ISA – RP1.1-.7

7-59

RECOMMENDED PRACTICE

THERMOCOUPLES AND THERMOCOUPLE EXTENSION WIRES

COLOR CODING

TERMINOLOGY

LIMITS OF ERROR

WIRE SIZES

FABRICATION

INSTALLATION

APPLICATION

EMF TABLES

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This is a revised composite of previously issued Tentative Recommended Practices RP1.1 through RP1.7 with the tentative status removed. Certain minor errors have been corrected and all have been brought into agreement with recent publications of the National Bureau of Standards. Because of active interest by the aeronautical industry, and the military particularly, in Chromel-Constantan thermocouples, and the advent of National Bureau of Standards work on a Chromel-Constantan EMF table, ISA plans a future supplementary Recommended Practice on the subject.

FOREWORD

This Tentative Recommended Practice has been prepared as a part of the service of the Instrument Society of America toward a goal of uniformity in the field of instrumentation. To be of real value this report should not be static, but should be subject to periodic review. Toward this end the Society welcomes all comments and criticisms, and asks that they be addressed to the Standards & Recommended Practices Board Secretary, Instrument Society of America, Penn–Sheraton Hotel, 530 William Penn Place, Pittsburgh 19, Pennsylvania.

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SECTION 1.1
CODING OF THERMOCOUPLE WIRE AND EXTENSION WIRE

1. SCOPE AND PURPOSE

1.1 This Recommended Practice applies to thermocouples and extension wires for industrial use.

1.2 Its purpose is to establish uniformity in the designation of various types 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.

2. INTRODUCTION

2.1 In 1821 Seebeck discovered that, in a closed circuit made up of wires of two dissimilar metals, electric current could be caused to flow if the temperature of one junction was elevated above that of the other. In 1886, Le Chatelier introduced a thermocouple consisting of one wire of platinum and the other of 90 per cent platinum-10 per cent rhodium. This combination (Type S) is still the international standard for purposes of calibration and comparison. This type of thermocouple was made and sold by W.C. Heraeus, g.m.b.h. of Hanau, Germany and is sometimes called the Heraeus Couple. Somewhat later, due largely to an error in preparation, it was learned that a thermocouple composed of 87 per cent platinum and 13 per cent rhodium (Type R) would give a somewhat higher e.m.f. output. This type is frequently used in industry.

2.2 In an effort to find less costly metals for use in thermocouples, a number of combinations were tried. Iron and nickel were useful and cheap. Pure nickel, however, becomes very brittle upon oxidation, but it was learned that an alloy of about 60 per cent copper, 40 per cent nickel (Constantan, Advance, Ideal) would eliminate this problem. Hence the Iron-Constantan (Type J) came into use. The calibration presently used for Type J was established by the National Bureau of Standards (see NBS Circular 561).

2.3 Hoskins, in an effort to find a better couple than the iron-nickel combination, developed a 90 per cent nickel, 10 per cent chromium alloy as a positive wire, and a 95 per cent nickel, 5 per cent aluminum, manganese, silicon alloy as a negative wire. This patented and trademarked combination has come to be known as Chromel-Alumel (Type K) and has proved to be very useful.

2.4 Another combination, Copper-Constantan (Type T), has proved very useful, particularly at below zero temperatures. The E.m.f.-Temperature Reference Table, in most general use, was prepared by the National Bureau of Standards in 1938 and is known as the 1938 calibration. An earlier (1921) calibration is still published but rarely used (see NBS Circular 561).

2.5 In 1938, in an effort to arrive at a more consistent Iron-Constantan calibration, the National Bureau of Standards issued Research Paper RP 1080 with new reference tables (Type Y).

2.6 Many other combinations such as carbon-tungsten, nickel-nickel molybdenum, carbon-silicon carbide, chromel-stainless steel (KA_2S) and chromel-constantan have been used but have yet to gain wide acceptance. Recently, the National Bureau of Standards has issued a ten degree Reference Table for Chromel-Constantan. This combination is receiving increasing attention in fields where corrosion of small diameter iron wire is a problem.

2.7 On the basis of general usage and NBS recognition, six types of thermocouples, J, K, Y, S, R, and T have been coded. These letters, which indicate standard combinations, were chosen arbitrarily but with an effort to eliminate any confusion which might arise from the use of such general letter usage as AC, DC, G, etc., and differences which already existed between manufacturers.

2.8 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 (metallic.)*

2.9 Much discussion was involved in the use of *red* to designate negative 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 thirty years.

2.10 The colors used to designate the various compositions and combinations of thermocouple and extension wire were 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.

3. RECOMMENDED SYMBOLS FOR TYPES OF THERMOCOUPLE WIRE

Thermocouple			Thermocouple Symbols		
Combination	Positive Wire	Negative Wire	Combination	Positive	Negative
Iron-Constantan (Type J)*	Iron	Constantan	J	JP	JN
Iron-Constantan (Type Y)*	Iron	Constantan	Y	YP	YN
Chromel-Alumel	Chromel	Alumel	K	KP	KN
Plat., 10% Rhodium-Plat.	Pt, 10% Rh	Platinum	S	SP	SN
Plat., 13% Rhodium-Plat.	Pt, 13% Rh	Platinum	R	RP	RN
Copper-Constantan	Copper	Constantan	T	TP	TN

4. RECOMMENDED SYMBOLS FOR TYPES OF EXTENSION WIRE

	Extension Wire			Extension Wire Symbols		
Thermocouple	Combination	Positive Wire	Negative Wire	Combination	Positive	Negative
Iron-Constantan (Type J)*	Iron-Constantan	Iron	Constantan	JX	JPX	JNX
Iron-Constantan (Type Y)*	Iron-Constantan	Iron	Constantan	YX	YPX	YNX
Chromel-Alumel (Type K)	Chromel-Alumel	Chromel	Alumel	KX	KPX	KNX
Chromel-Alumel	Iron-Alloy	Iron	Alloy	WX	WPX	WNX
Chromel-Alumel	Copper-Constantan	Copper	Constantan	VX	VPX	VNX
Plat., 10% or 13% Rh.-Plat. (Type S or R)	Copper-Alloy	Copper	Alloy	SX	SPX	SNX
Copper-Constantan (Type T)	Copper-Constantan	Copper	Constantan	TX	TPX	TNX

* Iron-Constantan Type J, is the calibration most widely used in industry today and is published in the NBS Circular 561, April 27, 1955, Reference Tables for Thermocouples.

Iron-Constantan Type Y, is the calibration indicated in Bureau of Standards Research Paper RP 1080, Tables 9 and 10 (March 1938).

5. RECOMMENDED COLOR CODE

Duplex Insulated Thermocouple Wire

Thermocouple			Color of Insulation		
Combination	Positive Wire	Negative Wire	Overall**	Positive**	Negative
Iron-Constantan (Type J)	Iron	Constantan	Brown	White	Red
Iron-Constantan (Type Y)	Iron	Constantan	Brown	Grey	Red
Chromel-Alumel (Type K)	Chromel	Alumel	Brown	Yellow	Red
Copper-Constantan (Type T)	Copper	Constantan	Brown	Blue	Red

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

6. RECOMMENDED COLOR CODE

Single Conductor Insulated Thermocouple Extension Wire

Thermocouple Material	Extension Wire Material		Color of Insulation	
	Positive	Negative	Positive	Negative*
Iron - Constantan (Type J)	Iron	Constantan	White	Red - White Trace
Iron - Constantan (Type Y)	Iron	Constantan	Grey	Red - Grey Trace
Chromel - Alumel (Type K)	Chromel	Alumel	Yellow	Red - Yellow Trace
Chromel - Alumel	Iron	Alloy	Green	Red - Green Trace
Chromel - Alumel	Copper	Constantan	Brown	Red - Brown Trace
Plat. 10% or 13% Rhodium - Plat. (Type S or R)	Copper	Alloy	Black	Red - Black Trace
Copper - Constantan (Type T)	Copper	Constantan	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 calibration 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.

7. RECOMMENDED COLOR CODE

Duplex Insulated Thermocouple Extension Wire

Thermocouple Material	Extension Wire Material		Color of Insulation		
	Positive	Negative	Overall	Positive	Negative**
Iron - Constantan (Type J)	Iron	Constantan	Black	White	Red
Iron - Constantan (Type Y)	Iron	Constantan	Black	Grey	Red
Chromel - Alumel (Type K)	Chromel	Alumel	Yellow	Yellow	Red
Chromel - Alumel	Iron	Alloy	White	Green	Red
Chromel - Alumel	Copper	Constantan	Red	Brown	Red
Plat. 10% or 13% Rhodium - Plat. (Type S or R)	Copper	Alloy RED	Green	Black	Red
Copper - Constantan (Type T)	Copper	Constantan	Blue	Blue	Red

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

SECTION 1.2
CODING OF INSULATED DUPLEX THERMOCOUPLE EXTENSION WIRES

1. SCOPE AND PURPOSE

1.1 This Recommended Practice applies to Duplex Thermocouple Extension Wires for Industrial purposes and is to be used in conjunction with Coding of Thermocouple Wire and Extension Wire, Section 1.1 of this Recommended Practice.

1.2 Its purpose is to provide descriptions of the construction of widely used types of duplex insulated extension wire most generally used and to offer a simple code system for the designation of such wire. Many other constructions are commercially available for services where they present advantages. It is not practical to include all types in the code system, but it is not intended to discourage their use.

2. INTRODUCTION

2.1 As an aid to manufacturer, purchaser and consumer, it is believed that a simple code system which describes widely used types of insulated duplex entension wire will be of considerable value. The types of duplex insulated extension wire originally covered in this Recommended Practice are: (1) Moisture-resistant, Type M; (2) Heat-resistant, Type H and (3) Waterproof, Type L. To keep pace with recent developments, a type which combines the heat-resistant qualities of Type H with the waterproof qualities of Type L, and is additionally corrosion resistant, has been designated HL. It is recognized that the rapid introduction of new wire coating materials may result in acceptable alternates.

2.2 The code system consists of three sets of characters which designate the type of extension wire, the wire size, and the insulation construction. They shall be written together, thus:

JX-14-M or JX14M
WX-16-H or WX16H
TX-16-L or TX16L

These above designations, in order, describe the following: JX14M is Type J (Iron-Constantan) Thermocouple Extension Wire (See Section 1.1), 14 indicates the wire or size gage and the letter M indicates moisture resistant insulation described later in this practice.

WX-16-H is Iron-Alloy Extension Wire for Type K (Chromel-Alumel) Thermocouples, 16 gage, covered by heat resistant insulation as described later in this Practice.

TX16L is extension wire for Type T (Copper-Constantan) Thermocouples, 16 gage, lead covered insulation as described for water-proof insulation.

3. TYPE M INSULATION FOR EXTENSION WIRE

3.1 Type M Insulation is intended for general service applications where a moderate degree of moisture is present, but where the wire is not likely to be submerged or subjected to temperatures below 0F. or above 150F.

3.2 *Insulation or Single Conductors:*

3.2.1 Nominal .015 inch polyvinyl chloride insulating compound per ASTM D734-50T, suitable for use over a minimum temperature range of 0F. to 150F.

3.2.2 Color coded as Section 1.1.

3.3 *Overall Covering:*

3.3.1 Nominal .020 inch polyvinyl chloride jacket over two single conductors laid parallel. Polyvinyl chloride compound shall be suitable for use over a minimum temperature range of 0F. to 150F.

3.3.2 Color coded as per Section 1.1.

3.3.3 Overall dimension 5/32 inch x 7/32 inch approximately.

4. TYPE H INSULATION FOR EXTENSION WIRE

4.1 Type H insulation is intended for application where the wires are exposed to high temperatures. This wire will withstand moderate degrees of moisture in sections not exposed to temperatures above 200F. It may be used continuously at 500F where moisture resistance is not required.

