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Standard

Temperature Measurement Thermocouples

ISA-MC96.1 — Temperature Measurement Thermocouples

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Preface

This Preface is included for information purposes and is not part of ISA-MC96.1.

The development of this standard has resulted from the work of the American National Standards Committee on Temperature Measurement, MC96. The Committee was organized in 1946 under the sponsorship of ISA, the scope of the Committee being designated as follows:

Requirements for temperature measurement thermocouples, including terminology, fabrication, wire sizes, installation, color codes of thermocouple and thermocouple extension wire, temperature-EMF tables and tolerances have been coordinated with the International Electrotechnical Commission (IEC).

Credit must be given to the National Bureau of Standards and to Committee E20 on Temperature Measurement of the American Society for Testing and Materials for the development of the temperature-EMF tables and for recommendations as to the maximum recommended temperature of the various materials. Special credit must also be given to G. W. Burns, NBS-Washington, D.C., and Dr. Robert Powell, formerly with NBS-Boulder, for providing the thermocouple reference tables.

This standard has been prepared as a part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value this document should not be static but should be subjected to periodic review. Toward this end the Society welcomes all comments and criticisms and asks that they be addressed to the Standards and Practices Board Secretary; ISA; P.O. Box 12277; Research Triangle Park, N.C. 27709; Telephone 919-549-8411, e-mail: standards@isa.org.

In 1821, Seebeck discovered that, in a closed circuit made up of wires of two dissimilar metals, electric current will flow if the temperature of one junction is elevated above that of the other. In 1886, Le Chatelier introduced a thermocouple consisting of one wire of platinum and the other of 90 percent platinum-10 percent rhodium. This combination, Type S, is still the international standard for purposes of calibration and comparison, and defines the International Practical Temperature Scale of 1968 from the antimony to the gold point. This type of thermocouple was made and sold by W. C. Heraeus, GmbH of Hanau, Germany, and is sometimes called the Heraeus Couple. Somewhat later, it was learned that a thermoelement composed of 87 percent platinum and 13 percent rhodium, Type R, would give a somewhat higher EMF output. This type is frequently used in industry. In 1954 a thermocouple was introduced in Germany whose positive leg is an alloy of platinum and 30 percent rhodium. Its negative leg is also an alloy of platinum and 6 percent rhodium. This combination, Type B, gives somewhat greater physical strength and greater stability and can withstand somewhat higher temperature than Types R and S.

In an effort to find less costly metals for use in thermocouples, a number of combinations were tried. Iron and nickel were useful and inexpensive. Pure nickel, however, becomes very brittle upon oxidation, and it was learned that an alloy of about 55 percent copper, 45 percent nickel originally known as constantan would eliminate this problem. This alloy combination, iron-constantan, has since been widely used and is designated Type J. The present calibration for Type J was established by the National Bureau of Standards (see NBS Monograph 125).

In an effort to find a couple useful to higher temperatures than the iron versus copper-nickel combination, a 90 percent nickel-10 percent chromium alloy as a positive wire, and a 95 percent nickel-5 percent aluminum, manganese, silicon alloy as a negative wire was developed. This combination (originally called Chromel-Alumel) is known as Type K. Similar alloys for specific applications have since become available, to the same curve.

Another combination, copper versus copper-nickel, Type T, is used particularly at below-zero temperatures. The temperature-EMF Reference Table was prepared by the National Bureau of Standards in 1938 and revised in NBS Monograph 125.

The Type E Thermocouple, 90 percent nickel-10 percent chromium versus copper-nickel, is receiving increasing attention and use where corrosion of small diameter iron wire is a problem and a higher EMF output is desirable.

Further information on the letter designated type thermocouples is given in Appendix C.

Several combinations using tungsten, rhenium and their binary alloys are widely used at high temperatures in inert or reducing atmospheres, and are nearing acceptance as standard.

