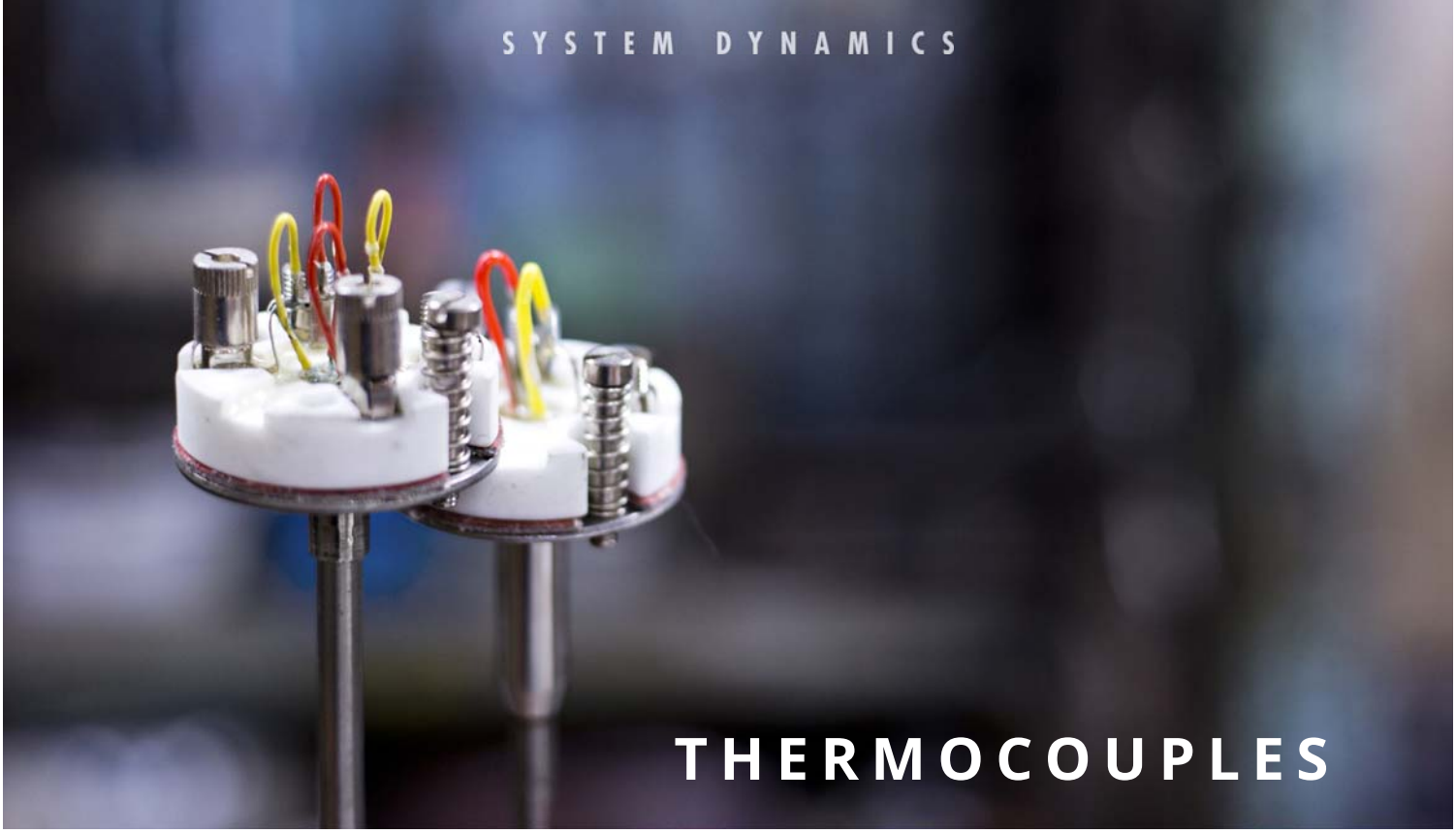
System Dynamics

Product Catalogue

SYSTEM DYNAMICS

Thermocouple

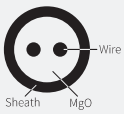
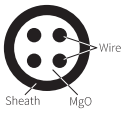
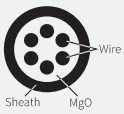