4.2 *Insulation on Single Conductors:*

4.2.1 Enameled or otherwise protected against moisture.

4.2.2 Nominal .020 inch asbestos impregnated with moisture resistant compound.

4.2.3 Color coded as per Section 1.1.

4.3 *Overall Braid:*

4.3.1 Asbestos braid over two single conductors laid parallel.

4.3.2 Moisture resistant impregnant.

4.3.3 Color coded as per Section 1.1.

4.3.4 Overall dimensions 7/32 inch x 10/32 inch approximately.

5. TYPE L INSULATION FOR EXTENSION WIRE

5.1 Type L is insulation intended for applications where the wire may be submerged in water or exposed to corrosive fluids which do not attack lead. It should not be subjected to temperatures below – 40F or above 150F.

5.2 *Insulation on Single Conductors:*

5.2.1 Nominal .015 inch polyvinyl chloride insulating compound per ASTM D-734-50T, suitable for use over a minimum temperature range of 0F. to 150F.

5.2.2 Color coded as per Section 1.1.

5.3 *Overall Covering:*

5.3.1 Nominal .020 inch polyvinyl chloride jacket over two single conductors laid parallel. Polyvinyl chloride compound shall be suitable for use over a minimum temperature range of 0F. to 150F.

5.3.2 Color coded as per Section 1.1

5.3.3 3/64 inch lead sheath overall.

5.3.4 Overall dimensions 9/32 inch x 12/32 inch approximately.

6. TYPE HL INSULATION FOR EXTENSION WIRE

6.1 Type HL insulation is intended for applications where the wires are exposed to high temperatures or may be submerged in water or exposed to corrosive fluids. It may be used continuously at –40 to 400°F.

6.2 *Insulation on Single Conductors:*

6.2.1 Nominal .015" "Teflon" FEP resin or "Teflon" TFE insulating component per ASTM D1457-56T, type 3.

6.2.2 Color coded as per Section 1.1.

6.3 *Overall Braid:*

6.3.1 Asbestos braid over two single conductors laid parallel.

6.3.2 Moisture resistant impregnant.

6.3.3 Color coded as per Section 1.1.

6.3.4 Overall dimensions 7/32 inch x 10/32 inch approximately.

SECTION 1.3
THERMOCOUPLES AND THERMOCOUPLE EXTENSION WIRES-TERMINOLOGY, LIMITS OF ERROR, AND WIRE SIZES

1. SCOPE AND PURPOSE

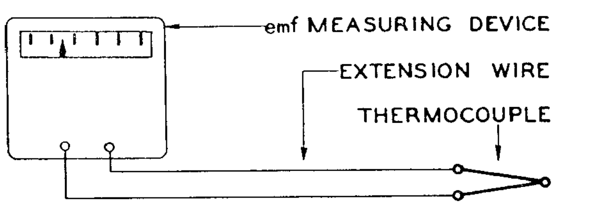
1.1 This section applies to thermocouples and thermocouple extension wires for industrial use.

1.2 The purpose of this section is to establish uniformity of terminology (including symbols), definitions, recommended wire sizes, temperature limits, and limits of error for thermocouples and thermocouple extension wires.

2. TERMINOLOGY

Note: The definitions and symbols in Paragraph 2 (except 2.4) are taken from SAMA "Tentative Standards on Thermocouple Thermometers."

2.1 *Thermocouple Thermometer (Pyrometer).* A temperature measuring instrument comprising an emf measuring device, a detecting means called a *thermocouple* and electrical conductors called *thermocouple extension wires* for operatively connecting the two.



THERMOCOUPLE THERMOMETER (PYROMETER)
FIG. I

2.2 *Thermocouple.* The detecting means of a thermocouple thermometer (pyrometer) comprising two conductors of dissimilar materials electrically insulated from each other except where connected together to form a *measuring junction,* the thermoelectric properties of the materials being such that, with the *reference junction* at a known temperature, the temperature of the measuring junction can be determined by measuring the emf developed.

Note: A thermocouple usually includes associated parts such as a connection head and protecting tube.

2.2.1 *Measuring Junction.* The junction of a thermocouple which is at the temperature to be measured. This junction is sometimes called the *hot junction.*

2.2.2 *Reference Junction.* The junction of a thermocouple which is at a known or reference temperature. This junction is sometimes called the *cold junction.*

Note: In normal industrial practice the thermocouple wire 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 wires.

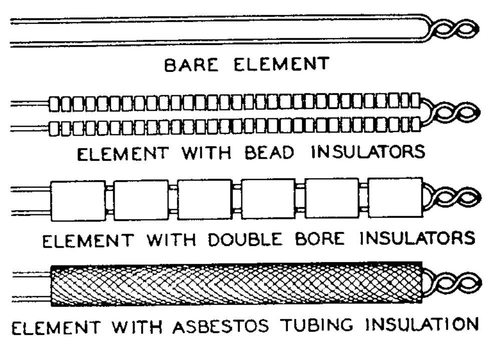
2.3 *Thermocouple Extension Wires.* A pair of wires having such temperature-emf characteristics relative to the thermocouple, with which the wires are intended to be used, that, when properly connected to the thermocouple, the thermocouple reference junction is in effect extended to the other end of the wires.

2.4 *Limit of Error.* The limit of error of a thermocouple (or of thermocouple extension wire) is the maximum deviation in degrees from the standard temperature-emf values for the type of thermocouple in question when the reference junction temperature of the thermocouple is at a known reference temperature and the measuring junction is at the temperature to be measured.

Note 1: In making acceptance tests on *thermocouples,* the reference junction temperature used may be any value agreed upon between the supplier and purchaser. The value most commonly used is either 32° F. or 75° F.

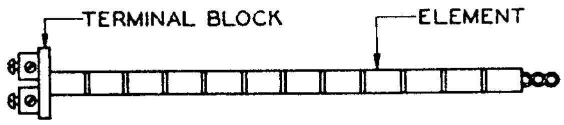
Note 2: In making acceptance tests on *thermocouple extension wires,* the two wires are joined to form a measuring junction and the extension wire is then tested as a thermocouple, with the measuring junction at the assumed connection head temperature of the thermocouple. The maximum measuring junction temperature is either 200° F. or 400° F., depending on the type of extension wires (see 5.1 and 5.2) and the reference junction is either 32° F. or 75° F. in accordance with 5.1 and 5.2.

2.5 *Thermocouple Element.* A thermocouple designed for use as part of an assembly such as a thermocouple with protecting tube but without associated parts such as terminal block, connection head or protecting tube.



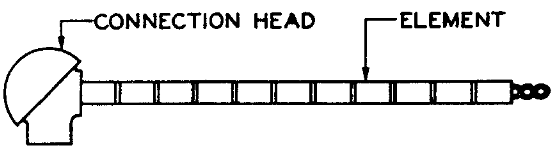
THERMOCOUPLE ELEMENTS
FIG. 2

2.6 *Thermocouple with Terminal Block.* An assembly consisting of a thermocouple element to which is attached a suitable terminal block for the connection of thermocouple extension wire.



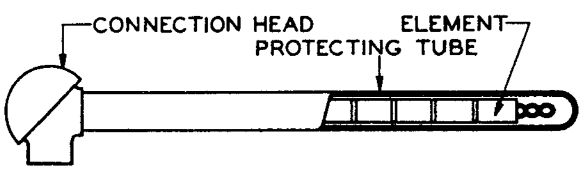
THERMOCOUPLE WITH TERMINAL BLOCK
FIG. 3

2.7 *Thermocouple with Head.* An assembly consisting of a thermocouple element with a connection head.



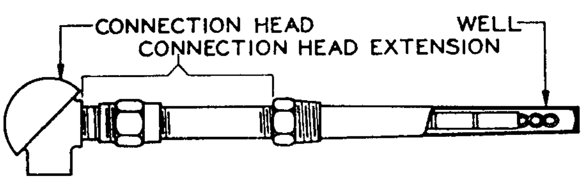
THERMOCOUPLE WITH HEAD
FIG. 4

2.8 *Thermocouple with Protecting Tube.* An assembly consisting of a thermocouple element, protecting tube and connection head.



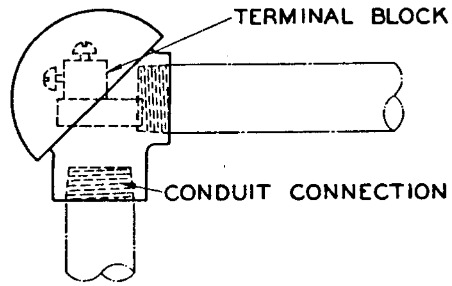
THERMOCOUPLE WITH PROTECTING TUBE
FIG. 5

2.9 *Thermocouple with Well.* An assembly consisting of a thermocouple element, well, and a connection head. The connection head is attached to the well, usually by means of a connection head extension.



THERMOCOUPLE WITH WELL
FIG. 6

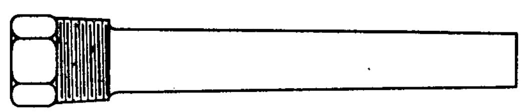
2.10 *Connection Head.* A protecting housing containing a terminal block and normally provided with threaded openings for mounting the connection head on a protecting tube or well and for the attachment of a conduit.



CONNECTION HEAD
FIG. 7

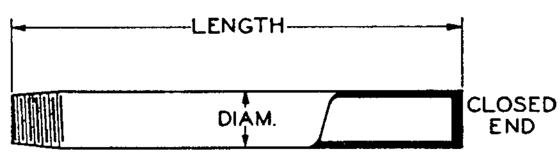
2.10.1 *Connection Head Extension.* A threaded fitting, usually a pipe nipple, or an assembly of fittings, extending between a well and a connection head.

2.11 *Well.* A pressure-tight receptacle adapted to receive a temperature-sensitive element, provided with external threads or other means for pressure-tight attachment to a vessel.



WELL
FIG. 8

2.12 *Protecting Tube.* A closed-end tube adapted to receive the measuring junction of a thermocouple, designed for attachment to a connection head and not primarily designed for pressure-tight attachment to a vessel.

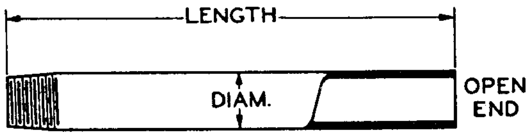


PROTECTING TUBE
FIG. 9

2.12.1 *Protecting Tube Length.* The overall length of a protecting tube.

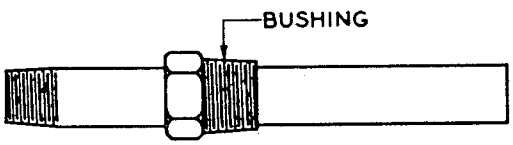
2.12.2 *Protecting Tube Diameter.* The outside diameter of a protecting tube.

2.13 *Open End Protecting Tube.* A tube adapted to receive the measuring junction of a thermocouple. It is designed at one end for attachment to a connection head and is open at the other end.



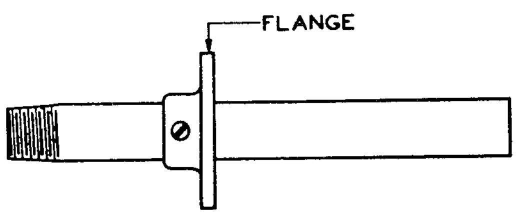
PROTECTING TUBE
FIG. 10

2.14 *Protecting Tube with Mounting Bushing.* A protecting tube with a threaded bushing welded or otherwise attached to the tube and not primarily designed for pressure-tight attachment to a vessel.



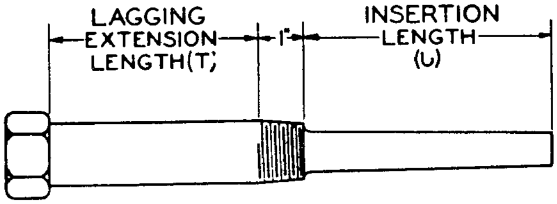
PROTECTING TUBE WITH MOUNTING BUSHING
FIG. 11

2.15 *Protecting Tube with Flange.* A protecting tube with a mounting flange welded or otherwise attached to the tube and not primarily designed for pressure-tight attachment to a vessel.



