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MILITARY HANDBOOK

SELECTION, INSTALLATION AND TROUBLESHOOTING OF RESISTANCE THERMOMETERS AND THERMOCOUPLE SENSORS

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FOREWORD

1. This Military Handbook is approved for use by Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

3. Problems occur with shipboard temperature measurement instrumentation which necessitate that fleet personnel have the knowledge and experience in the troubleshooting, selection, and replacement of both the monitoring system (which includes an analog or digital display) and the sensing device (thermocouple sensor or resistance thermometer). The troubleshooting and replacement of the monitoring system is covered by the applicable technical manual. This handbook was developed to guide the user in the selection, installation and troubleshooting of thermocouple sensors and resistance thermometers.

CONTENTS

CONTENTS - Continued

CONTENTS - Continued

CONTENTS - Continued

CONTENTS - Continued

FIGURES

FIGURES - Continued

TABLES

1. SCOPE

1.1 Scope. This handbook covers the selection, installation and trouble-shooting of thermocouple sensors and resistance thermometers that are constructed in accordance with MIL-T-24388.

1.2 Classification. The thermocouple sensors and resistance thermometers shall be classified in accordance with the following:

Type: Resistance thermometer with a platinum element (PRT).
Resistance thermometer with a nickel element (NRT).
Thermocouple type K (KTC).

Configuration: Thermowell (TW).
Bare bulb (BB).
Embedded (EM).

Designation: Sheath length.
Temperature range.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications. The following specifications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

FEDERAL

QQ-S-571	- Solder, Tin Alloy: Tin-Lead Alloy; and Lead Alloy.
QQ-T-390	- Tin Alloy Ingots and Castings and Lead Alloy Ingots and Castings (Antifriction Metal) for Bearing Applications.

MILITARY

MIL-C-915	- Cable and Cord, Electrical, for Shipboard Use, General Specification for.
MS3102	- Connector, Receptacle, Electric, Box Mounting, Solder Contacts, AN Type.
MS3106	- Connector, Plug, Electric, Straight, Solder Contacts, AN Type.
MIL-T-24270	- Thermowells for Thermometers and Electrical Temperature Sensors, General Specification for.
MIL-T-24388	- Thermocouple and Resistance Temperature Element Assemblies, General Specification for (Naval Shipboard).
MS27534	- Tool, Contact Insertion-Extraction, Electrical Connector.

MILITARY (Continued)

MIL-I-81969/14 - Installing and Removal Tools, Connector Electrical Contact, Type III, Class 2, Composition B.

MIL-I-81969/15 - Installing and Removal Tools, Connector Electrical Contact, Type II, Class 2, Composition A.

MIL-I-81969/17 - Installing and Removal Tools, Connector Electrical Contact, Type I, Class 1, Composition C.

MIL-I-81969/19 - Installing and Removal Tools, Connector Electrical Contact, Type II, Class 1, Composition C.

MIL-I-81969/29 - Installing and Removal Tools, Connector Electrical Contact, Type II, Class 1, Composition B.

(Unless otherwise indicated, copies of federal and military specifications are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.1.2 Other Government publication. The following other Government publication forms a part of this document to the extent specified herein. Unless otherwise specified, the issue is that cited in the solicitation.

PUBLICATION

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

0942-LP-016-1010 - Gear Reduction Maintenance.

(Application for copies should be addressed to the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.2 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Alumel. Alumel is a metal that is sometimes used as one of the two wires which make up a thermocouple. When joined to a chromel wire, the result is a type K thermocouple. Alumel metal is magnetic. As a part of a type K thermocouple, the alumel wire is considered to be the one with a negative electrical potential. When the wire insulation is color coded, the alumel wire insulation is color coded red.

3.2 Assembly, thermocouple sensor or resistance thermometer. The thermocouple sensor or resistance thermometer assembly consists of a thermocouple sensor or resistance thermometer, connection head and connection head extension. The thermocouple sensor or resistance thermometer assembly is applicable to the thermowell configuration (see figure 1).

3.3 Boss, thermowell. A thermowell boss is an insert or fitting attached to the piping that attaches the thermowell to the piping.

3.4 Calibration. Calibration is the process of determining if an instrument is within its specified accuracy limits. This can be accomplished by developing an error curve so that its reading can be correlated to the actual value being measured. For instruments in which an adjustment to its accuracy is possible, calibration can also include adjustments to bring the instrument within its specified accuracy limits.

3.5 Chromel. Chromel is a metal that is sometimes used as one of the two wires which make up a thermocouple. When joined to an alumel wire, the result is a type K thermocouple. Chromel metal is non-magnetic. As part of a type K thermocouple, the chromel wire is considered to be the one with a positive electrical potential.

3.6 Connecting wire end closure (thermowell and bare bulb configurations). A connecting wire end closure is a seal that is impenetrable to liquid or gases and is located at the opposite end of a sheath from an element (see figure 2).

3.7 Connecting wires, resistance thermometer. The connecting wires are a part of the resistance thermometer and serve as a means to electrically connect the resistance thermometer element to an external terminal board or to internal connector receptacle pins. The connecting wires originate at the resistance thermometer element, run up the inside of the sheath, and pass through the connecting wire end closure. The free ends of the connecting wires are either attached to an external terminal board or are soldered to internal connector receptacle pins.

3.8 Connecting wires, thermocouple sensor. The connecting wires are a portion of the thermocouple sensor that originates on both sides of, but does not include the measuring junction. The connecting wires originate at the measuring junction, run up the inside of the sheath, and pass through the connecting wire end closure. The free ends of the connecting wires are either attached to an external terminal board or are crimped to internal connector receptacle pins (see figure 2).

3.9 Connection head. The connection head is an encasement that holds the terminal board and acts as a junction box for connecting wires and extension wires. This item is applicable to the thermowell configuration (see figure 1).

3.10 Connection head extension. The connection head extension is a piece of tubing or pipe with threaded ends used to attach the connection head to the thermowell (see figure 1).

3.11 Contact, electrical. The electrical contact is a current carrying part of the electrical connector that is in the form of either a pin or a socket.

3.12 Decade box. A decade box is an assembly of resistors whose individual values vary in multiples of ones, tens, and hundreds. By setting each selector switch, a particular resistance can be obtained.

3.13 Double foot. A double foot is the combined length of a pair of wires, each being 1 foot in length. This term is normally associated with measuring resistance of thermocouple wire.

3.14 Double reversal. (See Reversal, double.)

3.15 Electrical connector. An electrical connector is a connector with a receptacle end and a plug end that is used to electrically connect the end of a cable run to a junction box, monitoring system, or other instrumentation. The electrical connector contacts are attached to the ends of the wires either by soldering or by crimping. The electrical connector is also known as an MS connector, a Cannon plug, a Bendix connector, a BNC connector, or by some other name.

3.16 Electrical interference. Electrical interference is any undesired electrical or electromagnetic signal that interferes with the reception of desired signals.

3.17 Electrical leakage. Electrical leakage is an undesired penetration of electromagnetic radiation into openings (joints or cracks) in the shielding cable or monitoring system.

3.18 Electromotive force. Electromotive force is the difference of potential produced by sources of electrical energy that can be used to drive currents through circuits.

3.19 Element, resistance thermometer. A resistance thermometer element is composed of a nickel or platinum wire wrapped around a mandrel that behaves like a variable resistor when influenced by temperature. The element is manufactured so that it produces a precise resistance versus temperature relationship (see figure 2).

3.20 Element, thermocouple sensor. A thermocouple sensor element is another term for thermocouple.

3.21 Error, zero adjustment. Zero adjustment error is the adjustment of the entire range of an instrument back to a reference point.

3.22 Extension wire. The extension wire is located between the thermocouple sensor or the resistance thermometer and the monitoring system. The extension wire serves to electrically connect either of these two types of sensors to that monitoring system.

3.23 Gasket. A gasket is a preformed, shapeable article that is placed between two adjoining parts to prevent electromagnetic radiation or fluid penetration into or escape from an enclosure or system. The primary function of a gasket is to isolate or seal, whereas a washer is used to provide an increased surface area or prevent movement.

3.24 Gauge. The gauge is the thickness of a wire. The thickness is an important dimension since it is a factor in determining the resistance and pull strength of a wire.

3.25 Grommet. A grommet is a flexible piece that is a part of the nylon stuffing tube. Its function is to provide a watertight seal.

3.26 Ground. Ground refers to any one of the following conditions. The ground can be considered as the electrical, neutral line having the same potential as the ship's hull, the negative side of the direct current (dc) power supply, or the reference point for an electrical system.

3.27 Ground loops. Ground loops exist when two or more points in an electrical system are at ground potential and cause a conducting path.

3.28 Hermetic seal. (See Connecting wire end enclosure.)

3.29 Immersion depth, minimum, instrumentation. Minimum instrumentation immersion depth is the depth that a resistance thermometer or thermocouple sensor must be immersed, such that a lesser immersion results in a change in the indicated temperature beyond the accuracy limits.

3.30 Immersion depth, instrumentation. The instrumentation immersion depth, is the depth to which the thermocouple sensor or resistance thermometer sheath penetrates below the surface of the medium being measured.

3.31 Immersion depth, thermowell. The thermowell immersion depth is the depth to which the thermowell penetrates below the surface of the medium being measured. In a pipe or vessel that is full of fluid, this distance is the same as the thermowell insertion length.

3.32 Insertion length, instrumentation. The instrumentation insertion length is the length from the bottom of the thermocouple sensor or resistance thermometer external threads to the tip of the sheath. The extension threads are those threads that mate with the internal threads in the thermowell, pipe, or vessel (see figures 1 and 5).

3.33 Insertion length, thermowell. The thermowell insertion length is the length from the bottom of the thermowell weld (that connects the thermowell to the boss), mating threads (with the pipe or vessel) or flange to the thermowell tip.

3.34 Insulation, sheath, interior. The interior sheath insulation is composed of a magnesium oxide powder, an aluminum oxide powder, or a solid ceramic cylinder with penetration holes located inside the resistance thermometer or thermocouple sensor sheath. The purpose of this insulation is to isolate the connecting wires from the sheath and from each other. This insulation also electrically isolates the resistance thermometer element or thermocouple sensor measuring junction from the sheath.

3.35 Jack, electrical, instrumentation. An instrumentation electrical jack is an electrical connection fitting constructed for use in a fixed location such as on a panel, enclosure (instrumentation case), or circuit board that contains one or more electrical contacts that mate both electrically and mechanically with one or more contacts in a plug of a compatible physical configuration.

3.36 Jack, test point, electrical, instrumentation. An instrumentation electrical test point jack is a single conductor jack containing one small diameter socket to which the pin of a test point plug can be inserted.

3.37 Junction box. A junction box is a protective enclosure for electrical connections. If required, it is located between the thermocouple sensor assembly or resistance thermometer assembly and the monitoring system.

3.38 Junction, grounded thermocouple. A grounded thermocouple junction is a thermocouple sensor construction where the element is in electrical contact with the sheath.

3.39 Junction, ungrounded thermocouple. An ungrounded thermocouple junction is a thermocouple sensor construction where the element is insulated from the sheath.

3.40 Lead. A lead is the uninsulated part of the connecting and extension wires that is used to make electrical connections with the terminal board and electrical connector.

3.41 Lead wire. A lead wire is used to electrically connect one extension wire to an instrument.

3.42 Measuring junction. A measuring junction is the point on a thermocouple where the two wires, each made from different metals, are welded together. This is the same point or junction of a thermocouple that is subjected to the temperature being measured. When the measuring junction is at a higher temperature than the reference junction, the measuring junction is commonly called the hot junction (see figure 2).

3.43 Medium. Medium is the fluid in which a resistance thermometer or thermocouple sensor is placed to measure temperature.

3.44 Millivolt potentiometer (mV POT). A device that simulates or receives a potential difference in a mV range is a mV POT.

3.45 Minimum immersion depth. (See Immersion depth, minimum.)

3.46 Monitoring system. The monitoring system is the instrumentation that receives an electrical response from a thermocouple sensor or resistance thermometer. This instrumentation may also convert this response to temperature readings.

3.47 Ohmmeter. An ohmmeter is an instrument for measuring electrical resistance that contains either one or various scales that provide a range of graduation in ohms.

3.48 Patch cord. A patch cord is a wire used to electrically connect one extension wire to another extension wire or a wire used to electrically connect an extension wire to a ground path. Spade lugs, pin and socket adapters are used with patch cords (see figure 3).

3.49 Pin, electrical. An electrical pin is a straight and usually solid contact that is constructed to mate with and be inserted into another type of contact (the socket).

3.50 Pin, jack. (See Jack, test point, electrical, instrumentation.)

3.51 Plug, electrical connector. The electrical connector plug is the part of a two-piece multiple contact electrical connector that is on the end of a cord or cable.

3.52 Plug, electrical, instrumentation. An instrumentation electrical plug is an electrical connection fitting found on one or both ends of a cord or cable that contains one or more electrical contacts that mate both electrically and mechanically with one or more contacts in a jack or receptacle of a compatible physical configuration.

3.53 Plug, test point, electrical, instrumentation. An instrumentation electrical test point plug is a single conductor plug containing one small diameter pin for insertion into a test point jack.

3.54 Receptacle, electrical connector. An electrical connector receptacle is the part of a two-piece multiple contact electrical connector that is fixed or stationary. The receptacle is the end of the electrical connector that is on a thermocouple sensor or resistance thermometer since a thermocouple sensor or resistance thermometer is considered fixed or stationary once placed in service.

3.55 Reference junction. The reference junction refers to the two unattached, free ends of the wires that comprise a thermocouple. These two ends of the wires are held at a stable, known temperature. The standard reference temperature is 32 degrees Fahrenheit (°F); however, any other temperature, as long as it is known, can be used.

3.56 Resistance. Resistance is electrical opposition that a device (load) offers to the flow of dc.

3.57 Resistance thermometer. A resistance thermometer is a temperature measurement device whose element behaves as a variable resistor when influenced by temperature. This resistance variation is accurately correlated as a function of temperature. The resistance thermometer consists of a platinum or nickel element, sheath, interior sheath insulation, connecting wires, and a connecting wire end closure (see figure 2).

3.58 Resistance thermometer assembly. (See Assembly, resistance thermometer.)

3.59 Resistor, variable. A variable resistor is constructed so that its resistance value may be changed without interrupting the circuit to which it is connected.

3.60 Reversal, double. A double reversal means that there is a reversal of the polarity of the extension wire at both ends of the cable. It produces measured errors that may not be immediately detected. A double reversal is only applicable in thermocouple extension wire.

3.61 Reversal, single. A single reversal means that there is a reversal of the polarity of the extension wires at one end of the cable. It produces noticeable measurement errors at the monitoring system.

3.62 Sheath. A sheath is a cylindrical metal tube welded closed at the end in which the resistance thermometer element or thermocouple sensor measuring junction is located (see figure 1).

3.63 Single reversal. (See Reversal, single.)

3.64 Socket, electrical. An electrical socket is a hollow contact or cavity that is constructed to mate with and have another type contact (pin) inserted into its interior. The socket contact is normally used on the side of the circuit that is providing the power.

3.65 Spring. A spring is part of a resistance thermometer or thermocouple sensor used to ensure that the sheath is in contact with the thermowell. The spring is only used in the thermowell configuration (see figure 1).

3.66 Stuffing tube, nylon. A nylon stuffing tube is a fitting used for making electrical cable penetration in naval shipboard enclosures for electrical equipment. It is classified by numerical sizes.

3.67 Stuffing tube, steel. A steel stuffing tube is a fitting used for making electrical cable penetrations in naval shipboard decks, bulkheads, and overheads. It is classified by alphabetical sizes.

3.68 Terminal board. A terminal board is a component used to provide a means to mechanically secure and electrically connect two wires or sets of two wires.

3.69 Terminal board binding screws. Terminal board binding screws are the screws in the terminal board that are used to mechanically secure and electrically connect two wires or sets of two wires.

3.70 Thermocouple. A thermocouple is a pair of wires in which each wire is of a different metal. At one end (measuring junction) the two wires are joined, and at the other end (reference junction), the two wires are individually connected to a cold junction compensating circuit. Holding the two ends at different temperatures generates a voltage across the wires. The voltage varies in relation to the temperature depending on the material of the two wires used.

3.71 Thermocouple sensor. A thermocouple sensor is a temperature measurement device whose element is comprised of a thermocouple. The open circuit mV output generated by the thermocouple is accurately correlated as a function of temperature. The thermocouple sensor consists of the thermocouple, sheath, interior sheath insulation, and connecting wire end closure (see figure 2).

3.72 Thermowell. A thermowell is a closed-end tube constructed to protect the thermocouple sensor or resistance thermometer sheath from adverse conditions such as a corrosive environment, high pressures, and large flow rates. The thermowell is connected to and becomes an integral part of the pressure boundary (piping) of the system. The thermowell material is constructed to be compatible with the sheath material. The thermocouple sensor or resistance thermometer can be removed from the thermowell without disturbing the pressure boundary (see figure 1).

3.73 Tip. The tip is the end of the sheath in which the resistance thermometer element or the thermocouple measuring junction is located.

3.74 Variable resistor. (See Resistor, variable.)

3.75 Washer. A washer is either a thin, flat, hollow-centered, circular plate that is used to widen the distribution of the load onto a mating surface or a thin, flattened ring-shaped component, sometimes externally or internally serrated, that is used to prevent movement from occurring between adjacent surfaces. The primary function of a gasket is to isolate or seal, whereas a washer is used to provide an increased surface area or prevent movement.

3.76 Zero adjustment error. (See Error, zero adjustment.)

4. GENERAL REQUIREMENTS

4.1 Selection guidelines. Resistance thermometers, thermocouple sensors and appropriate wiring cable shall be selected in accordance with the following guidelines.

4.1.1 Resistance thermometers. The two different elements have separate temperature ranges:

(a) Nickel: minus 40 to 400°F.
(b) Platinum: minus 40 to 1000°F for thermowell and bare bulb configurations, minus 40 to 400°F for embedded configuration.

4.1.1.1 Qualities. Resistance thermometers have high accuracy, excellent stability, and reproducibility, but are slow in response. They are easily interchangeable, but damage easily if not handled properly. They can be matched to close tolerances for temperature difference measurements.

4.1.1.2 Platinum and nickel resistance elements. Resistance thermometers with platinum elements shall be specified for all new construction and new instrument installations. Resistance thermometers with nickel elements shall be restricted to retrofits and replacements only.

4.1.2 Thermocouple sensors. Type K thermocouple sensors cover a temperature range of minus 40 to 1500°F for the thermowell and bare bulb configurations and a temperature range of minus 40 to 400°F for the embedded configuration.

4.1.2.1 Type K thermocouples. These sensors are of a simple construction. A small single output is produced that requires sensitive measuring instruments. They are lower in cost and have a faster response time than resistance thermometers. Compensation for reference junction temperature shall be required. They attain high accuracy, but with use are subject to changes within the accuracy limit. These changes become more pronounced as the temperature increases. They are preferable for use with thermowells having a 2-inch immersion depth because the thermocouple sensor minimum immersion depth is significantly smaller than that of a resistance thermometer (see 4.2.4).