THERMOCOUPLES

Basic Thermocouple Theory

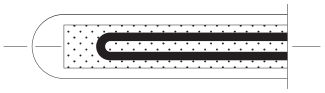
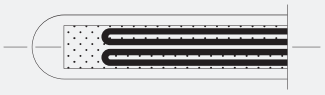
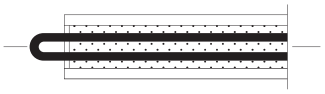
A thermocouple is a closed loop circuit that consists of two dissimilar metal wires welded together at both ends. When a temperature difference exists between the two junctions, an electromotive foce (thermal emf) develops and a thermo-electric current flows in the circuit. The emf and its polarity depend on the temperature difference and the combinations of two metal wires, and are not affected by the size or length of the wires. When the relation ship between the temperature difference and thermal emf induced within is known beforehand for a particular thermocouple, temperature can be measured.

Standard Specifications of System Dynamics Sheathed Thermocouples

	Sheath (mm)		Wire diameter	Type of Themocouple/Circuit Resistance*(1) and Sheath Material								Standard length	Approximate weight
				SK		SE		SJ		ST			
	Outer diameter	Wall thickness	(mm)	Sheath material	Circuit resistance	Sheath material	Circuit Resistance	Sheath material	Circuit Resistance	Sheath material	Circuit Resistance	(m)	(g/m)
Single element (2 wires) 	Ø0.25	0.035	Ø0.05	Inconel 600	Actually measured value	–	–	–	–	–	–	50	0.3
	Ø0.5	0.08	Ø0.1	316$^{st}/_{st}$, Inconel 600	Actually measured value	–	–	–	–	–	–	100	1.2
	Ø1.0	0.17	Ø0.17	316$^{st}/_{st}$	46.43	316$^{st}/_{st}$	Actually measured value	316$^{st}/_{st}$	Actually measured value	316$^{st}/_{st}$	Actually measured value	130	5
	Ø1.6	0.27	Ø0.27	316$^{st}/_{st}$	18.69	316$^{st}/_{st}$	23.06	316$^{st}/_{st}$	12.19	316$^{st}/_{st}$	10.73	100	10
	Ø3.2	0.47	Ø0.51	316$^{st}/_{st}$, 347$^{st}/_{st}$	5.07	316$^{st}/_{st}$ 347$^{st}/_{st}$	6.33	316$^{st}/_{st}$	3.33	316$^{st}/_{st}$	2.69	83	45
	Ø4.8	0.72	Ø0.76	316$^{st}/_{st}$, 347$^{st}/_{st}$	2.2	316$^{st}/_{st}$ 347$^{st}/_{st}$	2.76	316$^{st}/_{st}$	1.14	316$^{st}/_{st}$	1.18	35	100
	Ø6.4	0.93	Ø1.0	310S$^{st}/_{st}$, Inconel 600	1.25	316$^{st}/_{st}$	1.54	316$^{st}/_{st}$	0.81	316$^{st}/_{st}$	0.66	20	180
	Ø8.0	1.16	Ø1.3	310S$^{st}/_{st}$, Hastelloy X, Inconel 600	0.79	316$^{st}/_{st}$	0.97	316$^{st}/_{st}$	0.56	316$^{st}/_{st}$	0.41	11.5	280
Double element (4 wires) 	Ø3.2	0.47	Ø0.51	316$^{st}/_{st}$, 347$^{st}/_{st}$	5.07	316$^{st}/_{st}$ 347$^{st}/_{st}$	6.33	316$^{st}/_{st}$	3.33	–	–	83	45
	Ø4.8	0.72	Ø0.76	316$^{st}/_{st}$, 347$^{st}/_{st}$	2.2	316$^{st}/_{st}$ 347$^{st}/_{st}$	2.76	316$^{st}/_{st}$	1.41	316$^{st}/_{st}$	1.18	35	100
	Ø6.4	0.93	Ø1.0	310S$^{st}/_{st}$, Inconel 600	1.25	316$^{st}/_{st}$	1.54	316$^{st}/_{st}$	0.81	316$^{st}/_{st}$	0.66	20	180
	Ø8.0	1.16	Ø1.3	310S$^{st}/_{st}$, Inconel 600	0.79	316$^{st}/_{st}$	0.97	316$^{st}/_{st}$	0.56	316$^{st}/_{st}$	0.41	11.5	280
Triple element (6 wires) 	Ø4.8	0.72	Ø0.50	316$^{st}/_{st}$	Actually measured value	316$^{st}/_{st}$	Actually measured value	316$^{st}/_{st}$	Actually measured value	316$^{st}/_{st}$	Actually measured value	35	100
	Ø6.4	0.93	Ø0.72	310S$^{st}/_{st}$, Inconel 600	Actually measured value	316$^{st}/_{st}$	Actually measured value	316$^{st}/_{st}$	Actually measured value	316$^{st}/_{st}$	Actually measured value	20	180
	Ø8.0	1.16	Ø0.90	310S$^{st}/_{st}$, Inconel 600	Actually measured value	316$^{st}/_{st}$	Actually measured value	316$^{st}/_{st}$	Actually measured value	316$^{st}/_{st}$	Actually measured value	11.5	280