PROTECTING TUBE WITH MOUNTING FLANGE
FIG. 12

2.16 *Lagging Extension.* The portion of a well, above the external threads, intended to extend through the lagging of the vessel.

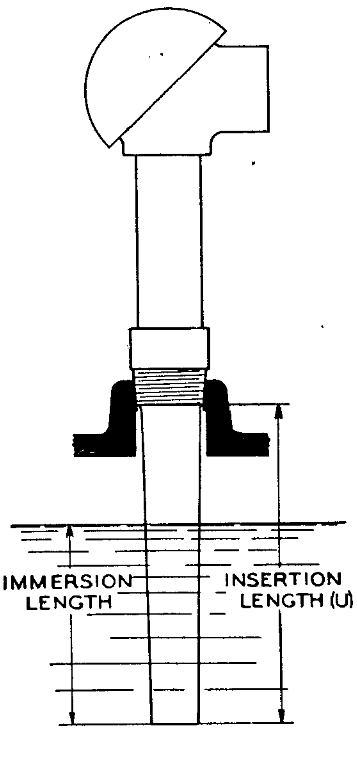


WELL WITH LAGGING EXTENSION
FIG. 13

2.16.1 *Lagging Extension Length (Symbol "T").* The length from the lower end of the external thread of the well to the upper end of the portion intended to pass through the lagging on the vessel, less one inch allowance for threads.
Note: The preferred lagging extension length is three inches.

2.17 *External Threads for Bushings or Wells.* The threads shall be American Standard Taper Pipe Threads (NPT) of the American Standards Association.
Note: Preferred sizes shall be ¾-inch and 1-inch NPT. For purposes of uniform dimensioning, the thread length shall be considered one inch.

2.18 *Immersion Length.* The length from the free end of the protecting tube, well, or thermocouple element, if unprotected, to the point of immersion in the medium, the temperature of which is being measured. (Physically, this point may be indistinguishable but it is important for proper accuracy.)



IMMERSION AND INSERTION LENGTHS FOR THERMOCOUPLE WITH WELL
FIG. 14

2.19 *Insertion Length (Symbol "U").* The length from the free end of the protecting tube, well, or thermocouple element, if unprotected, to (but not including) the external threads or other means of attachment to a vessel.

2.20 *Special Thermocouples.*

2.20.1 *Pipe (Pencil) Type Thermocouple.* A thermocouple comprising: (a) A wire inside a closed-end tube. The wire and the tube are joined at the closed end to form a measuring junction. (b) Two wires enclosed in a protecting tube and joined at the measuring junction to the protecting tube.

3. RECOMMENDED WIRE SIZES

3.1 *Thermocouples.* The recommended wire sizes for thermocouples are as follows:

3.1.1 *For Iron-Constantan and Chromel-Alumel:* 8, 14, 20, 24 and 28 AWG*.

3.1.2 *For Copper-Constantan:* 14, 20, 24, and 28 AWG*.

3.1.3 *For Platinum Rhodium-Platinum:* 24 AWG only.

3.2 *Extension Wires.* The recommended wire sizes for extension wire used singly or in pairs are 14 and 16 AWG*. 20 gage and smaller may be used when bundled and reinforced to provide strength for pulling. These sizes apply to all types of extension wires.

* American Wire Gage, also known as B & S, (Brown & Sharpe.)

4. RECOMMENDED UPPER TEMPERATURE LIMITS

4.1 Table I below gives the recommended upper temperature limits for the various thermocouples and wire sizes. These limits apply to "protected" thermocouples, i.e., thermocouples in closed-end protecting tubes.

In any general recommendation of thermocouple temperature limits, it is not practicable to take into account special cases. In actual operation, there may be instances where the temperature limits recommended will be exceeded. Likewise, there may be applications where satisfactory life will not be obtained at the recommended temperature limits. However, in general, the temperature limits listed are such as to provide satisfactory thermocouple life when the wires are operated continuously at these temperatures.

Various factors affecting thermocouple life are discussed under Section 1.6, "Thermocouples and Thermocouple Extension Wires – Installation."

Table I – Recommended Upper Temperature Limits for Protected Thermocouples

	UPPER TEMPERATURE LIMIT (°F.) FOR VARIOUS WIRE SIZES (AWG)				
	8	14	20	24	28
Thermocouple Type	(.128 in.)	(.064 in.)	(.032 in.)	(.020 in.)	(.013 in.)
Copper-Constantan	–	700° F.	500° F.	400° F.	400° F.
Iron-Constantan.....................	1400° F.	1100° F.	900° F.	700° F.	700° F.
Chromel-Alumel	2300° F.	2000° F.	1800° F.	1600° F.	1600° F.
Platinum Rhodium–Platinum	–	–	–	2700° F.	–

5. RECOMMENDED LIMITS OF ERROR

5.1 Table II on Page 12 gives the recommended standard and special limits of error for thermocouples and thermocouple extension wires. The limits of error for each type of thermocouple apply only over the temperature range for which the wire size in question is recommended. Furthermore, these limits of error should be applied only to standard wire sizes. The same limits of error may not be obtainable in special sizes.

Where limits of error are given in per cent in Table II, the percentage applies to the temperature being measured. For example, the standard limit of error of Iron-Constantan over the temperature range 530°F. to 1400°F. is ± ¾ per cent. If the temperature being measured is 1000°F., the limit of error is ± ¾ per cent of 1000, or ± 7.5°F.

The extension wires listed in Table II are of the same material as the thermocouple. The alternate extension wires used with Chromel-Alumel, (Iron-Alloy or Copper-Constantan) and also the copper-alloy extension wire used with Platinum Rhodium-Platinum thermocouples are covered in Table III.

Table II—Limits of Error of Thermocouples and Extension Wires for Standard Wire Sizes

THERMOCOUPLES				EXTENSION WIRES		
		Limits of Error			*Limits of Error, °F.*	
Type	*Temp. Range, °F.*	*Standard*	*Special*	*Temp. Range, °F.*	*Standard*	*Special*
Copper-Constantan	−300 to −75	−	± 1%			
	−150 to −75	± 2%	± 1%			
	−75 to +200	± 1½° F.	± ¾° F.	−75 to +200	± 1½	± ¾
	200 to 700	± ¾%	± ⅜%			
Iron-Constantan	0 to 530	± 4° F.	± 2° F.	0 to 400	± 4	± 2
	530 to 1400	± ¾%	± ⅜%			
Chromel-Alumel	0 to 530	± 4° F.	−	0 to 400	± 4	−
	530 to 2300	± ¾%				
Platinum Rhodium—Platinum..	0 to 1000	± 5° F.		SEE TABLE III		
	1000 to 2700	± 0.5%	−			

5.2 Table III below gives the recommended limits of error of alternate extension wires for use with Chromel-Alumel thermocouples and of the base metal extension wire used with Platinum Rhodium-Platinum thermocouples. The limits of error listed are applicable for a reference junction temperature of 75° F. only.

Table III—Limits of Error of Alternate Extension Wires for Standard Wire Sizes

Type of Thermocouple	*Type of Extension Wire*	*Temperature Range, °F.*	*Limits of Error, °F.*
Chromel-Alumel	Copper-Constantan	75 to 200	±6
Chromel-Alumel	Iron-Alloy	75 to 400	±6
Platinum Rhodium—Platinum	Copper-Alloy	75 to 400	±12

SECTION 1.4
THERMOCOUPLES-FABRICATION

1. GENERAL

1.1 Many users find it desirable to fabricate their own thermocouples. Although some degree of skill is required and a few precautions are necessary, the use of the instructions given in this section should produce successful results.

2. SOURCES OF MATERIALS

2.1 Thermocouple wires in various diameters are available. These wires have been manufactured, tested, and selected so that when paired as indicated in Table I, the thermal emf developed by them will be in accordance with the established values for that thermocouple.

It must be emphasized that the two elements for a given type of thermocouple should be purchased at the same time from the same supplier. Although correctly paired wires will conform to the specified calibration table, *random elements so paired may not.* For example, the Constantan for Type J Iron-Constantan thermocouples may not have the same thermal emf characteristics as that for Type T Copper-Constantan thermocouples.

3. WELDING OF THERMOCOUPLES

3.1 The two elements of a thermocouple must be permanently joined at one end to form the measuring junction (sometimes called the "hot" junction). Although soldering of the junction may be used where low temperatures only are encountered, welding is recommended for most applications.

There are three methods of welding in common use, namely: (1) gas welding, (2) electric arc welding, and (3) resistance welding.

Reference to Table I will indicate the welding methods applicable to the commonly used thermocouples. Where NR appears in the table, that particular method is *not recommended* for that thermocouple.

Where flux is required, powdered boric acid is generally satisfactory.

Table I—Welding of Thermocouples—Summary of Recommended Methods

THERMOCOUPLE		METHODS OF PREPARATION FOR VARIOUS WELDING METHODS			
		GAS	ELECTRIC ARC		RESISTANCE
Kind	*Size***	*(Welding Method 3.3)*	*Single Electrode (Welding Method 3.4.1)*	*Double Electrode (Welding Method 3.4.2)*	*(Welding Method 3.5)*
* Copper-Constantan	large	3.2.1	3.2.1	3.2.1	NR
	small	3.2.2	NR	3.2.2	NR
* Iron-Constantan	large	3.2.1	3.2.1	3.2.1	3.2.3
	small	3.2.2	NR	3.2.2	NR
Chromel-* Alumel †	large	3.2.1	3.2.1	3.2.1	3.2.3
	small	3.2.2	NR	3.2.2	3.5
Plat. Rhod. – * Plat.	–	NR	NR	3.2.4	3.5

** Large size includes 8 and 14 AWG; small size includes 20, 24, and 28 AWG
* Denotes lower melting point material
† Registered trade mark of Hoskins Corp.
NR Not recommended

3.2 *Preparation of Wires.* The matched wires must first be cut to the required lengths, as determined by the proposed thermocouple element assembly. The use of the different types of terminal blocks and connection heads which are available will influence the length to which the wires are cut initially. Experience will determine the dimensions which best suit the individual requirements.

The cut wires will be curved from having been coiled and should be carefully straightened. In this operation, hammering or excessive twisting and bending of the wires must be avoided. Excessive cold working or tool handling may alter the thermal emf or damage the surface and contribute to short life. Commercial wire straightening devices are available.

In all cases, care should be taken in the formation of the junction, to avoid nicks and other damage to the surface of the wire, as these may shorten the life of the thermocouple.

Where many thermocouples are to be made, a simple jig will be found helpful for twisting or shaping the ends of the wires.

In all cases the junctions should be formed so as to provide the required spacing between the wires to permit easy insertion into whatever insulators are to be used.

3.2.1 *For Gas and Electric Arc Welding — Large Size Wires.* In the case of large size (8 and 14 AWG) base metal wires, about one inch of each wire, at the end to be welded, should be cleaned preferably with abrasive paper or by very careful grinding or filing.

The cleaned ends should be twisted together with approximately one and a half turns, as shown in Fig. 1.

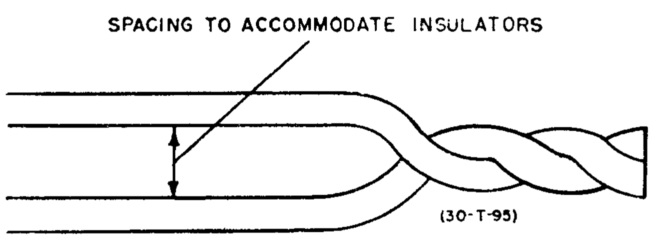


FIG. 1

METHOD OF TWISTING WIRES FOR GAS AND ELECTRIC ARC WELDING

3.2.2 *For Gas and Electric Arc Welding — Small Size Wires.* In the case of small size (20, 24, and 28 AWG) base metal wires, about one-half inch of each wire, at the end to be welded, should be cleaned with fine abrasive paper.

The cleaned ends should be twisted together with approximately one and a half turns, as shown in Fig. 1.

3.2.3 *For Resistance Welding — Large Size Wires.* In the case of large size (8 and 14 AWG) base metal wires, about one-half inch of each wire, at the end to be welded, should be cleaned preferably with abrasive paper or by very careful grinding or filing.