4.1.3 Extension wire. Requirements for wire shall be as specified in 4.1.3.1 through 4.1.3.3.

4.1.3.1 Minimum wire gauges. Single wires and pairs smaller than 16-gauge shall not be used because they do not have sufficient strength for pulling. When used in reinforced bundles to provide strength for pulling, 20-gauge and smaller wire may be used.

4.1.3.2 Thermocouple monitoring systems. The electrical resistance permissible on the extension wire puts limitations on the type of mV instruments that may be used. The older thermocouple mV POT monitoring systems require a definite resistance for the combined extension wire and sensor. (Excess extension wire needed to provide a precise value for resistance, but not length, shall be coiled in the instrument.) Other mV POTs do not require that a definite resistance (length) be used. The maximum resistance (length) of extension wire that may be used shall be specified. Electronic instruments generally have a high enough resistance so they do not place a restraint on the length of the extension wires found on shipboard applications.

4.1.3.3 Resistance thermometer monitoring systems. Two wire resistance thermometer monitoring systems also require that an adjustment be made to compensate for the precise length of extension wire.

4.1.4 Extension wire cable. Requirements for extension wire cable shall be as specified in 4.1.4.1 through 4.1.4.3.

4.1.4.1 General requirements. Extension wire cable used for installation of temperature monitoring systems shall conform to MIL-C-915. The specific cables that shall be used are specified in table I. The number of conductors or triads required in the application may be different than the ones specified in table I. If that is the case, the applicable type of cable specified in table I shall be acquired corresponding to the same requirements and number of conductors or triads needed.

TABLE I. Standard extension wire cable.

TABLE I(a). Thermocouple sensor cable.

Type	No. of CDRs in cable	Nominal diameter of CDR (inch)	Nominal area of CDR (MCM)	Cable (od) max (inch)	Approx. wt. per foot-pounds	Bend radius min (inch)	NSN 6145
TCKX-1	2	0.060	2.828	0.456	0.105	2.5	948-4135
TCKX-3	6	.060	2.828	.742	.250	4.0	901-6242
TCKX-7	14	.060	2.828	.983	.505	5.5	542-6703
TCKX-12	24	.060	2.828	1.269	.830	6.5	542-6703

TABLE I(b). Resistance thermometer cable.

Type	No. of CDRs in cable	Nominal diameter of CDR (inch)	Nominal area of CDR (MCM)	Cable (od) max (inch)	Approx. wt. per foot-pounds	Bend radius min (inch)	NSN 6145
TSS-4	3	0.076	4.497	0.500	0.200	1.5	905-6795
3SWU-3	9	.046	1.620	.700	.290	4.5	110-6289
3SWU-7	21						110-2191
3SWU-10	30	.046	1.620	1.190	.768	7.5	110-6547
3SWU-14	42	.046	1.620	1.290	1.022	8.5	110-6290
3SWU-19	57	.046	1.620	1.430	1.314	9.0	110-6578
3SWU-24	72	.046	1.620	1.670	1.747	10.5	110-6291
3SWU-30	90	.046	1.620	1.770	2.094	11.0	110-6594
3SWU-37	111	.046	1.620	1.930	2.587	12.0	110-6293

4.1.4.2 Type K thermocouple sensors. For type K thermocouple sensors, type TCKX extension wire cable shall be used. TCKX stands for Thermocouple, Multi Pairs that contains silicone rubber insulation on one chromel and one alumel conductor per pair, a silicone rubber jacket, and armor. For details see table I(a). Color coding shall be in accordance with table II.

TABLE II. Color identification code for thermocouple sensor cable.

Pair number	Alumel	Chromel	
		Base color	Trace color
1	Red	White	-----
2	Red	Black	-----
3	Red	Green	-----
4	Red	Orange	-----
5	Red	Blue	-----
6	Red	White	Black
7	Red	White	Green
8	Red	White	Orange
9	Red	White	Blue
10	Red	White	Red
11	Red	Black	White
12	Red	Green	White

4.1.4.3 Platinum and nickel elements. For resistance thermometer with platinum or nickel elements, type TSS or 3SWU extension wire cable shall be used. TSS stands for Three Conductor, Special Purpose, Shielded that contains a rubber insulation, overall braided shield, and a polychloroprene jacket. Triads, Shielded, Watertight, Unarmored, abbreviated 3SWU, contain a polyethylene insulation, braided shield over each triad, overall polyvinyl chloride jacket and have no armor. For details see table I(b). There is no specific color code for wire insulation on this type of cable.

4.1.5 Electrical connectors. Bare bulb configuration electrical connector plugs and the mating electrical connector receptacle attached to the extension wire shall be equivalent to those listed in table III. If the mating electrical connector receptacle is a part of a cable assembly specifically constructed for that installation, an identical cable assembly shall be used in lieu of constructing the applicable mating electrical connector receptacle in table III onto the appropriate cable in table I.

TABLE III. Equivalent electrical connectors for bare bulb configuration.

Type		Specification	Part number	Electrical connector contact material
NRT	receptacle	MS3102	MS3102R-12S-3P	Nickel-plated copper alloy
	plug	MS3106	MS3106F-12S-3S	
PRT	receptacle	MS3102	MS3102R-14S-7P	
	plug	MS3106	MS3106F-14S-7S	
KTC 1/	receptacle	MS3102	MS3102R-12S-3P	Chromel (+)
	plug	MS3106	MS3106F-12S-3S	Alumel (-)

1/ Crimped contacts made from thermocouple material (chromel and alumel) shall be specified along with the MS part number. Soldered contacts made from copper are normally provided.

4.1.6 Configurations. Configurations shall be as specified in 4.1.6.1 through 4.1.6.3.

4.1.6.1 Thermowell configuration. This configuration is used for applications where the temperature of the medium shall be measured, and where a break in the pressure or fluid boundary (piping system) that is mechanically closed by a gasket, seal, or other part is not permitted. The thermowell is an integral part of the pressure or fluid boundary of the system. The thermocouple sensor or resistance thermometer, placed in a thermowell, does not penetrate the pressure or fluid boundary and so is not intended to be exposed directly to the medium (see figures 1 and 4).

4.1.6.2 Bare bulb configuration. This configuration is used for applications where the thermocouple sensor or resistance thermometer shall be directly immersed into the medium. The sheath contains threads to mechanically secure the thermocouple sensor or resistance thermometer to the system and a gasket to maintain the pressure or fluid boundary of the system. When selecting this configuration, consideration shall be given to the material compatibility, pressure limits, and velocity limits of the medium (see figure 5).

4.1.6.3 Embedded configuration. This configuration shall be used to provide a measurement of bearing oil film temperature where it is not feasible to place a thermocouple sensor or resistance thermometer sheath through the bearing housing and into the bearing. The thermocouple sensor or resistance thermometer shall be embedded directly into the bearing (see figure 6).

4.2 Pre-installation considerations. Pre-installation considerations shall consist of the following (see 4.2.1 through 4.2.9).

4.2.1 Extension wire runs. One cable with enough conductors to accommodate multiple thermocouple sensors or resistance thermometers shall be run from the monitoring system to a junction box. At the junction box, an individual cable shall be run to each thermocouple sensor assembly or resistance thermometer assembly. In applications where a precise system accuracy of plus or minus 3°F is required, an individual cable shall be run from the monitoring system to each thermocouple sensor assembly or resistance thermometer assembly in one continuous run. Junction box connections will introduce errors (especially with thermocouple sensors) and shall only be used where unavoidable in an application requiring precise system accuracy.

4.2.2 Continuity check. Each of the connecting wires on the thermocouple sensor or resistance thermometer shall be checked for continuity. A continuity check is performed with an ohmmeter. The procedure to perform a continuity check is specified in 5.6.1.2(c) for thermocouple sensors and in 5.6.2.2(c) for resistance thermometers.

4.2.3 Lagging and insulation. The effect on the thermocouple due to lagging and insulation shall be as specified in 4.2.3.1 and 4.2.3.2.

4.2.3.1 Thermocouple sensor assembly. For the thermowell and embedded configuration, the thermocouple sensor connecting wires, the extension wires, and the metal plate on the terminal board may be of different grades of the same material. For the bare bulb configuration, the thermocouple sensor connecting wires, electrical connector receptacle pins, electrical connector plug contacts, and extension wires may be of different grades of the same material. The point at which any two of these components come into contact can form another thermocouple. A temperature variation or gradient at this contact point will cause a change in the overall thermocouple sensor mV output. The thermocouple sensor alone shall be exposed to the temperature gradient while the connection head, terminal board, or electrical connector shall be at ambient room temperature. Insulating the connection head, terminal board, or electrical connector would increase the temperature measurement error caused by the thermocouple effect; therefore, these items shall not be lagged or insulated.

4.2.3.2 Resistance thermometer assembly. Different materials or different grades of the same materials for the connecting wires, extension wires, and terminal board metal plates/electrical connector pins and sockets may be used in resistance thermometer construction and installation. In the presence of a temperature gradient, this will cause what is known as the thermocouple effect. For the reasons identified in 4.2.3.1, the connection head, terminal board, or electrical connector shall not be lagged or insulated.

4.2.4 Immersion depth. The thermocouple sensor or resistance thermometer shall be immersed to a depth so that further immersion does not produce a change in indicated temperature beyond the accuracy limits.

4.2.4.1 Thermocouple sensor. The measuring junction shall be located within 1/4 inch from the tip of the sheath for the thermowell and bare bulb configuration and within 1/8 inch from the tip of the sheath for the embedded configuration. As a general rule, the minimum immersion depth for the thermowell and bare bulb configuration should be at least ten times the outside diameter of the sheath. For a 1/4-inch sheath diameter, the immersion depth shall be 2-1/2 inches. The entire sheath of the embedded configuration shall be in contact with the bearing.

4.2.4.2 Resistance thermometer. The element is located within the bottom 2 inches from the tip of the sheath for the thermowell and bare bulb configuration. As a general rule, the minimum immersion depth should be at least 2 inches past the element. The embedded resistance thermometer shall be installed in a bearing, and the entire sheath shall be in contact with the bearing.

4.2.4.3 Thermowell. The immersion depth of a thermowell will influence the temperature being measured by a thermocouple sensor or a resistance thermometer. In some installations, thermowells with less than the full immersion depth have resulted in the measurement of significant temperature errors. The minimum thermowell depth will vary with each particular installation, but in no instance shall the thermowell immersion depth be less than the thermocouple sensor or resistance thermometer minimum immersion depth.

4.2.5 On-site accuracy verification. When the accuracy of a thermocouple sensor or a resistance thermometer is in doubt, the thermocouple sensor or resistance thermometer shall be checked to see if it is still within the required accuracy limits. This accuracy verification does not pertain to embedded configurations. This shall be done on-site using either a King Nutronics Corporation portable temperature comparator Model 3604-1-101, a Model 3605, or equal. The two models are used for two separate temperature ranges. The thermocouple sensor or resistance thermometer output signal shall be read on both the monitoring system and on either an mV POT (thermocouple sensor) or a resistance bridge (resistance thermometer). If the thermocouple sensor or the resistance thermometer is not within the specified accuracy limits, then it should be replaced. If the monitoring system and mV POT/resistance bridge readings do not agree, personnel shall proceed to the troubleshooting procedures (see 5.6.1 and 5.6.2, as applicable). If the two readings do agree, further investigation into the cause shall be performed as specified in 4.2.5.1 or 4.2.5.2, as applicable.

4.2.5.1 Thermocouple sensor. A previously performed on-site accuracy verification confirmed that the thermocouple sensor is within its specified accuracy limits; however, once reinstalled in place, the thermocouple sensor did not appear to be providing the correct temperature indication. A similar symptom occurs when the thermocouple sensor is installed in two separate locations. In this latter situation, the same thermocouple sensor would read different temperatures (with the temperature of the medium being the same). In both situations described above, some conditions were varied. The conditions include varying the immersion depth (see 4.2.4.1) and the temperature of the connection head, terminal board, or electrical connector (see 4.2.3.1). A thermocouple sensor that is immersed to at least the minimum immersion depth and which has the connection head, terminal board, or electrical connector maintained at the ambient temperature of the room shall have a minimal discrepancy in the temperature indication.

4.2.5.1.1 In-place check. An in-place check may be performed to confirm that the immersion depth and the temperature variation along the thermocouple sensor length are responsible for the discrepancy in the temperature indication. The thermocouple sensor in question shall be replaced with one that has been calibrated at a remote location. The thermocouple sensor (for the thermowell configuration the thermocouple sensor assembly containing the calibrated thermocouple sensor) shall be immersed in the medium. The temperature indication (or mV output) shall be obtained. Disagreement between the calibrated thermocouple sensor and the thermocouple sensor under question would indicate an inadequate immersion depth or a large temperature gradient at the connection head, terminal block or electrical connector. Correction of these two conditions should eliminate the error in the temperature reading.

4.2.5.2 Resistance thermometers. If properly installed so that the minimum immersion depth criterion is met (see 4.2.4.2) and the connection head, terminal block or electrical connector is at ambient temperature (see 4.2.3.1), then the temperature reading should be the same whether the resistance thermometer was verified in place, on-site, or at a remote location. An in-place check can be performed that is similar to the in-place check as specified in 4.2.5.1.1 to verify an inadequate immersion depth. The conditions that cause a large temperature gradient at the connection head, terminal block, or electrical connector are described in 4.2.5.1.

4.2.6 Calibration. Before installation, the thermocouple sensor or the resistance thermometer shall be calibrated at a certified calibration laboratory.

4.2.7 Thermocouple sensor or resistance thermometer removal from the piping system. When a thermowell configuration thermocouple sensor or resistance thermometer is removed from a thermowell in the system piping, a plug shall be installed in the thermowell to prevent stray dirt, oils, or other debris from entering the thermowell as shown on figure 4. When a bare bulb configuration thermocouple sensor or resistance thermometer is removed from the system piping, a plug shall be installed in the system piping to prevent stray dirt, oils, or other debris from entering the system piping. Once reinstalled and heated to operating temperature, the stray dirt or other debris causes the thermocouple sensor or resistance thermometer to seize in the thermowell or the system piping. Once seized in the thermowell or the system piping, the thermocouple sensor or resistance thermometer must be drilled out. If not performed carefully, the drilling process may damage the thermowell or the system piping.

4.2.8 Electrical interference. Electrical interference is caused by stray alternating current (ac) or static dc that enters circuitry and which causes improper operation in the monitoring system. Electrical interference may reduce accuracy in analog circuits and may trigger false input and output signals in both analog and digital circuitry.

4.2.8.1 Causes of electrical interference. The following are causes of electrical interference (see (a) through (e)).

(a) Electrical charges from loose power connections at the monitoring system or junction box terminal boards.
(b) Leakage paths that are a result of deteriorated cable insulation.

(c) Electrical interference experienced on one pair of thermocouple sensor or resistance thermometer cables by nearby power or instrumentation cables. This type of electrical interference is referred to as crosstalk.
(d) Electrostatic interference caused by capacitance coupling of two or more resistance thermometer or thermocouple sensor cables when those cables are run parallel to power cables.
(e) Electromagnetic interference (EMI) is introduced when cables are run through areas containing high magnetic fields. Transmitters and generators are good sources of EMI. Damaged or deteriorated cable shields allow EMI to penetrate to the conductors and cause interference.

4.2.8.2 Guidelines for reducing electrical interference. The following guidelines shall apply for reducing electrical interference:

(a) Cables shall contain a shield with an insulated jacket.
(b) Resistance thermometer conductors shall be of equal resistance.
(c) Shielded cable shall be grounded and only at one end. Ground loops, which may occur if the shield is grounded at more than one point, shall be prevented.

    (1) Cables shall be inspected for exterior damage. Ground loops and leakage paths may be caused by damaged cables. Damaged cables shall be repaired or replaced.
    (2) A check shall be made on thermocouple sensors to determine if they are grounded or ungrounded. Cable shields for resistance thermometers and ungrounded thermocouple sensors shall be grounded at the junction box or monitoring system. Cable shields for grounded thermocouple sensors shall be grounded at the thermocouple sensor end.

(d) EMI may be minimized by keeping resistance thermometer and thermocouple sensor cables away from power cables and high voltage generators. Further protection may be obtained by using twisted pair cabling. The greater the twist for each foot of cable, the greater the protection from EMI on cables. Shielding cables with a ferrous material may also be effective against EMI penetration.
(e) EMI and crosstalk may both be eliminated by the use of twisted pair shielded cable. Electrostatic voltages are canceled by twisted pair cables, and the possibility of crosstalk is diminished by shielded cables.
(f) EMI is transmitted through unintentional openings in the monitoring system cover plates and other access panels. Certain precautions and procedures shall be followed to alleviate the possibility of EMI being transmitted into the interior of the monitoring system circuitry. After all tests are performed and installations are made, all parts removed during testing shall be replaced, especially gaskets, panels, covers and washers. Screws and gaskets shall be replaced and securely fastened. Loose screws and gaskets will allow EMI to be transmitted into the monitoring system circuitry.

4.2.9 Tools and test equipment. Tables IV(a), IV(b), and IV(c) contain the tools and test equipment used to perform the installation and troubleshooting procedures. Patch cords needed to perform troubleshooting procedures are listed in table V and different configurations are shown on figure 3.

TABLE IV. List of tools, materials, and test equipment.

TABLE IV(a). General list.

Tools	SCAT#	SEIN	NSN	Installation	Troubleshooting
Screwdrivers					
Hold-tight		LCA7336	5120-00-618-4908	X	X
Phillips		LCA2943	5120-00-596-0858	X	X
Slotted, small blade		LCA2738	5120-00-516-3226	X	X
Slotted, heavy duty		LCA7331	5120-00-913-5843	X	X
Sidecutters, stripping pliers		LCA7230	5110-00-806-9551	X	X
Electrician's knife		LCA4180	5110-00-240-5943	X	
Needle nose pliers		LCA1567	5110-00-240-6213	X	X
Ohmmeter					
Digital	4245		89536-8020B	X	X
Analog	4245		55026-260-6XLP	X	X
Patch cords 1/					X
Millivolt potentiometer 2/	4128		31922-8686		X
Resistance bridge 3/	4122		31922-8064A2		X
Temperature comparator					
Mdl 3604			5895-01-094-2576		X
3605	1682	TCD0104	6685-01-094-2778		X
Flashlight		LCA4174	6230-00-270-5418	X	X
Inspection mirror		LCA2242	5120-00-278-9926	X	X
Decade box 3/					X

1/ Refer to table V for different types.
2/ Required for use with thermocouple sensors only.
3/ Required for use with resistance thermometers only.

TABLE IV(b). Additional list for embedded configuration.

Terminal board
Babbitt metal, in accordance with QQ-T-390, grade 2 (approximately 4 ounces)
Solder, in accordance with QQ-S-571 (for solder connections)
Epoxy resin adhesive, heat-resistant slow drying
RTV silicone adhesive
Solder, flux and brush
Cleaning solvent - pressure-pack spray can
Propane torch or oxyacetylene torch (fine tip on torch)
Digital multimeter (with alligator clip connection leads)
Small electrical drill - 3/16-, 1/4-, 9/32-, 1/2-inch drill bits
Small round, half-round and flat files
1/8-inch flat groove chisel
Center punch
Bearing scraper
400-grit wet and dry paper
Diesel fuel

TABLE IV(c). Additional list for bare bulb configuration.

