2. THERMOCOUPLES

Thermocouples sense temperatures based on the principle that an electrical current is generated when two different metals are combined in a closed circuit and subjected to a temperature difference; they are widely exploited in industry due to their simple construction and excellent reliability. There are many types of thermocouples in use. Those which are the most widely used, whose characteristics are understood, and which have demonstrated their reliability, have become the objects of standardization. This document deals primarily with those thermocouples standardized in the JIS, plus other typically used thermocouples that have been field-proven in particular applications.

2.1 Overview of the JIS '95 Revisions

JIS standards related to thermocouples were revised as of July 1, 1995. The major purpose of this revision is to make these JIS standards conform to the international standard IEC 584. Thermocouple codes, thermal EMF, and tolerance classes were revised to match IEC584, so JIS standard data are consistent with the standards used abroad now.

The major changes are "N thermocouple is newly stipulated" and "standard thermal EMFs revised". As shown in Figure 1, the difference between JIS'89 and JIS'95 thermal EMFs will have little effect on industrial temperature measurement.

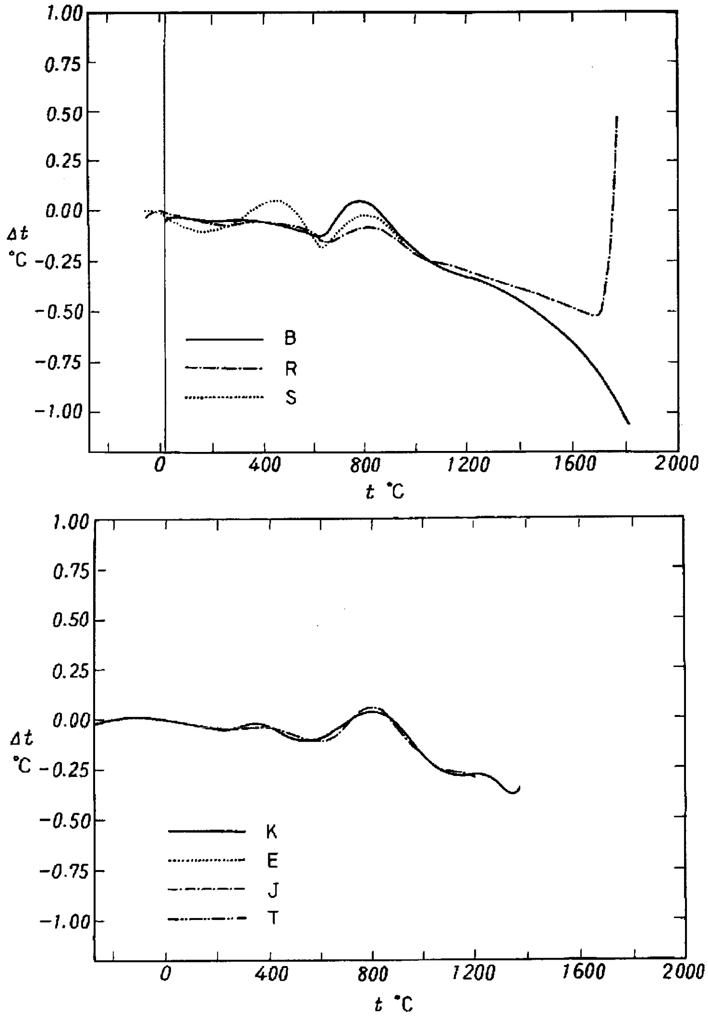

Figure 1 Revised Value of Thermal EMF

2.2 Types of Thermocouples

In most cases, a thermocouple's type is indicated by a code. Since the codes specified in JIS conform to the IEC standards, they are shared with other international standards, in particular with DIN (Germany) and ANSI (United States) [See Table 10]. Table 8 shows the codes, component materials, operating limits, and other features of thermocouples standardized in JIS. Table 9 shows representative non-JIS-standard-thermocouples in practical use.

Table 7 Thermocouple Codes, Component Materials, Normal Operating Limits, and Overheat Operating Limits (JIS C 1602-1981)

Code	Old code	Component materials		Class	Element diameter (mm)	Normal operating limits (° C)	Overheat operating limits (° C)	Properties
		+ side	– side					
B	–	Contains 30% Rhodium. Platinum-Rhodium alloy	Contains 6% Rhodium. Platinum-Rhodium alloy	Class 2 Class 3	0.50	1500	1700	Thermal EMF is very small at room temperature. Large differences in characteristics sometimes seen. Otherwise the same as Type R.
R	–	Contains 13% Rhodium. Platinum. Rhodium alloy	Platinum	Class 2	0.50	1400	1600	Very stable. Suitable as standard thermocouple. Suitable for corrosive environments. Sensitive to hydrogen, metal vapors. Small thermal EMF. Very slight secular change. Large extension wire error.
S	–	Contains 10% Rhodium. Platinum. Rhodium alloy	Platinum		0.50	1400	1600	
N		Alloy, primarily Nickel, Chrome, and Silicon	Alloy, primarily Nickel, and Silicon	Class 1 Class 2 Class 3	0.65	850	900	Excellent corrosion resistance (several times that of Type K). No error generation due to short-range ordering. Magnetic field influence relatively small.
					1.00	950	1000	
					1.60	1050	1100	
					2.30	1100	1150	
					3.20	1200	1250	
K	CA	Alloy, primarily Nickel and Chrome	Alloy, primarily Nickel	Class 1 Class 2 Class 3	0.65	650	850	Good EMF linearity. Suitable for corrosine environment. Resistant to metal vapors. Some secular change.
					1.00	750	950	
					1.60	850	1050	
					2.30	900	1100	
					3.20	1000	1200	
E	CRC	Alloy, primarily Nickel and Chrome	Alloy, primarily Copper and Nickel	Class 1 Class 2 Class 3	0.65	450	500	Lower cost than Type K, larger thermal EMF. Non-magnetic. Some drift over time.
					1.00	500	550	
					1.60	550	650	
					2.30	600	750	
					3.20	700	800	
J	IC	Iron	Alloy, primarily Copper and Nickel	Class 1 Class 2 Class 3	0.65	400	500	Low cost, with fairly large thermal EMF. Good EMF linearity. Suitable for reducing environments. Large sample-to-sample variations in dharacteristics, quality. Rusts easily. Drifts at high temperatures.
					1.00	450	550	
					1.60	500	650	
					2.30	550	750	
					3.20	600	750	
T	CC	Copper	Alloy, primarily Copper and Nickel	Class 1 Class 2 Class 3	0.32	200	250	Low cost, with good low-temperature characteristics. Good linearity, Suitable for reducing environments. Large extension wire error.
					0.65	200	250	
					1.00	250	300	
					1.60	300	350	

