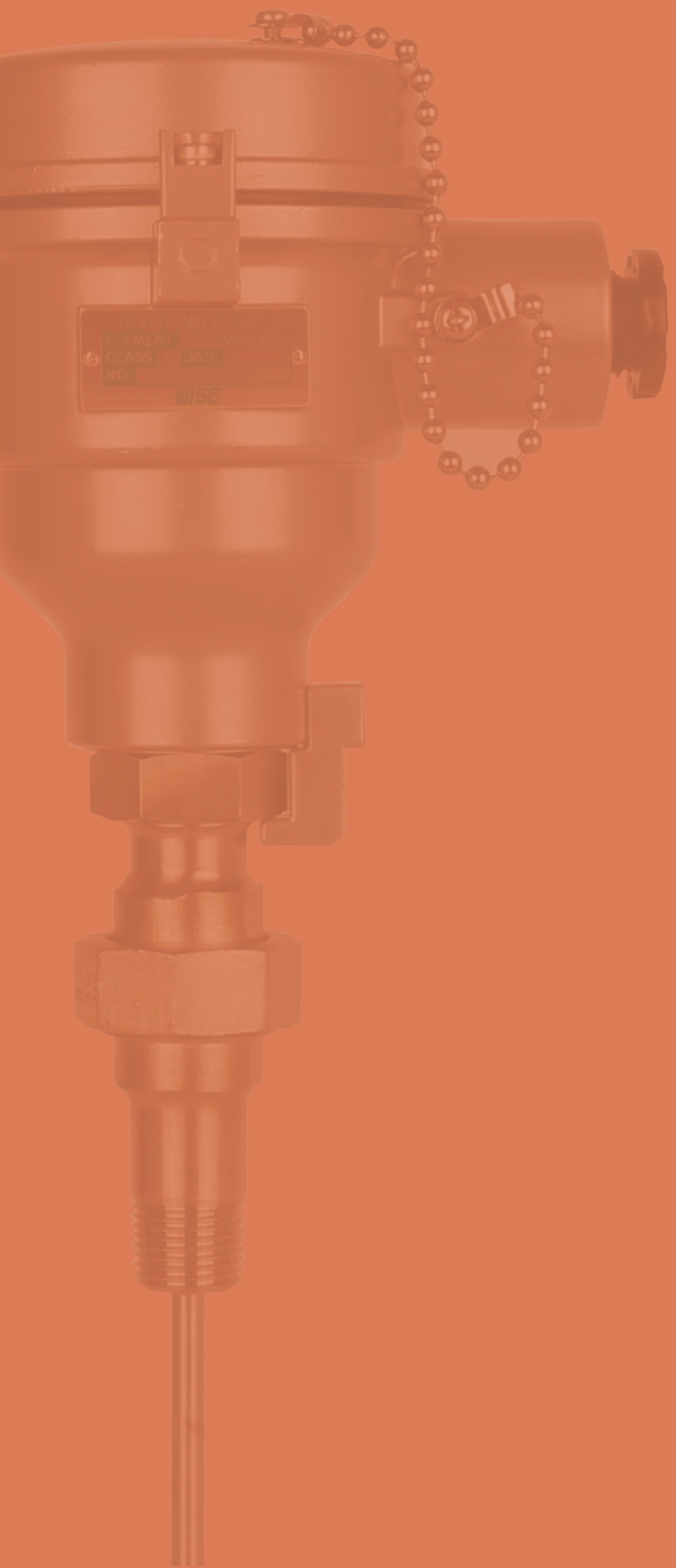


Thermocouple and RTD

WISE®

Contents

Thermocouple and Resistance temperature detectors

Thermocouples

Introduction

When two dissimilar conductors are connected together to form a closed circuit and the two junctions are kept in different temperatures, thermal electromotive force (EMF) is generated in the circuit (Seebeck's effect) Thus, when one end (Cold Junction) is kept constant at a certain temperature, normally at 0 °C , and the other end (Measuring Junction) is exposed to unknown temperature, the temperature at latter end can be determined by measurement of EMF so generated. This combination of two dissimilar conductors are called "Thermocouple"

1. Characteristics

-Type T (Copper vs constantan) : -200 ~ 350 °C
Is used for service in oxidizing, inert or reducing atmospheres or in vacuum. It is highly resistant to corrosion from atmospheric moisture and condensation and exhibits high stability at low temperatures; It is the only type with limits of error guaranteed for cryogenic temperatures.

-Type J (Iron vs constantan) : 0 ~ 750 °C
Is used protected or unprotected in vacuum, oxidizing, inert or reducing atmospheres.
Iron element oxidizes rapidly at temperatures exceeding 1,000 °C, and therefore heavier gauge wire is recommended for longer life at these temperatures.

-Type E (Chromel vs constantan) : -200 ~ 900 °C
May be used protected or unprotected in oxidizing, inert or dry reducing atmospheres, or for short periods of time under vacuum. Must be protected from sulfurous and degree of any standardized thermocouple.

-Type K (Chromel vs alumel) : -200 ~ 1,250 °C
Is used protected or exposed in oxidizing, inert or dry reducing atmospheres. Exposure to vacuum limited to short time periods. Must be protected from sulfurous and marginally oxidizing atmospheres. Reliable and accurate at high temperatures.

-Type N (Nicrosil / Nisil) : -200 ~ 1,250 °C
Type N thermocouple exhibits superior long-term stability and oxidation resistance over type K when use at high temperaturesraging 600 ~ 1,250 °C
By virture of fine adjustment of chromium content with additions of Si and Mg, it has less EMF shift in the region of “short range ordering” and also resistant to “Green rot” corrosion. In comparison with type K, rate of EMF drift is reported to be half or one third over the range of 1,000 °C and therefore recommended for use in oxidizing atmospere of 1,000 ~ 1,200 °C continuous.

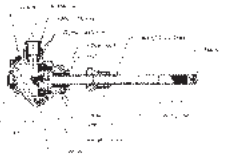
-Type S (Platinum, rhodium 10 % vs platinum)
: 0 ~ 1,600 °C
-Type R (Platinum, rhodium 13 % vs platinum)
: 0 ~ 1,600 °C
-Type B (Platinum, rhodium 30 % vs platinum 6 % rhodium)
: 600 ~ 1,700 °C
are all recommended for use in inert or oxidizing atmosphere, or for short periods of time in a vacuum. Easily contaminated, these elements must be protected from the effects of reducing atmospheres and contaminating vapors. Alumina protecting tubes are recommended for directly containing platinum elements.