Copper gasket
Wrench

TABLE V. Patch cords.

When using stack up standard banana plug patch cords (referred to as patch cords) with adapters, use these models or equivalent:

Equipment	Manufacturer	Model no.
Banana plug patch cord	ITT Pomona Electronics	B-12-0 (black cord) B-12-2 (red cord)
Spade lug adapter (for use with terminal board binding screws)	ITT Pomona Electronics	Black adapters: 1614-0, 3744-0 Red adapters: 1614-2, 3744-2
Socket adapter (for use with pins in plugs)	ITT Pomona Electronics	Black adapters: #22 socket 4690-0 0.040 socket 3560-0 0.063 socket 3562-0 0.093 socket 3564-0 Red adapters: #22 socket 4690-2 0.040 socket 3560-2 0.063 socket 3562-2 0.093 socket 3564-2

TABLE V. Patch cords - Continued

Equipment	Manufacturer	Model no.
Pin adapter or male (for use with sockets in receptacle)	ITT Pomona Electronics	Black adapters: #22 pin 4691-0 0.040 pin 3561-0 0.063 pin 3563-0 0.093 pin 3565-0 Red adapters: #22 pin 4691-2 0.040 pin 3561-2 0.063 pin 3563-2 0.093 pin 3565-2

5. DETAILED REQUIREMENTS

5.1 Installation of extension wire and cable entrances. Extension wire and cable entrances shall be installed as specified in 5.2 through 5.5.

5.2 Extension wire runs. Extension wire shall be run by one of the two methods specified in 4.2.1.

5.2.1 Extension wire length. Extension wire length shall be kept as short as possible unless the monitoring system specifies otherwise. Extension wires for each individual resistance thermometer shall be the same length so that the total resistance of each wire is the same. For a resistance thermometer with two connecting wires, replacement extension wires shall be at the same fixed length as the original ones. Also, for this two connecting wire configuration, the original fixed length shall not be shortened. The replacement wire shall have the same ohms for each foot. (The applicable technical manual shall be consulted.)

5.2.2 Securing extension wires. For nylon stuffing tube cable entrances, extension wires shall be fastened securely to terminal boards to ensure a solid electrical connection. For electrical connector cable entrances, extension wires for thermocouple sensors shall be crimped securely, and resistance thermometers shall be soldered adequately to ensure solid electrical connections.

5.2.3 Marking. Extension wires shall be marked, color coded, or otherwise identified at each end. The cable shall be marked at the junction box where the cable terminates.

5.2.4 Grounding. Extension wire cable shields shall be grounded to prevent interference from power equipment. Unshielded extension wire or other unshielded instrument wire shall not be run next to a power line in the same wireway.

5.2.5 Cable clamps. When necessary, the extension wires and other instrumentation wires shall be supported with cable clamps. This may be done by welding threaded studs to the overhead or bulkhead at a maximum interval of 2 feet. The cable clamps shall be threaded onto the threaded studs, the extension wire or the instrument wire placed in the cable clamp, and the cable clamp closed by crimping it.

5.2.6 Use of steel stuffing tube. When overheads, decks and bulkheads must be penetrated for runs of extension wire or other instrument wire, a steel stuffing tube shall be used to ensure that watertight integrity is maintained. Arrangements with the appropriate shipboard personnel shall be made to make the penetration and install the steel stuffing tube. Once the cable (extension wire or other instrumentation wire) is through the steel stuffing tube, the steel stuffing tube rings and packing material shall be correctly positioned to ensure a watertight seal.

5.3 Terminal board and electrical connector installations. The extension wire shall be routed to the connection head terminal board (thermowell configuration), bearing terminal board (embedded configuration), or electrical connector (bare bulb configuration) (see figures 7 and 8, as applicable). For correct extension wire cable selection, see table I.

5.3.1 Thermowell and embedded type K thermocouple sensors. For the thermowell and embedded configuration type K thermocouple sensors, the alumel extension wire (color coded red) shall be connected to the negative (-) terminal board binding screw as shown on figure 8. The chromel extension wire (see table II for color coding) shall be connected to the positive (+) terminal board binding screw as shown on figure 8. It shall be ensured that proper polarity (positive to positive, negative to negative) is maintained from the connection head terminal board (thermowell configuration) or bearing terminal board (embedded configuration) to the monitoring system.

5.3.2 Bare bulb type K thermocouple sensor. For the bare bulb configuration type K thermocouple sensor, alumel extension wire (color coded red) shall be inserted and crimped into the negative (-) socket of the electrical connector receptacle as shown on figure 7. The chromel extension wire (see table II for color coding) shall be inserted and crimped to the positive (+) socket of the electrical connector receptacle as shown on figure 7. It shall be ensured that proper polarity (positive to positive, negative to negative) is maintained from the electrical connector receptacle to the monitoring system.

5.3.3 Thermowell and embedded resistance thermometers. For the thermowell and embedded configuration resistance thermometers, extension wire leads shall be connected to the appropriate terminal board binding screws as shown on figure 8. There are no specific color codings on extension wires to correspond to the color codings on the connecting wires. The insulation on the three connecting wires are color coded red, white, and white, respectively, and are connected to the corresponding R, W, and W marked terminal board metal links with the terminal board binding screws. Some older terminal board metal links may be marked A, B, and C. It shall be ensured that the proper terminal board connections are made and that color coding is consistent at both ends of the extension wire run. If there is an electric schematic for the system, color coding on the schematic shall be used for extension wire connections.

5.3.4 Bare bulb resistance thermometers. For the bare bulb configuration resistance thermometers, the extension wire leads shall be connected to the appropriate electrical connector receptacle sockets as shown on figure 7. There are no specific color codings on the extension wires to correspond to the specifically marked electrical connector receptacle sockets. For the resistance thermometers with platinum elements, the electrical connector receptacle sockets are marked A, B, and C. The extension wire shall be inserted and soldered into the corresponding A, B, and C marked sockets in the electrical connector receptacle. For the resistance thermometers with nickel elements, the electrical connector receptacle sockets are marked A and B. The extension wire shall be inserted and soldered into the corresponding sockets marked A and B in the electrical connector receptacle.

5.4 Cable entrances. The cable entrance penetration into junction boxes or monitoring systems may be made by one of two methods: through stuffing tubes or by electrical connectors. The extension wire cable entrance into the thermowell configuration thermocouple sensor assembly or resistance thermometer assembly connection head is made only with a stuffing tube. The installation procedure for each of these two types of cable entrances shall be as specified in 5.4.1 and 5.4.2.

5.4.1 Installation of nylon stuffing tube. The following procedure shall be used when installing an extension wire through a nylon stuffing tube to a junction box, monitoring system, or other instrumentation. (When inserting a nylon stuffing tube into a thermocouple sensor assembly or a resistance thermometer assembly connecting head, a reducing bushing may be required to interface the connection head thread with the stuffing tube thread.)

WARNING

The monitoring system and junction box terminal board may contain 115 volts ac. It shall be ensured that electrical power is disconnected from the terminal board before installing the wire through the nylon stuffing tube, and the system shall be red tagged.

(a) Plug and nylon stuffing tube cap shall be removed from body of nylon stuffing tube and the plug discarded.
(b) Nylon stuffing tube cap shall be slid onto cable followed by the two large rings (see figure 9).
(c) The grommet shall be placed on the cable with the large end first, followed by the small ring (see figure 9).
(d) The wire shall be run through the nylon stuffing tube body and connected to input terminal board binding screws (see figure 9).
(e) Grommet and rings (large and small) shall be slid into the body of the nylon stuffing tube. Grommet shall be seated correctly in the nylon stuffing tube to ensure a watertight seal.
(f) The nylon stuffing tube cap shall be twisted onto the body of the nylon stuffing tube.

5.4.2 Installation of an electrical connector. The following procedures shall be used to install an electrical connector:

WARNING

The monitoring system and junction box terminal board may contain 115 volts ac. It shall be ensured that electrical power is disconnected from the terminal board before installing the wire through the nylon stuffing tube, and the system shall be red tagged.

(a) The insulation from each conductor on extension wire cable shall be removed to the dimensions shown in table VI.
(b) Endbell, ferrule, grommet and coupling nut shall be slid onto extension wire cable. The large end of coupling nut shall not be facing the grommet. (Grommet shall fit inside ferrule (see figure 10).)
(c) The contacts shall be inserted into contact body to form the contact body assembly (see figure 10). Insertion and removal tools shall be used as specified in table VII.
(d) Thermocouple conductor leads shall be crimped onto contacts or resistance thermometer conductor leads shall be soldered onto contacts (see figure 10).
(e) The contact body assembly shall be slid into barrel (see figure 10).
(f) The O-ring shall be slipped onto barrel.
(g) Barrel (containing contact body assembly) shall be screwed into endbell (containing ferrule and grommet) while lining up contacts with the grommet (see figure 10).

TABLE VI. Lengths to strip ends of individual conductors.

Wire size (AWG)	16	12	8	4	0
Length to strip ends (inches)	1/4	1/4	7/16	5/8	11/16

TABLE VII. Tools for insertion or removal of electrical connector contacts.

TABLE VII(a). Insertion tools.

Rear release	Front release
MIL-I-81969/14 MS27534	MIL-I-81969/17 MS27534

TABLE VII(b). Removal tools.

Rear release	Front release
MIL-I-81969/29 MIL-I-81969/14 MIL-I-81969/15	MIL-I-81969/19

5.5 Installation of thermocouple sensors and resistance thermometers. The installation of the thermocouple sensors and resistance thermometers shall be as specified in 5.5.1 through 5.5.5.

5.5.1 Tools, materials, and test equipment. The tools, materials, and test equipment needed to install the three configurations of thermocouple sensors and resistance thermometers are listed in table IV.

5.5.2 Thermowell configuration procedure. The procedure used to install a thermowell configuration thermocouple sensor assembly or resistance thermometer assembly shall be as specified in 5.5.2(a) through 5.5.2(g)(7).

(a) The connecting wire shall be cut and the outer insulation scraped away for a distance of approximately 1-1/2 inches and the same shall be done to the insulation on the individual wires for a distance of 1 inch. (A knife shall be used to avoid notching the wire.) For thermocouple sensors, the chromel connecting wire (color coded yellow) shall be connected to the positive terminal board binding screw as shown on figure 8. Distinction between chromel and alumel may be made by use of a magnet because alumel is the more magnetic of the two. The alumel connecting wire (color coded red) shall be connected to the negative terminal board binding screw as shown on figure 8. For resistance thermometers, single lead (color coded red) and the other two leads (color coded white) shall be connected to the appropriate terminal board binding screws as shown on figure 8. Wires shall be wrapped around terminal board binding screws clockwise, and then screws shall be tightened to ensure a solid electrical connection.

(b) It shall be ensured that the thermocouple sensor, the resistance thermometer, and the thermowell are at the minimum immersion depth. (For immersion depth, see 4.2.4.)

(c) When a thermowell is used, the connection head shall extend beyond the insulation surrounding the piping system, as shown on figure 11. The temperature of the connection head should then be close to the ambient temperature. This shall prevent a large temperature difference in the extension wire and shall significantly reduce extension wire error. For a thermocouple sensor or resistance thermometer inside a thermowell, bottoming is practiced to improve the response to temperature change. Bottoming consists of having the tip pressed tightly against the end or bottom of the thermowell as shown on figure 11.

(d) When measuring high temperatures, the thermocouple sensor or resistance thermometer shall be installed in an upright, vertical position whenever possible. If the sheath is distorted by sagging, stress will be placed on the internal connecting wires and element and may cause seizing of the sheath in a thermowell. Thermowell induced stress may also be aggravated by not putting the thermowell in an upright, vertical position.

(e) The correct type of extension wire (see table I) shall be routed through the connection head and connected to terminal board binding screws as shown on figures 7 and 8 (see 5.3).

(f) When connection head temperatures are hot enough that personnel could get burned upon contact, adequate protection shall be taken to screen (isolate) the connection head from personnel in that area.

(g) An installation checklist shall consist of the following steps:

(1) It shall be ensured that the nickel element resistance thermometer, platinum element resistance thermometer, or type K thermocouple sensor that is supposed to be installed in the system is what is presently there (see 5.6.1.2 and 5.6.2.2). It shall be ensured that the connecting wire is color coded properly (see 5.5.2(a)).

(2) It shall be ensured that extension wire is made of correct materials, minimum gauge requirements are met, and color coded wire is connected correctly (see tables I and II).

(3) It shall be ensured that all electrical connections are sound. Connecting and extension wires shall be rewrapped around terminal board binding screws in a clockwise direction and the screws tightened (see 5.6.1.1(a) through (c) and 5.6.2.1(a) through (c)).

(4) It shall be ensured that the thermocouple sensor, resistance thermometer, and thermowell are placed in the system so that the minimum immersion depth is met (see 4.2.4).

(5) It shall be ensured that no mechanical stress or vibration is placed on the extension or connecting wires that could strain the wires (see 5.5.2(d)).

(6) It shall be ensured that electrical power wires are not placed in same conduit as unshielded extension wire.

(7) It shall be ensured that cable shields are properly grounded (see 4.2.8.2).

5.5.3 Bare bulb configuration procedure. The procedure used to install a bare bulb configuration thermocouple sensor or resistance thermometer shall be as specified in 5.5.3(a) through 5.5.3(d)(6).

(a) It shall be ensured that a new copper gasket (see table IV(c) and figure 5) is placed between the piping and the thermocouple sensor or the resistance thermometer before inserting the thermocouple sensor or resistance thermometer into the piping. Personnel shall be careful not to overtighten and crush the copper gasket.

(b) The extension wire electrical connector receptacle shall be inserted into the thermocouple sensor or resistance thermometer electrical connector plug.

(c) When electrical connector temperatures are hot enough that personnel could be burned upon contact, adequate protection shall be taken to screen (isolate) the electrical connector from personnel in that area.

(d) Installation checklist shall consist of the following steps:

(1) It shall be ensured that the nickel element resistance thermometer, platinum element resistance thermometer, or type K thermocouple sensor that is supposed to be installed in the system is what is presently there (see 5.6.1.2 and 5.6.2.2). It shall be ensured that the electrical connector receptacle is compatible with the electrical connector portion of the thermocouple sensor or resistance thermometer.
(2) It shall be ensured that the extension wire is made of correct materials, minimum gauge requirements are met, and color coded wire is connected correctly (see tables I and II).
(3) It shall be ensured that the thermocouple sensor or resistance thermometer is placed in the system so that the minimum immersion depth is met (see 4.2.4).
(4) It shall be ensured that no mechanical stress or vibration is placed on the extension wires that could strain the wires (see 5.5.2(d)).
(5) It shall be ensured that electrical power wires are not placed in the same conduit as unshielded extension wire.
(6) It shall be ensured that the cable shields are properly grounded (see 4.2.8.2).

5.5.4 Embedded configuration replacement procedure. The procedure used to remove and then replace the embedded configuration thermocouple sensor or resistance thermometer installed in a bearing shall be as specified in 5.5.4 through 5.5.4(x). Before this procedure is used, it is mandatory that the user has already determined that the location of the trouble is between the electrical connector and the thermocouple sensor or resistance thermometer. Erroneous temperature readings may be caused by a faulty thermocouple sensor or resistance thermometer (bearing), terminal board, electrical connector, or interconnecting extension and connecting wires (see figures 12 and 13). In most instances, the trouble may be attributed to an open circuit, a short circuit, or poor isolation to ground. Before replacing the thermocouple sensor or resistance thermometer, it must be proven faulty. The thermocouple sensor or resistance thermometer may be checked at the terminal board with a multimeter as stated in 5.5.4(k). A troubleshooting procedure for thermocouple sensors is provided in 5.6.1 and for resistance thermometers in 5.6.2.

(a) In accordance with NAVSEA 0942-LP-016-1010, the thermocouple sensor or resistance thermometer extension wires shall be disconnected from the electrical connector (see figure 14). The bearing that contains the faulty thermocouple sensor or resistance thermometer shall be removed from the housing.
(b) The epoxy in the back groove of the bearing half shall be removed and cleaned out (see figure 12). It shall be ensured that no epoxy is left in the back groove from the thermocouple sensor or resistance thermometer to the terminal board.

(c) The thermocouple sensor or resistance thermometer terminal board shall be unstaked and removed from its location in the bearing half. The thermocouple sensor or resistance thermometer connecting wires shall be removed from the back groove. The thermocouple sensor or resistance thermometer connecting wires shall be broken free from the thermocouple sensor or resistance thermometer.

(d) A 3/16-inch diameter radial hole shall be drilled from the back of the bearing through the thermocouple sensor or resistance thermometer connecting wire hole, through the thermocouple sensor or resistance thermometer, and then through the bearing babbitt metal (see figure 13).

(e) A 1/4-inch diameter radial hole shall be drilled from the face of the bearing using the 3/16-inch hole as a pilot guide deep enough to remove the babbitt covering and the thermocouple sensor or resistance thermometer. The thermocouple sensor or resistance thermometer shall be removed.

(f) Any remaining thermocouple sensor or resistance thermometer metal shall be drilled and cleaned out using a 9/32-inch drill to a 5/16-inch depth (see figure 15).

(g) The babbitt surface shall be chamfered approximately 1/16 inch using a 1/2-inch drill. This chamfer shall help accept the new thermocouple sensor or resistance thermometer and assist rebabbitting of the bearing surface. As shown, the corner shall be broken to prevent thermocouple sensor or resistance thermometer connecting wires from being cut by sharp edges (see figure 15).

(h) The thermocouple sensor or resistance thermometer connecting wire hole (see figure 16) and back groove shall be thoroughly cleaned out using a pressure-pak spray can of a cleaning solvent.

(i) The machined surfaces shall be cleaned so they are free of oil, chips, and other debris. Also, tinned sides and the babbitt tip of the new thermocouple sensor or resistance thermometer shall be cleaned with fine steel wool. Care shall be take not to damage the tinned sides or the babbitted surface. Steel wool shall be carefully removed.

(j) The thermocouple sensor or resistance thermometer connecting wires shall be inserted in the 0.278/0.281-inch diameter counterbore hole. They shall be extended through the 3/16-inch diameter radial hole in the bearing shell. The connecting wires shall be carefully drawn through, making sure they are not kinked or damaged in any manner (see figure 16). The connecting wires shall not be pulled to seat the thermocouple sensor or resistance thermometer in the 0.278/0.281-inch diameter hole. Fingers should be used to guide the thermocouple sensor or resistance thermometer into the hole and to press it into place. When the thermocouple sensor or resistance thermometer is correctly seated in the hole, the body of the thermocouple sensor or resistance thermometer should be about 1/16 inch below the bearing surface (see figure 15).

(k) The connecting wires shall be connected to a Fluke Digital multimeter, or equal, using an alligator clip.

