-4 411	-4 669	-4 913	-5 141	-5 354	-5 550	-5 730	-5 891
0	0	-392	-778	-1 156	-1 527	-1 889	-2 243	-2 587	-2 920	-3 243	-3 554
°C	0	10	20	30	40	50	60	70	80	90	100
0	0	397	798	1 203	1 612	2 023	2 436	2 851	3 267	3 682	4 096
100	4 096	4 509	4 920	5 328	5 735	6 138	6 540	6 941	7 340	7 739	8 138
200	8 138	8 539	8 940	9 343	9 747	10 153	10 561	10 971	11 382	11 795	12 209
300	12 209	12 624	13 040	13 457	13 874	14 293	14 713	15 133	15 554	15 975	16 397
400	16 397	16 820	17 243	17 667	18 091	18 516	18 941	19 366	19 792	20 218	20 644
500	20 644	21 071	21 497	21 924	22 350	22 776	23 203	23 629	24 055	24 480	24 905
600	24 905	25 330	25 755	26 179	26 602	27 025	27 447	27 869	28 289	28 710	29 129
700	29 129	29 548	29 965	30 382	30 798	31 213	31 628	32 041	32 453	32 865	33 275
800	33 275	33 685	34 093	34 501	34 908	35 313	35 718	36 121	36 524	36 925	37 326
900	37 326	37 725	38 124	38 522	38 918	39 314	39 708	40 101	40 494	40 885	41 276
1000	41 276	41 665	42 053	42 440	42 826	43 211	43 595	43 978	44 359	44 740	45 119
1100	45 119	45 497	45 873	46 249	46 623	46 995	47 367	47 737	48 105	48 473	48 838
1200	48 838	49 202	49 565	49 926	50 286	50 644	51 000	51 355	51 708	52 060	52 410
1300	52 410	52 759	53 106	53 451	53 795	54 138	54 479	54 819			

N Thermocouple										μV	ITS-90
°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
-200	-3 990	-4 083	-4 162	-4 226	-4 277	-4 313	-4 336	-4 345			
-100	-2 407	-2 612	-2 808	-2 994	-3 171	-3 336	-3 491	-3 634	-3 766	-3 884	-3 990
0	0	-260	-518	-772	-1 023	-1 269	-1 509	-1 744	-1 972	-2 193	-2 407
°C	0	10	20	30	40	50	60	70	80	90	100
0	0	261	525	793	1 065	1 340	1 619	1 902	2 189	2 480	2 774
100	2 774	3 072	3 374	3 680	3 989	4 302	4 618	4 937	5 259	5 585	5 913
200	5 913	6 245	6 579	6 916	7 255	7 597	7 941	8 288	8 637	8 988	9 341
300	9 341	9 696	10 054	10 413	10 774	11 136	11 501	11 867	12 234	12 603	12 974
400	12 974	13 346	13 719	14 094	14 469	14 846	15 225	15 604	15 984	16 366	16 748
500	16 748	17 131	17 515	17 900	18 286	18 672	19 059	19 447	19 835	20 224	20 613
600	20 613	21 003	21 393	21 784	22 175	22 566	22 958	23 350	23 742	24 134	24 527
700	24 527	24 919	25 312	25 705	26 098	26 491	26 883	27 276	27 669	28 062	28 455
800	28 455	28 847	29 239	29 632	30 024	30 416	30 807	31 199	31 590	31 981	32 371
900	32 371	32 761	33 151	33 541	33 930	34 319	34 707	35 095	35 482	35 869	36 256
1000	36 256	36 641	37 027	37 411	37 795	38 179	38 562	38 944	39 326	39 706	40 087
1100	40 087	40 466	40 845	41 223	41 600	41 976	42 352	42 727	43 101	43 474	43 846
1200	43 846	44 218	44 588	44 958	45 326	45 694	46 060	46 425	46 789	47 152	47 513
1300	47 513										