(1) Loop resistance is ±30% (Ω/m) at room temperature.

Type of Hot Junction

Symbol	Type	Shape
G	Grounded type	
U	Ungrounded type	
U	Ungrounded separate type	
G	Exposed type	

Type of Thermocouple

Type			Remarks
Symbol	Former symbol	Constituent material	
B	**–**	Platinum·Rhodium 30 — Platinum·Rhodium 6	
R	**–**	Platinum·Thodium 13 — Platinum	
S	**–**	Platinum·Rhodium 10 — Platinum	
K	**CA**	Chromel — Alumel	
E	**CRC**	Chromel — Constantan	
J	**IC**	Iron — Constantan	
T	**CC**	Copper — Constantan	
W/W-26Re		Tungsten — Tungsten·Rhenium 26	
W-5Re/W-26Re		Tungsten·Rhenium 5 — Tungsten·Thenium 26	

Operating Temperature Limits in Wire Diameter and Applicable Protection Tube Size

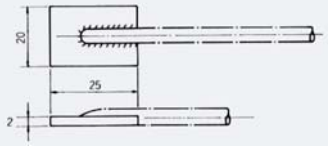
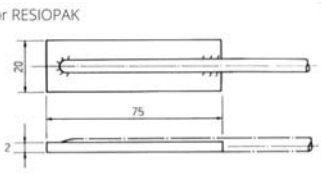
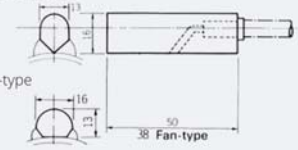
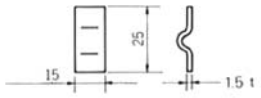
Type of thermocouple	Wire diameter		Operating temperature limit		Applicable protectuon tube O.D × I.D size	
	Symbol	Outer diameter (mm)	Normal limit	Overheat operating limit	Metal protection tube (Ø mm)	Non-metallic protection tube (Ø mm)
B Platinum rhodium 30%—Platinum rhodium 6%	L	0.5	1500°C	1700°C	–	15 × 11
R Platinum rhodium 13%—Platinum	L	0.5	1400°C	1600°C	–	15 × 11
S Platinum rhodium 10%—Platinum	L	0.5	1400°C	1600°C	–	15 × 11
K (Chromel—Alumel)	D	3.2	1000°C	1200°C	21.7 × 16.1	17 × 13
	C	2.3	900°C	1100°C	21.7 × 16.1	17 × 13
	B	1.6	850°C	1050°C	15 × 11	15 × 11
	A	1.0	750°C	950°C	12 × 9	15 × 11
	H	0.65	650°C	850°C	10 × 7	10 × 6
E (Chromel—Constantan)	B	1.6	550°C	650°C	15 × 11	–
	A	1.0	500°C	550°C	12 × 9	–
	H	0.65	450°C	500°C	10 × 7	–
	T	0.32	300°C	400°C	10 × 7	–
J (Iron—Constantan)	C	2.3	550°C	750°C	21.7 × 16.11	17 × 13
	B	1.6	500°C	650°C	15 × 11	15 × 11
	A	1.0	450°C	550°C	12 × 9	15 × 11
	H	0.65	400°C	500°C	10 × 7	10 × 6
T (Copper-Constantan)	B	1.6	300°C	350°C	15 × 11	–
	A	1.0	250°C	300°C	12 × 9	–
	H	0.65	200°C	250°C	10 × 7	–
	T	0.32	200°C	250°C	10 × 7	–