(l) The ambient temperature readings of the new thermocouple sensor or resistance thermometer shall be checked in accordance with table VIII or IX. Note that the thermocouple sensor or resistance thermometer temperature must be constantly monitored during the following babbitting operation to avoid excess heat damage to the new thermocouple sensor or resistance thermometer. The maximum temperature permissible for a short period of time (15 minutes maximum) is:

Resistance thermometer with platinum element:
500°F (200 ohms)

Resistance thermometer with nickel element:
500°F (380 ohms)

Thermocouple sensor - type K:
500°F (10.6 mVs)

TABLE VIII. Temperature versus mV characteristics for type K (chromel versus alumel) thermocouples. 1/

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
-40	-1.50	-1.52	-1.54	-1.56	-1.58	-1.60	-1.62	-1.64	-1.66	-1.68
-30	-1.30	-1.32	-1.34	-1.36	-1.38	-1.40	-1.42	-1.44	-1.46	-1.48
-20	-1.10	-1.12	-1.14	-1.16	-1.18	-1.20	-1.22	-1.24	-1.26	-1.28
-10	-0.89	-0.91	-0.93	-0.95	-0.97	-0.99	-1.01	-1.03	-1.05	-1.07
0	-0.68	-0.66	-0.64	-0.62	-0.60	-0.58	-0.56	-0.54	-0.52	-0.49
10	-0.47	-0.45	-0.43	-0.41	-0.39	-0.37	-0.34	-0.32	-0.30	-0.28
20	-0.26	-0.24	-0.22	-0.19	-0.17	-0.15	-0.13	-0.11	-0.09	-0.07
30	-0.04	-0.02	-0.00	0.02	0.04	0.07	0.09	0.11	0.13	0.15
40	0.18	0.20	0.22	0.24	0.26	0.29	0.31	0.33	0.35	0.37
50	0.40	0.42	0.44	0.46	0.48	0.51	0.53	0.55	0.57	0.60
60	0.62	0.64	0.66	0.68	0.71	0.73	0.75	0.77	0.80	0.82
70	0.84	0.86	0.88	0.91	0.93	0.95	0.97	1.00	1.02	1.04
80	1.06	1.09	1.11	1.13	1.15	1.18	1.20	1.22	1.24	1.27
90	1.29	1.31	1.33	1.36	1.38	1.40	1.43	1.45	1.47	1.49
100	1.52	1.54	1.56	1.58	1.61	1.63	1.65	1.68	1.70	1.72
110	1.74	1.77	1.79	1.81	1.84	1.86	1.88	1.90	1.93	1.95
120	1.97	2.00	2.02	2.04	2.06	2.09	2.11	2.13	2.16	2.18
130	2.20	2.23	2.25	2.27	2.29	2.32	2.34	2.36	2.39	2.41
140	2.43	2.46	2.48	2.50	2.52	2.55	2.57	2.59	2.62	2.64

See footnote at end of table.

TABLE VIII. Temperature versus mV characteristics for type K (chromel versus alumel) thermocouples 1/ - Continued.

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
150	2.66	2.69	2.71	2.73	2.75	2.78	2.80	2.82	2.85	2.87
160	2.89	2.92	2.94	2.96	2.98	3.01	3.03	3.05	3.08	3.10
170	3.12	3.15	3.17	3.19	3.22	3.24	3.26	3.29	3.31	3.33
180	3.36	3.38	3.40	3.43	3.45	3.47	3.49	3.52	3.54	3.56
190	3.59	3.61	3.63							
200	3.82	3.84	3.87	3.89	3.91	3.94	3.96	3.98	4.01	4.03
210	4.05	4.08	4.10	4.12	4.15	4.17	4.19	4.21	4.24	4.26
220	4.28	4.31	4.33	4.35	4.38	4.40	4.42	4.44	4.47	4.49
230	4.51	4.54	4.56	4.58	4.61	4.63	4.65	4.67	4.70	4.72
240	4.74	4.77	4.79	4.81	4.83	4.86	4.88	4.90	4.92	4.95
250	4.97	4.99	5.02	5.04	5.06	5.08	5.11	5.13	5.15	5.17
260	5.20	5.22	5.24	5.26	5.29	5.31	5.33	5.35	5.38	5.40
270	5.42	5.44	5.47	5.49	5.51	5.53	5.56	5.58	5.60	5.62
280	5.65	5.67	5.69	5.71	5.73	5.76	5.78	5.80	5.82	5.85
290	5.87	5.89	5.91	5.93	5.96	5.98	6.00	6.02	6.05	6.07
300	6.09	6.11	6.13	6.16	6.18	6.20	6.22	6.25	6.27	6.29
310	6.31	6.33	6.36	6.38	6.40	6.42	6.45	6.47	6.49	6.51
320	6.53	6.56	6.58	6.60	6.62	6.65	6.67	6.69	6.71	6.73
330	6.76	6.78	6.80	6.82	6.84	6.87	6.89	6.91	6.93	6.96
340	6.98	7.00	7.02	7.04	7.07	7.09	7.11	7.13	7.15	7.18
350	7.20	7.22	7.24	7.26	7.29	7.31	7.33	7.35	7.38	7.40
360	7.42	7.44	7.46	7.49	7.51	7.53	7.55	7.58	7.60	7.62
370	7.64	7.66	7.69	7.71	7.73	7.75	7.78	7.80	7.82	7.84
380	7.87	7.89	7.91	7.93	7.95	7.98	8.00	8.02	8.04	8.07
390	8.09	8.11	8.13	8.16	8.18	8.20	8.22	8.24	8.27	8.29
400	8.31	8.33	8.36	8.38	8.40	8.42	8.45	8.47	8.49	8.51
410	8.54	8.56	8.58	8.60	8.62	8.65	8.67	8.69	8.71	8.74
420	8.76	8.78	8.80	8.82	8.85	8.87	8.89	8.91	8.94	8.96
430	8.98	9.00	9.03	9.05	9.07	9.09	9.12	9.14	9.16	9.18
440	9.21	9.23	9.25	9.27	9.30	9.32	9.34	9.36	9.39	9.41
450	9.43	9.45	9.48	9.50	9.52	9.54	9.57	9.59	9.61	9.63
460	9.66	9.68	9.70	9.73	9.75	9.77	9.79	9.82	9.84	9.86
470	9.88	9.91	9.93	9.95	9.97	10.00	10.02	10.04	10.06	10.09
480	10.11	10.13	10.16	10.18	10.20	10.22	10.25	10.27	10.29	10.31
490	10.34	10.36	10.38	10.40	10.43	10.45	10.47	10.50	10.52	10.54

See footnote at end of table.

TABLE VIII. Temperature versus mV characteristics for type K (chromel versus alumel) thermocouples 1/ - Continued.

°F	0	1	2	3	4	5	6	7	8	9
					Millivolts					
500	10.57	10.59	10.61	10.63	10.66	10.68	10.70	10.72	10.75	10.77
510	10.79	10.82	10.84	10.86	10.88	10.91	10.93	10.95	10.98	11.00
520	11.02	11.04	11.07	11.09	11.11	11.13	11.16	11.18	11.20	11.23
530	11.25	11.27	11.29	11.32	11.34	11.36	11.39	11.41	11.43	11.45
540	11.48	11.50	11.52	11.55	11.57	11.59	11.61	11.64	11.66	11.68
550	11.71	11.73	11.75	11.78	11.80	11.82	11.84	11.87	11.89	11.91
560	11.94	11.96	11.98	12.01	12.03	12.05	12.07	12.10	12.12	12.14
570	12.17	12.19	12.21	12.24	12.26	12.28	12.30	12.33	12.35	12.37
580	12.40	12.42	12.44	12.47	12.49	12.51	12.53	12.56	12.58	12.60
590	12.63	12.65	12.67	12.70	12.72	12.74	12.76	12.79	12.81	12.83
600	12.86	12.88	12.90	12.93	12.95	12.97	13.00	13.02	13.04	13.06
610	13.09	13.11	13.13	13.16	13.18	13.20	13.23	13.25	13.27	13.30
620	13.32	13.34	13.36	13.39	13.41	13.44	13.46	13.48	13.50	13.53
630	13.55	13.57	13.60	13.62	13.64	13.67	13.69	13.71	13.74	13.76
640	13.78	13.81	13.83	13.85	13.88	13.90	13.92	13.95	13.97	13.99
650	14.02	14.04	14.06	14.09	14.11	14.13	14.15	14.18	14.20	14.22
660	14.25	14.27	14.29	14.32	14.34	14.36	14.39	14.41	14.43	14.46
670	14.48	14.50	14.53	14.55	14.57	14.60	14.62	14.64	14.67	14.69
680	14.71	14.74	14.76	14.78	14.81	14.83	14.85	14.88	14.90	14.92
690	14.95	14.97	14.99	15.02	15.04	15.06	15.09	15.11	15.13	15.16
700	15.18	15.20	15.23	15.25	15.27	15.30	15.32	15.34	15.37	15.39
710	15.41	15.44	15.46	15.48	15.51	15.53	15.55	15.58	15.60	15.62
720	15.65	15.67	15.69	15.72	15.74	15.76	15.79	15.81	15.83	15.86
730	15.88	15.90	15.93	15.95	15.98	16.00	16.02	16.05	16.07	16.09
740	16.12	16.14	16.16	16.19	16.21	16.23	16.26	16.28	16.30	16.33
750	16.35	16.37	16.40	16.42	16.45	16.47	16.49	16.52	16.54	16.56
760	16.59	16.61	16.63	16.66	16.68	16.70	16.73	16.75	16.77	16.80
770	16.82	16.84	16.87	16.89	16.92	16.94	16.96	16.99	17.01	17.03
780	17.06	17.08	17.10	17.13	17.15	17.17	17.20	17.22	17.24	17.27
790	17.29	17.31	17.34	17.36	17.39	17.41	17.43	17.46	17.48	17.50
800	17.53	17.55	17.57	17.60	17.62	17.64	17.67	17.69	17.71	17.74
810	17.76	17.78	17.81	17.83	17.86	17.88	17.90	17.93	17.95	17.97
820	18.00	18.02	18.04	18.07	18.09	18.11	18.14	18.16	18.18	18.21
830	18.23	18.25	18.28	18.30	18.33	18.35	18.37	18.40	18.42	18.44
840	18.47	18.49	18.51	18.54	18.56	18.58	18.61	18.63	18.65	18.68

See footnote at end of table.

TABLE VIII. Temperature versus mV characteristics for type K (chromel versus alumel) thermocouples 1/ - Continued.

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
850	18.70	18.73	18.75	18.77	18.80	18.82	18.84	18.87	18.89	18.91
860	18.94	18.96	18.99	19.01	19.03	19.06	19.08	19.10	19.13	19.15
870	19.18	19.20	19.22	19.25	19.27	19.29	19.32	19.34	19.36	19.39
880	19.41	19.44	19.46	19.48	19.51	19.53	19.55	19.58	19.60	19.63
890	19.65	19.67	19.70	19.72	19.75	19.77	19.79	19.82	19.84	19.86
900	19.89	19.91	19.94	19.96	19.98	20.01	20.03	20.05	20.08	20.10
910	20.13	20.15	20.17	20.20	20.22	20.24	20.27	20.29	20.32	20.34
920	20.36	20.39	20.41	20.43	20.46	20.48	20.50	20.53	20.55	20.58
930	20.60	20.62	20.65	20.67	20.69	20.72	20.74	20.76	20.79	20.81
940	20.84	20.86	20.88	20.91	20.93	20.95	20.98	21.00	21.03	21.05
950	21.07	21.10	21.12	21.14	21.17	21.19	21.21	21.24	21.26	21.28
960	21.31	21.33	21.36	21.38	21.40	21.43	21.45	21.47	21.50	21.52
970	21.54	21.57	21.59	21.62	21.64	21.66	21.69	21.71	21.73	21.76
980	21.78	21.81	21.83	21.85	21.88	21.90	21.92	21.95	21.97	21.99
990	22.02	22.04	22.07	22.09	22.11	22.14	22.16	22.18	22.21	22.23
1000	22.26	22.28	22.30	22.33	22.35	22.37	22.40	22.42	22.44	22.47
1010	22.49	22.52	22.54	22.56	22.59	22.61	22.63	22.66	22.68	22.71
1020	22.73	22.75	22.78	22.80	22.82	22.85	22.87	22.90	22.92	22.94
1030	22.97	22.99	23.01	23.04	23.06	23.08	23.11	23.13	23.16	23.18
1040	23.20	23.23	23.25	23.27	23.30	23.32	23.35	23.37	23.39	23.42
1050	23.44	23.46	23.49	23.51	23.54	23.56	23.58	23.61	23.63	23.65
1060	23.68	23.70	23.72	23.75	23.77	23.80	23.82	23.84	23.87	23.89
1070	23.91	23.94	23.96	23.99	24.01	24.03	24.06	24.08	24.10	24.13
1080	24.15	24.18	24.20	24.22	24.25	24.27	24.29	24.32	24.34	24.36
1090	24.39	24.41	24.44	24.46	24.49	24.51	24.53	24.55	24.58	24.60
1100	24.63	24.65	24.67	24.70	24.72	24.74	24.77	24.79	24.82	24.84
1110	24.86	24.89	24.91	24.93	24.96	24.98	25.01	25.03	25.05	25.08
1120	25.10	25.12	25.15	25.17	25.20	25.22	25.24	25.27	25.29	25.31
1130	25.34	25.36	25.38	25.41	25.43	25.46	25.48	25.50	25.53	25.55
1140	25.57	25.60	25.62	25.65	25.67	25.69	25.72	25.74	25.76	25.79
1150	25.81	25.83	25.86	25.88	25.91	25.93	25.95	25.98	26.00	26.02
1160	26.05	26.07	26.09	26.12	26.14	26.16	26.19	26.21	26.24	26.26
1170	26.28	26.31	26.33	26.35	26.38	26.40	26.42	26.45	26.47	26.49
1180	26.52	26.54	26.56	26.59	26.61	26.63	26.66	26.68	26.70	26.73
1190	26.75	26.77	26.80	26.82	26.85	26.87	26.89	26.91	26.94	26.96

See footnote at end of table.

TABLE VIII. Temperature versus mV characteristics for type K (chromel versus alumel) thermocouples 1/ - Continued.

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
1200	26.98	27.01	27.03	27.06	27.08	27.10	27.12	27.15	27.17	27.20
1210	27.22	27.24	27.27	27.29	27.31	27.34	27.36	27.38	27.40	27.43
1220	27.45	27.48	27.50	27.52	27.55	27.57	27.59	27.62	27.64	27.66
1230	27.69	27.71	27.73	27.76	27.78	27.80	27.83	27.85	27.87	27.90
1240	27.92	27.94	27.97	27.99	28.01	28.04	28.06	28.08	28.11	28.13
1250	28.15	28.18	28.20	28.22	28.25	28.27	28.29	28.32	28.34	28.37
1260	28.39	28.41	28.44	28.46	28.48	28.50	28.53	28.55	28.58	28.60
1270	28.62	28.65	28.67	28.69	28.72	28.74	28.76	28.79	28.81	28.83
1280	28.86	28.88	28.90	28.93	28.95	28.97	29.00	29.02	29.04	29.07
1290	29.09	29.11	29.14	29.16	29.18	29.21	29.23	29.25	29.28	29.30
1300	29.32	29.35	29.37	29.39	29.42	29.44	29.46	29.49	29.51	29.53
1310	29.56	29.58	29.60	29.63	29.65	29.67	29.70	29.72	29.74	29.77
1320	29.79	29.81	29.84	29.86	29.88	29.91	29.93	29.95	29.97	30.00
1330	30.02	30.05	30.07	30.09	30.11	30.14	30.16	30.18	30.21	30.23
1340	30.25	30.28	30.30	30.32	30.35	30.37	30.39	30.42	30.44	30.46
1350	30.49	30.51	30.53	30.56	30.58	30.60	30.63	30.65	30.67	30.70
1360	30.72	30.74	30.77	30.79	30.81	30.83	30.86	30.88	30.90	30.93
1370	30.95	30.97	31.00	31.02	31.04	31.07	30.09	31.11	31.14	31.16
1380	31.18	31.21	31.23	31.25	31.28	31.30	31.32	31.34	31.37	31.39
1390	31.42	31.44	31.46	31.48	31.51	31.53	31.55	31.58	31.60	31.62
1400	31.65	31.67	31.69	31.72	31.74	31.76	31.78	31.81	31.83	31.85
1410	31.88	31.90	31.92	31.95	31.97	31.99	32.02	32.04	32.06	32.08
1420	32.11	32.13	32.15	32.18	32.20	32.22	32.25	32.27	32.29	32.31
1430	32.34	32.36	32.38	32.41	32.43	32.45	32.48	32.50	32.52	32.54
1440	32.57	32.59	32.61	32.64	32.66	32.68	32.70	32.73	32.75	32.77
1450	32.80	32.82	32.84	32.86	32.89	32.91	32.93	32.96	32.98	33.00
1460	33.02	33.05	33.07	33.09	33.12	33.14	33.16	33.18	33.21	33.23
1470	33.25	33.28	33.30	33.32	33.34	33.37	33.39	33.41	33.43	33.46
1480	33.48	33.50	33.53	33.55	33.57	33.59	33.62	33.64	33.66	33.69
1490	33.71	33.73	33.75	33.78	33.80	33.82	33.84	33.87	33.89	33.91

1/ Reference junction at 32°F.

TABLE IX. Temperature versus resistance characteristics for resistance thermometers.

TABLE IX(a). Nickel resistance thermometer elements.

Temperature °F	Ohms	Temperature °F	Ohms
-40	92.75	180	184.94
-30	96.39	190	189.81
-20	100.07	200	194.75
-10	103.80	210	199.75
0	107.57	220	204.83
10	111.40	230	209.97
20	115.28	240	215.18
30	119.21	250	220.46
32	120.00	260	225.82
40	123.19	270	231.24
50	127.23	280	236.74
60	131.32	290	242.32
70	135.46	300	247.96
80	139.66	310	253.69
90	143.92	320	259.48
100	148.24	330	265.36
110	152.61	340	271.32
120	157.04	350	277.35
130	161.54	360	283.46
140	166.09	370	289.66
150	170.71	380	295.93
160	175.39	390	302.29
170	180.13	400	308.73

TABLE IX(b). Platinum resistance thermometer elements.

Temperature °F	Ohms	Temperature °F	Ohms
-40	83.97	500	199.58
-20	88.44	520	203.66
0	92.90	540	207.72
20	97.34	560	211.77
32	100.00	580	215.81
40	101.77	600	219.83
60	106.18	620	223.83
80	110.58	640	227.82
100	114.96	660	231.80
120	119.33	680	235.76
140	123.69	700	239.71
160	128.03	720	243.64
180	132.35	740	247.56
200	136.67	760	251.46
212	139.24	780	255.35
220	140.96	800	259.23
240	145.24	820	263.09
260	149.51	840	266.93
280	153.76	860	270.77
300	158.00	880	274.58
320	162.22	900	278.39
340	166.43	920	282.17
360	170.63	940	285.95
380	174.81	960	289.71
400	178.97	980	293.45
420	183.12	1000	297.18
440	187.26		
460	191.38		
480	195.49		

(m) A fine-tipped propane or oxyacetylene torch shall be lit and the local bearing surface area slowly heated to 300°F for approximately a 1-inch radius around the thermocouple sensor or resistance thermometer. At 300°F, the resistance thermometer with platinum element should measure 158 ohms, the resistance thermometer with nickel element should measure 248 ohms, and type K thermocouple should measure 61 mVs. Melting and puddling of the bearing babbitt metal shall be avoided. A small amount of soldering flux shall be applied to the thermocouple sensor or resistance thermometer tip.