Ref : JIS C 1602-1995
IEC-Pub584-2
ASTM E988-1996

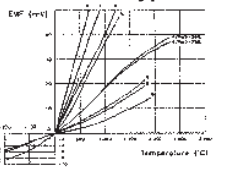
Type	Alloy composite of the conductors	
	Positive (+) leg	Negative (-) leg
B	BP (70 % Platinum / 30% rhodium)	BN (94 % Platinum / 6 % rhodium)
R	RP (87 % Platinum / 13 % rhodium)	RN (100 % Platinum)
S	SP (90 % Platinum / 10 % rhodium)	SN (100 % Platinum)
K	KP (90 % Ni / 10 % Cr)	KN (95 % Ni / 2 % Mn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

Note:
'Thermocouples and thermocouple material are normally supplied to meet the tolerances specified in the table for the normal specified range.
The same materials, however, may not fall within the cryogenic tolerances in the second section of the table.
If materials are required:o meet the cryogenic tolerances, the purchase order must so state. selection of materials usually will be required.
Tolerances indicated in this table are not necessarily an indication or the accuracy of temperature measurements in use after initial heating of the materials.
"Little information is available to justify establishing special tolerances for cryogenic temperatures. Limited experience suggests the following tolerances for Types E and T thermocouples:
Type E -200 to 0 °C: +/- 1 °C or +/-5 % (whichever is greater)
Type T -200 to 0 °C: +/-0.5 °C or +/-0.8 % (whichever is greater)
These tolerances are given only as guide for discussion between purchaser and supplier.
Due to the characteristics
of the materials, cryogenic tolerances for Type J thermocouples and special cryogenic tolerances for Type K thermocouples are not listed.

2. Structure



3. EMF chart typical thermocouple



4. Tolerance on temperature reading

4.1 JIS C1602-1995 IEC 584-2-1982 (Amendment 1-1989) BS/EN 60584-2-1993 DIN/IEC 584-2-1992

Type		Classfication of tolerances		
		Class 1	Class 2	Class 3
B	Temp. range	-	-	Above 600 ℃ below 800 ℃
	Tolerance	-	-	±4 ℃
	Temp. range	-	Above 600 ℃ below 1700 ℃	Above 600 ℃ below 1700 ℃
	Tolerance	-	±0.0025 * | t |	±0.005 * | t |
	Previous class	-	-	Class 0.5
R	Temp. range	*Above 1100 ℃ below 1600 ℃	Above 0 ℃ below 600 ℃	-
	Tolerance	±[1+0.003(t-1100)]	±1.5 ℃	-
S	Temp. range	Above 0 ℃ below 1100 ℃	Above 600 ℃ below 1600 ℃	-
	Tolerance	±1 ℃	±0.0025 * | t |	-
	Previous class	-	Class 0.25	-
N	Temp. range	Above -40 ℃ below 375 ℃	Above -40 ℃ below 333 ℃	Above -167 ℃ below 40 ℃
	Tolerance	±1.5 ℃	±2.5 ℃	±2.5 ℃
	Temp. range	Above 375 ℃ below 1000 ℃	Above 333 ℃ below 1200 ℃	Above -200 ℃ below -167 ℃
	Tolerance	±0.004 * | t |	±0.0075 * | t |	±0.015 * | t |
K	Temp. range	Above -40 ℃ below 375 ℃	Above -40 ℃ below 333 ℃	Above -167 ℃ below 40 ℃
	Tolerance	±1.5 ℃	±2.5 ℃	±2.5 ℃
	Temp. range	Above 375 ℃ below 1000 ℃	Above 333 ℃ below 1200 ℃	Above -200 ℃ below -167 ℃
	Tolerance	±0.004 * | t |	±0.0075 * | t |	±0.015 * | t |
	Previous class	Class 0.4	Class 0.75	Class 1.5
E	Temp. range	Above -40 ℃ below 375 ℃	Above -40 ℃ below 333 ℃	Above -167 ℃ below 40 ℃
	Tolerance	±1.5 ℃	±2.5 ℃	±2.5 ℃
	Temp. range	Above 375 ℃ below 800 ℃	Above 333 ℃ below 900 ℃	Above -200 ℃ below -167 ℃
	Tolerance	±0.004 * | t |	±0.0075 * | t |	±0.015 * | t |
	Previous class	Class 0.4	Class 0.75	Class 1.5
J	Temp. range	Above -40 ℃ below 375 ℃	Above -40 ℃ below 333 ℃	-
	Tolerance	±1.5 ℃	±2.5 ℃	-
	Temp. range	Above 375 ℃ below 750 ℃	Above 333 ℃ below 750 ℃	-
	Tolerance	±0.004 * | t |	±0.0075 * | t |	-
	Previous class	Class 0.4	Class 0.75	-
T	Temp. range	Above -40 ℃ below 125 ℃	Above -40 ℃ below 133 ℃	Above -67 ℃ below 40 ℃
	Tolerance	±1.5 ℃	±1 ℃	±1 ℃
	Temp. range	Above 125 ℃ below 350 ℃	Above 133 ℃ below 350 ℃	Above -200 ℃ below -67 ℃
	Tolerance	±0.004 * | t |	±0.0075 * | t |	±0.015 * | t |
	Previous class	Class 0.4	Class 0.75	Class 1.5

Note:
1. Tolerance denotes the maximum allowable value obtained by subtracting the temperature reading or the temperature at the hot function from the standard temperature converted from the applicable temperature EMF table.
* not standardized yet by JIS
2. Tolerance class 1 for types R and S only apply to the standard or reference thermocouple.
3. \| t \| denotes the value of temperature (℃) irrespective of positive (+) or negative (-) sign.
4. Tolerances listed in this page apply to the new thermocouple wires.