The cleaned ends should be shaped to bring them into longitudinal contact, as shown in Fig. 2.

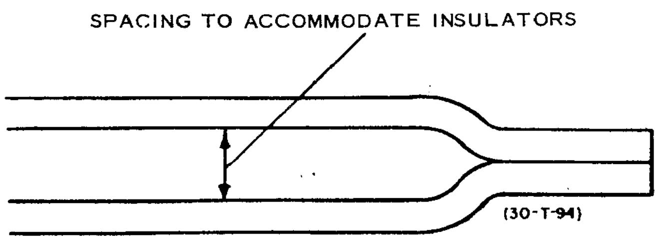


FIG. 2

METHOD OF FORMING BASE METAL WIRES FOR RESISTANCE WELDING

3.2.4 *For Electric Arc Welding — Noble Metal Wires.* Extra care should be taken in handling to avoid cold working and contamination by dirt, oil, perspiration, etc.

No surface preparation is required.

The ends of the wires to be welded should be brought together as shown in Fig. 3.

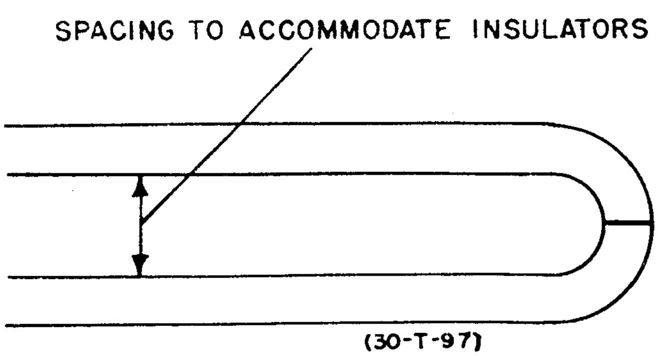


FIG. 3

METHOD OF FORMING NOBLE METAL WIRES FOR ELECTRIC ARC WELDING

3.3 *Gas Welding.* The character of the flame is the most important consideration in the gas welding of thermocouple elements. AN OXIDIZING FLAME SHOULD NEVER BE USED; such a flame is injurious to the metals and will not produce a good weld. The proper flame is illustrated in Fig. 4.

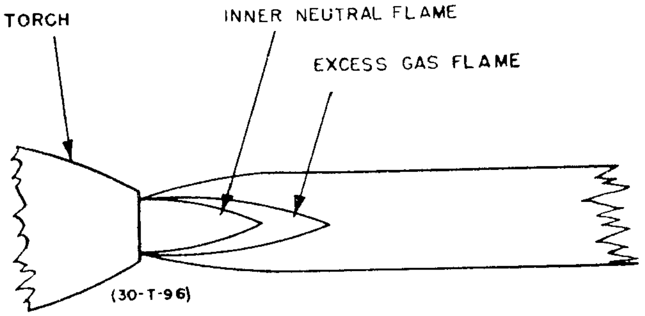


FIG. 4

FORM OF FLAME FOR GAS WELDING

The proper size tip to use depends upon the kind of gas, the size and kind of wire. Select the smallest tip that will be sufficient for the operation.

Direct the tip of the inner (neutral) flame at the end of the twisted wires and heat bright red.

Immediately dip the heated ends of the wires into the flux.

Again direct the tip of the inner (neutral) flame at the ends of the wires. Since one wire melts at a lower temperature than the other (as indicated in the table), manipulate the weld in the flame until both wires reach their melting point at about the same time. This can be done by keeping the wire that melts first in the cooler part of the flame until the other wire is about to melt. As soon as both wires reach the melting point, revolve the weld in the flame until both metals flow together forming a ball at the tip.

Remove the remaining flux by dipping in water immediately.

The weld should be made, if possible, on the first attempt. Continued heating at welding temperatures will result in a poor weld.

The weld should be inspected with a low power magnifying glass to disclose evidence of burning. This can be detected by the presence of small pits on the surface.

If a good weld is not obtained and a shorter thermocouple can be used, cut off the ends and repeat the procedure. Otherwise, discard the thermocouple.

3.4 *Electric Arc Welding.*

3.4.1 *Single Carbon Electrode Type.*

3.4.1.1 *Principle.* The principle of single electrode carbon arc welding is that an electric arc is drawn between the junction to be welded, which forms one electrode for the circuit, and a carbon electrode. By placing the carbon electrode in contact with the junction, thus closing the circuit, and immediately withdrawing it, an arc is drawn. The high temperature of the arc heats and fuses the junction.

3.4.1.2 *Equipment Required.* The essential elements in single carbon arc welding are:

(a) a source of electric current;

(b) a suitable rheostat for regulating the current;

(c) a carbon electrode with insulated holder;

(d) a clamp or vise to hold the wires and to act as the other terminal for the electric current.

The electrode should be pure soft carbon of size to suit. Alternating current (ac) or direct current (dc) may be used. Direct current (dc) is preferred.

3.4.1.3 *The Welding Operation.* The ends of the wires to be joined should be dipped into water and then into the recommended flux.

The wires should then be clamped in a vise with the ends pointing upward. Avoid injury to the wires. The positive lead (if direct current is used) should be connected to the vise.

The carbon electrode, connected to the negative lead, should then be brought into contact with the junction and withdrawn to draw an arc.

A quick weld should be made, the quicker the better. Care should be taken, however, not to use too much current as the metals may be burned. The correct arc should have a gap of about 1/16 of an inch, which will minimize oxidation and nitrogen absorption.

For an 8 AWG thermocouple, the voltage across the electrodes should be adjusted to approximately 30 to 45 volts. Proportionately lower voltage should be used for the smaller sizes of wire. Experience will indicate the optimum voltage to use.

A small solid bead should be produced on the ends of the wires and care should be taken not to obtain any bridged welds or gaps of metal between the two wires for these are structurally weak.

3.4.2 *Double Carbon Electrode Type.*

3.4.2.1 *Principle.* The principle of double carbon arc welding is that of an electric arc drawn between two electrodes. By placing the junction to be welded between the two electrodes, it will be heated to fusion temperature.

3.4.2.2 *Equipment Required.* The essential elements in double electrode carbon arc welding are:
(a) a source of electric current;
(b) a suitable rheostat for regulating the current;
(c) two carbon electrodes with insulated holders;
(d) a clamp or vise to hold the wires.

The electrodes should be pure soft carbon of size to suit. Alternating current (ac) or direct current (dc) may be used.

3.4.2.3 *The Welding Operation.* The ends of the wires to be joined should be dipped into water and then into the flux.

The wires should then be clamped in a vise with the ends pointing upward. Avoid injury to the wires.

The two carbon electrodes should be brought together and separated to draw an arc.

The electrodes should then be moved so as to bring the arc into contact with the junction to be welded.

A quick weld should be made, the quicker the better. Care should be taken, however, not to use too much current as the metals may be burned.

For an 8 AWG thermocouple, the voltage across the electrodes should be adjusted to approximately 30 to 45 volts. Proportionately lower voltage should be used for the smaller sizes of wire. Experience will indicate the optimum voltage to use.

A small solid bead should be produced on the ends of the wires and care should be taken not to obtain any bridged welds or gaps of metal between the two wires for these are structurally weak.

3.5 *Electric Resistance Welding.* In this method, the contact resistance between the two wires at the junction, and the resistance of the wires themselves, cause heat to be generated when sufficient electric current is passed through them, thus fusing them.

The junction should be placed between the electrodes of a resistance welder. Pressure and current should be applied for the necessary time to produce a good weld.

The amount of pressure, time, and current necessary varies with the welding equipment available, the size of the wires, and the material. Too great a pressure will reduce the resistance between the wires, and produce a weld which looks good, but will be fused only around the edges. This is a precise technique and should be so conducted.

SECTION 1.5
THERMOCOUPLES - CHECKING PROCEDURES

1. GENERAL

1.1 New thermocouples, thermocouple materials, and thermocouple extension wire are controlled by the supplier to fit a published temperature-emf table or curve within stated tolerances. Thermocouple extension wire normally retains its original characteristic but thermocouples, which are exposed to high temperatures in various atmospheres, may change characteristics. To avoid the continued use of thermocouples with excessive deviations from the original characteristic, due to such exposure or contamination, it is good practice to check the thermocouples at intervals. Furthermore, the user may wish to determine the characteristics of new thermocouples and thermocouple materials.

2. SCOPE AND PURPOSE

2.1 Recommendations and suggestions are given below for simple and ordinarily adequate procedures for checking installed thermocouples. Calibrating procedures for new thermocouple materials are given in Circular 590 of the National Bureau of Standards, "Methods of Testing Thermocouples and Thermocouple Materials" by Wm. F. Roeser and S. T. Lonberger, which describes various testing methods, and the precautions which must be observed in order to attain various degrees of accuracy. In particular, it describes in detail the methods developed and used at the National Bureau of Standards.

NOTE
WRITE FOR.

3. PROCEDURE

3.1 The checking of installed thermocouples is complicated by the thermo-electric non-uniformity resulting from contamination or deterioration of the elements. The unheated terminals of the used thermocouple will normally be like new; the actual junction, contaminated or deteriorated; and the intermediate material, affected to various degrees.

The output of a contaminated or deteriorated thermocouple will not be determined solely by the temperature of the heated junction and of the reference junction, as with a new homogeneous thermocouple, but also by the temperature gradient between the hot and cold end, and the pattern of contamination and deterioration in the temperature gradient zone. For this reason a used thermocouple should not be removed from its installed location and placed in a calibrating furnace for checking since it is highly improbable that the temperature gradients in the two locations will be the same.

A used thermocouple must be checked in its normal installed location. The purpose of checking an installed thermocouple is not to determine its temperature-emf characteristics, but to determine the temperature error in actual service. This can most readily be done by temporarily installing a new or checking thermocouple alongside the service thermocouple, or in its place, and comparing the readings.

3.2 Where the protecting tube is large enough, a checking thermocouple may be inserted beside the service thermocouple. It is recommended that a separate checking instrument be used with the checking thermocouple, to permit checking of the service instrument, as well as of the service thermocouple.

Where the protecting tube is not large enough to permit the insertion of an additional thermocouple, it is necessary to remove the service thermocouple and to replace it with a checking thermocouple. When this method is used, it is essential that stable temperature conditions be maintained. In general, the higher the temperature or more contaminating the atmosphere, the more frequently checks should be made.

3.3 Large temperature gradients can exist in commonly used furnaces and other devices, and points physically close together may be at surprisingly different temperatures. The procedure of checking a thermocouple installation by means of a checking thermocouple inserted through a furnace door or otherwise installed in a different part of the apparatus from the service thermocouple is not recommended, since the thermocouple readings may fail to agree, and yet both be correct.

3.4 Checking thermocouples or secondary standards should be homogeneous and uncontaminated. Any new thermocouple may be used but it should be checked against a primary standard and tagged with its deviation from the standard curve. If a user does not have the equipment and technique for doing this, calibrated and tagged thermocouples are available. The National Bureau of Standards will furnish a report on the temperature-emf characteristics of a submitted thermocouple.

3.5 The accuracy of a checking thermocouple or secondary standard will become questionable after use. Noble metal thermocouples may normally be relied upon for a considerable period of use, provided that the checking temperatures have not been excessive and that contamination has been avoided. Base metal thermocouples used for checking purposes should be checked frequently.

3.6 A thermocouple can be calibrated by comparing it with a standard thermocouple when both are at the same temperature. This procedure is deceptively simple and should be adopted only when suitable equipment and experienced personnel are available. If laboratory facilities are to be set up to determine the condition of used checking couples and of thermocouple materials in general, helpful information may be found in National Bureau of Standards Circular 590, and in the publications of suppliers of suitable laboratory equipment such as potentiometers and galvanometers.

SECTION 1.6

THERMOCOUPLES AND THERMOCOUPLE EXTENSION WIRES - INSTALLATION

1. SCOPE AND PURPOSE

1.1 This Section presents general information on the installation of commonly used industrial thermocouples and thermocouple extension wires.