(n) Heat temperature shall be brought up until babbitt just begins to melt. Additional babbitt metal (QQ-T-390, grade 2) shall be puddled into the area on the top of the thermocouple sensor or resistance thermometer to ensure a solid liquid bond between the two babbitt metals. Temperature at which puddling occurs is 400°F. The resistance thermometer with platinum element should measure 179 ohms, the resistance thermometer with nickel element should measure 309 ohms, and type K thermocouple sensor should measure 8.3 mVs. The diameter of the finished babbitt puddle shall be approximately 3/8 to 1/2 inch with the thermocouple sensor or resistance thermometer in the center of puddle (see figure 15). The flame should not be allowed to contact the thermocouple sensor or the resistance thermometer and the flame should not be held on one place for any length of time. It should be kept circulating.

(o) As the bearing cools down, the satisfactory return of the thermocouple sensor or resistance thermometer ambient temperature shall be monitored. The multimeter shall be disconnected from the thermocouple sensor or resistance thermometer and the connecting wires shall be taped to the bearing so they do not get damaged.

(p) Using a bearing scraper or round file, the excess babbitt metal shall be scraped from the bearing until the original surface diameter is obtained. The bearing surface shall be blended with 400 wet and dry paper with diesel fuel (see figure 17). Paper shall be wrapped around a dowel for finishing so a flat spot is not created in the babbitt metal over the new thermocouple sensor or resistance thermometer. Extreme care shall be exercised during installation of the thermocouple sensor or resistance thermometer terminal board, connecting wires, and extension wires. It shall be ensured that no bare wire touches the bearing half and creates a short to ground. Continuity checks shall be taken between the thermocouple sensor or resistance thermometer connecting wires and bearing half. When the bearing is installed, if connecting wires are of sufficient length to allow for direct connection to the electrical connector, then the thermocouple sensor or resistance thermometer terminal board may be eliminated. If this is the case, then the thermocouple sensor or resistance thermometer terminal board recess area in the bearing should also be filled with epoxy. This will hold the thermocouple sensor or resistance thermometer connection wires securely in the same relative position for connection to the electrical connector.

(q) The bottom of the new thermocouple sensor or resistance thermometer terminal board and the terminal board recess shall be lightly smeared in the bearing with RTV compound or equal. The thermocouple sensor or resistance thermometer terminal board shall be inserted into the bearing, seated firmly on the RTV seal, and four corner locating points shall be staked with a center punch.

(r) The epoxy shall be mixed and filled in the milled groove in the bearing shell from the thermocouple sensor or resistance thermometer to the terminal board (see figure 18). The thermocouple sensor or resistance thermometer connecting wires shall be laid flat in the bottom of the milled groove. The corresponding thermocouple sensor or resistance thermometer connecting wires and the extension wires to the terminal board shall be soldered (see figure 14). The terminal board, the soldered connecting wires, and the extension wires shall be filled and sealed with the RTV compound. This is to encapsulate the connecting wires for protection from oil and moisture.

(s) Masking tape shall be placed over the RTV compound and epoxy to retain it in place during the 24-hour drying process. The masking tape will prevent the epoxy from running out of the groove while setting.

(t) The masking tape shall be removed and any excess RTV compound or epoxy shall be cleaned off. The extension wires shall be connected to the multimeter, and the ambient temperature readings shall be checked. This check will ensure that soldered connections are satisfactory. Note that the thermocouple sensor or resistance thermometer terminal board is located 5 degrees from the bearing split line. Rotating the bearing beyond 55 degrees will shear the extension wires.

(u) The bearing shall be installed into the housing. Care should be taken to thread the thermocouple sensor or resistance thermometer extension wires through the hole in the electrical connector adaptor and to secure the appropriate attaching hardware (see figure 14).

(v) The extension wires shall be soldered to the electrical connector using solder as specified in QQ-S-571. The electrical connector shall be installed and a continuity check shall be made using a multimeter. The two electrical connectors shall be connected together. The embedded thermocouple sensor or resistance thermometer reading shall be checked on monitoring system digital or analog display.

(w) Installation checklist shall consist of the following steps:

(1) It shall be ensured that extension wire is made of correct materials, minimum gauge requirements are met, and color coded wire is connected correctly (see tables I and II).

(2) It shall be ensured that all connections are sound.

(3) It shall be ensured that no mechanical stress or vibration is placed on the extension wires that could strain the wires (see 5.5.2(d)).

(4) It shall be ensured that electrical power wires are not placed in the same conduit as unshielded extension wires.
(5) It shall be ensured that the cable shield is properly grounded.

(x) The equipment needed for thermocouple sensor or resistance thermometer installation into a bearing is listed in table IV.

5.5.5 Embedded configuration initial installation procedure. The procedure to initially install a new embedded configuration thermocouple sensor or resistance thermometer into a bearing that is not machined to accept a thermocouple sensor or resistance thermometer shall be as specified in 5.5.5(a) through 5.5.5(e):

(a) A 3/16-inch diameter hole shall be drilled through the bearing shell (including babbitt layer) at the designated location.
(b) This 3/16-inch diameter hole shall now be used as the pilot hole for a counterbore. Using a 9/32-inch diameter counterbore, a 0.278/0.281-inch diameter hole shall be drilled to a 5/16-inch depth from the bearing surface (see figure 13).
(c) A groove shall be milled 1/8-inch wide by 3/16-inch deep along the back of the bearing shell. The groove shall extend from the 3/16-inch diameter hole to the location where the connecting wires either leave the bearing or are attached to a terminal board (see figure 13). The corners of the groove shall be chamfered to prevent breakage of the connecting wires by sharp edges.
(d) If required, the appropriate size hole shall be drilled for a terminal board.
(e) This procedure shall continue as specified in 5.5.4(i).

5.6 Troubleshooting procedures.

5.6.1 Troubleshooting procedure for thermocouple sensor instrumentation systems. The following should be noted:

CAUTION

Before starting the troubleshooting procedure, yellow tag the circuit. Before working on junction box or monitoring system, ensure that there shall be no hot wires on terminal board, binding screws or electrical connectors.

(a) Tools and test equipment needed to conduct the troubleshooting procedure are listed in table IV and patch cords are listed in table V.
(b) A schematic diagram for a typical temperature instrumentation system containing a thermocouple sensor is shown on figure 7.
(c) Instrumentation terminology used to describe plugs, jacks, and the various parts of an electrical connector that may be encountered during the troubleshooting procedure is illustrated on figure 19 and defined in section 3.

(d) Some figures used in the thermocouple sensor troubleshooting section show a three wire configuration (a triad) instead of two (a pair). The third wire assists in illustrating the method to check the system when the cable contains more than one pair. Thermocouples never have a triad of wires. They always have only one pair of wires.

5.6.1.1 Visual examination. The necessary hardware shall be removed in order to inspect the connection head terminal board (thermowell configuration), bearing terminal board (embedded configuration) or electrical connector sockets, pins and crimped joints (bare bulb configuration). Connecting wires and extension wires (see figure 7) shall be making solid electrical connections.

(a) The insulation shall not be frayed and expose any bare wire.
(b) The uninsulated end of the wires connected to the terminal board or crimped to the electrical connector plug and receptacle shall not be in contact with metal surfaces.
(c) For terminal boards containing binding screws (see figure 8), the wires shall be wrapped tightly around the terminal board binding screws so that loose ends will not hang from the terminal board.
(d) For electrical connectors containing crimped contacts, the wires inside the contacts shall be securely attached without any evidence of movement. Note that the word contacts is used herein when referring to both the electrical connector pins and the electrical connector sockets (see figure 19).
(e) Correct connecting wires and extension wires shall be connected to the proper terminal board binding screws or electrical connector contacts (see 5.3.1 and 5.5.2(a)). They shall be color coded to differentiate between positive and negative (see table II). Double and single reversal shall be checked (see figure 20).
(f) Extension wires from the thermocouple sensor to the monitoring system shall be inspected for breaks or cuts.

5.6.1.2 Thermocouple sensor check. Thermocouple sensor check shall be performed as follows:

(a) The thermocouple sensor shall be isolated electrically from the rest of the instrumentation system and the mV POT and trouble-shooting wires (lead wires) shall be connected to the thermo-couple sensor as shown on figure 21. Correct polarity shall be observed. It shall be ensured that the thermocouple trouble-shooting wires are of the same material as the extension wires that were just removed.

(1) For the thermowell configuration, the thermocouple trouble-shooting wires shall be connected to the terminal board binding screws where the connecting wires are also attached. The extension wires shall be disconnected from the terminal board (see figure 7).

(2) For the bare bulb configuration, the thermocouple troubleshooting wires shall be connected to the electrical connector receptacle portion of the thermocouple sensor. Either an electrical connector plug or the appropriate patch cord (see table V) shall be used to connect the thermocouple troubleshooting wires to the thermocouple sensor.
(3) For the embedded configuration, the thermocouple troubleshooting wires shall be connected to the terminal board. If the terminal board is not accessible, then the electrical connector receptacle shall be used (see figure 14) and the thermocouple sensor connections shall be made as specified in 5.6.1.2(a)(2).

(b) Readings shall be taken using the mV POT and converted to temperature using table VIII. The temperature reading may be used to determine if the thermocouple sensor is functioning incorrectly or if an incorrect type of thermocouple sensor was installed. If no mV reading is indicated, it shall be ensured that the thermocouple sensor is not really a two-lead resistance thermometer. If it is suspected that a resistance thermometer is installed, the procedure as specified in 5.6.2.2 shall be used to confirm that it is a resistance thermometer. Note that table VIII shall only be used to find the measuring junction temperature if the mV reading is taken when the cold reference junction is at 32°F. If the mV POT does not contain a reference junction compensator, a calculation shall be performed to find the equivalent mV reading for a reference junction at 32°F. An ice point reference junction or ice bottle may be used in lieu of performing the calculations (see 5.6.1.2(b)(5)).

(1) If no voltage is detected, the measuring junction could be burned out or broken.
(2) If voltage is intermittent, check for a loose connection.
(3) Low temperature reading may be a result of a breakdown of insulation inside the thermocouple sensor. High temperature exposure causes inadequate insulation to break down which in turn will lower the resistance path and will affect the reading.
(4) Vibration can cause the thermocouple to separate at the measuring junction or at a weak point which results in an open circuit. If this occurs, an ohmmeter shall be used with one lead wire contacting one connecting wire or electrical connector receptacle pin and the other lead wire contacting the other connecting wire or other electrical connector receptacle pin. An open circuit is indicated if the ohmmeter reading is infinite. Vibration may also cause one of the connecting wires to touch the sheath which will result in a short circuit. If this occurs, an ohmmeter shall be used with one lead wire contacting the sheath and the other lead wire contacting one of the connecting wires or an electrical connector receptacle pin. A short circuit is indicated if the ohmmeter reading is 0.

(5) When the reference junction is at a temperature other than 32°F, table VIII may not be used unless the instrumentation contains a compensating circuit or a reference measurement compensation calculation is performed. The mV reading should be obtained, but not immediately converted to a temperature. The temperature at the reference junction will also need to be measured, and the mV value for this reference junction temperature shall be obtained from table VIII. The mV value for the reference junction temperature shall be added algebraically to the original mV reading. This algebraic sum shall then be converted to a temperature using table VIII. Temperatures shall not be added algebraically. Only mV values shall be added. If the temperature at an uncompensated reference junction is 72°F (0.88 mV) for a measurement junction reading of 12.86 mV, then the temperature will be approximately 638°F (12.86 plus 0.88 equals 13.74 mV). Two negative numbers or a positive and a negative number may be algebraically added. Algebraically adding a minus 2 to a minus 3 will equal a minus 5, whereas algebraically adding a minus 5 to a plus 3 will equal a minus 2.

(c) A thermocouple sensor continuity check shall be performed if the intent is only to verify that an open circuit does not exist along the length of the thermocouple. A continuity check performed with an ohmmeter should read less than 5 ohms across the connecting wires (or two pins). The functional check in 5.6.1.2(b) shall still be performed to verify that it is the correct type of thermocouple sensor.

(d) The resistance between each connecting wire or electrical connector receptacle pin and sheath shall be checked to ensure it is an ungrounded thermocouple. Ohmmeter lead wires shall be used touching one lead wire to sheath and touching the other lead wire to one of the connecting wires or electrical connector receptacle pins. To have an ungrounded thermocouple sensor, the reading should be infinite.

5.6.1.3 Monitoring system check. The monitoring system shall be checked in accordance with (a) through (c) as follows:

(a) The extension wires shall be removed from contact with the thermocouple sensor (if not previously removed see 5.6.1.2(a)) and connected to mV POT as shown on figure 22. Then the mV POT shall be set to the output setting and provide a mV output from the POT to the monitoring system through the extension wire. If temperature reading does not correspond to the mV output (see table VIII), the monitoring system shall be checked (see 5.6.1.3(b)).

(b) Extension wire shall be disconnected at monitoring system and thermocouple troubleshooting wires shall be connected to the monitoring system terminal board binding screws or electrical connector receptacle where extension wires (or electrical connector plugs) were just removed. Other end of troubleshooting wires shall be connected to a mV POT as shown on figure 22, and provided a mV output from POT to monitoring system. If temperature reading corresponds to mV output (see table VIII), extension wire continuity shall be checked.

(c) If monitoring system reads low, high, or fluctuates:

(1) A zero adjustment may be needed.
(2) A check for polarity reversal at the thermocouple sensor connection or at the monitoring system (junction box) shall be made (single or double reversal as shown on figure 20).
(3) A check for loose connections at binding screws, a broken wire, or a poor soldering connection shall be made.
(4) Calibration of monitoring system shall be checked.

5.6.1.4 Extension wire continuity check. Each individual extension wire in the cable shall be checked for continuity and proper connections. The order in which these extension wire cables shall be checked is as follows:

(a) Thermocouple sensor connection to monitoring system extension wire continuity check (see 5.6.1.4.1).
(b) Thermocouple sensor connection to junction box extension wire continuity check (see 5.6.1.4.2).
(c) Junction box to monitoring system extension wire continuity check (see 5.6.1.4.3).

Each extension wire cable will terminate at one of two cable entrance configurations. These two configurations are the stuffing tube cable entrance and the electrical connector cable entrance. When an extension wire ends at a stuffing tube cable entrance, ends shall be checked to see if they are marked or color coded properly. If color coding cannot be determined and wires are not marked, a wiring schematic shall be obtained. When an extension wire ends at an electrical connector, a wiring schematic shall be obtained as a check against pin numbers. The ends of the extension wire being tested are shown for each of the three extension wire continuity checks (see 5.6.1.4.1 through 5.6.1.4.3) on figure 23. This figure shows only the electrical connector cable entrance.

5.6.1.4.1 Thermocouple sensor connection to monitoring system extension wire continuity check. The extension wire check shall be as specified in 5.6.1.4.1.1 and 5.6.1.4.1.2.

5.6.1.4.1.1 Stuffing tube cable entrance configuration. The stuffing tube cable entrance configuration shall be checked first using steps (a) through (e) or steps (a) and (f) through (h), then following with steps (i) through (n). Steps (f) through (h) are preferred and should be the steps used when cable shield or ship's piping ground is sufficient. Steps (a) through (e) are less preferred since a short circuit between two wires in the cable (an unacceptable condition) would be interpreted incorrectly as an acceptable continuity condition. Steps (i) through (k) shall be used to ensure that the extension wires are ungrounded.

(a) If not previously removed (see 5.6.1.2(a) and 5.6.1.3(a)), the extension wire shall be removed from contact with the thermocouple sensor and from the monitoring system.

(b) At monitoring system end of extension wire cable, the ends of the extension wire shall be connected together using patch cords.
(c) At the thermocouple sensor connection end of extension wire cable, the extension wire ends shall be connected to an ohmmeter lead wire as shown on figure 24.
(d) If there is continuity, the reading should be between 0 and 500 ohms. Note: When measuring thermocouple extension wire resistance, the resistance of chromel wire is approximately 160 ohms per 1000 feet at 68°F and the resistance of alumel wire is approximately 66 ohms per 1000 feet at 68°F. The resistance of a double foot of thermocouple wire will be different depending on the material of the pair being tested. The pair may consist of two chromel, two alumel, or a combination of chromel and alumel wires.
(e) If all or some readings show discontinuity, the continuity of each individual extension wire shall be checked by using the procedure discussed in steps (f) and (g) and as illustrated on figure 24.
(f) At monitoring system end of extension wire cable, one end of the extension wire shall be connected to ground using a patch cord. (For purposes of installation, the ground will be shown as the cable shield or the ship's piping on the figures in this handbook.)
(g) At the thermocouple sensor connection end of extension wire cable, one ohmmeter lead wire shall be connected to ground. The other ohmmeter lead wire shall be touched to each extension wire end, one at a time, as shown on figure 24.
(h) A reading between 0 and 500 ohms shall identify the particular extension wire, indicate a correct installation, and indicate continuity in extension wire cable (see note in 5.6.1.4.1.1(d)).
(i) At the monitoring system end of the extension wire cable, ensure that the extension wires are disconnected.
(j) At the thermocouple sensor end of the extension wire cable, touch one ohmmeter lead wire to each extension wire end in the cable, one at a time, as shown on figure 24. The other ohmmeter lead wire shall be in contact with ground.
(k) An infinite resistance reading shall indicate an ungrounded extension wire.
(l) Steps (b) and (c), (b) and (g), or (i) and (j), as appropriate, shall be repeated for other extension wires.
(m) If discontinuity is found in the extension wire:

    (1) A check for broken wire shall be made (see figure 25).
    (2) A check for reversal of wires shall be made (see figure 25).
    (3) A check for an incomplete ground path shall be made (see figure 25).
    (4) Solder joints and electrical connections shall be checked to ensure proper electrical and mechanical continuity exist.
    (5) A check for corrosion shall be made.

(n) If continuity is found in the extension wire, the last two items of step (m) shall be checked.

5.6.1.4.1.2 Electrical connector cable entrance configuration. The electrical connector cable entrance configuration shall be checked first using either steps (a) through (e) or steps (a) and (f) through (h), then following with steps (i) through (n). Steps (f) through (h) are preferred and should be the steps used when cable shield or ship's piping ground is sufficient. Steps (a) through (e) are less preferred since a short circuit between two wires in the cable (an unacceptable condition) would be interpreted incorrectly as an acceptable continuity condition. Steps (i) through (k) shall be used to ensure that the extension wires are ungrounded.