E Thermocouple										μV	ITS-90
°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
-200	-8 825	-9 063	-9 274	-9 455	-9 604	-9 718	-9 797	-9 835			
-100	-5 237	-5 681	-6 107	-6 516	-6 907	-7 279	-7 632	-7 963	-8 273	-8 561	-8 825
0	0	-582	-1 152	-1 709	-2 255	-2 787	-3 306	-3 811	-4 302	-4 777	-5 237
°C	0	10	20	30	40	50	60	70	80	90	100
0	0	591	1 192	1 801	2 420	3 048	3 685	4 330	4 985	5 648	6 319
100	6 319	6 998	7 685	8 379	9 081	9 789	10 503	11 224	11 951	12 684	13 421
200	13 421	14 164	14 912	15 664	16 420	17 181	17 945	18 713	19 484	20 259	21 036
300	21 036	21 817	22 600	23 386	24 174	24 964	25 757	26 552	27 348	28 146	28 946
400	28 946	29 747	30 550	31 354	32 159	32 965	33 772	34 579	35 387	36 196	37 005
500	37 005	37 815	38 624	39 434	40 243	41 053	41 862	42 671	43 479	44 286	45 093
600	45 093	45 900	46 705	47 509	48 313	49 116	49 917	50 718	51 517	52 315	53 112
700	53 112	53 908	54 703	55 497	56 289	57 080	57 870	58 659	59 446	60 232	61 017
800	61 017	61 801	62 583	63 364	64 144	64 922	65 698	66 473	67 246	68 017	68 787
900	68 787	69 554	70 319	71 082	71 844	72 603	73 360	74 115	74 869	75 621	76 373
1000	76 373										

J Thermocouple										μV	ITS-90
°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
-200	-7 890	-8 095									
-100	-4 633	-5 037	-5 426	-5 801	-6 159	-6 500	-6 821	-7 123	-7 403	-7 659	-7 890
0	0	- 501	- 995	-1 482	-1 961	-2 431	-2 893	-3 344	-3 786	-4 215	-4 633
°C	0	10	20	30	40	50	60	70	80	90	100
0	0	507	1 019	1 537	2 059	2 585	3 116	3 650	4 187	4 726	5 269
100	5 269	5 814	6 360	6 909	7 459	8 010	8 562	9 115	9 669	10 224	10 779
200	10 779	11 334	11 889	12 445	13 000	13 555	14 110	14 665	15 219	15 773	16 327
300	16 327	16 881	17 434	17 986	18 538	19 090	19 642	20 194	20 745	21 297	21 848
400	21 848	22 400	22 952	23 504	24 057	24 610	25 164	25 720	26 276	26 834	27 393
500	27 393	27 953	28 516	29 080	29 647	30 216	30 788	31 362	31 939	32 519	33 102
600	33 102	33 689	34 279	34 873	35 470	36 071	36 675	37 284	37 896	38 512	39 132
700	39 132	39 755	40 382	41 012	41 645	42 281	42 919	43 559	44 203	44 848	45 494
800	45 494	46 141	46 786	47 431	48 074	48 715	49 353	49 989	50 622	51 251	51 877
900	51 877	52 500	53 119	53 735	54 347	54 956	55 561	56 164	56 763	57 360	57 953
1000	57 953	58 545	59 134	59 721	60 307	60 890	61 473	62 054	62 634	63 214	63 792
1100	63 792	64 370	64 948	65 525	66 102	66 679	67 255	67 831	68 406	68 980	69 553
1200	69 553										

T Thermocouple										μV	ITS-90
°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
-200	-5 603	-5 753	-5 888	-6 007	-6 105	-6 180	-6 232	-6 258			
-100	-3 379	-3 657	-3 923	-4 177	-4 419	-4 648	-4 865	-5 070	-5 261	-5 439	-5 603
0	0	- 383	- 757	-1 121	-1 475	-1 819	-2 153	-2 476	-2 788	-3 089	-3 379
°C	0	10	20	30	40	50	60	70	80	90	100
0	0	391	790	1 196	1 612	2 036	2 468	2 909	3 358	3 814	4 279
100	4 279	4 750	5 228	5 714	6 206	6 704	7 209	7 720	8 237	8 759	9 288
200	9 288	9 822	10 362	10 907	11 458	12 013	12 574	13 139	13 709	14 283	14 862
300	14 862	15 445	16 032	16 624	17 219	17 819	18 422	19 030	19 641	20 255	20 872
400	20 872										