1.2 The purpose of this Section is to provide a guide to assist the industrial user in selecting the proper type of thermocouple for a particular application, and in installing the thermocouple and its associated extension wire.

2. TYPES AND USES

2.1 Four types of thermocouples are in general use today, namely; Copper-Constantan; Iron-Constantan; Chromel-Alumel*; and Platinum Rhodium–Platinum. Each of these types has individual characteristics that render it desirable for some applications and unsuitable for others.

2.2 Copper-Constantan is commonly used for subzero temperatures and has an upper temperature limit of 700°F. It may be used in either oxidizing or reducing atmospheres.

2.3 Iron-Constantan is occasionally used for subzero temperatures but the possible rusting or embrittlement of the iron wire under these conditions is sometimes objectionable. This thermocouple has an upper temperature limit of 1400°F. It may be used in either oxidizing or reducing atmospheres.

In addition to the usual form of two wires, the Iron Constantan thermocouple is available with the iron element in the form of a tube surrounding the Constantan element which is in wire form. This type of thermocouple ("pipe" type or "pencil" type) is commonly used without a protecting tube. In small sizes it has high speed of response.

2.4 Chromel-Alumel may be used from 0°F to its upper temperature limit of 2300°F. It should be used in oxidizing atmospheres since it has a short life in reducing atmospheres or in atmospheres that are alternately oxidizing and reducing. An oxidizing atmosphere inside the protecting tube may be obtained by providing adequate ventilation. The use of a sufficiently large protecting tube and an open head will be of material assistance. NOTE

2.5 Platinum Rhodium–Platinum may be used for temperatures up to 2700°F. This thermocouple is easily contaminated and should always be used in a protecting tube. The protecting tube should be *non-metallic*, since the thermocouple is contaminated by metallic vapors at high temperatures. It should be used in oxidizing atmospheres only. The Platinum Rhodium – Platinum thermocouple is frequently used for calibration or checking since it is one of the primary standards.

* *Trademark registered Hoskins Corp.*

3. ASSEMBLY

3.1 The fabrication of thermocouples requires special techniques as described in Section 1.4. If the equipment and skill required to fabricate thermocouples properly is not available, the user should purchase fabricated thermocouples, since improper techniques can result in significant errors in temperature measurements.

3.2 The wires for making thermocouples should preferably be purchased in matched pairs. Suppliers select elements which when used together have limits of error within specified tolerances as given in Section 1.3.

3.3 It is essential that the thermocouple have the same calibration as the instrument with which it is to be used. For example, several calibration curves have been used in the past for Copper-Constantan and Iron-Constantan thermocouples, and some of these curves deviate widely from those in common use today. Likewise, the two Platinum Rhodium – Platinum thermocouples, Types S and R, differ in calibration by about 10 per cent.

3.4 Ceramic insulators are used on most thermocouples. Insulators are available in a variety of shapes and lengths, with one or more holes for the wires. For Platinum Rhodium–Platinum thermocouples, it is recommended that, wherever practicable, the ceramic insulators be as long as the thermocouple so as to provide maximum protection from contamination.

For base metal thermocouples, insulators made from braided glass or asbestos are sometimes used. Such materials should not be used with Platinum Rhodium – Platinum, as they will contaminate the thermocouple. Thermocouples may be made from insulated thermocouple wire but should not be made from thermocouple extension wire.

3.5 Protecting tubes are used for most thermocouple installations to prevent contamination of the thermocouple and provide mechanical protection and support. The diameter of the protecting tube should be such as to provide clearance for the thermocouple. One-inch nominal diameter tubes are most commonly used.

This size permits checking by inserting a checking thermocouple by the method described in Section 1.5, and also may be utilized to provide ventilation of the thermocouple where necessary. The length of the protecting tube should be such as to place the measuring junction of the thermocouple well into the medium, the temperature of which is to be measured.

3.6 A wide range of metal and ceramic protecting tubes are available. Depending upon the application, the protecting tube should have some or all of the following properties:

3.6.1 Mechanical strength to withstand pressure, vibration or to resist sagging at high temperatures.

3.6.2 Temperature resistance to withstand the temperatures being measured; thermal shock resistance so that sudden temperature changes will not damage the tube.

3.6.3 Corrosion resistance to avoid chemical action with the medium in which the tube is immersed.

3.6.4 Erosion resistance.

3.6.5 Low porosity at operating temperature. This is especially true of protecting tubes installed in furnaces since furnace gases are generally injurious to thermocouples.

4. INSTALLATION—THERMOCOUPLES

4.1 Selection of the place in the process where the thermocouple is to be installed should be made with care. In large furnaces, tanks, and the like, there are likely to be dead spots where fluid circulation is sluggish and the temperature is not representative. Where practicable, the thermocouple should be installed at baffles, in the uptake to a stack, in a pipe line, or similar location where the fluid is flowing rapidly so that better heat transfer and a rapid response of the thermocouple to temperature change is obtained.

The protecting tube should be immersed sufficiently to minimize heat transfer along its length. Ten times the outside diameter of the protecting tube is the recommended minimum immersion; this value should be increased where space permits. With flowing liquids, six diameters immersion may be used if the pipe and the external portion of the protecting tube are well insulated. Thermocouples should be installed vertically if possible. When mounted horizontally, it may be necessary to support the protecting tube, especially at high temperatures.

4.2 A thermocouple connection head is recommended to provide positive connections between the thermocouple and the extension wire. The head also permits easy replacement of the thermocouple.

4.3 The protecting tube should extend beyond the outer surface of the vessel, furnace, or processing equipment sufficiently so that the temperature of the connection head approximates the ambient atmospheric temperature. This is especially true for Platinum Rhodium — Platinum thermocouples and for Chromel-Alumel thermocouples using alternate extension wires. The connection head temperature should never exceed the temperature limits given in Section 1.3 for thermocouple extension wires.

4.4 After all the steps outlined above have been carried out, the actual installation of a thermocouple still requires some care. Both the thermocouple and the extension wire should be cleaned before fastening in the connection block to assure good electrical contacts. Color-coded insulation identifies the positive and negative elements of the extension wire. It is necessary to have the thermocouple wires tagged or otherwise identified as to polarity. The following information can be used to determine polarity in the field:

4.4.1 For extension wire having insulation color-coded in accordance with Section 1.1, the *negative wire insulation is always colored red.*

4.4.2 For Iron-Constantan, the iron wire is frequently rusty and is magnetic. The iron wire is the positive element.

4.4.3 For Chromel-Alumel, the Alumel wire is slightly magnetic. The Alumel wire is the negative element.

4.4.4 For Platinum Rhodium — Platinum, the platinum wire is softer than the alloy wire. The platinum wire is the negative element.

4.4.5 For Copper-Constantan, the copper wire is red and the Constantan wire is silver in appearance. The copper wire is the positive element.

4.5 Bottoming of the thermocouple in the protecting tube is often practiced to improve the response to temperature change. Bottoming consists of having the thermocouple junction pressed tightly against the end or "bottom" of the protecting tube. However, bottoming may ground the thermocouple which, with some types of installations, causes difficulties.

When thermocouples are used for temperature difference or in thermopiles, bottoming may cause shorts that will render the installation useless. Consequently, bottoming is only recommended to the extent that the user knows that it will not cause trouble.

4.6 It must be borne in mind that zero error is unattainable. In addition to the instrument error, the thermocouple and the extension wire will introduce errors. In Section 1.3 are tabulated the limits of error that can be expected in new materials. The installed components may deteriorate with use and methods of checking the installation are given in Section 1.5.

5. INSTALLATION—EXTENSION WIRE

5.1 Recommended types of extension wires for use with the various types of thermocouples are listed in Table I.

Table I—Recommended Types of Extension Wire

Theromcouple Type	*Recommended Type of Extension Wires*
Iron-Constantan, Type J Iron-Constantan, Type Y	Iron-Constantan, Type JX Iron-Constantan, Type YX
Copper-Constantan, Type T	Copper-Constantan, Type TX
Chromel-Alumel, Type K	*Chromel-Alumel, Type KX **Iron-Alloy, Type WX ***Copper-Constantan, Type VX
Platinum Rhodium – Platinum (Type S) Platinum Rhodium – Platinum (Type R)	Copper-Alloy, (Type SX) Copper-Alloy, Type SX

*For Maximum Accuracy
**For use up to 400°F. (More economical but introduces some error. See Section 1.3, Paragraph 5.2)
***Should not be used where head temperature exceeds 200°F. (See Section 1.3, Paragraph 5.2)

5.2 Potentiometer type instruments are not critical as to extension wire resistance. However, single wires and pairs smaller than 16-gauge are not recommended for use in conduit, as they do not have sufficient strength for pulling. 20 gage and smaller wire may be used when assembled in suitably reinforced bundles to provide pulling strength. Where extension wire smaller than 16-gauge is required, insulated thermocouple wire may be used. The total resistance of the extension wire is important when used with millivoltmeter type instruments. Some millivoltmeters require a specific resistance in the extension wire.

Many of the more recent millivoltmeters are made with a high internal resistance. The extension wire used with these instruments does not have to be calibrated but the total resistance should be kept to approximately the value given on the instrument scale. Therefore, it is usually necessary to use a large size wire. Sizes 14- and 16-gauge are recommended.

5.3 The insulation used on extension wires may be divided into three general classifications: waterproof, moisture resistant, and heat resistant. Materials used for insulating extension wire are selected to perform a variety of functions. These include: physical protection, bonding, mechanical separation, and electrical insulation.

In a permanently dry location these functions can be performed by non-conducting substances such as cotton, glass, asbestos fibers, paper tapes, and ceramic beads. Where moisture may be present, more or less impervious barriers are required. These may be enamel coatings, asphalt or wax impregnations, plastic, rubber or lead sheaths. Where heat resistance is necessary, glass, asbestos fibers, and ceramics may be used. Where the extension wire may be exposed to varying degrees of heat and moisture, a combination of two or more of these materials may give a satisfactory insulation.

5.4 Thermocouple extension wire should always be installed in the best manner to protect it from excessive heat, moisture, and mechanical damage. Wherever practicable it should be installed in conduit so that it is not subjected to excessive flexing or bending, which might change the thermoelectric characteristics.

The layout and arrangement of the conduits for a thermocouple system should be given considerable thought. Long radius bends should be used instead of elbows where possible; cold working of thermocouple elements can introduce inhomogeneity and pulling of the extension wire through a number of elbows cold works the wires unnecessarily.

While it is generally desirable to keep the length of extension wire as short as possible, it is often possible to have one conduit serve a number of thermocouples. The extent of conduit fills is not as significant with thermocouples as with power wiring because of much lower heating. (Conduit fill is the ratio between the cross sectional area of all of the wires and the area of the conduit.)

The extension wire should be run from the thermocouple connection head to the instrument terminals in one continuous length; junction boxes may introduce errors and can be avoided by design of the conduit system with the proper pull points. When splices are unavoidable, they should be made by compressing the two wires to be joined, in intimate contact with a compression device. *No other electrical wires should ever be run in the same conduit with extension wires.*

When installing extension wire underground, always use waterproof insulation. Running extension wires parallel to or in close proximity to power lines should be avoided. When connecting extension wires to an instrument or to a thermocouple, the polarity must be strictly observed.

SECTION 1.7

TEMPERATURE - EMF TABLES FOR THERMOCOUPLES

1. SCOPE AND PURPOSE

1.1 This section applies to Thermocouples for industrial use.

1.2 Its purpose is to provide Reference Tables of Temperature — Emf. data for Type J, K, R, S and T thermocouples, in a form convenient for industrial and field use.

2. INTRODUCTION

2.1 All of the values in these Tables are based upon the International Temperature Scale of 1948 and upon the Absolute Volt adopted in 1948. These data have been extracted from two publications of the National Bureau of Standards, Research Paper 2415 from the Journal of Research, National Bureau of Standards, Vol.50, No.5, May 1953, and National Bureau of Standards Circular 561, April 27, 1955. It is suggested that both of these sources be examined.