4.2 Tolerance on temperature reading to ASTM E230-1998, E988-1996

Type		Tolerance grades	
		Standard (Which is greater)	Special (Which is greater)
W5	Above 426 ℃ below 2,315 ℃	±1 %	-
B	Above 870 ℃ below 1,700 ℃	±0.5 %	±0.25 %
R.S	Above 0 ℃ below 1,480 ℃	±1.5 ℃ or ±0.5 %	±0.6 ℃ or ±0.1 %
N	Above 0 ℃ below 1,260 ℃	±2.2 ℃ or ±0.75 %	±1.1 ℃ or ±0.4 %
K	Above -200 ℃ below 0 ℃	±2.2 ℃ or ±2 %	-
	Above 0 ℃ below 1,260 ℃	±2.2 ℃ or ±0.75 %	±1.1 ℃ or ±0.4 %
E	Above -200 ℃ below 0 ℃	±1.7 ℃ or ±1 %	-
	Above 0 ℃ below 870 ℃	±1.7 ℃ or ±0.5 %	±1.0 ℃ or ±0.4 %
J	Above 0 ℃ below 760 ℃	±2.2 ℃ or ±0.75 %	±1.1 ℃ or ±0.4 %
T	Above -200 ℃ below 0 ℃	±1.0 ℃ or ±0.5 %	-
	Above 0 ℃ below 370 ℃	±1.0 ℃ or ±0.75 %	±0.5 ℃ or ±0.4 %

5. Typical resistance of standard thermocouple

Ref : JIS C 1602 * Hoskins unit: /m

AWG wire dia. (mm)		Type / Old JIS type B	R PR	S	K CA	E CRC	J IC	T CC	N*
28	0.32	•	•	•	•	•	•	6.17	16.43
24	0.50	1.75	1.47	1.43	•	•	•	•	6.50
22	0.65	•	•	•	2.95	3.56	1.70	1.50	4.08
18	1.00	•	•	•	1.25	1.50	0.72	0.63	1.62
14	1.60	•	•	•	0.49	0.59	0.28	0.25	0.64
11	2.30	•	•	•	0.24	0.28	0.14	•	0.32
8	3.20	•	•	•	0.12	0.15	0.07	•	0.13

Note. Resistance at 0℃ (Ro) measured between (+) and (-) legs.

6. Operating and maximum temperature limits

Type	Wire diameter (mm)	Operating temp. Limit (℃) (1)	Maximum limit (℃) (2)
B	0.50	1,500	1,700
R	0.50	1,400	1,600
S	0.50	1,400	1,600
K	0.65	650	850
	1.00	750	950
	1.60	850	1,050
	2.30	900	1,100
	3.20	1,000	1,200
E	0.65	450	500
	1.00	500	550
	1.60	550	650
	2.30	600	750
	3.20	700	800
J	0.65	400	500
	1.00	450	550
	1.60	500	650
	2.30	550	750
	3.20	600	750
T	0.32	200	250
	0.65	200	250
	1.00	250	300
	1.60	300	350
N	1.60	900	1,100
	2.30	1,100	1,200
	3.20	1,200	1,300

Note : 1. Operating temperature limit means the upper temperature, where thermocouple can be used continuously in air.
2. Maximum limit means the upper temp, where thermocouple can be used temporarily owing to inevitable circumstances.

7. Protection tubes

Metallic tubes

Material	Operating temp. (℃)	Maximum temp. (℃)
304SS	900	1,000
316SS	900	1,000
321SS	900	1,000
310SS	950	1,050
347SS	900	1,000
446SS	1,050	1,125
Inconel 600	1,180	1,250
Inconel 800	870	1,000
Hastelloy-C	1,000	1,100
Hastelloy-B	800	1,100
Titanium	Oxi.250 red.1,000	
Monel	500	600
Tantalum	Oxi.300 red.2,200	
A182 F11	565	
A182 F22	593	

Non-metallic tubes

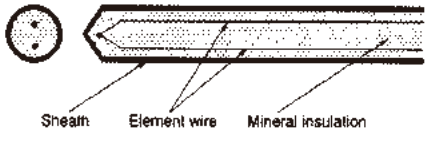
Material	Symbol	Operating temp. (℃)
Recrystallized silicon carbide	GK-SIC	1,600
Self-bonded silicon carbide	SI-SIC	1,650
Clay-bonded silicon carbide	Y3-SIC	1,500
Recrystallized alumina	SSA-S	1,600
Mulite	HB	1,500

8. Sheathed thermocouple

Sheathed Thermocouple is one sheathed thermocouple that is composed of a fine gauged metal sheath in which high purity MgO powder is tightly compacted around thermoelement wires.
Sheathed thermocouple has high insulation and pressure resistance. It has also high reliability because of its EMF tolerance falling within the limits stipulated by JIS, ANSI, BS, DIN, etc.

Features

- Quick response:
  By virtue of its integrated structure composed of thermoelement wires insulating material and a protection tube, one has very quick response to temperature change.
- High flexibility and mechanical strength:
  With its tightly compacted from, sheathed thermocouple has mechanical strength and pliability up to bending radius equal to 2 time of the sheath O.D
- Excellent resistance to heat Corrosion and Pressure
  As high purity MgO powder is tightly compacted in a heat resistant metal tube, Sheath thermocouple is highly gas-tight, no corrosion from surrounding atmospheres and withstand high pressures up to 500 kg / cm².
- Wide selection of cable specifications :
  From very fine gauge of 0.25 mm to 12.7 mm in O.D. and up to 300 meters in length are available.
  Thermoelement wires of 2-pair and 3-pair are also available.



Grounded

Thermoelement wires are welded together directly at hot end of the sheath to form a hot junction

Quick response and suitable at high temperature and pressure but not recommendable for use in critical and noise generating field.

Ungrounded

Thermoelement wires are welded together to form a hot junction which is completely insulated from the sheath.

Slower response than grounded but less aging deterioration of EMF and good for long service in critical and noise generating field.

Exposed

Both ends of thermoelement wires are welded together to form a hot junction protruding from sheath.

Quickest response and can detect even slight temperature change but not usable for long time in corrosive, high temperature and high pressure atmospheres.