C Thermocouple										μV	ITS-90
°C	0	10	20	30	40	50	60	70	80	90	100
0	0	135	273	413	555	699	846	994	1 145	1 297	1 451
100	1 451	1 608	1 766	1 926	2 087	2 251	2 415	2 582	2 750	2 919	3 090
200	3 090	3 262	3 436	3 610	3 786	3 963	4 141	4 321	4 501	4 682	4 865
300	4 865	5 048	5 232	5 417	5 603	5 789	5 976	6 164	6 353	6 542	6 732
400	6 732	6 922	7 113	7 305	7 497	7 689	7 882	8 075	8 269	8 463	8 657
500	8 657	8 851	9 046	9 241	9 436	9 631	9 827	10 022	10 218	10 413	10 609
600	10 609	10 804	10 999	11 195	11 390	11 585	11 780	11 974	12 169	12 364	12 559
700	12 559	12 753	12 947	13 141	13 335	13 529	13 723	13 916	14 109	14 301	14 494
800	14 494	14 686	14 878	15 069	15 260	15 451	15 641	15 831	16 021	16 210	16 398
900	16 398	16 587	16 775	16 962	17 149	17 335	17 521	17 707	17 892	18 076	18 260
1000	18 260	18 444	18 627	18 809	18 991	19 172	19 353	19 533	19 713	19 892	20 071
1100	20 071	20 249	20 426	20 603	20 779	20 955	21 130	21 305	21 479	21 652	21 825
1200	21 825	21 997	22 169	22 340	22 510	22 680	22 849	23 018	23 186	23 353	23 520
1300	23 520	23 686	23 852	24 017	24 181	24 345	24 508	24 671	24 833	24 994	25 155
1400	25 155	25 315	25 475	25 633	25 792	25 949	26 107	26 263	26 419	26 574	26 729
1500	26 729	26 883	27 037	27 190	27 342	27 493	27 645	27 795	27 945	28 094	28 243
1600	28 243	28 391	28 538	28 685	28 831	28 977	29 122	29 266	29 410	29 553	29 696
1700	29 696	29 838	29 979	30 120	30 260	30 399	30 538	30 676	30 813	30 950	31 087
1800	31 087	31 222	31 357	31 491	31 625	31 758	31 890	32 022	32 153	32 283	32 413
1900	32 413	32 542	32 670	32 797	32 924	33 050	33 175	33 300	33 424	33 547	33 669
2000	33 669	33 791	33 911	34 031	34 151	34 269	34 387	34 503	34 619	34 734	34 849
2100	34 849	34 962	35 074	35 186	35 296	35 406	35 515	35 623	35 730	35 836	35 940
2200	35 940	36 044	36 147	36 249	36 350	36 449	36 548	36 645	36 742	36 837	36 931
2300	36 931	37 024									

Remarks : The EMF tables given above completely conform to the following standards

JIS C 1602 (Japan) IEC 584-1 (International) ASTM E 230 (U.S.A.)

(C Thermocouple is specified in JIS C1602, IEC and ASTM standards issued in 2015.)