As a result of the above changes, these tables will differ slightly from older tables.

2.2 Type J tables are taken from National Bureau of Standards 2415, included in NBS Circular 561, which is the report of a joint effort of the Recorder-Controller Section of the Scientific Apparatus Makers of America (SAMA) and the National Bureau of Standards, supported in part by a grant by SAMA, and in part by funds from the Bureau. In this study the Bureau modified the 1913 Reference Table for Iron-Constantan Thermocouples, and recalculated it to 1948 standards. Authorization by both the Recorder-Controller Section of SAMA, and the National Bureau of Standards to use these data is gratefully acknowledged herewith.

Type K, R, S, and T tables are taken from NBS Circular 561 which is the recalculation of older tables to the 1948 standards. The tables for Type S (Platinum 10% Rhodium-Platinum) Thermocouples are based on formulas in Journal of Research NBS 10, 275 (1933) RP530. The tables for Type R (Platinum 13% Rhodium-Platinum) Thermocouples are based on tables from this same reference. The tables for Type K (Chromel-Alumel) Thermocouples are based on Journal Research NBS 14,239 (1935) RP767. The tables for Type T (Copper-Constantan) Thermocouples are based upon Journal Research NBS 20,337 (1938) RP1080 and Table 1 of Journal Research NBS 25, 459 (1940) RP1339.

2.3 These ISA Reference Tables are ten-degree tables (Emf values for each ten degrees of temperature), except for the Reference Junction Correction Tables which are one degree. This was done for the sake of conciseness and usefulness in the field. It will be noted that the NBS Tables are one degree tables throughout, and these should be consulted where one degree accuracy is desired. Emf — Temperature Tables are also included in the NBS data but have not been made a part of the ISA Tables, since their use is limited.

TABLE 1

TYPE J (Iron-Constantan) THERMOCOUPLES
EMF IN ABSOLUTE MILLIVOLTS. TEMPERATURE IN DEGREES FAHRENHEIT*
REFERENCE JUNCTION AT 32 F

°F.	0	10	20	30	40	50	60	70	80	90	100
-300	-7.52	-7.66	-7.79								
-200	-5.76	-5.96	-6.16	-6.35	-6.53	-6.71	-6.89	-7.06	-7.22	-7.38	-7.52
-100	-3.49	-3.73	-3.97	-4.21	-4.44	-4.68	-4.90	-5.12	-5.34	-5.55	-5.76
(-)0	-0.89	-1.16	-1.43	-1.70	-1.96	-2.22	-2.48	-2.74	-2.99	-3.24	-3.49
(+)0	-0.89	-0.61	-0.34	-0.06	+0.22	0.50	0.79	1.07	1.36	1.65	1.94
100	1.94	2.23	2.52	2.82	3.11	3.41	3.71	4.01	4.31	4.61	4.91
200	4.91	5.21	5.51	5.81	6.11	6.42	6.72	7.03	7.33	7.64	7.94
300	7.94	8.25	8.56	8.87	9.17	9.48	9.79	10.10	10.41	10.72	11.03
400	11.03	11.34	11.65	11.96	12.26	12.57	12.88	13.19	13.50	13.81	14.12
500	14.12	14.42	14.73	15.04	15.34	15.65	15.96	16.26	16.57	16.88	17.18
600	17.18	17.49	17.80	18.11	18.41	18.72	19.03	19.34	19.64	19.95	20.26
700	20.26	20.56	20.87	21.18	21.48	21.79	22.10	22.40	22.71	23.01	23.32
800	23.32	23.63	23.93	24.24	24.55	24.85	25.16	25.47	25.78	26.09	26.40
900	26.40	26.70	27.02	27.33	27.64	27.95	28.26	28.58	28.89	29.21	29.52
1000	29.52	29.84	30.16	30.48	30.80	31.12	31.44	31.76	32.08	32.40	32.72
1100	32.72	33.05	33.37	33.70	34.03	34.36	34.68	35.01	35.35	35.68	36.01
1200	36.01	36.35	36.69	37.02	37.36	37.71	38.05	38.39	38.74	39.08	39.43
1300	39.43	39.78	40.13	40.48	40.83	41.19	41.54	41.90	42.25	42.61	42.96
1400	42.96	43.32	43.68	44.03	44.39	44.75	45.10	45.46	45.82	46.18	46.53
1500	46.53	46.89	47.24	47.60	47.95	48.31	48.66	49.01	49.36	49.70	50.05
1600	50.05										

CORRECTION TABLE FOR REFERENCE JUNCTION OTHER THAN 32 F

°F.	0	1	2	3	4	5	6	7	8	9	10
30	-0.06	-0.03	0.00	+0.03	0.05	0.08	0.11	0.14	0.17	0.19	0.22
40	0.22	0.25	0.28	0.31	0.34	0.36	0.39	0.42	0.45	0.48	0.50
50	0.50	0.53	0.56	0.59	0.62	0.65	0.67	0.70	0.73	0.76	0.79
60	0.79	0.82	0.84	0.87	0.90	0.93	0.96	0.99	1.02	1.04	1.07
70	1.07	1.10	1.13	1.16	1.19	1.22	1.25	1.28	1.30	1.33	1.36
80	1.36	1.39	1.42	1.45	1.48	1.51	1.54	1.56	1.59	1.62	1.65
90	1.65	1.68	1.71	1.74	1.77	1.80	1.83	1.85	1.88	1.91	1.94
100	1.94	1.97	2.00	2.03	2.06	2.09	2.12	2.14	2.17	2.20	2.23
110	2.23	2.26	2.29	2.32	2.35	2.38	2.41	2.44	2.47	2.50	2.52

*Based on 1948 International Temperature Scale.

TABLE 2

TYPE J (Iron-Constantan) THERMOCOUPLES
EMF IN ABSOLUTE MILLIVOLTS. TEMPERATURE IN DEGREES CELSIUS (Int. 1948)
REFERENCE JUNCTION AT 0 C

°C.	0	10	20	30	40	50	60	70	80	90	100
-100	-4.63	-5.03	-5.42	-5.80	-6.16	-6.50	-6.82	-7.12	-7.40	-7.66	
(-)0	-0.00	-0.50	-1.00	-1.48	-1.96	-2.43	-2.89	-3.34	-3.78	-4.21	-4.63
(+)0	+0.00	+0.50	1.02	1.54	2.06	2.58	3.11	3.65	4.19	4.73	5.27
+100	5.27	5.81	6.36	6.90	7.45	8.00	8.56	9.11	9.67	10.22	10.78
+200	10.78	11.34	11.89	12.45	13.01	13.56	14.12	14.67	15.22	15.77	16.33
+300	16.33	16.88	17.43	17.98	18.54	19.09	19.64	20.20	20.75	21.30	21.85
+400	21.85	22.40	22.95	23.50	24.06	24.61	25.16	25.72	26.27	26.83	27.39
+500	27.39	27.95	28.52	29.08	29.65	30.22	30.80	31.37	31.95	32.53	33.11
+600	33.11	33.70	34.29	34.88	35.48	36.08	36.69	37.30	37.91	38.53	39.15
+700	39.15	39.78	40.41	41.05	41.68	42.32	42.96	43.60	44.25	44.89	45.53
+800	45.53	46.18	46.82	47.46	48.09	48.73	49.36	49.98			

CORRECTION TABLE FOR REFERENCE JUNCTION OTHER THAN 0 C

°C.	0	1	2	3	4	5	6	7	8	9	10
0	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
10	0.50	0.56	0.61	0.66	0.71	0.76	0.81	0.86	0.91	0.97	1.02
20	1.02	1.07	1.12	1.17	1.22	1.28	1.33	1.38	1.43	1.48	1.54
30	1.54	1.59	1.64	1.69	1.74	1.80	1.85	1.90	1.95	2.00	2.06
40	2.06	2.11	2.16	2.22	2.27	2.32	2.37	2.42	2.48	2.53	2.58

TABLE 3

TYPE K (Chromel-Alumel) THERMOCOUPLES
EMF IN ABSOLUTE MILLIVOLTS. TEMPERATURE IN DEGREES FAHRENHEIT*
REFERENCE JUNCTION AT 32 F

°F.	0	10	20	30	40	50	60	70	80	90	100
-300	-5.51	-5.60									
-200	-4.29	-4.44	-4.57	-4.71	-4.84	-4.96	-5.08	-5.19	-5.30	-5.41	-5.51
-100	-2.65	-2.84	-3.01	-3.19	-3.36	-3.52	-3.69	-3.84	-4.00	-4.15	-4.29
(-)0	-0.68	-0.89	-1.10	-1.30	-1.50	-1.70	-1.90	-2.09	-2.28	-2.47	-2.65
(+)0	-0.68	-0.47	-0.26	-0.04	+0.18	0.40	0.62	0.84	1.06	1.29	1.52
100	1.52	1.74	1.97	2.20	2.43	2.66	2.89	3.12	3.36	3.59	3.82
200	3.82	4.05	4.28	4.51	4.74	4.97	5.20	5.42	5.65	5.87	6.09
300	6.09	6.31	6.53	6.76	6.98	7.20	7.42	7.64	7.87	8.09	8.31
400	8.31	8.54	8.76	8.98	9.21	9.43	9.66	9.88	10.11	10.34	10.57
500	10.57	10.79	11.02	11.25	11.48	11.71	11.94	12.17	12.40	12.63	12.86
600	12.86	13.09	13.32	13.55	13.78	14.02	14.25	14.48	14.71	14.95	15.18
700	15.18	15.41	15.65	15.88	16.12	16.35	16.59	16.82	17.06	17.29	17.53
800	17.53	17.76	18.00	18.23	18.47	18.70	18.94	19.18	19.41	19.65	19.89
900	19.89	20.13	20.36	20.60	20.84	21.07	21.31	21.54	21.78	22.02	22.26
1000	22.26	22.49	22.73	22.97	23.20	23.44	23.68	23.91	24.15	24.39	24.63
1100	24.63	24.86	25.10	25.34	25.57	25.81	26.05	26.28	26.52	26.75	26.98
1200	26.98	27.22	27.45	27.69	27.92	28.15	28.39	28.62	28.86	29.09	29.32
1300	29.32	29.56	29.79	30.02	30.25	30.49	30.72	30.95	31.18	31.42	31.65
1400	31.65	31.88	32.11	32.34	32.57	32.80	33.02	33.25	33.48	33.71	33.93
1500	33.93	34.16	34.39	34.62	34.84	35.07	35.29	35.52	35.75	35.97	36.19
1600	36.19	36.42	36.64	36.87	37.09	37.31	37.54	37.76	37.98	38.20	38.43
1700	38.43	38.65	38.87	39.09	39.31	39.53	39.75	39.96	40.18	40.40	40.62
1800	40.62	40.84	41.05	41.27	41.49	41.70	41.92	42.14	42.35	42.57	42.78
1900	42.78	42.99	43.21	43.42	43.63	43.85	44.06	44.27	44.49	44.70	44.91
2000	44.91	45.12	45.33	45.54	45.75	45.96	46.17	46.38	46.58	46.79	47.00
2100	47.00	47.21	47.41	47.62	47.82	48.03	48.23	48.44	48.64	48.85	49.05
2200	49.05	49.25	49.45	49.65	49.86	50.06	50.26	50.46	50.65	50.85	51.05
2300	51.05	51.25	51.45	51.64	51.84	52.03	52.23	52.42	52.62	52.81	53.01
2400	53.01	53.20	53.39	53.59	53.78	53.97	54.16	54.35	54.54	54.73	54.92
2500	54.92										

CORRECTION TABLE FOR REFERENCE JUNCTION OTHER THAN 32 F

°F.	0	1	2	3	4	5	6	7	8	9	10
30	-0.04	-0.02	0.00	0.02	0.04	0.07	0.09	0.11	0.13	0.15	0.18
40	0.18	0.20	0.22	0.24	0.26	0.29	0.31	0.33	0.35	0.37	0.40
50	0.40	0.42	0.44	0.46	0.48	0.51	0.53	0.55	0.57	0.60	0.62
60	0.62	0.64	0.66	0.68	0.71	0.73	0.75	0.77	0.80	0.82	0.84
70	0.84	0.86	0.88	0.91	0.93	0.95	0.97	1.00	1.02	1.04	1.06
80	1.06	1.09	1.11	1.13	1.15	1.18	1.20	1.22	1.24	1.27	1.29
90	1.29	1.31	1.33	1.36	1.38	1.40	1.43	1.45	1.47	1.49	1.52
100	1.52	1.54	1.56	1.58	1.61	1.63	1.65	1.68	1.70	1.72	1.74
110	1.74	1.77	1.79	1.81	1.84	1.86	1.88	1.90	1.93	1.95	1.97

*Based on 1948 International Temperature Scale.