- Operating temperature and typical resistance of sheathed thermocouple

Sheath outer diameter	K			T		J		E		
	Operating temp.		Resistance Ω/m	Operating temp.	Resistance Ω/m	Operating temp.	Resistance Ω/m	Operating temp.		Resistance Ω/m
	316SS 347SS	310SS Inconel		316SS		316SS 347SS		316SS 347SS	Inconel	
1.0 mm	450 ℃	•	31.8	200 ℃	16.2	250 ℃	19.4	450 ℃	•	38.0
1.6 mm	600 ℃	700 ℃	12.4	250 ℃	6.3	350 ℃	7.6	600 ℃	700 ℃	14.9
3.2 mm	700 ℃	900 ℃	4.5	250 ℃	2.3	450 ℃	2.8	700 ℃	900 ℃	5.4
4.8 mm	800 ℃	1,000 ℃	2.2	300 ℃	1.1	500 ℃	1.3	800 ℃	1,000 ℃	2.6
6.4 mm	850 ℃	1,050 ℃	1.0	300 ℃	0.5	550 ℃	0.6	850 ℃	1,050 ℃	1.2
8.0 mm	900 ℃	1,050 ℃	0.8	300 ℃	0.4	600 ℃	0.5	900 ℃	1,050 ℃	0.9

Thermocouple EMF table

Type B Thermocouple

IEC-Pub584-2
ASTM E988-1996 Unit : mV

℃	0	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	℃
0	0.000	0.033	0.178	0.431	0.786	1.241	1.791	2.430	3.154	3.957	4.833	5.777	6.783	7.845	8.952	10.094	11.257	12.426	13.585	**0**
10	-0.002	0.043	0.199	0.462	0.827	1.292	1.851	2.499	3.231	4.041	4.924	5.875	6.887	7.953	9.065	10.210	11.374	12.543	13.699	**10**
20	-0.003	0.053	0.220	0.494	0.870	1.344	1.912	2.569	3.308	4.126	5.016	5.973	6.991	8.063	9.178	10.325	11.491	12.659	13.814	**20**
30	-0.002	0.065	0.243	0.527	0.913	1.397	1.974	2.639	3.387	4.212	5.109	6.073	7.096	8.172	9.291	10.441	11.608	12.776		**30**
40	0.000	0.078	0.266	0.561	0.957	1.450	2.036	2.710	3.466	4.298	5.202	6.172	7.202	8.283	9.405	10.558	11.725	12.892		**40**
50	0.002	0.092	0.291	0.598	1.002	1.505	2.100	2.782	3.546	4.386	5.297	6.273	7.308	8.393	9.519	10.674	11.842	13.008		**50**
60	0.006	0.107	0.317	0.632	1.048	1.560	2.164	2.855	3.626	4.474	5.391	6.374	7.414	8.504	9.634	10.790	11.959	13.124		**60**
70	0.011	0.123	0.344	0.669	1.095	1.617	2.230	2.928	3.708	4.562	5.487	6.475	7.521	8.616	9.748	10.907	12.076	13.239		**70**
80	0.017	0.140	0.372	0.707	1.143	1.674	2.296	3.003	3.790	4.652	5.583	6.577	7.628	8.727	9.863	11.024	12.193	13.354		**80**
90	0.025	0.159	0.401	0.746	1.192	1.732	2.363	3.078	3.873	4.742	5.680	6.680	7.736	8.839	9.974	11.141	12.310	13.470		**90**
100	0.033	0.178	0.431	0.786	1.241	1.791	2.430	3.154	3.957	4.833	5.777	6.783	7.845	8.952	10.094	11.257	12.426	13.585		**100**

Type S Thermocouple

IEC-Pub584-2
ASTM E988-1996 Unit : mV

℃	0	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	℃
0	0.000	0.645	1.440	2.323	3.260	4.234	5.237	6.274	7.345	8.448	9.585	10.754	11.947	13.155	14.368	15.576	16.771	17.942	**0**
10	0.055	0.719	1.525	2.414	3.356	4.333	5.339	6.380	7.454	8.560	9.700	10.872	12.067	13.276	14.489	15.697	16.890	18.056	**10**
20	0.113	0.795	1.611	2.506	3.452	4.432	5.442	6.486	7.563	8.673	9.816	10.991	12.188	13.397	14.610	15.817	17.008	18.170	**20**
30	0.173	0.872	1.698	2.599	3.549	4.532	5.544	6.592	7.672	8.786	9.932	11.110	12.308	13.519	14.731	15.937	17.125	18.282	**30**
40	0.235	0.950	1.785	2.692	3.645	4.632	5.648	6.699	7.782	8.899	10.148	11.229	12.429	13.640	14.852	16.057	17.243	18.394	**40**
50	0.299	1.029	1.873	2.786	3.743	4.732	5.751	6.805	7.892	9.012	10.165	11.348	12.550	13.761	14.973	16.176	17.360	18.504	**50**
60	0.365	1.109	1.962	2.880	3.840	4.832	5.855	6.913	8.003	9.126	10.282	11.467	12.671	13.883	15.094	16.296	17.477	18.612	**60**
70	0.432	1.190	2.051	2.974	3.938	4.933	5.960	7.020	8.114	9.240	10.400	11.587	12.792	14.004	15.215	16.415	17.594		**70**
80	0.502	1.273	2.141	3.069	4.036	5.034	6.064	7.128	8.225	9.355	10.517	11.707	12.913	14.125	15.336	16.534	17.711		**80**
90	0.573	1.356	2.232	3.164	4.135	5.136	6.169	7.236	8.336	9.470	10.635	11.827	13.034	14.247	15.456	16.653	17.826		**90**
100	0.645	1.440	2.323	3.260	4.234	5.237	6.274	7.345	8.448	9.585	10.754	11.947	13.155	14.368	15.576	16.771	17.942		**100**