(a) If not previously removed (see 5.6.1.2(a) and 5.6.1.3(a)), extension wires shall be removed from contact with the thermocouple sensor, and the electrical connector plug from the electrical connector receptacle in the monitoring system shall be removed.
(b) At the thermocouple sensor connection end of extension wire cable, the two individual extension wires shall be connected together using patch cord.
(c) At the monitoring system end, a check shall be made for continuity by touching the extension wire electrical connector pins and ohmmeter lead wires together as shown on figure 24.
(d) If there is continuity, the reading should be between 0 and 500 ohms (see note in 5.6.1.4.1.1(d)).
(e) If some or all readings show discontinuity, a check shall be made for continuity of each individual extension wire by using the procedure discussed in steps (f) and (g) as illustrated on figure 24.
(f) At the thermocouple sensor connection end of the extension wire cable, one end of extension wire shall be connected to ground using a patch cord.
(g) At the electrical connector plug found at the monitoring system and of the extension wire cable, one ohmmeter lead wire shall be connected to ground. The other ohmmeter lead wire shall be touched to each pin, one at a time, as shown on figure 24.
(h) A reading between 0 and 500 ohms identifies the correct pin for that particular wire. This procedure also serves as a continuity check (see note in 5.6.1.4.1.1(d)).
(i) At the monitoring system end of the extension wire cable, ensure that the electrical connector plug is disconnected from the mating electrical connector receptacle.
(j) At the thermocouple sensor end of the extension wire cable, touch one ohmmeter lead wire to each socket on the electrical connector plug, one at a time, as shown on figure 24. The other ohmmeter lead wire shall be in contact with ground.
(k) An infinite resistance reading shall indicate an ungrounded extension wire.
(l) If the electrical connector plug has three or more pins, steps (b) and (c), (f) and (g), or (i) and (j), as appropriate, shall be repeated for other extension wires in the cable.
(m) If extension wires show discontinuity:

(1) A check for broken wire shall be made (see figure 25).
(2) A check for reversal of wires shall be made (see figure 25).
(3) A check for an incomplete ground path shall be made (see figure 25).
(4) Solder joints and electrical connections (pins and sockets) shall be checked to ensure proper electrical and mechanical continuity exist.
(5) A check for corrosion shall be made.

(n) If continuity is found in the extension wire, the last two items of step (m) shall be checked.

5.6.1.4.2 Thermocouple sensor connection to junction box extension wire continuity check. Thermocouple sensor connection to junction box extension wire continuity shall be checked in accordance with (a) and (b) as follows:

(a) For the stuffing tube cable entrance configuration, the same procedure as specified in 5.6.1.4.1.1 shall be followed, substituting the words junction box for the words monitoring system (see figure 24).
(b) For the electrical connector cable entrance configuration, the same procedure as specified in 5.6.1.4.1.2 shall be followed, substituting the words junction box for the words monitoring system (see figure 24).

5.6.1.4.3 Junction box to monitoring system extension wire continuity check. Junction box to monitoring system extension wire continuity shall be checked in accordance with (a) through (d) as follows:

(a) If both junction box and monitoring system have stuffing tube cable entrance configurations, the same procedure as specified in 5.6.1.4.1.1 shall be followed substituting the words junction box for the words thermocouple sensor connection (see figure 24).
(b) If junction box has a stuffing tube cable entrance configuration, and monitoring system has an electrical connector cable entrance configuration, the same procedure as specified in 5.6.1.4.1.2 shall be followed substituting the words junction box for the words thermocouple sensor connection (see figure 24).
(c) If junction box contains an electrical connector cable entrance configuration, and monitoring system has a stuffing tube cable entrance configuration, the same procedure shall be followed as specified in 5.6.1.4.1.2 by substituting the words monitoring system, junction box, and sockets for the words thermocouple sensor connection, monitoring system and pin, respectively (see figure 24).
(d) If both junction box and monitoring system contain electrical connector cable entrance configurations, the following procedure shall be used. The extension wire shall be checked first by using either steps (1) through (5) or steps (1) and (6) through (8), then followed with steps (9) through (14). Steps (6) through (8) are preferred and shall be the steps used when cable shield or ship's piping ground is sufficient. Steps (1) through

(5) are less preferred since a short circuit between two wires in the cable (an unacceptable condition) would be interpreted incorrectly as an acceptable continuity condition. Steps (9) through (11) shall be used to ensure that the extension wire is ungrounded.

(1) The electrical connector plugs shall be removed from the electrical connector receptacles in both the junction box and monitoring system.
(2) For the electrical connector plug on the monitoring system end, any two pins shall be connected together with a patch cord.
(3) For the electrical connector plug on the junction box end, a check shall be made for continuity by touching ohmmeter lead wires and sockets together, as shown on figure 24.
(4) A reading between 0 and 500 ohms indicates continuity (see note in 5.6.1.4.1.1(d)).
(5) If all readings show discontinuity, the continuity of each individual extension wire shall be checked by using the procedure discussed in steps (6) and (7) as illustrated on figure 24.
(6) For the electrical connector plug on the monitoring system end, one pin shall be attached to ground using a patch cord.
(7) For the electrical connector plug on the junction box end, one ohmmeter lead wire shall be connected to ground and the other ohmmeter lead wire shall be touched to each socket, one at a time, as shown on figure 24.
(8) A reading between 0 and 500 ohms identifies the correct pin in the electrical connector plug at one end of the extension wire that corresponds to the socket in the electrical connector plug at the other end of the extension wire. This step also serves as a continuity check (see note 5.6.1.4.1.1(d)).
(9) At the monitoring system end of the extension wire cable, ensure that the electrical connector plug is disconnected from the mating electrical connector receptacle.
(10) At the junction box end of the extension wire cable, touch one ohmmeter lead wire to each socket on the electrical connector plug, one at a time, as shown on figure 24. The other ohmmeter lead wire shall be in contact with the ground.
(11) An infinite resistance reading shall indicate an ungrounded extension wire.
(12) If the electrical connector plug has three or more pins, steps (2) and (3), steps (6) and (7) or steps (9) and (10), as appropriate, shall be repeated for other extension wires in the cable.
(13) If extension wires show discontinuity:

    a. A check for broken wire shall be made (see figure 25).
    b. A check for reversal of wires shall be made (see figure 25).

c. A check for incomplete ground path shall be made (see figure 25).
d. Solder joints and electrical connections (pins and sockets) shall be checked to ensure proper electrical and mechanical continuity.
e. A check for corrosion shall be made.

(14) If continuity is found in the electrical connector or in the extension wire, the last two items of step (13) shall be checked.

5.6.1.5 Junction box continuity check. A continuity check shall be made as specified in 5.6.1.5.1 and 5.6.1.5.2.

5.6.1.5.1 Junction box with stuffing tube cable entrance configuration. If junction box has the stuffing tube cable entrance configuration on both sides, the terminal board shall be checked for continuity.

(a) Extension wires shall be removed from the junction box terminal board binding screws. Using an ohmmeter, the pair of binding screws on each terminal lug with lead wire as shown on figure 26 shall be touched.
(b) To indicate a closed circuit, reading should be 0 ohms.

5.6.1.5.2 Junction box with electrical connector cable entrance. If both sides of the junction box have the electrical connector cable entrance configuration, the following procedure shall be used. The junction box shall be checked by first using either steps (a) through (e) or steps (a), (f), (g) and (h), then by following with steps (i) through (n). Steps (a), (f), (g) and (h) are preferred and shall be the steps used when cable shield or ship's ground is sufficient. Steps (a) through (e) are less preferred since a short circuit between two wires (an unacceptable condition) would be interpreted incorrectly as an acceptable continuity condition. Steps (i) through (n) shall be used to ensure that the extension wire is ungrounded.

(a) Extension wire electrical connector plugs shall be removed from the electrical connector receptacles on the junction box.
(b) For the electrical connector receptacle on one side of junction box, two pins in one of the electrical connector receptacles shall be attached together using a patch cord.
(c) For the electrical connector receptacle on other side of junction box, continuity shall be checked by touching the ohmmeter lead wires and sockets together as shown on figure 26.
(d) A reading between 0 and 500 ohms indicates continuity (see note in 5.6.1.4.1.1(d)).
(e) If some or all readings show discontinuity, a check shall be made for continuity of wires connecting the electrical connector receptacles of both sides of junction box by using the procedure as discussed in steps (f) and (g) (as illustrated on figure 26).
(f) On one side of junction box, one pin of the electrical connector receptacle shall be connected to ground using a patch cord.

(g) At other side of junction box, one ohmmeter lead wire shall be connected to ground and the other lead wire touched to each socket, one at a time, as shown on figure 26.

(h) A reading between 0 and 500 ohms identifies the pin in the electrical connector plug at the monitoring system end that corresponds to the socket in the electrical connector plug at the thermocouple sensor end. This reading also serves as a continuity check (see note in 5.6.1.4.1.1(d)).

(i) At the monitoring system end of the junction box, ensure that the mating electrical connector plug is disconnected from the electrical connector receptacle.

(j) At the thermocouple sensor end of the junction box, touch one ohmmeter lead wire to each socket on the electrical connector plug, one at a time, as shown on figure 26. The other ohmmeter lead wire shall be in contact with the ground.

(k) An infinite resistance reading shall indicate an ungrounded wire path.

(l) If the electrical connector receptacle has three or more pins (sockets), steps (b) and (c), steps (f) and (g), or steps (i) and (j), as appropriate, shall be repeated for the other pins (sockets) in the electrical connector receptacle.

(m) If discontinuity is found in electrical connector:

  (1) A check for broken wire shall be made (see figure 27).
  (2) A check for reversal of wires shall be made (see figure 27).
  (3) A check for an incomplete ground path shall be made (see figure 27).
  (4) Solder joints and electrical connections (pins and sockets) shall be checked to ensure proper electrical and mechanical continuity.
  (5) A check for corrosion shall be made.

(n) If continuity is found in electrical connector, the last two items in step (m) shall be checked.

5.6.2 <u>Troubleshooting procedure for resistance thermometer instrumentation systems</u>. The following should be noted:

<u>CAUTION</u>

Before starting the troubleshooting procedure, the circuit shall be yellow-tagged. Before working on junction box or monitoring system, ensure that there shall be no hot wires on terminal board binding screws or electrical connectors.

(a) Tools and test equipment needed to conduct the troubleshooting procedure are listed in table IV, and patch cords are listed in table V.

(b) A schematic diagram for a typical temperature instrumentation system containing a resistance thermometer is shown on figure 7.

(c) Instrumentation terminology used to describe plugs, jacks, and the various parts of an electrical connector that may be encountered during the troubleshooting procedure is illustrated on figure 19 and defined in section 3.

(d) Figures used in the resistance thermometer troubleshooting section show a three wire configuration (a triad). Some resistance thermometers only contain two connecting wires (a pair). For a two wire configuration extension wire or junction box continuity check, the third wire assists in illustrating the method to check the system when the cable or junction box contains more than one pair. In the other figures, one of the W wires or the C wires should be ignored for the two wire configuration. New resistance thermometers built in accordance with MIL-T-24388 contain the standardized color code on the external connecting wire insulation or standardized electrical connector pin notation given in 5.3.3 and 5.3.4, respectively. Older resistance thermometers may contain a different variation of this code. Before performing the troubleshooting procedure, ensure that the red insulated connecting wire (R) or the B pin designates the single connecting wire on one side of the resistance thermometer element (see figure 2) for a three connecting wire configuration.

5.6.2.1 Visual examination. A visual examination shall consist of the following procedures. The necessary hardware shall be removed in order to inspect the connection head terminal board (thermowell configuration), bearing terminal board (embedded configuration) or electrical connector sockets, pins and soldered joints (bare bulb configuration). It shall be ensured that all connecting wires and extension wires (see figure 7) are making solid electrical connections.

(a) The insulation shall not be frayed and expose any bare wire.
(b) The uninsulated end of the wires connected to the terminal board or soldered to the electrical connector plug and receptacle shall not be in contact with metal surfaces.
(c) For terminal boards containing binding screws (see figure 8), the wires shall be wrapped tightly around the terminal board binding screws so that loose ends are not hanging from the terminal board.
(d) For electrical connectors containing crimped as opposed to soldered contacts, the wires inside the contacts shall be securely attached without any evidence of movement. Loose wires in crimped connectors shall be soldered for resistance thermometer applications. Note that the word contacts is used when referring to both the electrical connector pins and the electrical connector sockets (see figure 19).
(e) The correct connecting wire and extension wires shall be connected to the proper terminal board binding screws or electrical connector contacts (see 5.3.3, 5.3.4 and 5.5.2(a)). Single reversal shall be checked (see figure 28).
(f) Extension wires from the resistance thermometer to the monitoring system shall be inspected for breaks or cuts.

5.6.2.2 Resistance thermometer check. When making a resistance thermometer check, caution should be taken. When taking a resistance measurement of the resistance thermometer, a digital ohmmeter or a resistance bridge shall be used. The current output in some analog ohmmeters may affect or even burn out the resistance thermometer element.

(a) The resistance thermometer shall be isolated electrically from the rest of the instrumentation system and a digital ohmmeter and lead wires shall be connected to the resistance thermometer as shown on figure 29. One lead wire shall be attached to the resistance thermometer red wire or B pin, while the other lead wire shall be connected to either the white insulated wire or to either the A or C pin.

(1) For the thermowell configuration, the lead wires shall be connected to the same terminal board binding screws where the connecting wires are also attached. The extension wires from the terminal board shall be disconnected (see figure 7).

(2) For the bare bulb configuration, the lead wires shall be connected to the electrical connector receptacle portion of the resistance thermometer. An electrical connector plug or an appropriate patch cord (see table V) shall be used to connect the lead wires to the resistance thermometer.

(3) For the embedded configuration, the lead wires shall be connected to the terminal board. If the terminal board is not accessible, then the electrical connector receptacle shall be used (see figure 14), and the lead wire connections shall be made as specified in 5.6.2.2(a)(2).

(b) Readings shall be taken using the digital ohmmeter and converted to temperature using table IX. The temperature reading may be used to determine if the resistance thermometer is functioning incorrectly or if an incorrect type of resistance thermometer was installed. For a resistance thermometer with three connecting wires, a second and different resistance reading shall be taken before using table IX. After taking a resistance reading between the red insulated and one of the white insulated connecting wires (or between the B pin and either the A or C pin), a second resistance reading shall be taken between the two white insulated connecting wires (or between the A and C pins). The second resistance reading (between two white insulated connecting wires) shall be subtracted from the first resistance reading (between red and white wires) and this resistance (the answer) converted to temperature using table IX. Subtracting the second resistance compensates for the resistance in the connecting wires.

(1) A type J thermocouple sensor also has one red insulated and one white insulated connecting wire. If a thermocouple sensor is suspected, the procedure as specified in 5.6.1.2 shall be used to obtain an mV reading and confirm that it is a thermocouple sensor.

(2) If resistance thermometer is not providing a realistic output, a temperature comparator shall be used to obtain the resistance output at various temperatures. The resistance versus temperature table (see table IX) for both platinum and nickel elements shall be referred to determine which element the resistance thermometer contains.

(3) Low temperature reading may be a result of a breakdown of insulation inside the resistance thermometer. High temperature exposure causes inadequate insulation to break down which in turn will lower the resistance path and affect the reading.

(4) Variation may cause the resistance thermometer element to separate at a weak point which results in an open circuit. An open circuit shall be detected by taking a resistance reading between the red insulated and one of the white insulated connecting wires (or between the B pin and either the A or C pin). For a resistance thermometer with three connecting wires (three-pin electrical connector receptacle), a resistance reading shall also be taken between the two white insulated connecting wires (or between the A and C pins). An open circuit is indicated if the ohmmeter reading is infinite. Vibration may also cause the portion of the connecting wire internal to the sheath to come in contact with the sheath. This condition creates a short circuit between the affected connecting wire and the sheath. If this were to occur, the short circuit shall be detected by taking a resistance reading between each of the connecting wires (or electrical connector receptacle pin) and the sheath and reading a value of 0 ohms.

(c) A resistance thermometer continuity check may be performed if the intent is only to verify that an open circuit does not exist along the length of the connecting wires or resistance thermometer element. A continuity check shall only be performed with a digital ohmmeter (see the statement at the beginning of 5.6.2.2). For a resistance thermometer with three connecting wires, the digital ohmmeter should read less than one ohm, between the two white insulated connecting wires (or between pins A and C). The reading between the red insulated connecting wire (or the B pin) and either of the two white insulated connecting wires (or either the A or C pins) shall correspond to the resistance values in table IX at ambient temperature (for the appropriate resistance thermometer element). For a resistance thermometer with two connecting wires (or two pins), the resistance reading shall correspond to the appropriate value in table IX. The resistance value will be a little higher than the value in table IX because there is no compensation for the resistance in the connecting wire.

5.6.2.3 Monitoring system check. The monitoring system check shall be as specified in 5.6.2.3 (a) through (c).

(a) If not previously removed (see 5.6.2.2(a)), extension wires shall be removed from contact with the resistance thermometer and connected to a decade box as shown on figure 30. The decade box shall be used to simulate a resistance to the monitoring system. Table IX shall be referred to, a realistic resistance value shall be selected, and the decade box shall be set to that resistance value. If the temperature reading does not correspond to resistance simulated, the monitoring system shall be checked (see 5.6.2.3(b)).

(b) A set of lead wires shall be connected to a decade box as shown on figure 30. Extension wire shall be disconnected at monitoring system and other end of lead wires shall be connected to the monitoring system terminal board binding screws (or electrical connector receptacle). If monitoring system displays the temperature corresponding to the simulated resistance displays the temperature corresponding to the simulated resistance, proceed to 5.6.2.4.

(c) If monitoring system reads low, high or fluctuates:

(1) A zero adjustment may be needed.
(2) A check for reversal of the extension wires at the resistance thermometer connection or at the monitoring system (junction box) shall be made. (Single reversal is shown on figure 28.)
(3) A check for loose connections at binding screws, broken wire or a poor soldering connection shall be made.
(4) The calibration of monitoring system shall be checked.

5.6.2.4 <u>Extension wire continuity check</u>. Each individual extension wire in the cable shall be checked for continuity and proper connection. The order in which these extension cables shall be checked is as follows:

(a) Resistance thermometer connection to monitoring system extension wire continuity check (see 5.6.2.4.1).
(b) Resistance thermometer connection to junction box extension wire continuity check (see 5.6.2.4.2).
(c) Junction box to monitoring system extension wire continuity check (see 5.6.2.4.3).

Each extension wire cable shall terminate at one of two cable entrance configurations. These two configurations are the stuffing tube cable entrance and the electrical connector cable entrance. When an extension wire ends at a stuffing tube cable entrance, the ends shall be checked to see if they are marked or color coded properly. If color coding cannot be determined and wires are not marked, obtain a wiring schematic. When the extension wire ends at an electrical connector, obtain a wiring schematic as a check against pin numbers. The ends of the extension wire being tested are shown for each of the three extension wire continuity checks (see 5.6.2.4.1 through 5.6.2.4.3 and figure 23). Note that the figure only shows the electrical connection cable entrance.

5.6.2.4.1 <u>Resistance thermometer connection to monitoring system extension wire continuity check</u>. The extension wire check shall consist of the following as specified in 5.6.2.4.1.1 and 5.6.2.4.1.2.