Thermocouple Tolerance and Applicable Standard List

Standard / Type	JIS C 1602–'81			ANSI MC 96.1–'82			DIN 43710'77		IEC STANDARD Publication 584–2–'82		
	Temperature range	Grade	Tolerance*(1)	Temperature range	Grade	Tolerance	Temperature range	Tolerance	Temperature range	Grade	Tolerance (±)
B PtRh30—PtRh6	200 to 1700°C	0.5	±4°C or ±0.5%	800 to 1700°C	STD	±0.5°C	–	–	600 to 1700°C	2	1.5°C or 0.0025 . |t|
										3	4°C or 0.05 . |t|
R PtRh13—Pt	0 to 1600°C	0.25	±1.5°C or ±0.25%	0 to 1450°C	SP	±0.6°C or ±0.1%	–	–	0 to 1600°C	1	1°C or [1+0.003 (t - 1100)]°C
					STD	±1.5°C or ±0.25%					
S PtRh10—Pt	0 to 1600°C	0.25	±1.5°C or ±0.25%	0 to 1450°C	SP	±0.6°C or ±0.1%	0 to 1600°C	±3°C		2	1.5°C or 0.0025 . |t|
					STD	±1.5°C or ±0.25%	600 to 1600°C	±0.5%			
K NiCr—NiAl	0 to 1000°C	0.4	±1.5°C or ±0.4%	0 to 1250°C	SP	±1.1°C or ±0.4%	0 to 400°C	±3°C	-40 to 1000°C	1	1.5°C or 0.004 . |t|
	0 to 1200°C	1.75	±2.5°C or ±0.75%		STD	±2.2°C or ±0.75%	400 to 1200°C	±3/4%	-40 to 1200°C	2	2.5°C or 0.0075 . |t|
	-200 to 0°C	1.5	±2.5°C or ±1.5%	-200 to 0°C	STD	±2.2°C or ±2%			-200 to 40°C	3	2.5°C or 0.015 . |t|
E NiCr—CuNi	0 to 800°C	0.4	±1.5°C or ±0.4%	0 to 900°C	SP	±1°C or ±0.4%	–	–	-40 to 800°C	1	1.5°C or 0.004 . |t|
		0.75	±2.5°C or ±0.75%		STD	±1.7°C or ±0.5%			-40 to 900°C	2	2.5°C or 0.0075 . |t|
	-200 to 0°C	1.5	±2.5°C or ±1.5%	-200 to 0°C	STD	±1.7°C or ±1%			-200 to 40°C	3	2.5°C or 0.015 . |t|
J Fe—CuNi	0 to 750°C	0.4	±1.5°C or ±0.4%	0 to 750°C	SP	±1.1°C or ±0.4%	0 to 400°C	±3°C	-40 to 750°C	1	1.5°C or 0.004 . |t|
		0.75	±2.5°C or ±0.75%		STD	±2.2°C or ±0.75%	400 to 900°C	±3/4%		2	2.5°C or 0.0075 . |t|
T Cu—CuNi	0 to 350°C	0.4	±0.5°C or ±0.4%	0 to 350°C	SP	±0.5°C or ±0.4%	0 to 400°C	±3°C	-40 to 350°C	1	0.5°C or 0.004 . |t|
		0.75	±1°C or ±0.75%		STD	±1°C or ±0.75%	400 to 600°C	±3/4%		2	1°C or 0.0075 . |t|
	-200 to 0°C	1.5	±1°C or ±1.5%	-200 to 0°C	STD	±1°C or ±1.5%			-200 to 40°C	3	1°C or 0.015 . |t|

(1) Tolerence is referred to as the maximum allowable deviation between hot junction temperature and the temperature derived from the emf table. JIS/ANSI tolerance is °C or % value for the measured temperature, whichever is greater.

Pads for Surface

Shape	Added specification code	Specification	Applicable sheath O.D.
For AEROPAK 	/PD-A	Pad material: 304SS/St	Ø 3.2 Ø 4.8
For RESIOPAK 	/PD-R	Pad material: 304SS/St	Ø 3.2 Ø 4.8
Knife edge type  Fan-type	/PD-N /PD-F	Pad material: Hastelloy X	Ø 3.2 Ø 4.8 Ø 6.4
Strap 	/ST-D /ST-E	Material: 304SS/St	Ø 3.2 Ø 4.8

Compensating Cable

Type of Compensating Cable

The compensating cable is classified as shown in the table below, depending on the type of thermocouple combined therewith.