Type R Thermocouple

IEC-Pub584-2
ASTM E988-1996 Unit : mV

℃	0	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	℃
0	0.000	0.647	1.468	2.400	3.407	4.471	5.582	6.741	7.949	9.203	10.503	11.846	13.224	14.624	16.035	17.445	18.842	20.215	**0**
10	0.054	0.723	1.557	2.492	3.511	4.580	5.696	6.860	8.072	9.331	10.636	11.983	13.363	14.765	16.176	17.585	18.981	20.350	**10**
20	0.111	0.800	1.647	2.596	3.616	4.689	5.810	6.979	8.196	9.460	10.768	12.119	13.502	14.906	16.317	17.726	19.119	20.483	**20**
30	0.171	0.879	1.738	2.695	3.721	4.799	5.925	7.098	8.320	9.589	10.902	12.257	13.642	15.047	16.458	17.866	19.257	20.616	**30**
40	0.232	0.959	1.830	2.795	3.826	4.910	6.040	7.218	8.445	9.718	11.035	12.394	13.782	15.188	16.599	18.006	19.395	20.748	**40**
50	0.296	1.041	1.923	2.896	3.933	5.021	6.155	7.339	8.570	9.848	11.170	12.532	13.922	15.329	16.741	18.146	19.533	20.878	**50**
60	0.363	1.124	2.111	2.997	4.039	5.132	6.272	7.460	8.696	9.978	11.304	12.669	14.062	15.470	16.882	18.286	19.670	21.006	**60**
70	0.431	1.208	2.207	3.099	4.146	5.244	6.388	7.582	8.822	10.109	11.439	12.808	14.202	15.611	17.022	18.425	19.807		**70**
80	0.501	1.294	2.141	3.201	4.254	5.356	6.505	7.703	8.949	10.240	11.574	12.946	14.343	15.752	17.163	18.564	19.944		**80**
90	0.573	1.380	2.303	3.304	4.362	5.469	6.623	7.826	9.076	10.371	11.710	13.085	14.483	15.893	17.304	18.703	20.080		**90**
100	0.647	1.468	2.400	3.407	4.471	5.582	6.741	7.949	9.203	10.503	11.846	13.224	14.624	16.035	17.445	18.842	20.215		**100**

Type K Thermocouple

IEC-Pub584-2
ASTM E988-1996 Unit : mV

℃	-100	0	℃	0	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	℃
0	-3.553	0.000	**0**	0.000	4.095	8.137	12.207	16.395	20.640	24.902	29.128	33.277	37.325	41.269	45.108	48.828	52.398	**0**
-10	-3.852	-0.392	**10**	0.397	4.508	8.537	12.623	16.818	21.066	25.327	29.547	33.686	37.724	41.657	45.486	49.192	52.747	**10**
-20	-4.138	-0.777	**20**	0.798	4.919	8.938	13.039	17.241	21.493	25.751	29.965	34.095	38.122	42.045	45.863	49.555	53.093	**20**
-30	-4.410	-1.156	**30**	1.203	5.327	9.341	13.456	17.664	21.919	26.176	30.383	34.502	38.519	42.432	46.238	49.916	53.439	**30**
-40	-4.699	-1.527	**40**	1.611	5.733	9.745	13.874	18.088	22.346	26.599	30.799	34.909	38.915	42.817	46.612	50.276	53.782	**40**
-50	-4.912	-1.898	**50**	2.022	6.137	10.151	14.292	18.513	22.772	27.022	31.214	35.314	39.310	43.202	46.985	50.633	54.125	**50**
-60	-5.141	-2.243	**60**	2.436	6.539	10.560	14.712	18.938	23.198	27.445	31.629	35.718	39.703	43.585	47.356	50.990	54.466	**60**
-70	-5.354	-2.586	**70**	2.850	6.939	10.969	15.132	19.363	23.624	27.867	32.042	36.121	40.096	43.968	47.726	51.344	54.807	**70**
-80	-5.550	-2.920	**80**	3.266	7.338	11.381	15.552	19.788	24.050	28.288	32.455	36.524	40.488	44.349	48.095	51.697		**80**
-90	-5.730	-3.242	**90**	3.681	7.737	11.793	15.974	20.214	24.476	28.709	32.866	36.925	40.879	44.729	48.462	52.049		**90**
-100	-5.891	-3.553	**100**	4.095	8.137	12.207	16.395	20.640	24.902	29.128	33.277	37.325	41.269	45.108	48.828	52.398		**100**

Type J thermocouple

IEC-Pub584-2
ASTM E988-1996 Unit : mV

℃	-100	0	℃	0	100	200	300	400	500	600	700	800	900	1,000	1,100	℃
0	-4.632	0.000	0	0.000	5.268	10.777	16.325	21.846	27.388	33.096	39.130	45.498	51.875	57.942	63.777	0
-10	-5.036	-0.501	10	0.507	5.812	11.332	16.879	22.397	27.949	33.683	39.754	46.144	52.496	58.533	64.355	10
-20	-5.426	-0.995	20	1.019	6.359	11.887	17.432	22.949	28.511	34.273	40.382	46.790	53.115	59.121	64.933	20
-30	-5.801	-1.481	30	1.536	6.907	12.442	17.984	23.501	29.075	34.867	41.013	47.434	53.729	59.708	65.510	30
-40	-6.159	-1.960	40	2.058	7.457	12.996	18.537	24.054	29.642	35.464	41.647	48.076	54.341	60.293	66.067	40
-50	-6.499	-2.431	50	2.585	8.008	13.553	19.089	24.607	30.210	36.066	42.283	48.716	54.948	60.876	66.664	50
-60	-6.821	-2.892	60	3.115	8.560	14.108	19.640	25.161	30.782	36.671	42.922	49.354	55.553	61.459	67.240	60
-70	-7.122	-3.344	70	3.649	9.113	14.663	20.192	25.716	31.356	37.280	43.563	49.989	56.155	62.039	67.815	70
-80	-7.402	-3.785	80	4.186	9.667	15.217	20.743	26.272	31.933	37.893	44.207	50.621	56.753	62.619	68.390	80
-90	-7.659	-4.215	90	4.725	10.222	15.771	21.295	26.829	32.513	38.510	44.852	51.246	57.349	63.199	68.964	90
-100	-7.890	-4.632	100	5.268	10.777	16.325	21.846	27.388	33.096	39.130	45.498	51.875	57.942	63.777	69.536	100

Type E thermocouple

IEC-Pub584-2
ASTM E988-1996 Unit : mV

℃	-100	0	℃	0	100	200	300	400	500	600	700	800	900	℃
0	-5.237	0.000	0	0.000	6.371	13.419	21.033	28.943	36.999	45.085	53.110	61.022	68.783	0
-10	-5.680	-0.581	10	0.591	6.996	14.161	21.814	29.744	37.808	45.891	53.907	61.806	69.549	10
-20	-6.107	-1.151	20	1.192	7.983	14.909	22.597	30.546	38.617	46.697	54.703	62.588	70.313	20
-30	-6.516	-1.709	30	1.801	8.377	15.661	23.383	31.350	39.426	47.502	55.498	63.368	71.075	30
-40	-6.907	-2.254	40	2.419	9.078	16.417	24.171	32.155	40.236	48.306	56.291	64.147	71.835	40
-50	-7.279	-2.787	50	3.047	9.787	17.178	24.961	32.960	41.045	49.109	57.083	64.924	72.593	50
-60	-7.631	-3.306	60	3.683	10.501	17.942	25.754	33.767	41.853	49.991	57.873	65.700	73.350	60
-70	-7.963	-3.811	70	4.329	11.222	18.710	26.549	34.574	42.662	50.713	58.663	66.473	74.104	70
-80	-8.273	-4.302	80	4.983	11.949	19.481	27.354	35.382	43.470	51.513	59.451	67.245	74.857	80
-90	-8.561	-4.777	90	5.646	12.681	20.256	28.143	36.190	44.278	52.312	60.237	68.015	75.608	90
-100	-8.824	-5.237	100	6.371	13.419	21.033	28.943	36.999	45.085	53.110	61.022	68.783	76.358	100