TABLE 4

TYPE K (Chromel-Alumel) THERMOCOUPLES
EMF IN ABSOLUTE MILLIVOLTS. TEMPERATURE IN DEGREES CELSIUS (Int. 1948)
REFERENCE JUNCTION AT 0 C

°C.	0	10	20	30	40	50	60	70	80	90	100
-100	-3.49	-3.78	-4.05	-4.32	-4.57	-4.81	-5.03	-5.24	-5.43	-5.60	-5.75
(-)0	-0.00	-0.39	-0.77	-1.14	-1.50	-1.86	-2.21	-2.55	-2.87	-3.19	-3.49
(+)0	0.00	0.40	0.80	1.20	1.61	2.02	2.43	2.85	3.26	3.68	4.10
+100	4.10	4.51	4.92	5.33	5.73	6.13	6.53	6.93	7.33	7.73	8.13
200	8.13	8.54	8.94	9.34	9.75	10.16	10.57	10.98	11.39	11.80	12.21
300	12.21	12.63	13.04	13.46	13.88	14.29	14.71	15.13	15.55	15.98	16.40
400	16.40	16.82	17.24	17.67	18.09	18.51	18.94	19.36	19.79	20.22	20.65
500	20.65	21.07	21.50	21.92	22.35	22.78	23.20	23.63	24.06	24.49	24.91
600	24.91	25.34	25.76	26.19	26.61	27.03	27.45	27.87	28.29	28.72	29.14
700	29.14	29.56	29.97	30.39	30.81	31.23	31.65	32.06	32.48	32.89	33.30
800	33.30	33.71	34.12	34.53	34.93	35.34	35.75	36.15	36.55	36.96	37.36
900	37.36	37.76	38.16	38.56	38.95	39.35	39.75	40.14	40.53	40.92	41.31
1000	41.31	41.70	42.09	42.48	42.87	43.25	43.63	44.02	44.40	44.78	45.16
1100	45.16	45.54	45.92	46.29	46.67	47.04	47.41	47.78	48.15	48.52	48.89
1200	48.89	49.25	49.62	49.98	50.34	50.69	51.05	51.41	51.76	52.11	52.46
1300	52.46	52.81	53.16	53.51	53.85	54.20	54.54	54.88			

CORRECTION TABLE FOR REFERENCE JUNCTION OTHER THAN 0 C

°C.	0	1	2	3	4	5	6	7	8	9	10
0	0.00	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.32	0.36	0.40
10	0.40	.44	.48	.52	.56	.60	.64	.68	.72	.76	.80
20	.80	.84	.88	.92	.96	1.00	1.04	1.08	1.12	1.16	1.20
30	1.20	1.24	1.28	1.32	1.36	1.40	1.44	1.49	1.53	1.57	1.61
40	1.61	1.65	1.69	1.73	1.77	1.81	1.85	1.90	1.94	1.98	2.02

TABLE 5

TYPE S (Platinum — 10 Percent Rhodium Versus Platinum) THERMOCOUPLES EMF IN ABSOLUTE MILLIVOLTS. TEMPERATURE IN DEGREES FAHRENHEIT* REFERENCE JUNCTION AT 32 F

°F.	0	10	20	30	40	50	60	70	80	90	100
0					0.024	0.056	0.087	0.120	0.153	0.187	0.221
100	0.221	0.256	0.291	0.327	0.364	0.401	0.439	0.477	0.516	0.555	0.595
200	0.595	0.635	0.676	0.717	0.758	0.800	0.843	0.886	0.929	0.973	1.017
300	1.017	1.061	1.106	1.151	1.196	1.242	1.287	1.334	1.380	1.427	1.474
400	1.474	1.521	1.569	1.616	1.664	1.712	1.761	1.809	1.858	1.907	1.956
500	1.956	2.005	2.055	2.105	2.155	2.205	2.255	2.306	2.357	2.407	2.458
600	2.458	2.510	2.561	2.613	2.664	2.716	2.768	2.820	2.872	2.924	2.977
700	2.977	3.029	3.082	3.135	3.188	3.240	3.293	3.347	3.400	3.453	3.506
800	3.506	3.560	3.614	3.667	3.721	3.775	3.829	3.883	3.937	3.991	4.046
900	4.046	4.100	4.155	4.210	4.264	4.319	4.374	4.430	4.485	4.540	4.596
1000	4.596	4.651	4.707	4.763	4.818	4.874	4.930	4.987	5.043	5.099	5.156
1100	5.156	5.212	5.269	5.326	5.383	5.440	5.497	5.555	5.612	5.669	5.726
1200	5.726	5.784	5.842	5.899	5.957	6.015	6.073	6.131	6.190	6.248	6.307
1300	6.307	6.365	6.424	6.483	6.542	6.601	6.660	6.719	6.778	6.838	6.897
1400	6.897	6.957	7.017	7.076	7.136	7.196	7.257	7.317	7.377	7.438	7.498
1500	7.498	7.559	7.620	7.681	7.742	7.803	7.864	7.925	7.987	8.048	8.110
1600	8.110	8.172	8.234	8.296	8.358	8.420	8.482	8.545	8.607	8.670	8.732
1700	8.732	8.795	8.858	8.921	8.984	9.048	9.111	9.174	9.238	9.302	9.365
1800	9.365	9.429	9.493	9.557	9.621	9.686	9.750	9.815	9.879	9.944	10.009
1900	10.009	10.074	10.139	10.204	10.269	10.334	10.400	10.465	10.531	10.597	10.662
2000	10.662	10.728	10.794	10.860	10.926	10.992	11.058	11.124	11.190	11.257	11.323
2100	11.323	11.389	11.456	11.522	11.589	11.655	11.722	11.789	11.855	11.922	11.989
2200	11.989	12.055	12.122	12.189	12.256	12.322	12.389	12.456	12.523	12.590	12.657
2300	12.657	12.724	12.790	12.857	12.924	12.991	13.058	13.124	13.191	13.258	13.325
2400	13.325	13.391	13.458	13.525	13.591	13.658	13.725	13.791	13.858	13.924	13.991
2500	13.991	14.058	14.124	14.191	14.257	14.324	14.390	14.457	14.523	14.589	14.656
2600	14.656	14.722	14.789	14.855	14.921	14.988	15.054	15.120	15.186	15.253	15.319
2700	15.319	15.385	15.451	15.517	15.583	15.649	15.715	15.781	15.847	15.913	15.979
2800	15.979	16.045	16.111	16.177	16.243	16.308	16.374	16.440	16.506	16.571	16.637
2900	16.637	16.702	16.768	16.834	16.899	16.965	17.030	17.095	17.161	17.226	17.292
3000	17.292	17.357	17.422	17.487	17.552	17.618	17.683	17.748	17.813	17.878	17.943
3100	17.943	18.008	18.073	18.137	18.202	18.267	18.332	18.396	18.461	18.526	18.590
3200	18.590	18.655									

CORRECTION TABLE FOR REFERENCE JUNCTION OTHER THAN 32 F

°F.	0	1	2	3	4	5	6	7	8	9	10
30			0.000	0.003	0.006	0.009	0.012	0.015	0.018	0.021	0.024
40	0.024	0.028	.031	.034	.037	.040	.043	.046	.049	.052	.056
50	.056	.059	.062	.065	.068	.071	.075	.078	.081	.084	.087
60	.087	.091	.094	.097	.100	.104	.107	.110	.113	.117	.120
70	.120	.123	.126	.130	.133	.136	.140	.143	.146	.150	.153
80	.153	.156	.160	.163	.166	.170	.173	.176	.180	.183	.187
90	.187	.190	.193	.197	.200	.204	.207	.211	.214	.218	.221
100	.221	.224	.228	.231	.235	.238	.242	.245	.249	.252	.256
110	.256	.259	.263	.266	.270	.274	.277	.281	.284	.288	.291

*Based on 1948 International Temperature Scale.

TABLE 6

Type S (Platinum — 10 Percent Rhodium Versus Platinum) THERMOCOUPLES
EMF IN ABSOLUTE MILLIVOLTS. TEMPERATURE IN DEGREES CELSIUS (Int. 1948)
REFERENCE JUNCTION AT 0 C

°C.	0	10	20	30	40	50	60	70	80	90	100
0	0.000	0.056	0.113	0.173	0.235	0.299	0.364	0.431	0.500	0.571	0.643
100	.643	.717	.792	.869	.946	1.025	1.106	1.187	1.269	1.352	1.436
200	1.436	1.521	1.607	1.693	1.780	1.868	1.956	2.045	2.135	2.225	2.316
300	2.316	2.408	2.499	2.592	2.685	2.778	2.872	2.966	3.061	3.156	3.251
400	3.251	3.347	3.442	3.539	3.635	3.732	3.829	3.926	4.024	4.122	4.221
500	4.221	4.319	4.419	4.518	4.618	4.718	4.818	4.919	5.020	5.122	5.224
600	5.224	5.326	5.429	5.532	5.635	5.738	5.842	5.946	6.050	6.155	6.260
700	6.260	6.365	6.471	6.577	6.683	6.790	6.897	7.005	7.112	7.220	7.329
800	7.329	7.438	7.547	7.656	7.766	7.876	7.987	8.098	8.209	8.320	8.432
900	8.432	8.545	8.657	8.770	8.883	8.997	9.111	9.225	9.340	9.455	9.570
1000	9.570	9.686	9.802	9.918	10.035	10.152	10.269	10.387	10.505	10.623	10.741
1100	10.741	10.860	10.979	11.098	11.217	11.336	11.456	11.575	11.695	11.815	11.935
1200	11.935	12.055	12.175	12.296	12.416	12.536	12.657	12.777	12.897	13.018	13.138
1300	13.138	13.258	13.378	13.498	13.618	13.738	13.858	13.978	14.098	14.217	14.337
1400	14.337	14.457	14.576	14.696	14.815	14.935	15.054	15.173	15.292	15.411	15.530
1500	15.530	15.649	15.768	15.887	16.006	16.124	16.243	16.361	16.479	16.597	16.716
1600	16.716	16.834	16.952	17.069	17.187	17.305	17.422	17.539	17.657	17.774	17.891
1700	17.891	18.008	18.124	18.241	18.358	18.474	18.590				

CORRECTION TABLE FOR REFERENCE JUNCTION OTHER THAN 0 C

°C.	0	1	2	3	4	5	6	7	8	9	10
0	0.000	0.005	0.011	0.016	0.022	0.028	0.033	0.039	0.044	0.050	0.056
10	.056	.061	.067	.073	.078	.084	.090	.096	.102	.107	.113
20	.113	.119	.125	.131	.137	.143	.149	.155	.161	.167	.173
30	.173	.179	.185	.191	.198	.204	.210	.216	.222	.229	.235
40	.235	.241	.247	.254	.260	.266	.273	.279	.286	.292	.299

TABLE 7

TYPE R (Platinum — 13 Percent Rhodium Versus Platinum) THERMOCOUPLES
EMF IN ABSOLUTE MILLIVOLTS. TEMPERATURE IN DEGREES FAHRENHEIT*
REFERENCE JUNCTION AT 32 F