9.2 Color Codes for Compensating Cables

Table 15 Color Codes for Compensating Cables

Combined Thermo- couple	Material		JIS C 1610:2012 IEC 60584-3:2007				JIS C 1610:1995 Division 2				ASTM E230-2012				
			Code	Insulator		Sheath	Code	Insulator		Sheath	Insulator		Sheath		
	+	-		+	-			+	-		+	-			
B	Cu	Cu	BC	Grey	W	Grey	BC	Red	W	Grey	Grey	Red	Grey		
R	Cu	Cu-Ni	RCA /RCB	Orange		Orange	RCA /RCB			Black	Black		Green		
S	Cu	Cu-Ni	SCA /SCB	Orange		Orange	SCA /SCB			Black	Black		Green		
N	Ni-Cr	Ni-Si	NX	Pink		Pink	NX			-	-		-	Orange	Orange
K	Ni-Cr	Ni-Al	KX	Green		Green	KX			Red	W		Blue	Yellow	Yellow
	Ni-Cr	Ni-Al	-	-	-	KCA	-	-	-						
	Fe	Cu-Ni	KCA	Green	Green	KCB	-	-	-						
	Cu	Cu-Ni	KCB		Green	KCC	-	-	-						
E	Ni-Cr	Cu-Ni	EX	Purple	W	Purple	EX	Red	W	Purple	Purple	Red	Purple		
J	Fe	Cu-Ni	JX	Black		Black	JX			Yellow	W		Black		
T	Cu	Cu-Ni	TX	Brown		Brown	TX			Brown	Blue		Blue		

9.3 Tolerance of Thermocouples

Table 16 Thermocouple Tolerances

Type	JIS C 1602:2015 / IEC 60584-2:2013			ASTM E 230-2012		
	Temp. Range	Class	Tolerance	Temp. Range	Class	Tolerance
B	600°C ~ 1700°C	2	$\pm 0.0025 t ^\circ\text{C}$	870°C ~ 1700°C	STD.	$\pm 0.5\%$
	600°C ~ 800°C	3	$\pm 4^\circ\text{C}$			
	800°C ~ 1700°C		$\pm 0.005 t ^\circ\text{C}$			
R & S	0°C ~ 1600°C	1	$\pm 1^\circ\text{C}$ or $\pm [1 + 0.003 (t - 1100)]^\circ\text{C}$	0°C ~ 1480°C	SP.	$\pm 0.6^\circ\text{C}$ or $\pm 0.1\%$
	0°C ~ 600°C	2	$\pm 1.5^\circ\text{C}$		STD.	$\pm 1.5^\circ\text{C}$ or $\pm 0.25\%$
	600°C ~ 1600°C		$\pm 0.0025 t ^\circ\text{C}$			
C	426°C ~ 2315°C	2	$\pm 0.01 t ^\circ\text{C}$	0°C ~ 2315°C	STD.	$\pm 4.4^\circ\text{C}$ or $\pm 1\%$
N & K	-40°C ~ 375°C	1	$\pm 1.5^\circ\text{C}$	0°C ~ 1260°C	SP.	$\pm 1.1^\circ\text{C}$ or $\pm 0.4\%$
	375°C ~ 1000°C		$\pm 0.004 t ^\circ\text{C}$			
	-40°C ~ 333°C	2	$\pm 2.5^\circ\text{C}$		STD.	$\pm 2.2^\circ\text{C}$ or $\pm 0.75\%$
	333°C ~ 1200°C		$\pm 0.0075 t ^\circ\text{C}$			
	-167°C ~ 40°C	3	$\pm 2.5^\circ\text{C}$	-200°C ~ 0°C	STD.	$\pm 2.2^\circ\text{C}$ or $\pm 2\%$
	-200°C ~ -167°C		$\pm 0.015 t ^\circ\text{C}$			
E	-40°C ~ 375°C	1	$\pm 1.5^\circ\text{C}$	0°C ~ 870°C	SP.	$\pm 1.0^\circ\text{C}$ or $\pm 0.4\%$
	375°C ~ 800°C		$\pm 0.004 t ^\circ\text{C}$			
	-40°C ~ 333°C	2	$\pm 2.5^\circ\text{C}$		STD.	$\pm 1.7^\circ\text{C}$ or $\pm 0.5\%$
	333°C ~ 900°C		$\pm 0.0075 t ^\circ\text{C}$			
	-167°C ~ 40°C	3	$\pm 2.5^\circ\text{C}$	-200°C ~ 0°C	STD.	$\pm 1.7^\circ\text{C}$ or $\pm 1\%$
	-200°C ~ -167°C		$\pm 0.015 t ^\circ\text{C}$			
J	-40°C ~ 375°C	1	$\pm 1.5^\circ\text{C}$	0°C ~ 760°C	SP.	$\pm 1.1^\circ\text{C}$ or $\pm 0.4\%$
	375°C ~ 750°C		$\pm 0.004 t ^\circ\text{C}$			
	-40°C ~ 333°C	2	$\pm 2.5^\circ\text{C}$		STD.	$\pm 2.2^\circ\text{C}$ or $\pm 0.75\%$
	333°C ~ 750°C		$\pm 0.0075 t ^\circ\text{C}$			
T	-40°C ~ 125°C	1	$\pm 0.5^\circ\text{C}$	0°C ~ 370°C	SP.	$\pm 0.5^\circ\text{C}$ or $\pm 0.4\%$
	125°C ~ 350°C		$\pm 0.004 t ^\circ\text{C}$			
	-40°C ~ 133°C	2	$\pm 1.0^\circ\text{C}$		STD.	$\pm 1.0^\circ\text{C}$ or $\pm 0.75\%$
	133°C ~ 350°C		$\pm 0.0075 t ^\circ\text{C}$			
	-67°C ~ 40°C	3	$\pm 1.0^\circ\text{C}$	-200°C ~ 0°C	STD.	$\pm 1.0^\circ\text{C}$ or $\pm 1.5\%$
	-200°C ~ -67°C		$\pm 0.015 t ^\circ\text{C}$			