5.6.2.4.1.1 <u>Stuffing tube cable entrance configuration</u>. The stuffing tube cable entrance configuration shall be checked first using steps (a) through (e) or steps (a) and (f) through (h), then following with steps (i) through (n). Steps (f) through (h) are preferred and should be the steps used when cable shield or ship's piping ground is sufficient. Steps (a) through (e) are less preferred since a short circuit between two wires in the cable (an unacceptable condition) would be interpreted incorrectly as an acceptable continuity condition. Steps (i) through (k) shall be used to ensure that the extension wires are ungrounded.

(a) If not previously removed (see 5.6.2.2(a) and 5.6.2.3(a)), the extension wire shall be removed from contact with the resistance thermometer and from the monitoring system.
(b) At monitoring system end of extension wire cable, the ends of two extension wires shall be connected together using patch cords.
(c) At resistance thermometer connection end of extension wire cable, lead wires of an ohmmeter shall be touched to the other ends of the two extension wires as shown on figure 24.
(d) Continuity of the two extension wires tested shall be determined by an ohmmeter reading between 0 and 10 ohms.
(e) If some or all readings indicate discontinuity, a check shall be made for continuity of individual wires in extension wire by using the procedures discussed in steps (f) and (g) as illustrated on figure 24.
(f) At the monitoring system end of extension wire cable, one extension wire shall be connected to a ground using a patch cord. (For purposes of installation, the ground will be shown as the cable shield on the ship's piping on figures in this handbook.)
(g) At the resistance thermometer connection end of extension wire cable, one ohmmeter lead wire shall be connected to ground. The other ohmmeter lead wire shall be touched to each extension wire end, one at a time, as shown on figure 24.
(h) A reading between 0 and 10 ohms shall identify the particular extension wire, indicate a correct installation, and indicate continuity in the extension cable.
(i) At the monitoring system end of the extension wire cable, ensure that the extension wires are disconnected.
(j) At the resistance thermometer end of the extension wire cable, touch one ohmmeter lead wire to each extension wire end in the cable, one at a time, as shown on figure 24. The other ohmmeter lead wire shall be on contact with ground.
(k) An infinite resistance reading shall indicate an ungrounded extension wire.
(l) Steps (b) and (c), (f) and (g) or (i) and (j), as appropriate, shall be repeated for remaining extension wires.
(m) If discontinuity is found in the extension wires:

    (1) A check for broken wire shall be made (see figure 25).
    (2) A check for reversal of wires shall be made (see figure 25).
    (3) A check for an incomplete ground path shall be made (see figure 25).
    (4) Solder joints and electrical connections (pins and sockets) shall be checked to ensure proper electrical and mechanical continuity.
    (5) A check for corrosion shall be made.

(n) If continuity is found in the extension wire, the last two items of step (m) shall be checked.

5.6.2.4.1.2 Electrical connector cable entrance configuration. The electrical connector cable entrance configuration shall be checked first using either steps (a) through (e) or steps (a) and (f) through (h), then following with steps (i) through (n). Steps (f) through (h) are preferred and should be the steps used when cable shield or ship's piping ground is sufficient. Steps (a) through (e) are less preferred since a short circuit between two wires in the cable (an unacceptable condition) would be interpreted incorrectly as an acceptable continuity condition. Steps (i) through (k) shall be used to ensure that the extension wires are ungrounded.

(a) If not previously removed (see 5.6.2.2(a) and 5.6.2.3(a)), extension wires shall be removed from contact with the resistance thermometer, and the electrical connector plug shall be removed from the electrical connector receptacle in the monitoring system.
(b) At the resistance thermometer connection end of extension wire cable, the ends of two individual extension wires shall be connected together using patch cords.
(c) At monitoring system end of extension wire cable, a check shall be made for continuity by touching the pins to the ohmmeter lead wires as shown on figure 24.
(d) When reading is between 0 and 10 ohms, continuity is determined.
(e) If some or all readings show a discontinuity, the continuity of each individual extension wire shall be checked by using the procedure discussed in steps (f) and (g) (as illustrated on figure 24).
(f) At the resistance thermometer connection head end of extension wire cable, one end of the extension wire shall be connected to ground using a patch cord.
(g) At the electrical connector plug found at the monitoring system end of the extension wire cable, one ohmmeter lead wire shall be connected to ground. The other ohmmeter lead wire shall be touched to each pin, one at a time, as shown on figure 24.
(h) A reading between 0 and 10 ohms identifies the correct pin for that particular wire. This procedure also serves as a continuity check.
(i) At the monitoring system end of the extension wire cable, ensure that the electrical connector plug is disconnected from the mating electrical connector receptacle.
(j) At the resistance thermometer end of the extension wire cable, touch one ohmmeter lead wire to each socket on the electrical connector plug, one at a time, as shown on figure 24. The other ohmmeter lead wire shall be in contact with ground.
(k) An infinite resistance reading shall indicate an ungrounded extension wire.
(l) If the electrical connector plug has three or more pins, steps (b) and (c), (f) and (g) or (i) and (j), as appropriate, shall be repeated for other extension wires in the cable.
(m) If extension wires show discontinuity:

    (1) A check for broken wire shall be made (see figure 25).
    (2) A check for reversal of wires shall be made (see figure 25).

(3) A check for an incomplete ground path shall be made (see figure 25).
(4) Solder joints and electrical connections (pins and sockets) shall be checked to ensure proper electrical and mechanical continuity.
(5) A check for corrosion shall be made.

(n) If continuity is found in the extension wire, the last two items in step (m) shall be checked.

5.6.2.4.2 Resistance thermometer connection to junction box extension wire continuity check. The extension wire continuity check shall be in accordance with (a) and (b) as follows:

(a) For the stuffing tube cable entrance configuration, the same procedure shall be followed as specified in 5.6.2.4.1.1, substituting the words junction box for the words monitoring system (see figure 24).
(b) For the electrical connector cable entrance configuration, the same procedure shall be followed as specified in 5.6.2.4.1.2, substituting the words junction box for the words monitoring system (see figure 24).

5.6.2.4.3 Junction box to monitoring system extension wire continuity check. Junction box to monitoring system extension wire continuity check shall be as follows (see (a) through (d)):

(a) If both junction box and monitoring system have stuffing tube cable entrance configurations, the same procedure shall be followed as specified in 5.6.2.4.1.1, substituting the words junction box for the words resistance thermometer connection (see figure 24).
(b) If junction box has a stuffing tube cable entrance configuration and monitoring system has an electrical connector cable entrance configuration, the same procedure shall be followed as specified in 5.6.2.4.1.2, substituting the words junction box for the words resistance thermometer connection (see figure 24).
(c) If junction box contains an electrical connector cable entrance configuration and monitoring system has a stuffing tube cable entrance configuration, the same procedure shall be followed as specified in 5.6.2.4.1.2, substituting the words monitoring system, junction box, and socket for the words resistance thermometer connection, monitoring system, and pin, respectively (see figure 24).
(d) If both junction box and monitoring system contain electrical connector cable entrance configuration, the following procedure shall be used. The extension wire shall be checked by using either steps (1) through (5) or steps (1) and (6) through (8), then followed with steps (9) through (14). Steps (6) through (8) are preferred and shall be the steps used when cable shield or ship's piping ground is sufficient. Steps (1) through (5) are less preferred since a short circuit between two wires in the

cable (an unacceptable condition) would be interpreted incorrectly as an acceptable continuity condition. Steps (9) through (11) shall be used to ensure that the extension wire is ungrounded.

(1) The electrical connector plugs shall be removed from the electrical connector receptacles in both the junction box and monitoring system.
(2) For the electrical connector plug on the monitoring system end, any two pins shall be connected together with a patch cord.
(3) For the electrical connector plug on the junction box end, a check shall be made for continuity by touching ohmmeter lead wires and sockets together, as shown on figure 24.
(4) A reading between 0 and 10 ohms indicates continuity.
(5) If some or all readings show discontinuity, continuity of each individual extension wire shall be checked by using the procedure specified in steps (6) and (7) (as illustrated on figure 24).
(6) For the electrical connector plug on the monitoring system end, one pin shall be attached to ground using a patch cord.
(7) For the electrical connector plug on the junction box end, one ohmmeter lead wire shall be connected to ground and the other ohmmeter lead wire shall be touched to each socket, one at a time, as shown on figure 24.
(8) A reading between 0 and 10 ohms identifies the correct pin in the electrical connector plug at one end of the extension wire that corresponds to the socket in the electrical connector plug at the other end of the extension wire. This step also serves as a continuity check.
(9) At the monitoring system end of the extension wire cable, ensure that the electrical connector plug is disconnected from the mating electrical connector receptacle.
(10) At the junction box end of the extension wire cable, touch one ohmmeter lead wire to each socket on the electrical connector plug, one at a time, as shown on figure 24. The other ohmmeter lead wire shall be in contact with the ground.
(11) An infinite resistance reading shall indicate an ungrounded extension wire.
(12) If the electrical connector plug has three or more pins, steps (2) and (3), steps (6) and (7) or steps (9) and (10), as appropriate, shall be repeated for the other extension wires in the cable.
(13) If extension wires show discontinuity:

    a. A check for broken wire shall be made (see figure 25).
    b. A check for reversal of wires shall be made (see figure 25).
    c. A check for an incomplete ground path shall be made (see figure 25).

d. Solder joints and electrical connections (pins and sockets) shall be checked to ensure proper electrical and mechanical continuity.

e. A check for corrosion shall be made.

(14) If continuity is found in the electrical connector or in the extension wire, the last two items of step (13) shall be checked.

5.6.2.5 Junction box continuity check. Junction box continuity shall be checked in accordance with 5.6.2.5.1 and 5.6.2.5.2.

5.6.2.5.1 Junction box with stuffing tube cable entrance configuration. If junction box has the stuffing tube cable entrance configuration on both sides, the terminal board shall be checked for continuity.

(a) Extension wires shall be removed from the junction box terminal board binding screws. Using an ohmmeter, the pair of binding screws shall be touched on each terminal lug with the ohmmeter lead wires as shown on figure 26.

(b) Reading should be 0 ohms to indicate a closed circuit.

5.6.2.5.2 Junction box with electrical connector cable entrance configuration. If both sides of the junction box have the electrical connector cable entrance configuration, the following procedure shall be used. The junction box shall be checked by first using either steps (a) through (e) or steps (a) and (f) through (h), then by following with steps (i) through (n). Steps (f) through (h) are preferred and shall be the steps used when cable shield or ship's ground is sufficient. Steps (a) through (e) are less preferred since a short circuit between two wires (an unacceptable condition) would be interpreted incorrectly as an acceptable continuity condition. Steps (i) through (n) shall be used to ensure that the extension wire is ungrounded.

(a) Extension wire electrical connector plugs shall be removed from the electrical connector receptacles on the junction box.

(b) For the electrical connector receptacle on one side of the junction box, two pins in one of the electrical connector receptacles shall be attached together using patch cord.

(c) For the electrical connector receptacle on other side of junction box, continuity shall be checked by touching ohmmeter lead wires and sockets together as shown on figure 26.

(d) A resistance reading between 0 and 10 ohms indicates continuity.

(e) If some or all readings show discontinuity, continuity of wires connecting the electrical connector receptacles of both sides of junction box shall be checked by using the following procedure as specified in steps (f) and (g) (as illustrated on figure 26).

(f) On one side of junction box, one pin of electrical connector receptacle shall be connected to ground using a patch cord.

(g) At other side of junction box, one ohmmeter lead wire shall be connected to ground and the other ohmmeter lead wire shall be touched to each socket, one at a time, as shown on figure 26.

(h) A reading between 0 and 10 ohms identifies the pin in the electrical connector plug at the monitoring system end that corresponds to the socket in the electrical connector plug at the resistance thermometer end. This reading also serves as a continuity check.
(i) At the monitoring system end of the junction box, ensure that the mating electrical connector plug is disconnected from the electrical connector receptacle.
(j) At the resistance thermometer end of the junction box, touch one ohmmeter lead wire to each socket on the electrical connector plug, one at a time, as shown on figure 26. The other ohmmeter lead wire shall be in contact with the ground.
(k) An infinite resistance reading shall indicate an ungrounded wire path.
(l) If the electrical connector receptacle has three or more pins sockets), steps (b) and (c), steps (f) and (g), or steps (i) and (j), as appropriate, shall be repeated for the other pins sockets) in the electrical connector receptacle.
(m) If discontinuity is found in electrical connector:

(1) A check for broken wire shall be made (see figure 27).
(2) A check for reversal of wires shall be made (see figure 27).
(3) A check for an incomplete ground path shall be made (see figure 27).
(4) Solder joints and electrical connections (pins and sockets) shall be checked to ensure proper electrical and mechanical continuity.
(5) A check for corrosion shall be made.

(n) If continuity is found in the electrical connector, the last two items in step (m) shall be checked.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

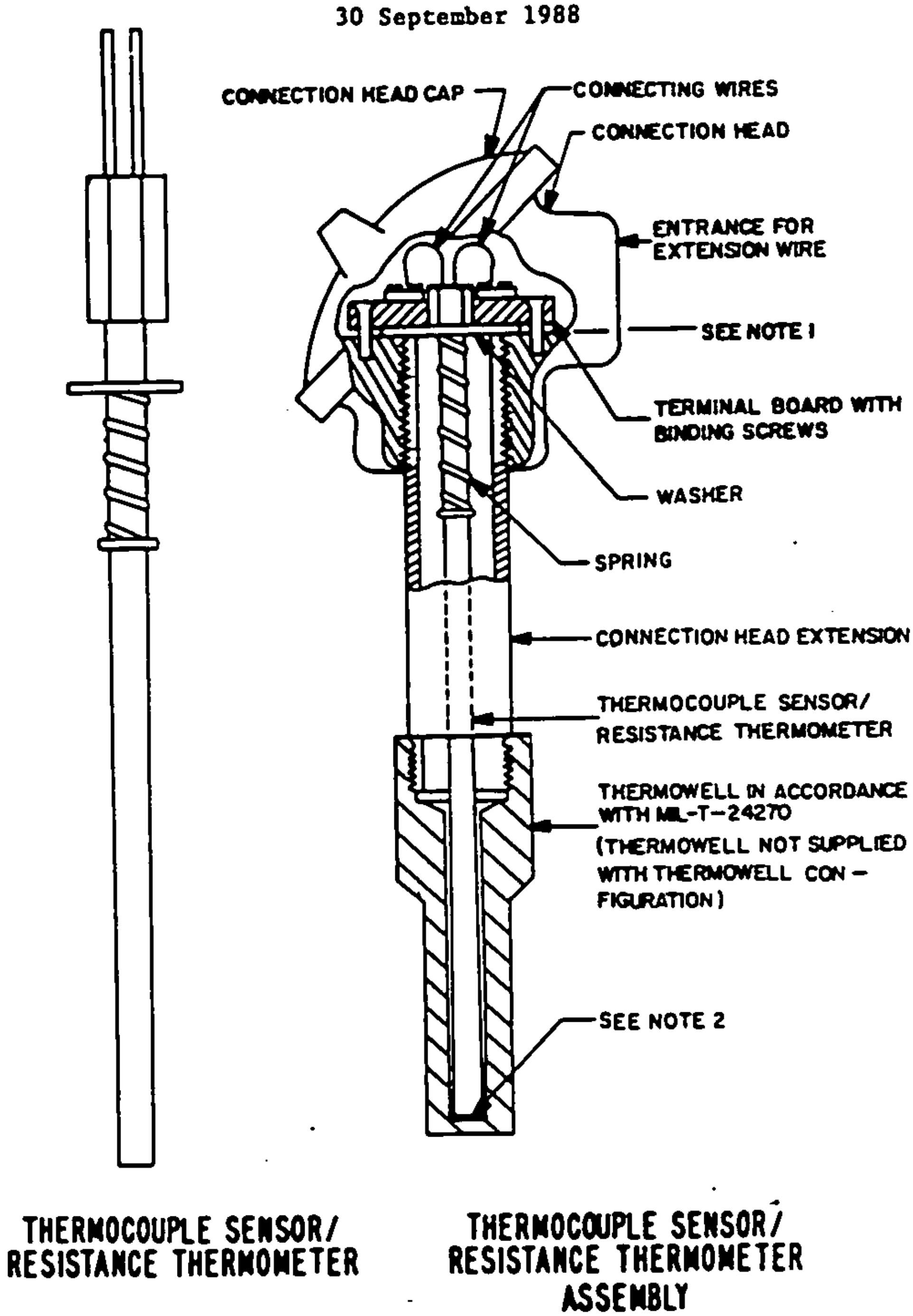
6.1 Intended use. This handbook contains requirements for the selection, installation and troubleshooting of thermocouple sensors and resistance thermometers constructed in accordance with MIL-T-24388.

6.2 Issue of DoDISS. When this handbook is used in acquisition, the issue of the DoDISS to be applicable to this solicitation must be cited in this solicitation (see 2.1.1).

6.3 Subject term (key word) listing.

Babbitt
Bare bulb configuration
Embedded configuration
Ohmmeter
Potentiometer

Preparing activity:
Navy - SH
(Project 6685-N791)



NOTES:
1. Top of connection head extension and bottom of washer must be on same datum line.
2. Resistance thermometer or thermocouple sensor tip is compressed against bottom of thermowell.
3. See figure 11 for an application of installation.

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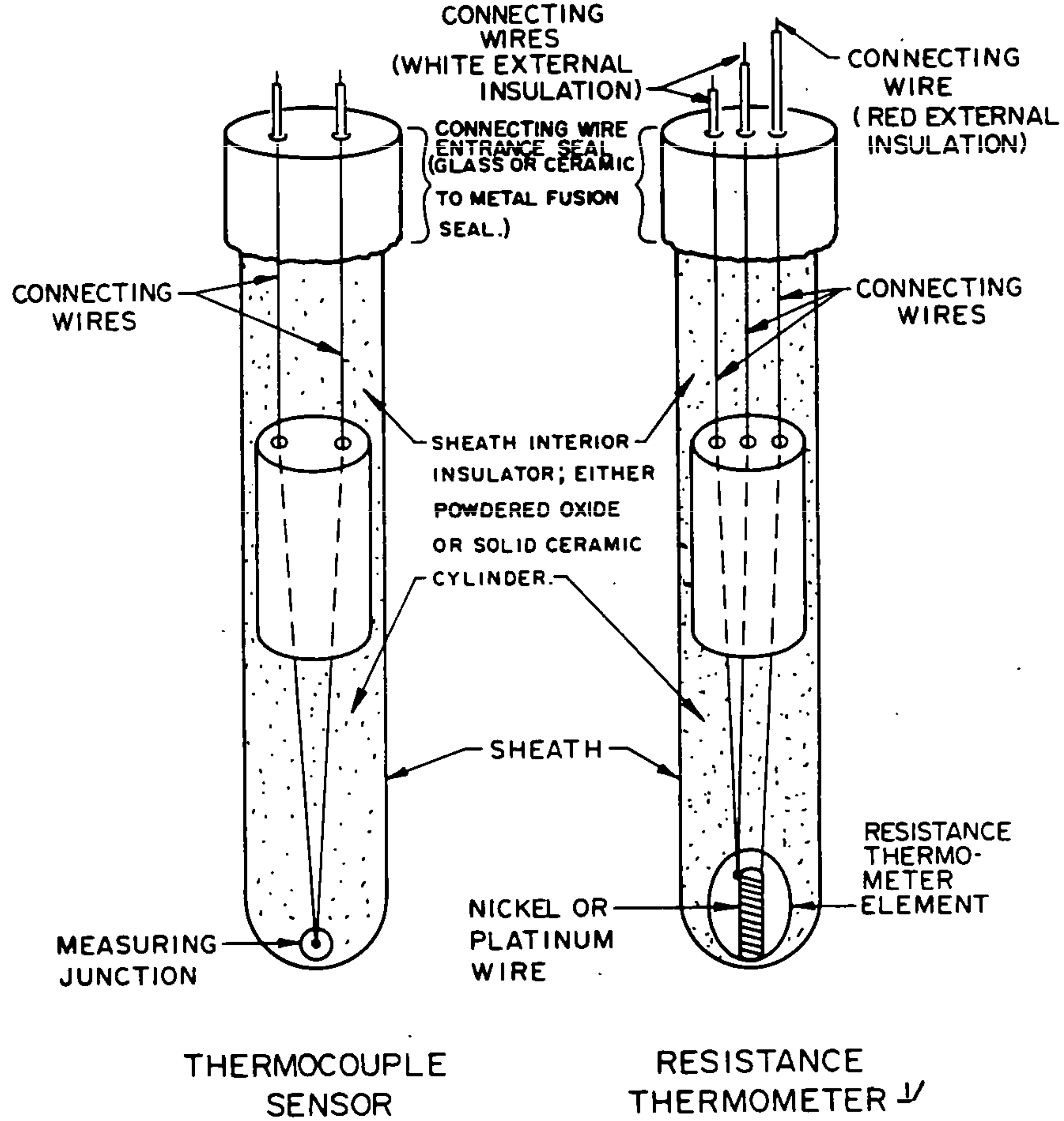
FIGURE 1. Thermowell configuration.