°F.	0	10	20	30	40	50	60	70	80	90	100
0					0.024	0.055	0.086	0.119	0.152	0.186	0.220
100	0.220	0.255	0.291	0.327	.363	.400	.438	.476	.516	.556	.596
200	.596	.637	.678	.721	.763	.807	.850	.894	.939	.984	1.030
300	1.030	1.075	1.121	1.167	1.214	1.261	1.309	1.357	1.406	1.455	1.504
400	1.504	1.553	1.603	1.653	1.703	1.754	1.805	1.856	1.908	1.960	2.012
500	2.012	2.065	2.117	2.170	2.223	2.277	2.330	2.384	2.438	2.493	2.547
600	2.547	2.602	2.657	2.712	2.768	2.823	2.879	2.935	2.991	3.047	3.103
700	3.103	3.160	3.217	3.273	3.330	3.387	3.445	3.502	3.560	3.618	3.677
800	3.677	3.735	3.794	3.852	3.911	3.970	4.029	4.087	4.146	4.205	4.264
900	4.264	4.324	4.384	4.443	4.503	4.563	4.624	4.685	4.746	4.807	4.868
1000	4.868	4.930	4.991	5.053	5.115	5.176	5.238	5.301	5.363	5.426	5.488
1100	5.488	5.551	5.614	5.677	5.741	5.805	5.869	5.933	5.996	6.060	6.125
1200	6.125	6.188	6.252	6.317	6.381	6.446	6.511	6.577	6.642	6.706	6.773
1300	6.773	6.838	6.904	6.970	7.037	7.103	7.169	7.235	7.302	7.369	7.436
1400	7.436	7.503	7.571	7.639	7.706	7.774	7.842	7.911	7.979	8.047	8.116
1500	8.116	8.184	8.253	8.322	8.391	8.460	8.530	8.599	8.669	8.739	8.809
1600	8.809	8.879	8.949	9.019	9.090	9.161	9.232	9.303	9.374	9.445	9.516
1700	9.516	9.587	9.659	9.730	9.802	9.874	9.946	10.019	10.092	10.164	10.237
1800	10.237	10.310	10.383	10.456	10.529	10.603	10.676	10.749	10.823	10.898	10.973
1900	10.973	11.048	11.122	11.197	11.273	11.348	11.424	11.499	11.575	11.651	11.726
2000	11.726	11.802	11.878	11.954	12.029	12.105	12.182	12.258	12.335	12.411	12.488
2100	12.488	12.564	12.641	12.718	12.795	12.871	12.948	13.025	13.102	13.178	13.255
2200	13.255	13.332	13.409	13.486	13.564	13.641	13.718	13.795	13.872	13.949	14.027
2300	14.027	14.104	14.181	14.258	14.335	14.412	14.490	14.567	14.644	14.721	14.798
2400	14.798	14.875	14.952	15.029	15.107	15.184	15.261	15.338	15.415	15.492	15.568
2500	15.568	15.645	15.722	15.800	15.877	15.954	16.031	16.108	16.185	16.263	16.340
2600	16.340	16.417	16.494	16.571	16.648	16.725	16.802	16.880	16.957	17.033	17.110
2700	17.110	17.186	17.263	17.340	17.416	17.493	17.569	17.646	17.723	17.799	17.875
2800	17.875	17.951	18.027	18.103	18.179	18.255	18.332	18.408	18.484	18.560	18.636
2900	18.636	18.712	18.788	18.864	18.940	19.016	19.092	19.168	19.243	19.318	19.394
3000	19.394	19.470	19.545	19.621	19.697	19.773	19.848	19.924	19.999	20.075	20.150
3100	20.150										

CORRECTION TABLE FOR REFERENCE JUNCTION OTHER THAN 32 F

°F.	0	1	2	3	4	5	6	7	8	9	10
30			0.000	0.003	0.006	0.009	0.012	0.015	0.018	0.021	0.024
40	0.024	0.027	.030	.033	.036	.039	.042	.045	.048	.052	.055
50	.055	.058	.061	.064	.068	.071	.074	.077	.080	.083	.086
60	.086	.090	.093	.096	.099	.103	.106	.109	.112	.116	.119
70	.119	.122	.126	.129	.132	.135	.139	.142	.145	.149	.152
80	.152	.155	.159	.162	.165	.169	.172	.175	.179	.182	.186
90	.186	.189	.192	.196	.199	.203	.206	.210	.213	.217	.220
100	.220	.224	.227	.230	.234	.237	.241	.244	.248	.251	.255
110	.255	.258	.262	.265	.269	.272	.276	.280	.284	.287	.291

*Based on 1948 International Temperature Scale.

TABLE 8

TYPE R (Platinum — 13 Percent Rhodium Versus Platinum) THERMOCOUPLES
EMF IN ABSOLUTE MILLIVOLTS. TEMPERATURE IN DEGREES CELSIUS (Int. 1948)
REFERENCE JUNCTION AT 0 C

°C.	0	10	20	30	40	50	60	70	80	90	100
0	0.000	0.055	0.112	0.172	0.234	0.298	0.363	0.431	0.500	0.572	0.645
100	.645	.721	.798	.877	.957	1.039	1.121	1.205	1.290	1.377	1.465
200	1.465	1.553	1.643	1.734	1.826	1.918	2.012	2.107	2.202	2.298	2.395
300	2.395	2.493	2.591	2.690	2.790	2.890	2.991	3.092	3.194	3.296	3.399
400	3.399	3.502	3.607	3.712	3.817	3.923	4.029	4.134	4.241	4.348	4.455
500	4.455	4.563	4.672	4.782	4.893	5.004	5.115	5.226	5.338	5.450	5.563
600	5.563	5.677	5.792	5.907	6.022	6.137	6.252	6.368	6.485	6.602	6.720
700	6.720	6.838	6.957	7.076	7.195	7.315	7.436	7.557	7.679	7.801	7.924
800	7.924	8.047	8.170	8.294	8.419	8.544	8.669	8.795	8.921	9.047	9.175
900	9.175	9.303	9.431	9.559	9.687	9.816	9.946	10.077	10.208	10.339	10.471
1000	10.471	10.603	10.735	10.869	11.003	11.138	11.273	11.408	11.544	11.681	11.817
1100	11.817	11.954	12.090	12.227	12.365	12.503	12.641	12.779	12.917	13.055	13.193
1200	13.193	13.332	13.471	13.610	13.749	13.888	14.027	14.165	14.304	14.443	14.582
1300	14.582	14.721	14.860	14.999	15.138	15.276	15.415	15.553	15.692	15.831	15.969
1400	15.969	16.108	16.247	16.386	16.524	16.663	16.802	16.940	17.079	17.217	17.355
1500	17.355	17.493	17.631	17.768	17.906	18.043	18.179	18.316	18.453	18.590	18.727
1600	18.727	18.864	19.001	19.137	19.273	19.409	19.545	19.682	19.818	19.954	20.090

CORRECTION TABLE FOR REFERENCE JUNCTION OTHER THAN 0 C

°C.	0	1	2	3	4	5	6	7	8	9	10
0	0.000	0.005	0.011	0.016	0.022	0.027	0.033	0.038	0.043	0.049	0.055
10	.055	.061	.066	.072	.078	.083	.089	.095	.101	.106	.112
20	.112	.118	.124	.130	.136	.142	.148	.154	.160	.166	.172
30	.172	.178	.184	.190	.196	.203	.209	.215	.221	.228	.234
40	.234	.240	.246	.252	.259	.265	.272	.278	.285	.291	.298

TABLE 9

TYPE T (Copper-Constantan) THERMOCOUPLES
EMF IN ABSOLUTE MILLIVOLTS. TEMPERATURE IN DEGREES FAHRENHEIT*
REFERENCE JUNCTION AT 32 F

°F.	0	10	20	30	40	50	60	70	80	90	100
-300	-5.284	-5.379									
-200	-4.111	-4.246	-4.377	-4.504	-4.627	-4.747	-4.863	-4.974	-5.081	-5.185	-5.284
-100	-2.559	-2.730	-2.897	-3.062	-3.223	-3.380	-3.533	-3.684	-3.829	-3.972	-4.111
(-)0	-0.670	-0.872	-1.072	-1.270	-1.463	-1.654	-1.842	-2.026	-2.207	-2.385	-2.559
(+)0	-0.670	-0.463	-0.254	-0.042	+0.171	0.389	0.609	0.832	1.057	1.286	1.517
100	1.517	1.751	1.987	2.226	2.467	2.711	2.958	3.207	3.458	3.712	3.967
200	3.967	4.225	4.486	4.749	5.014	5.280	5.550	5.821	6.094	6.370	6.647
300	6.647	6.926	7.208	7.491	7.776	8.064	8.352	8.642	8.935	9.229	9.525
400	9.525	9.823	10.123	10.423	10.726	11.030	11.336	11.643	11.953	12.263	12.575
500	12.575	12.888	13.203	13.520	13.838	14.157	14.477	14.799	15.122	15.447	15.773
600	15.773	16.101	16.429	16.758	17.089	17.421	17.754	18.089	18.425	18.761	19.100
700	19.100	19.439	19.779	20.120	20.463	20.805					

CORRECTION TABLE FOR REFERENCE JUNCTION OTHER THAN 32 F

°F.	0	1	2	3	4	5	6	7	8	9	10
30			0.000	0.021	0.042	0.064	0.086	0.107	0.129	0.150	0.171
40	0.171	0.193	.215	.236	.258	.280	.302	.324	.346	.367	.389
50	.389	.411	.433	.455	.477	.499	.521	.543	.565	.587	.609
60	.609	.631	.654	.676	.698	.720	.743	.765	.787	.809	.832
70	.832	.854	.877	.899	.922	.944	.967	.990	1.012	1.035	1.057
80	1.057	1.080	1.103	1.126	1.148	1.171	1.194	1.217	1.240	1.263	1.286
90	1.286	1.309	1.332	1.355	1.378	1.401	1.424	1.448	1.471	1.494	1.517
100	1.517	1.540	1.563	1.587	1.610	1.633	1.657	1.680	1.704	1.727	1.751
110	1.751	1.774	1.798	1.821	1.845	1.869	1.893	1.916	1.940	1.963	1.987

*Based on 1948 International Temperature Scale.

TABLE 10

TYPE T (Copper-Constantan) THERMOCOUPLES
EMF IN ABSOLUTE MILLIVOLTS. TEMPERATURE IN DEGREES CELSIUS (Int. 1948)
REFERENCE JUNCTION AT 0 C

°C.	0	10	20	30	40	50	60	70	80	90	100
-100	-3.349	-3.624	-3.887	-4.138	-4.377	-4.603	-4.817	-5.018	-5.205	-5.379	
(-)0	0.000	-0.380	-0.751	-1.112	-1.463	-1.804	-2.135	-2.455	-2.764	-3.062	-3.349
(+)0	0.000	0.389	0.787	1.194	1.610	2.035	2.467	2.908	3.357	3.813	4.277
100	4.277	4.749	5.227	5.712	6.204	6.703	7.208	7.719	8.236	8.759	9.288
200	9.288	9.823	10.363	10.909	11.459	12.015	12.575	13.140	13.710	14.285	14.864
300	14.864	15.447	16.035	16.626	17.222	17.821	18.425	19.032	19.642	20.257	20.874
400	20.874										

CORRECTION TABLE FOR REFERENCE JUNCTION OTHER THAN 0 C

°C.	0	1	2	3	4	5	6	7	8	9	10
0	0.000	0.038	0.077	0.116	0.154	0.193	0.232	0.271	0.311	0.350	0.389
10	0.389	0.429	0.468	0.508	0.547	0.587	0.627	0.667	0.707	0.747	0.787
20	0.787	0.827	0.868	0.908	0.949	0.990	1.030	1.071	1.112	1.153	1.194
30	1.194	1.235	1.277	1.318	1.360	1.401	1.443	1.485	1.526	1.568	1.610
40	1.610	1.652	1.694	1.737	1.779	1.821	1.864	1.907	1.949	1.992	2.035

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	Pad 3b Thermocouples	1.25	1.75
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	Pad 5b Pressure Instruments	1.25	1.75
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	Pad 6b Pressure Gages	1.25	1.75
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