- 1) Tolerance is referred to as the maximum allowable deviation between hot junction temperature and the temperature derived from the EMF table.
- 2) ASTM temperature is $^\circ\text{C}$ or % value for the measured temperature, which is greater.
- 3) $| t |$ is the measuring temperature indicated by the temperature irrelevant to the symbol + or -.
- 4) Class 1, 2, or 3 conforms to the old JIS Class 0.4, 0.75 or 1.5, respectively.
- 5) JIS Standard is identical with IEC, BS or DIN Standard except for a part.
- 6) The tolerance of JISC1605 and JISC1602 is completely the same.
- 7) ASTM Standard is same as the old ANSI Standard.
- 8) Tolerances given in this table apply only to new wire as delivered to the user and do not allow for changes in characteristics with use. (ASTM E230)
- 9) The standard tolerances shown do not apply to Type E mineral-insulated, metal-sheathed (MIMS) thermocouples and thermocouple cables as described in Specifications E608/E608M and E585/E585M. The standard tolerances for MIMS Type E constructions are the greater of 2.2°C or 0.75 % from 0 to 870°C and the greater of 2.2°C or 2 % from -200 to 0°C .

9.4 Resistance Thermometer Sensor Reference Resistance Value Table

Table 17 JIS C 1604-1997/ IEC 60751-2008 Reference Resistance Value

Pt100 at 0°C				R100/10=1.3851			Unit Ω		ITS-90		
°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
-200	18.52										
-100	60.26	56.19	52.11	48.00	43.88	39.72	35.54	31.34	27.10	22.83	18.52
0	100.00	96.09	92.16	88.22	84.27	80.31	76.33	72.33	68.33	64.30	60.26
°C	0	10	20	30	40	50	60	70	80	90	100
0	100.00	103.90	107.79	111.67	115.54	119.40	123.24	127.08	130.90	134.71	138.51
100	138.51	142.29	146.07	149.83	153.58	157.33	161.05	164.77	168.48	172.17	175.86
200	175.86	179.53	183.19	186.84	190.47	194.10	197.71	201.31	204.90	208.48	212.05
300	212.05	215.61	219.15	222.68	226.21	229.72	233.21	236.70	240.18	243.64	247.09
400	247.09	250.53	253.96	257.38	260.78	264.18	267.56	270.93	274.29	277.64	280.98
500	280.98	284.30	287.62	290.92	294.21	297.49	300.75	304.01	307.25	310.49	313.71
600	313.71	316.92	320.12	323.30	326.48	329.64	332.79	335.93	339.06	342.18	345.28
700	345.28	348.38	351.46	354.53	357.59	360.64	363.67	366.70	369.71	372.71	375.70
800	375.70	378.68	381.65	384.60	387.55	390.48					