Type of thermocouple Symbol		Type of compensating cable		Usage division and division by tolerance	Material	
JIS C 1602	JIS C 1605	Symbol	Former symbol		Positive wire	Negative wire
B	–	BX-G	–	Common grade for general use	Copper	Copper
R	–	RX-G SX-G	–	Common grade for general use	Copper	Alloy consisting mainly of copper and nickel
S		RX-H SX-H		Heat resistant common grade		
K	SK	KX-G	WCA-G	Common grade for general use	Alloy consisting mainly of nickel and chromium	Alloy consisting mainly of nickel
		KX-GS	WCA-GS	General-purpose precision grade		
		KX-H	WCA-H	Heat resistant common grade		
		KX-HS	WCA-HS	Heat resistant precision grade	Iron	Alloy consisting mainly of copper and nickel
		WX-G	WCA-G	Common grade for general use		
		WX-H	WCA-H	Heat resistant common grade		
		VX-G	WCA-G	Common grade for general use	Copper	Alloy consisting mainly of copper and nickel
E	SE	EX-G	WCRC-G	Common grade for general use	Alloy consisting mainly of nickel and chromium	Alloy consisting mainly of copper and nickel
		EX-H	WCRC-H	Heat resistant common grade		
J	SJ	JX-G	WIC-G	Common grade for general use	Iron	Alloy consisting mainly of copper and nickel
		JX-H	WIC-H	Heat resistant common grade		
T	ST	TX-G	WCC-G	Common grade for general use	Copper	Alloy consisting mainly of copper and nickel
		TX-GS	–	General-purpose precision grade		
		TX-H	WCC-H	Heat resistant common grade		
		TX-HS	–	Heat resistant precision grade		

Compensating Cable Error and Tolerance

The error is defined as deviation from a standard temperature/emf table with tolerance being the allowable error. Typical tolerances are shown in the table below:

JIS C 1610 – 1981								ANSI MC. 96.1 – 1982		
Symbol of compensating cable		Core wire material		Temperature range between thermocouple and connecting point (°C)	Tolerance (°C)		Type	Temperature range between thermocouple and connecting point (°C)	Tolerance (°C)	
JIS-'81	JIS-'74	+	-		Common grade	Precision grade			Standard	Special
BX	–	Cu	Cu	0 to 100	– *(1)	–	BX	0 to 100	+0 -3.7	–
RX SX	–	Cu	Cu-Ni Alloy	0 to 150	+3 -7	–	RX SX	0 to 100	±5	–
–	WPR	–	–	–	–	–	–	–	–	–
KX	WCA	Ni-Cr Alloy	Ni Alloy	-20 to 150	±2.5	±1.5	KX	0 to 200	±2.2	–
WX		Fe	Cu-Ni Alloy	-20 to 150	±3.0	–	–	–	–	–
VX		Cu	Cu-Ni Alloy	-20 to 100	±2.5	–	–	–	–	–
EX	WCRC	Ni-Cr Alloy	Cu-Ni Alloy	-20 to 150	±2.5	–	EX	0 to 200	±1.7	–
JX	WIC	Fe	Cu-Ni Alloy	-20 to 150	±2.5	–	JX	0 to 200	±2.2	±1.1
TX	WCC	Cu	Cu-Ni Alloy	-20 to 150	±2.0	±1.0	TX	-60 to 100	±1.0	±0.5