Table 8 Non-JIS Thermocouples in practical Use

<table>
<tr><th rowspan="2">Name</th><th colspan="2">Component materials</th><th rowspan="2">Operating temperature range Overheat limit in ( )</th><th rowspan="2">Properties</th><th rowspan="2">Standard thermal EMF table, and authority</th></tr>
<tr><th>+ side</th><th>-side</th></tr>
<tr><td rowspan="2">Platinum-Rhodium</td><td>Contains 20% Rhodium. Platinum-Rhodium alloy</td><td>Contains 5% Rhodium. Platinum-Rhodium alloy</td><td>300 to 1500° C (1800° C)</td><td rowspan="2">Usable at high temperatures. Small thermal EMF. Otherwise, same as Type R.</td><td rowspan="2">Appendix Table B22</td></tr>
<tr><td>Contains 40% Rhodium. Platinum-Rhodium alloy</td><td>Contains 20% Rhodium. Platinum-Rhodium alloy</td><td>1100 to 1600° C (1800° C)</td></tr>
<tr><td rowspan="3">Tungsten-Rhenium</td><td>Contains 5% Rhodium. Platinum-Rhodium alloy</td><td>Contains 26% Rhodium. Platinum-Rhodium alloy</td><td rowspan="3">0 to 2400° C (3000° C)</td><td rowspan="3">Suitable for reducing environments, inert gasses, hydrogen gas. Fragile.</td><td>Appendix Tables B20
ASTM E988-84</td></tr>
<tr><td>Contains 3% Rhodium. Platinum-Rhodium alloy</td><td>Contains 25% Rhodium. Platinum-Rhodium alloy</td><td rowspan="2">Appendix Table B22
ASTM E988-84</td></tr>
<tr><td>Tungsten</td><td>Contains 26% Rhodium. Platinum-Rhodium alloy</td></tr>
<tr><td>Platinel</td><td>Alloy, primarily Palladium, Platium, and Gold</td><td>Alloy, primarily Gold and Palladium</td><td>0 to 1100° C (1300° C)</td><td>High resistance to abrasion. Thermal EMF nearly the same as that of Type K.</td><td>Appendix Table B22 NBS Journal of Research, vol. 68C. N08</td></tr>
<tr><td>Chromel/ Gold-Iron</td><td>Alloy, primarily Nickel and Chrome o4?0 (Chromel)</td><td>Contains 0.07 mole% Iron. Gold-Iron alloy</td><td>1 to 300K</td><td>Thermal EMF relatively large at 20 K and below. Good EMF linearity.</td><td>ASTM SPT430
Appendix Table B21</td></tr>
</table>

2.3 Thermal EMF Characteristics

The standard thermal EMFs of the various thermocouple types are shown in Appendix Tables B1 through B19.

Because JIS C 1602-1995 was written to be consistent with the standards used in other countries, particularly IEC, ANSI, etc., this is beneficial when importing and exporting. However, attention is required since the DIN standard adopts its own unique specifications for Type U and Type L. Table 10 gives a list of the standard thermal EMF document selections for the individual national and international standards. Equations for interpolation of standard thermal EMFs are provided for reference at the end of this document.

Table 9 Thermal EMF Document Selection List

Thermocouple generic name	Thermocouple standard dexignation					Standard thermal EMF document number	Remarks
	Standard type						
	JIS	IEC	ANSI	BS	DIN		
Platinum-Rhodium/6-30	TYPE B					Appecdix Table-B1	
Platinum-Rhodium/Platinum	TYPE R					Appendix Table-B2	
	TYPE S					Appendix Table-B3	
Nichrosil/Nisil (N)	TYPE N					Appendix Table-B4	
Chromel/Alumel	TYPE K					Appendix Table-B5	
Chromel-Constantan	TYPE E					Appendix Table-B6	
Iron-Constantan	TYPE J					Appendix Table-B7	
	–				Type L (Fe-CuNi)	Appendix Table-B19	
Copper-Constantan	TYPE T					Appendix Table-B8	
	–				Type U (Cu-CuNi)	Appendix Table-B18	

Note:
1. A line drawn in the table indicates that the thermocouple in question is not covered in thet standard. Those for which the same document number is given have the same standard thermal EMFs even if their names are different.
2. ASTM'93 is a national standard of the U.S. which regulates thermocouple reference thermal E.M.F.. : ASTM E230-93.