Type T thermocouple

IEC-Pub584-2
ASTM E988-1996 Unit : mV

℃	-200	-100	0	℃	0	100	200	300	℃
0	-5.603	-3.378	0.000	0	0.000	4.277	9.286	14.860	0
-10	-5.753	-3.656	-0.383	10	0.391	4.749	9.820	15.443	10
-20	-5.889	-3.923	-0.757	20	0.789	5.227	10.360	16.030	20
-30	-6.007	-4.177	-1.121	30	1.196	5.712	10.905	16.621	30
-40	-6.105	-4.419	-1.475	40	1.611	6.204	11.456	17.217	40
-50	-6.181	-4.648	-1.819	50	2.035	6.702	12.011	17.816	50
-60	-6.232	-4.865	-2.152	60	2.467	7.207	12.572	18.420	60
-70	-6.258	-5.069	-2.475	70	2.908	7.718	13.137	19.027	70
-80		-5.261	-2.788	80	3.357	8.235	13.707	20.252	80
-90		-5.439	-3.089	90	3.813	8.757	14.281	20.869	90
-100		-5.603	-3.378	100	4.277	9.286	14.860		100

Type N thermocouple

IEC-Pub584-2
ASTM E988-1996 Unit : mV

℃	0	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	℃
0	0.000	2.774	5.912	9.340	12.927	16.744	20.609	24.526	28.456	32.370	36.248	40.076	43.836	47.502	0
10	0.261	3.072	6.243	9.695	13.344	17.127	20.999	24.919	28.849	32.760	36.633	40.456	44.207		10
20	0.525	3.374	6.577	10.053	13.717	17.511	21.390	25.312	29.241	33.149	37.018	40.835	44.578		20
30	0.793	3.679	6.914	10.412	14.092	17.896	21.781	25.705	29.633	33.583	37.403	41.213	44.947		30
40	1.064	3.988	7.254	10.773	14.467	18.282	22.172	26.098	30.025	33.927	37.786	41.590	45.315		40
50	1.340	4.301	7.596	11.135	14.844	18.668	22.564	26.491	30.417	34.315	38.169	41.966	45.682		50
60	1.619	4.617	7.940	11.499	15.222	19.055	22.956	26.885	30.808	34.702	38.552	42.342	46.048		60
70	1.902	4.936	8.287	11.865	15.601	19.443	23.348	27.278	31.199	35.089	38.934	42.717	46.413		70
80	2.188	5.258	8.636	12.233	15.981	19.831	23.747	27.671	31.590	35.476	39.316	43.091	46.777		80
90	2.479	5.584	8.987	12.602	16.362	20.220	24.133	28.063	31.980	35.862	39.696	43.464	47.140		90
100	2.774	5.912	9.340	12.927	16.744	20.609	24.526	28.456	32.370	36.248	40.076	43.836	47.502		100

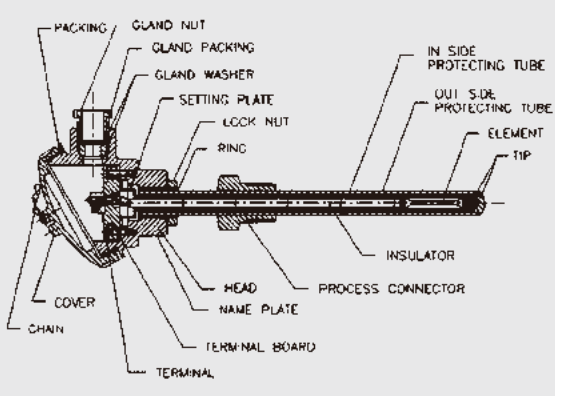
Resistance temperature detector

Introduction

Resistance temperature detectors (RTD's) operate under the principle the electrical resistance of certain metals increases or decreases in a repeatable and predictable manner with a temperature change.
RTD's may have a lower temperature range than some thermocouples and a slower response time however they are more stable and repeatable over long periods of time. RTD's are used in chemical and petrochemical industry, pulp and paper industry. RTD's are available in the same configurations as thermocouples to suit applications.

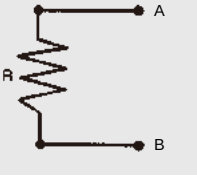
1. Structure

Metal wire that changes of its electric resistance to changes in temperature are utilized is called "Resistance wires"
This resistance wire, normally of platinum, is used for manufacturing a temperature sensor called "Resistance temperature detector (RTD) element". Generally speaking RTD is composed of RTD element, lead wire, protection tube and terminals.

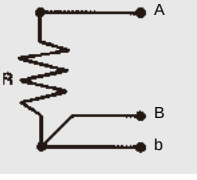


2. Lead wires connection method

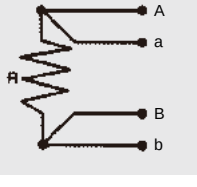
■ 2 wires connection :
One wire is connected to one end of the RTD. Generally used when the changes in lead wires resistance due to ambient temperature changes can be ignored.



■ 3 wires connection :
Two wires are connected to one end of the RTD and one wires to the other. This is the most commonly used. The third wire compensates for changes in lead wire resistance.



■ 4 wire connection
Two wires are connected to each end of the RTD
This type of connection is used for high precision measurements.



3. Temperature tolerance

Type	Nominal resistance (Ω at 0℃)	Resistance ratio R100 / R0	Class	Tolerance (℃)	Rated current (mA)
Pt100	100	1.3850	A	±(0.15 + 0.002l t l)	1, 2
			B	±(0.3 + 0.005l t l)	1, 2, 5

R100 is resistance value at 100 °C
R_0 is resistance value at 0 °C
l t l means the measurement temperature expressed by a temperature (ºC) unrelated to signs +, -.