Table 18 JIS C 1604-1989 Reference Resistance Value

JPt100 at 0°C				R100/10=1.3916			Unit Ω		IPTS-68		
°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
-200	17.14										
-100	59.57	55.44	51.29	47.11	42.91	36.68	34.42	30.12	25.80	21.46	17.14
0	100.00	96.02	92.02	88.01	83.99	79.96	75.91	71.85	67.77	63.68	59.57
°C	0	10	20	30	40	50	60	70	80	90	100
0	100.00	103.97	107.93	111.88	115.81	119.73	123.64	127.54	131.42	135.30	139.16
100	139.16	143.01	146.85	150.67	154.49	158.29	162.08	165.86	169.63	173.38	177.13
200	177.13	180.86	184.58	188.29	191.99	195.67	199.35	203.01	206.66	210.30	213.93
300	213.93	217.54	221.15	224.74	228.32	231.89	235.45	238.99	242.53	246.05	249.56
400	249.56	253.06	256.55	260.02	263.49	266.94	270.38	273.80	277.22	280.63	284.02
500	284.02	287.40									

9.5 Resistance Thermometer Sensor Tolerances

Table 19 Resistance Thermometer Sensor Tolerances

(Temperature range of wire-wound resistance element shall be in accordance with company standards)

Nominal resistance	Class	Tolerance (°C)	JIS C 1604:1997 IEC 751-1983	IEC 60751:2008		ASTM E 1137
				Wire wound resistor	Thin film resistor	
			Temperature range (°C)			
Pt 100Ω at 0°C (R100/R0=1.3851)	AA	± 0.1+0.0017 t	-	-196~450	0~150	-
	A	± 0.15+0.002 t	-200~500	-196~450	-30~300	-
		± 0.13+0.0017 t	-	-	-	-200~650
	B	± 0.3+0.005 t	-200~500	-196~600	-50~500	-
		± 0.25+0.0042 t	-	-	-	-200~650
C	± 0.6+0.01 t	-	-196~600	-50~600	-	

Remarks

- (1) Only the tolerances for resistance elements shall be specified in IEC 60751:2008/JIS C1604:2013
- (2) Since the criteria considering the uncertainty is incorporated in IEC 60751:2008/JIS C 1604:2013, the value from the specified tolerance minus our uncertainty shall be the our tolerances at the time of delivery. In the company, as of April 2015, the uncertainty at 0 °C shall be 0.03 °C in all factories. If the length of sheath part is 700 mm or less, the uncertainty shall be 0.03 °C even if the B and b terminal is replaced.