For additional information on temperature measurement thermocouples, reference may be made to NBS Special Publication 300, Volume II, "Precision Measurement and Calibration-Temperature," 1968 and to NBS Monographs 124 and 125, published by United States Department of Commerce, National Bureau of Standards. Specific attention is called to the reference categories on Thermoelectric Theory and Calibration, and Thermoelectric Devices. Additional information is in STP-470B, "Manual on the Use of Thermocouples," 1981, published by the American Society for Testing and Materials.

For many years, letter designations have been assigned by ANSI Committee MC96 and endorsed by international standards as a device to identify certain common types without using proprietary trade names, and to associate them with temperature-EMF relationships established by the National Bureau of Standards. Color codes for the insulation of letter-designated wires are also assigned by MC96 to facilitate identification in the field. The assignment of a letter designation and/or color code by MC96 constitutes an acknowledgment of an existing recognition by NBS of a defining temperature-EMF relationship and an existing general usage, and does not constitute an endorsement of the thermocouple type by ISA, ANSI, and NBS. The letter designation applies only to the temperature-EMF relationship and not to the material. Other material, having different temperature-EMF relationships, may well be equivalent or superior in some applications.

The use of the letter X to indicate thermocouple extension wire appeared obvious. The use of the term lead wire, or compensating lead wire, is to be discouraged because it frequently is confused with the term lead (element).

Much discussion was involved in the use of the color red to designated polarity, since red is used popularly in electrical circuits to indicate positive. No nationally-accepted code known to the committee covered this point. Research into manufacturers' records showed that, in thermocouple circuits, the red negative had been in use for more than forty years.

The colors used to designate the various compositions and combination of thermocouple and extension wire were originally selected upon an almost arbitrary basis. Colors which had been used by large manufacturers were given very careful consideration and comparison so that as few changes as possible would be required to establish uniformity. Millions of miles of wire with these color codes are presently in use.

In ISA-MC96.1 thermocouple and thermocouple extension wires are designated by letters. This has been done primarily to eliminate the use of proprietary names. The designations are given in Table 1 of the text.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards. The Department is further aware of the benefits to USA users of ISA Standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end this Department will endeavor to introduce SI and SI-acceptable metric units as optional alternatives to English units in all new and revised standards to the greatest extent possible. *The ASTM Metric Practice Guide*, endorsed and published as National Bureau of Standards Handbook 102 and as ANSI Z210.1, is the reference guide for definitions, symbols, abbreviations and conversion factors.

Contents

1 Coding of thermocouple wire and extension wires

This standard applies to thermocouples and extension wires.

Its purpose is to establish uniformity in the designation of thermocouples and extension wires and to provide, by means of the color of its insulation, an identification of its type or composition as well as its polarity when used as part of a thermocouple system.

Table 1 — Thermocouple type letter designations

Type	Nominal Temperature Range	Temperature-EMF Relationship Data	Material Identification* (Positive Material in Caps) **
B	0 to 1820°C	Refer to Table 11	PLATINUM-30 PERCENT RHODIUM versus platinum-6 percent rhodium
E	–270 to 1000°C	Refer to Table 12	NICKEL-10 PERCENT CHROMIUM† versus copper-nickel
J	–210 to 760°C	Refer to Table 13	IRON versus copper-nickel
K	–270 to 1372°C	Refer to Table 14	NICKEL-10 PERCENT CHROMIUM † versus nickel-5 percent (aluminium, silicon) ††
R	–50 to 1768°C	Refer to Table 15	PLATINUM-13 PERCENT RHODIUM versus platinum
S	–50 to 1768°C	Refer to Table 16	PLATINUM-10 PERCENT RHODIUM versus platinum
T	–270 to 400°C	Refer to Table 17	COPPER versus copper-nickel

*Any combination of thermocouple materials having EMF-temperature relationships within the tolerances for any of the above-mentioned tables shall bear that table's appropriate type letter designation.

**The indicated polarity of the thermocouple materials applies for conditions when the measuring junction is at higher temperatures than the reference junction.

†It should not be assumed that thermoelements used with more than one thermocouple type are interchange-able or have the same millivolt limits of error.

††Silicon, or aluminum and silicon may be present in combination with other elements.