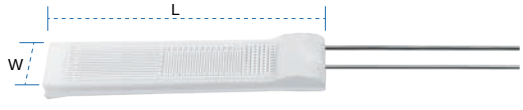
Measuring temp. (℃)		-200	-100	0	100	200	300	400	500	600	650
Tolerance (Ω)	Class A	±0.55	±0.35	±0.15	±0.35	±0.55	±0.75	±0.95	±1.15	±1.35	±1.45
	Class B	±1.3	±0.8	±0.3	±0.8	±1.3	±1.8	±2.3	±2.8	±3.3	±3.6

4. Type of platinum RTD element

■ **Glass sealed platinum RTD element :**
It is composed of a high purity platinum wire wound noninductively around a special glass body, of which resistivity at 0 ℃ is adjusted to fall within the respective standard ranges, instead of another special glass tube and heat sealed overall.
Quick response and excellent in insulation, withstand voltage, vibration and high resistance to liquid, chemicals and gases.

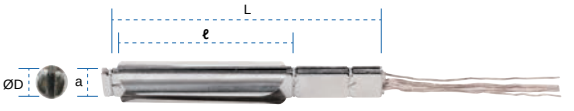
Type	Nominal resistance (0℃)	Dimension (mm) D	Dimension (mm) ℓ	Dimension (mm) L	Operating temp. (℃)	Rated current (mA)	Class
HG-2015	100	2	10	15	-220 ~ 450	1 2 5	B

■ **Film type platinum RTD element :**
The temperature sensor consists of a photo-lithographically structured, high-purity platinum coating arranged in the shape of a meander. The platinum thin-film structures are laser trimmed to form resistive paths with very precisely defined basic value of the resistivity.
The sensors are covered with a glass passivation layer to protect the sensor against mechanical and chemical damage. The bonded leadwires which are additionally covered with a drop of glass make electrical contacts to the resistive structure.



Type	Nominal Resistance (ohm)	Dimension (mm) L	Dimension (mm) W	Operation temp. (0ºC)	Rated current (mA)	Class
P0K1.520.6W.A.010	100	5	2	-200~600	1	A (-90 ~ 300 ºC)
P0K1.102.6W.B.010	100	10	2		Max. 5	B (-200 ~ 600 ºC)

■ **MICA type platinum RTD element :**
It is composed of a mica plate wound with a high purity platinum wire and sandwiches between two mica plates for insulation and between two stainless steel plate springs, and fixed tightly by stainless steel wires. Because of ease in handling and rigid structure, it is being used widely in industrial applications.



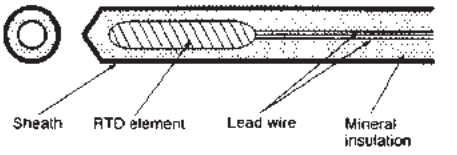
Type	Nominal resistance (Ω)	Dimension (mm)				I.D. of protection tube (mm)	Operation temp. (0℃)	Rated current (mA)	Class
		D	a	ℓ	L				
RM-4	100	4	3.5	35.5	52	4	-80 ~ 350	1 2 5	A B
RM-4(D)	100 X 2	4	3.5	35.5	52	4			
RM-6	100	6	5	33	55	6			
RM-6(D)	100 X 2	6	5	33	55	6			
RM-8	100	8	6	33	55	8			
RM-8(D)	100 X 2	8	6	33	55	8			
RM-10	100	10	7	33	55	10			

■ **Ceramic type platinum RTD element**
It is composed of a coil-formed high purity platinum wire instead of bored of a fine polished recrystallized alumina ceramic body and fixed on its bottom by special heat resistant frit. As approximately 80 % of the resistance wire is free of heat strain from temperature change, drift in resistivity is minimized and its reproducibility and long term stability are superior to any of conventional core-wound element.

Type	Nominal resistance (Ω)	Dimension (mm)			Operation temp. (℃)	Rated current (mA)	Class
		D	L	ℓ			
RC0912	100	0.90±0.05	12±1	8±2	-200 ~ 650	1 2 5	A B
RC1210	100	1.2±0.05	10±1	8±2			
RC1215	100	1.2±0.05	15±1	8±2			
RC1610	100	1.6±0.1	10±1	8±2			
RC1615	100	1.6±0.1	15±1	8±2			
RC1620	100	1.6±0.1	20±1	8±2			
RC2010	100	2.0±0.1	10±1	8±2			
RC2015	100	2.0±0.1	15±1	8±2			
RC2020	100	2.0±0.1	20±1	8±2			
RC2810	100	2.8±0.1	10±1	8±2			
RC2815	100	2.8±0.1	15±1	8±2			
RC2820	100	2.8±0.1	20±1	8±2			
RC2828	100	2.8±0.1	28±1	8±2			
RCD1412	100 X 2	1.4±0.1	12±1	8±2			
RCD1615	100 X 2	1.6±0.1	15±1	8±2			
RCD2015	100 X 2	2.0±0.1	15±1	8±2			
RCD2020	100 X 2	2.0±0.1	20±1	8±2			
RCD2815	100 X 2	2.8±0.1	15±1	8±2			
RCD2820	100 X 2	2.8±0.1	20±1	8±2			
RCD2828	100 X 2	2.8±0.1	28±1	8±2			

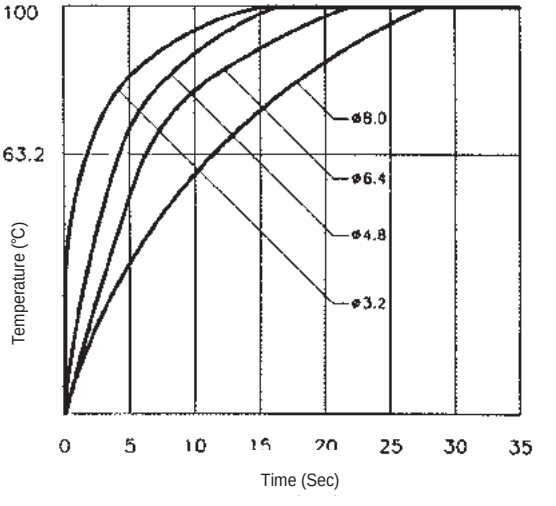
5. Sheathed RTD

■ Sheathed RTD is a registered trade name of one metal sheathed RTD that has a monolithic structure comprising of sheathed element and MI Cable (MgO compacted, metal sheathed lead wires). This is newly developed RTD with quick response, longer service and life and high accuracy under critical conditions.