9.6 Major Standards List

Table 20 Major standards list

Type	Country	Symbol	Number	Year	Name of standard
Thermocouple	Japan	JIS	C 1602	1995	Thermocouples
		JIS	C 1605	1995	Mineral insulated thermocouples
	I.N.	IEC	60584-1	1995	Thermocouples Part 1:Reference Tables (Ed.2.0b:1995)
		IEC	60584-2	1982	Thermocouples Part 2: Tolerances (Amd.1 Ed.1.0b:1989)
		IEC	61515	1995	Mineral insulated thermocouple cables and thermocouples (Ed.1.0b: 1995)
	USA	ANSI / ISA	MC96.1	1982	TEMPERATURE MEASUREMENT THERMOCOUPLES (Latest year : 1982→ Move to ASTM E230)
		ASTM	E230	2012	Temperature-Electromotive Force (EMF) Tables for Standardized thermocouples
		ASTM	E608	2006	Standard Specification for Metal-Sheathed Base-Metal Thermocouples (Reapproved-2004)
	G.B.	BS	4937	Deleted	Part1~ Part8: Reference Tables (Move to BS EN 60584-1)
		BS EN	60584-1	1996	Thermocouples Part 1:Reference Tables
		BS EN	60584-2	1993	Thermocouples Part 2:Tolerances
		BS EN	61515	1996	Mineral insulated thermocouple cables and thermocouples
	Germany	DIN	43710	Deleted	Measurement and control; electrical temperature sensors; Reference Tables (Latest year :1985)
		DIN	43721	1980	Measurement and control; electrical temperature sensors; mineral insulated thermo cables and mineral insulated thermocouples
		DIN EN	60584-1	1996	Thermocouples Part 1:Reference Tables
		DIN EN	60584-2	1994	Thermocouples Part 2: Tolerances
		DIN EN	61515	1996	Mineral insulated thermocouple cables and thermocouples
Compensation cable	Japan	JIS	C1610	2012	Extension and compensating cables for thermocouples
	I.N.	IEC	60584-3	2007	Thermocouples Part 3:Extension and compensating cables-Tolerance and identification system (Ed.2.0b: 2007)
	G.B.	BS EN	60584-3	2008	Thermocouples Part 3:Extension and compensating cables-Tolerance and identification system
	Germany	DIN EN	60584-3	2008	Thermocouples Part 3:Extension and compensating cables-Tolerance and identification system
Resistance thermometer	Japan	JIS	C 1604	1997	Resistance thermometer sensors
		JEM	1252	2000	Platinum resistance thermometer sensors for rotating electrical machines
	I.N.	IEC	60751	2008	Industrial platinum resistance thermometer sensors (Amd. 2.Ed2.0b: 2008)
	USA	SAMA	RC21-4	1966	Temperature-resistance values for resistance thermometer element of platinum, nickel and copper
		ASTM	E1137	2004	Standard Specification for industrial Platinum Resistance Thermometers
	G.B.	BS EN	60751	2008	Industrial platinum resistance thermometers and platinum temperature sensors
	Germany	DIN	43760	Deleted	Electrical temperature sensors; resistance tables for sensing resistors for resistance elements (Latest: 1987, Move to DIN EN 60751)
		DIN EN	60751	2009	Industrial platinum resistance thermometers and platinum temperature sensors
Other	Japan	JIS	Z 8704	1993	Temperature measurement-electrical methods
		JIS	Z 8710	1993	Temperature measurement-general requirement
	USA	ASME	PTC 19.3	1974	Part3: Temperature Measurement (instruments and apparatus) reaffirmed 1986
		ASTM	E644	2004	Standard test Method for Testing industrial Resistance Thermometers
	G.B.	BS	1041-3	1989	Part3: Guide to selection and use of industrial Resistance Thermometers
		BS	1041-4	1992	Part4: Guide to selection and use of thermocouples

Note: For a certain reason, the standard issue year of this data should also give me as reference the standard which is not owned at our company.

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contact the above-mentioned address.**

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E-mail : sales@okazaki-mfg.com

WARRANTY

Our products have cleared proper inspection conducted by us in accordance with the standards established by our company. Should any irregularity of the Products take place, however, please contact our branch offices or business offices nearly your places.

PERIOD OF WARRANTY

Period of warranty will be limited to one year from the date of the delivery.

SCOPE OF WARRANTY

Should any irregularity of the Products take place during the foregoing period of warranty, such Products will be either replaced with new ones or repaired by our judgment. However, if the irregularity happened due to any of the following, such Products will not be covered by the foregoing warranty.

- (1) improper use or handling of the Products*
- (2) any reason irrelevant to the Products*
- (3) remodeling, alteration or repair by other person or company*
- (4) products were the ones manufactured for the purpose of consumption (expendable supply)*
- (5) irregularities of the Products were caused by fire, accident or any other natural reason such as act of god*

In addition, the foregoing warranty is limited to the replacement or repair of the Products of irregularity and excludes compensation of any other indirect or consequential damage.

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