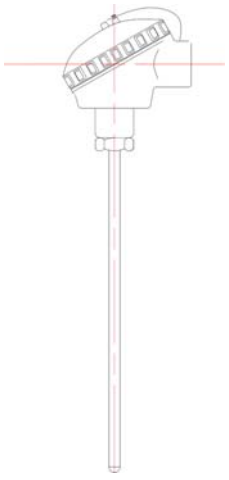
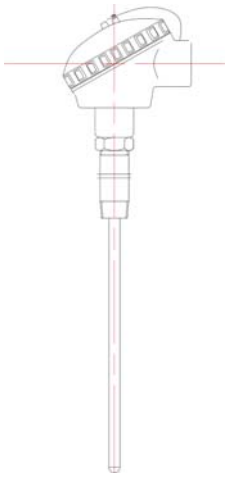
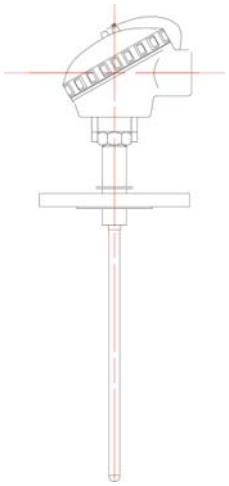
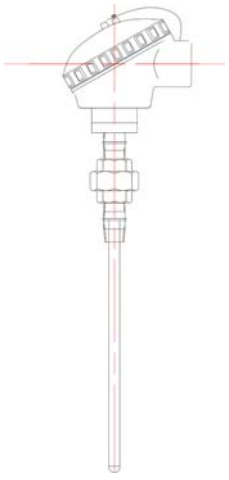
(1) Since BX uses the same conductor (copper) for both positive and negative, no error tolerance is specified.

Standard Colour Coding of Compensating Cable

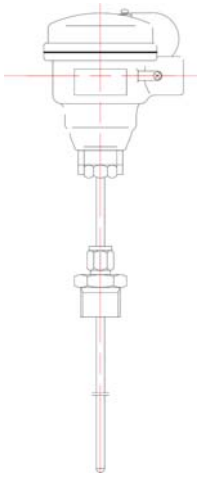
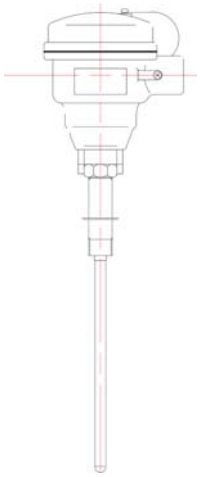
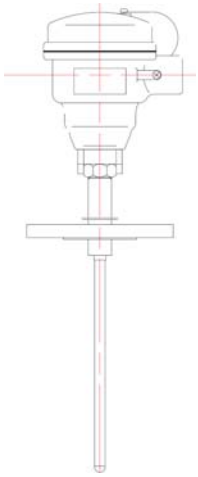
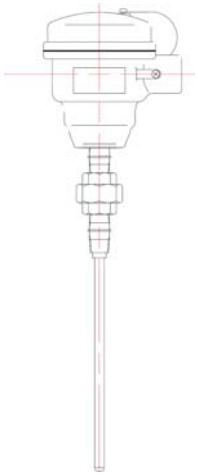
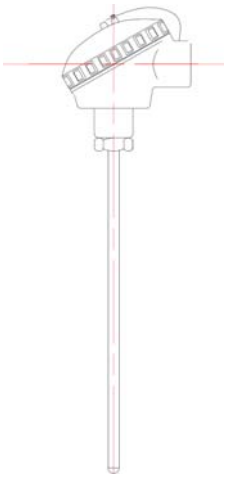
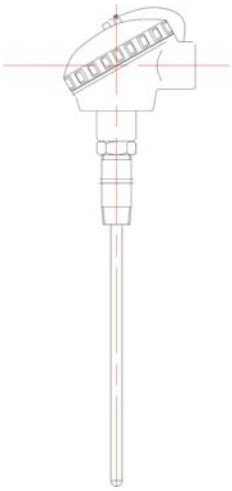
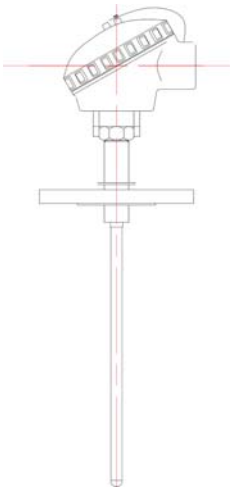
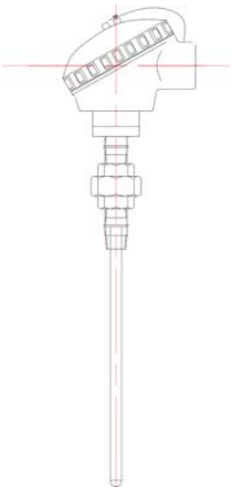
The color coding of a general standard of compensating cable is shown in the table below:

Type of thermocouple in combined use	Cable material		JIS C 1610			ANSI MC 96.1			BS 1843			DIN-43711		
			Insulation		Overall jacket	Insulation		Overall jacket	Insulation		Overall jacket	Insulation		Overall jacket
Symbol	+	-	+	-		+	-		+	-		+	-	
B	**Cu**	**Cu**	Red	White	Grey	Grey	Red	Grey	–	–	–	–	–	–
R	**Cu**	**Cu·Ni**	Red	White	Black	Black	Red	Green	White	Blue	Green	–	–	–
S	**Cu**	**Ni·Al**	Red	White	Black	Black	Red	Green	–	–	–	Red	White	White
K	**Ni·Cr**	**Cu·Ni**	Red	White	Blue	Yellow	Red	Yellow	Brown	Blue	Red	Red	Green	Green
	Cu	**Cu·Ni**	Red	White	Blue	–	–	–	White	Blue	Red	–	–	–
	Fe	**Cu·Ni**	Red	White	Blue	–	–	–	–	–	–	–	–	–
E	**Ni·Cr**	**Cu·Ni**	Red	White	Violet	Violet	Red	Violet	Brown	Blue	Brown	–	–	–
J	**Fe**	**Cu·Ni**	Red	White	Yellow	White	Red	Black	Yellow	Blue	Black	Red	Blue	Blue
T	**Cu**	**Cu·Ni**	Red	White	Brown	Blue	Red	Blue	White	Blue	Black	Red	Brown	Brown

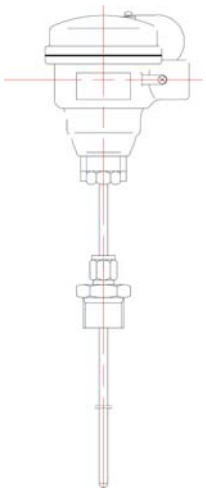
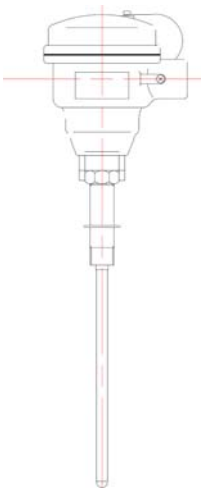
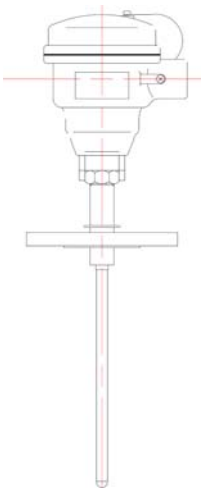
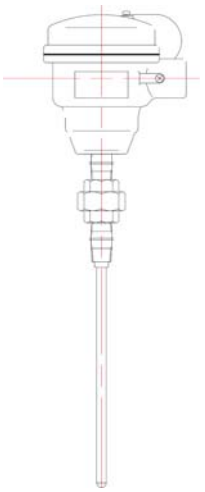
Diagrams

TSD96	TSD96N	TSD96S	TSD96U
Non-spring-loaded thermocouple with non-explosion proof connection head	Non-spring-loaded thermocouple with non-explosion proof connection head and nipple	Non-spring-loaded thermocouple with non-explosion proof connection head and support pipe	Non-spring-loaded thermocouple with non-explosion proof connection head and nipple union
			

Diagrams

TSD97 Non-spring-loaded thermocouple with explosion proof connection head	TSD97N Non-spring-loaded thermocouple with explosion proof connection head and nipple	TSD97S Non-spring-loaded thermocouple with explosion proof connection head and support pipe	TSD97U Non-spring-loaded thermocouple with explosion proof connection head and nipple union
			
TSD400 Spring-loaded thermocouple with non-explosion proof connection head	TSD400N Spring-loaded thermocouple with non-explosion proof connection head and nipple	TSD400S Spring-loaded thermocouple with non-explosion proof connection head and support pipe	TSD400U Spring-loaded thermocouple with non-explosion proof connection head and nipple union
			

Diagrams

TSD407 Spring-loaded thermocouple with explosion proof connection head	TSD407N Spring-loaded thermocouple with explosion proof connection head	TSD407S Spring-loaded thermocouple with explosion proof connection head and support pipe	TSD407U Spring-loaded thermocouple with explosion proof connection head and nipple union
			

System Dynamics Product Catalogue No. 3
Thermocouple Product Catalogue

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