Table 2 — Symbols for types of thermocouple wire

	Thermoelements	
Type*	Positive	Negative
B	BP	BN
E	EP	EN
J	JP	JN
K	KP	KN
R	RP	RN
S	SP	SN
T	TP	TN

*Any thermocouple material having temperature-EMF relationships within the tolerances for any of the above-mentioned tables shall bear that table's appropriate "type-letter" designation. Identification of some typical materials is contained in Appendix C (Table C-1).

Table 3 — Symbols for types of extension wire

Type	Combination	Positive	Negative
B	BX**	BPX	BNX
E	EX	EPX	ENX
J	JX	JPX	JNX
K	KX	KPX	KNX
R or S	SX*	SPX	SNX
T	TX	TPX	TNX

*Both Type R or S Thermocouples use the same SX compensating extension wire.
**Special compensating extension wires are not required for reference junction temperatures up to 100 ° C. Generally copper conductors are used. However, proprietary alloys may be obtained for use at higher reference junction temperatures.

NOTE: Identification of some typical materials is contained in Appendix C (Table C-3).

Table 4 — Color code — duplex insulated thermocouple wire

Thermocouple			Color of Insulation		
Type	**Positive**	**Negative**	**Overall***	**Positive***	**Negative**
E	EP	EN	Brown	Purple	Red
J	JP	JN	Brown	White	Red
K	KP	KN	Brown	Yellow	Red
T	TP	TN	Brown	Blue	Red

* A tracer color of the positive wire code color may be used in the overall braid.

Table 5 — Color code — single conductor insulated thermocouple extension wire

Extension Wire Type			Color of Insulation	
Type	**Positive**	**Negative**	**Positive**	**Negative***
B	BPX	BNX	Gray	Red-Gray Trace
E	EPX	ENX	Purple	Red-Purple Trace
J	JPX	JNX	White	Red-White Trace
K	KPX	KNX	Yellow	Red-Yellow Trace
R or S	SPX	SNX	Black	Red-Black Trace
T	TPX	TNX	Blue	Red-Blue Trace

*The color identified as a trace may be applied as a tracer, braid, or by any other readily identifiable means.

NOTE OF CAUTION: In the procurement of random lengths of single conductor insulated extension wire, it must be recognized that such wire is commercially combined in matching pairs to conform to established temperature-EMF curves. Therefore, it is imperative that all single conductor insulated extension wire be procured in pairs, at the same time, and from the same source.

Table 6 — Color code — duplex insulated thermocouple extension wire

Extension Wire Type			Color of Insulation		
Type	Positive	Negative	Overall	Positive	Negative*
B	BPX	BNX	Gray	Gray	Red
E	EPX	ENX	Purple	Purple	Red
J	JPX	JNX	Black	White	Red
K	KPX	KNX	Yellow	Yellow	Red
R or S	SPX	SNX	Green	Black	Red
T	TPX	TNX	Blue	Blue	Red

*A tracer having the color corresponding to the positive wire code color may be used on the negative wire color code.

2 Terminology, wire size, upper temperature limit, and initial calibration tolerance for thermocouples and extension wire

2.1 Scope and purpose

This section applies to thermocouples and extension wire.

This section establishes terminology, symbols, normal wire size, recommended upper temperature limit, and tolerance for thermocouples and extension wire.

2.2 Terminology and symbols

2.2.1 Thermoelement

A thermoelement is one of the two dissimilar electrical conductors comprising a thermocouple.

2.2.2 Thermocouple

A thermocouple is two dissimilar thermoelements so joined as to produce a thermal EMF when the measuring and reference junctions are at different temperatures.

1) *Measuring Junction:* The measuring junction is that junction of a thermocouple which is subjected to the temperature to be measured.

2) *Reference Junction:* The reference junction is that junction of a thermocouple which is at a known temperature or which is automatically compensated for its temperature.

NOTE: In normal industry practice the thermocouple element is terminated at the connection head. However, the Reference Junction is not ordinarily located in the connection head but is transferred to the instrument by the use of thermocouple extension wire.