■ Features
- Quick response
- High flexibility
- High accuracy
- Wide selection of specification :
  Available for outer diameters 3.2 ~ 8.0 mm
  and total length up to 150 mm

■ Sheathed RTD response time
The time constants (63.2 %) when sheathed RTD is immersed into 100 ℃ (boiling water) from 0 ℃ (ice bath.)
- 3.2 less than 2sec
- 4.8 less than 4sec
- 6.4 less than 6sec
- 8.0 less than 11sec

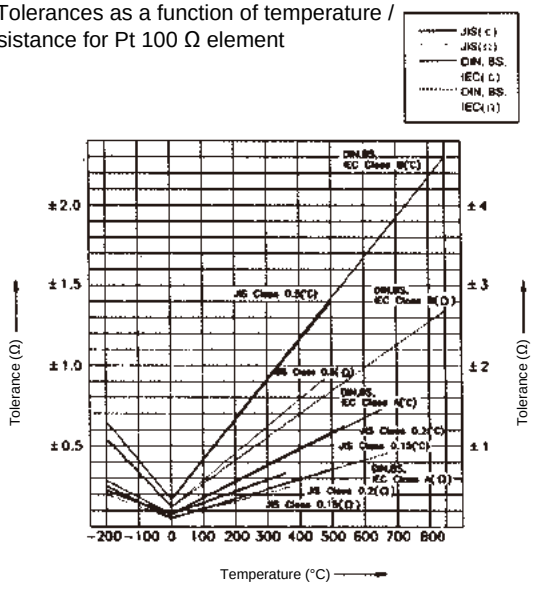


■ Temperature resistance table
nominal resistance for Pt 100 Ω element
JIS C1604, C1606, DIN43760, BS1904, IEC60751

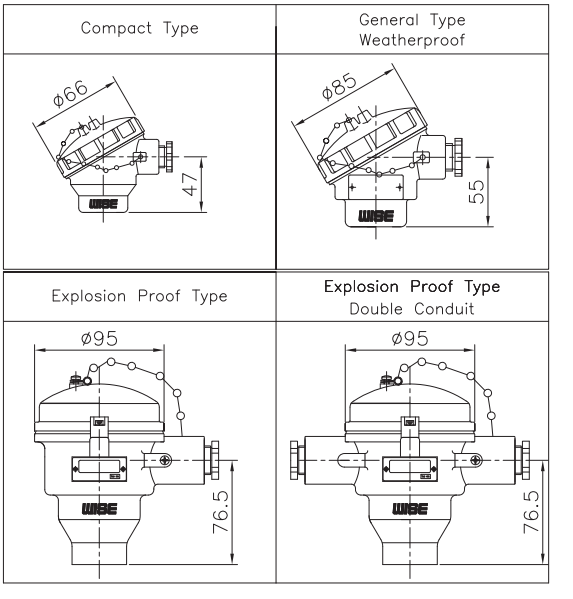
Std ℃	JPt	DIN BS IEC	Std ℃	JPt	DIN BS IEC	Std ℃	JPt	DIN BS IEC
-200	17.14	18.49	**0**	100.00	100.00	**200**	177.13	175.84
-190	21.46	22.80	**10**	103.97	103.90	**210**	180.86	179.51
-180	25.80	27.08	**20**	107.93	107.79	**220**	184.50	183.17
-170	30.12	31.32	**30**	111.88	111.67	**230**	188.29	186.82
-160	34.42	35.53	**40**	115.81	115.54	**240**	191.99	190.45
-150	38.68	39.71	**50**	119.73	119.40	**250**	195.67	194.07
-140	42.91	43.87	**60**	123.64	123.24	**260**	199.35	197.69
-130	47.11	48.00	**70**	127.54	127.07	**270**	203.01	201.29
-120	51.29	52.11	**80**	131.42	130.89	**280**	206.66	204.88
-110	55.44	56.19	**90**	135.30	134.70	**290**	210.30	208.45
-100	59.57	60.25	**100**	139.16	138.50	**300**	213.93	212.02
-90	63.68	64.30	**110**	143.01	142.29	**310**	217.54	215.57
-80	67.77	68.33	**120**	146.85	146.06	**320**	221.15	219.12
-70	71.85	72.33	**130**	150.67	149.82	**330**	224.74	222.65
-60	75.91	76.33	**140**	154.49	153.58	**340**	228.32	226.17
-50	79.96	80.31	**150**	158.29	157.31	**350**	231.89	229.67
-40	83.99	84.27	**160**	162.08	161.04	**360**	235.45	233.17
-30	88.01	88.22	**170**	165.86	164.76	**370**	238.99	236.65
-20	92.02	92.16	**180**	169.63	168.46	**380**	242.53	240.13
-10	96.02	96.09	**190**	173.38	172.16	**390**	246.05	243.59

Std ℃	JPt	DIN BS IEC	Std ℃	JPt	DIN BS IEC	Std ℃	JPt	DIN BS IEC
400	249.56	247.04	**600**	317.28	313.59	**800**		375.51
410	253.06	250.48	**610**	320.54	316.80	**810**		378.48
420	256.55	253.90	**620**	323.78	319.99	**820**		381.45
430	260.02	257.32	**630**	327.02	323.18	**830**		384.40
440	263.49	260.72	**640**	330.24	326.35	**840**		387.34
450	266.94	264.11	**650**		329.51	**850**		390.26
460	270.38	267.49	**660**		332.66			
470	273.80	270.86	**670**		335.79			
480	277.22	274.22	**680**		338.92			
490	280.63	277.56	**690**		345.13			
500	284.02	280.90	**700**		348.22			
510	287.40	284.22	**710**		351.30			
520	290.77	287.53	**720**		354.37			
530	294.12	290.83	**730**		357.42			
540	297.47	294.11	**740**		360.47			
550	300.80	297.39	**750**		363.50			
560	304.12	300.65	**760**		366.52			
570	307.43	303.91	**770**		369.53			
580	310.72	307.15	**780**		372.52			
590	314.01	310.38	**790**					

■ Tolerances as a function of temperature / resistance for Pt 100 Ω element



■ Head type (WISE standard)



Memo