1/ For bare bulb configuration, the resistance thermometer with nickel element will have two connecting wires.

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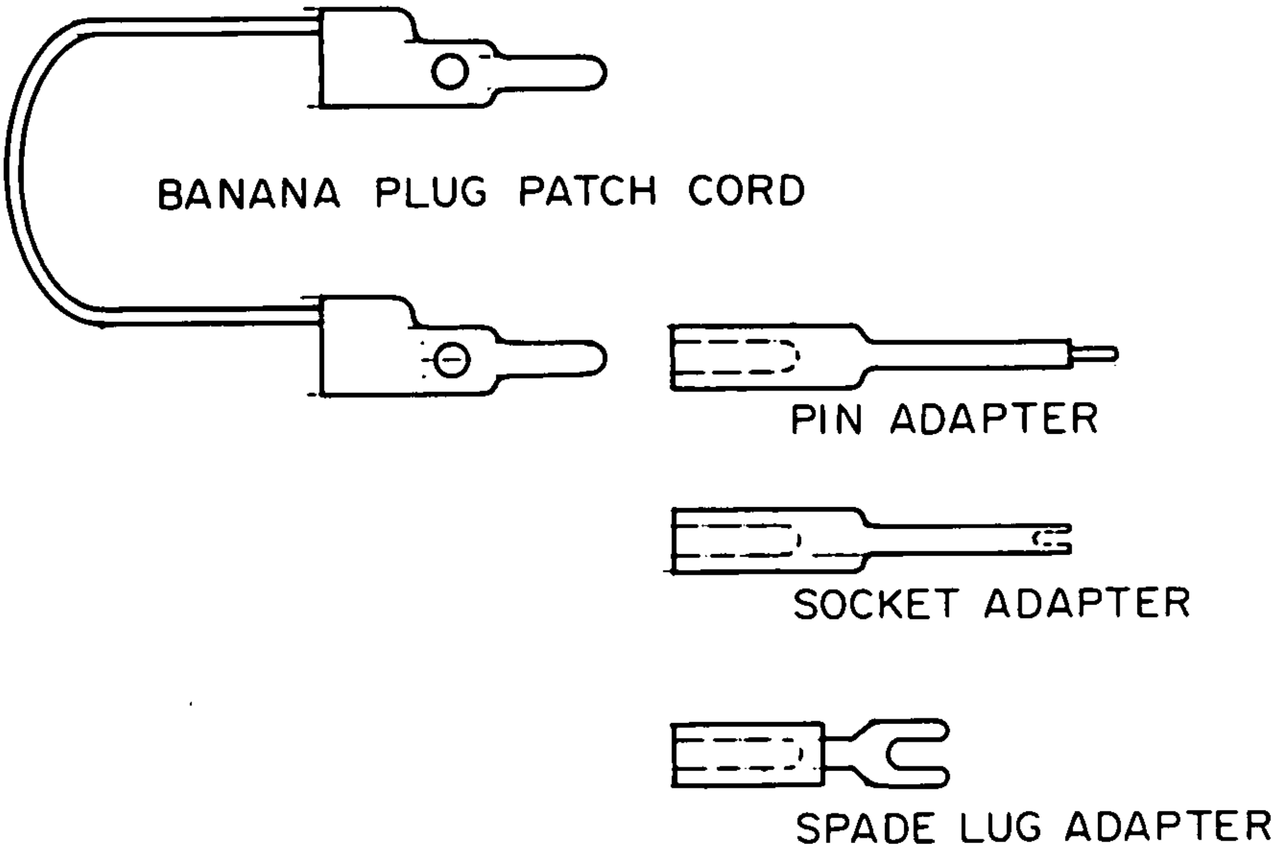
FIGURE 2. Components for thermowell and bare bulb configuration.



SH 132316720

FIGURE 3. Patch cords.

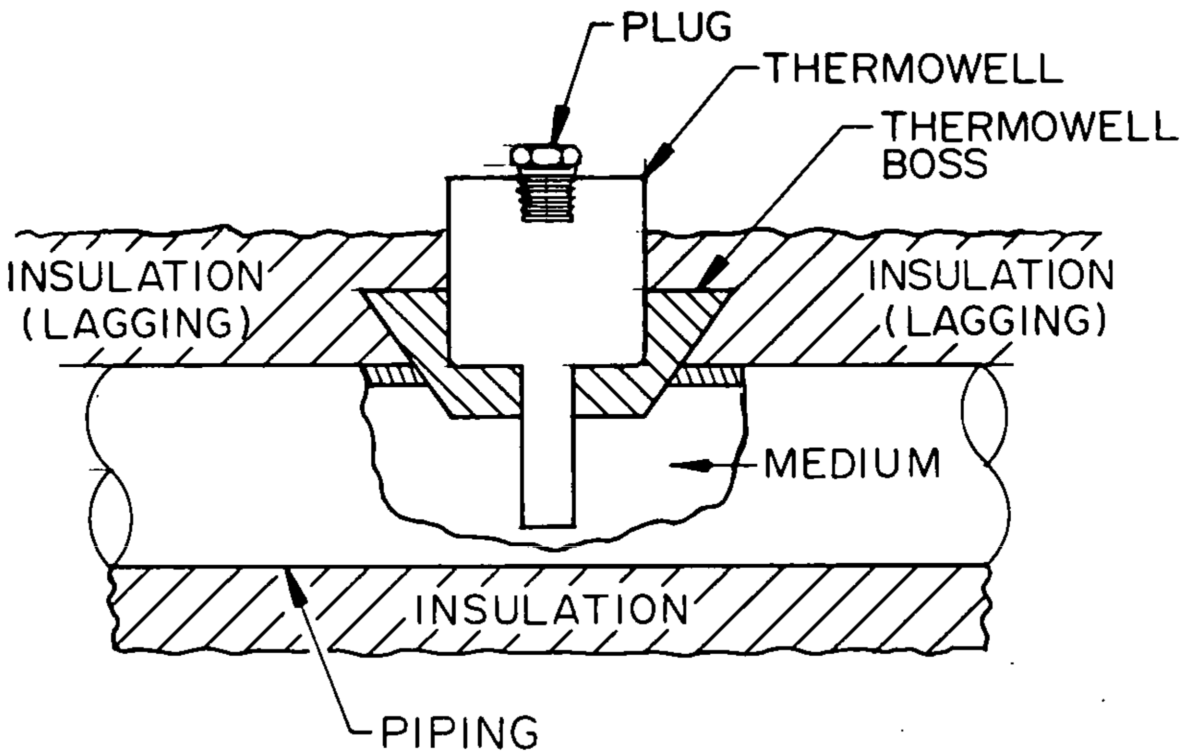


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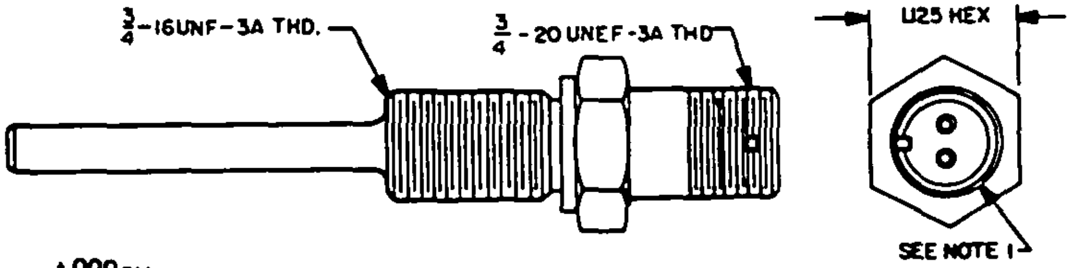
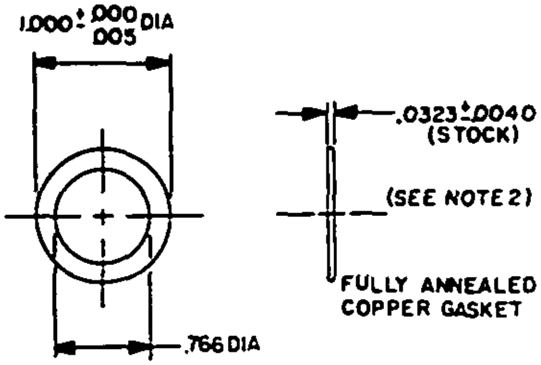
FIGURE 4. Pipe plug protection for thermowell bore.





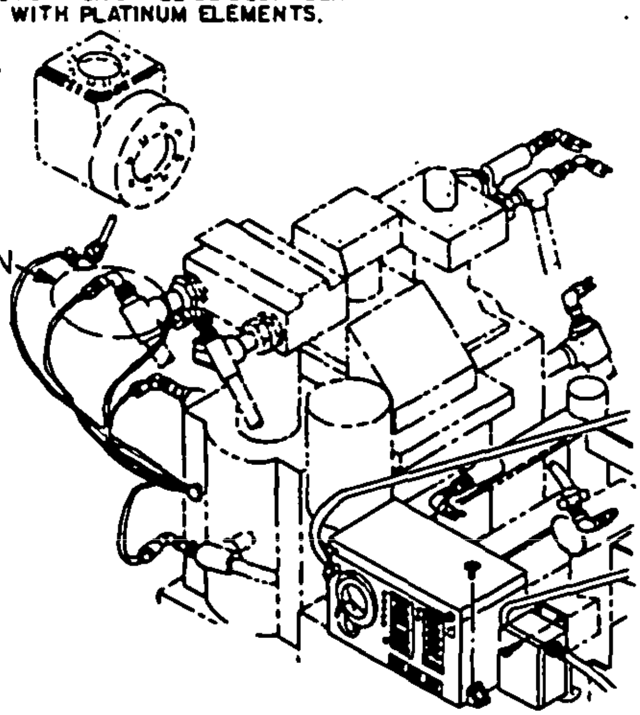
Bare bulb configuration thermocouple sensor/ resistance thermometer.

NOTES:

(1) BARE BULB TYPE RESISTANCE THERMOMETER AND THERMOCOUPLE SENSOR SHEATHS ARE CONSTRUCTED IN ONE PIECE. THE CONFIGURATION FOR THE CONNECTOR RECEPTACLE PORTION SHALL BE EQUIVALENT TO MS3102R-12S-3P FOR TYPE K THERMOCOUPLE SENSORS AND RESISTANCE THERMOMETERS WITH NICKEL ELEMENTS. THE CONFIGURATION FOR THE CONNECTOR RECEPTACLE PORTION SHALL BE EQUIVALENT TO MS3102R-14S-7P FOR RESISTANCE THERMOMETERS WITH PLATINUM ELEMENTS.

(2) THIS GASKET MUST BE INSTALLED DURING THERMOCOUPLE SENSOR/ RESISTANCE THERMOMETER INSTALLATION.

TYPICAL INSTALLATION



Typical bare bulb configuration installation.

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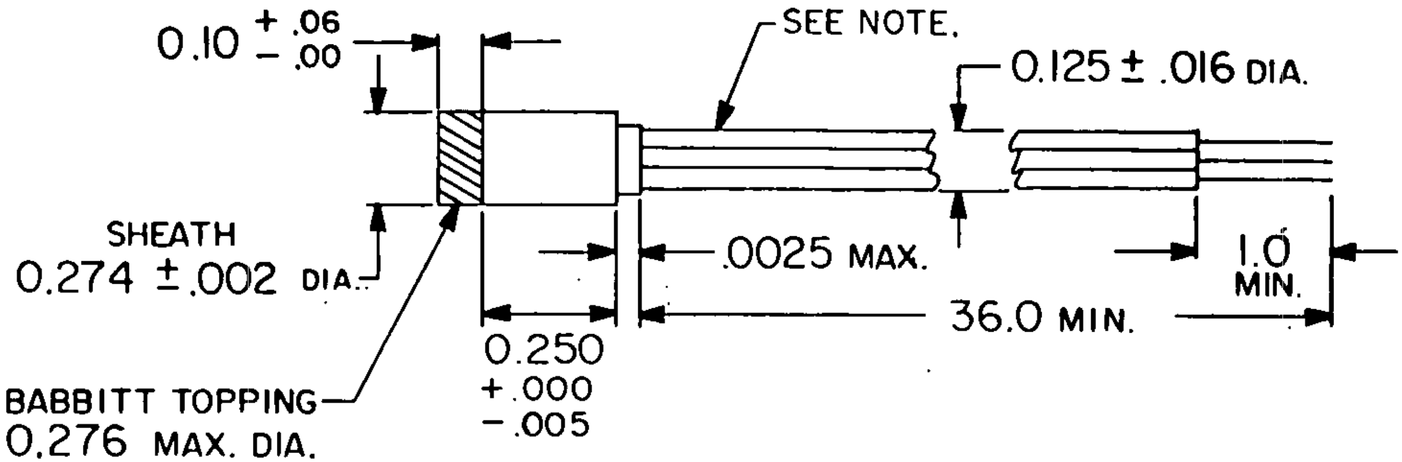
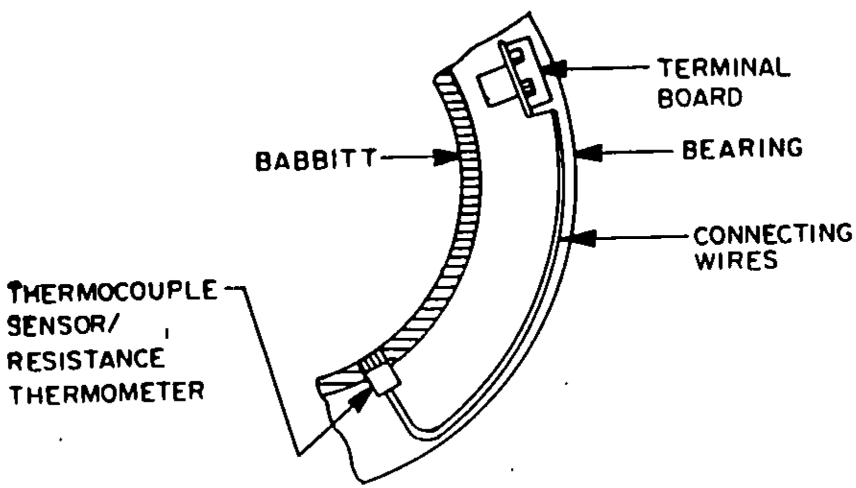
FIGURE 5. Bare bulb configuration and typical installation.



NOTE: If two connecting wires, then thermocouple sensor; if three connecting wires, then resistance thermometer.

Embedded configuration thermocouple sensor/resistance thermometer.



Typical embedded configuration installation.

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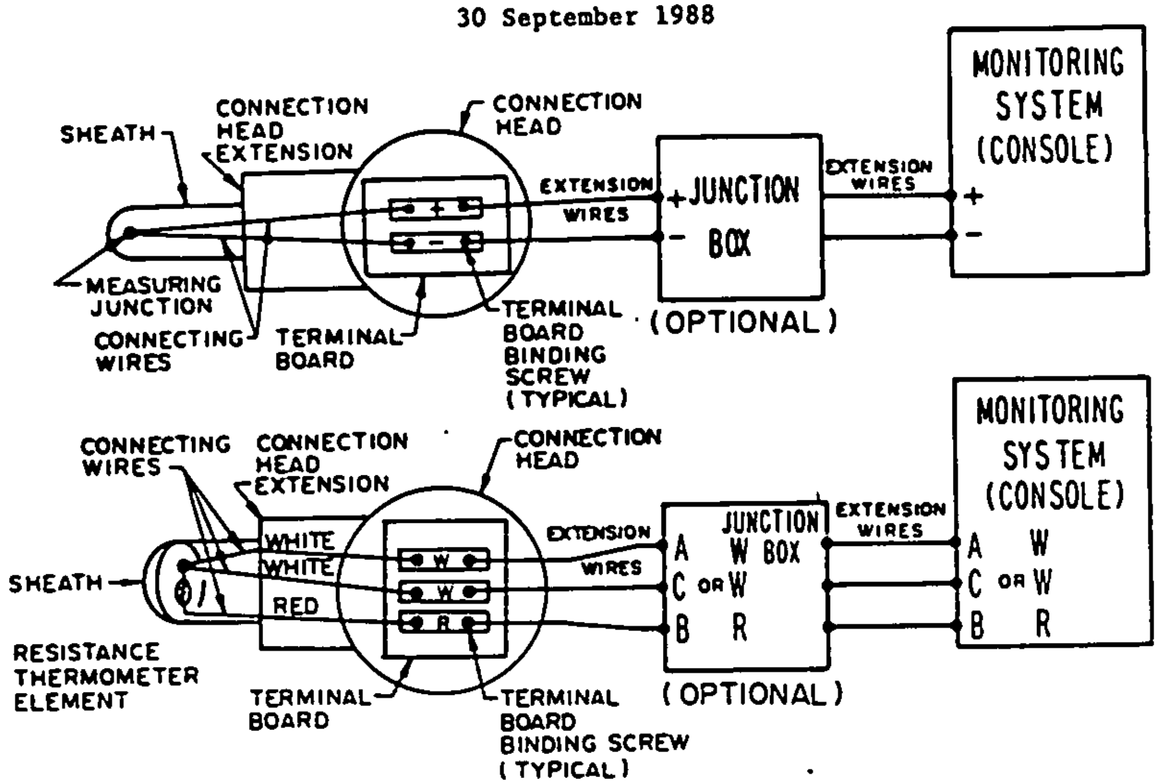
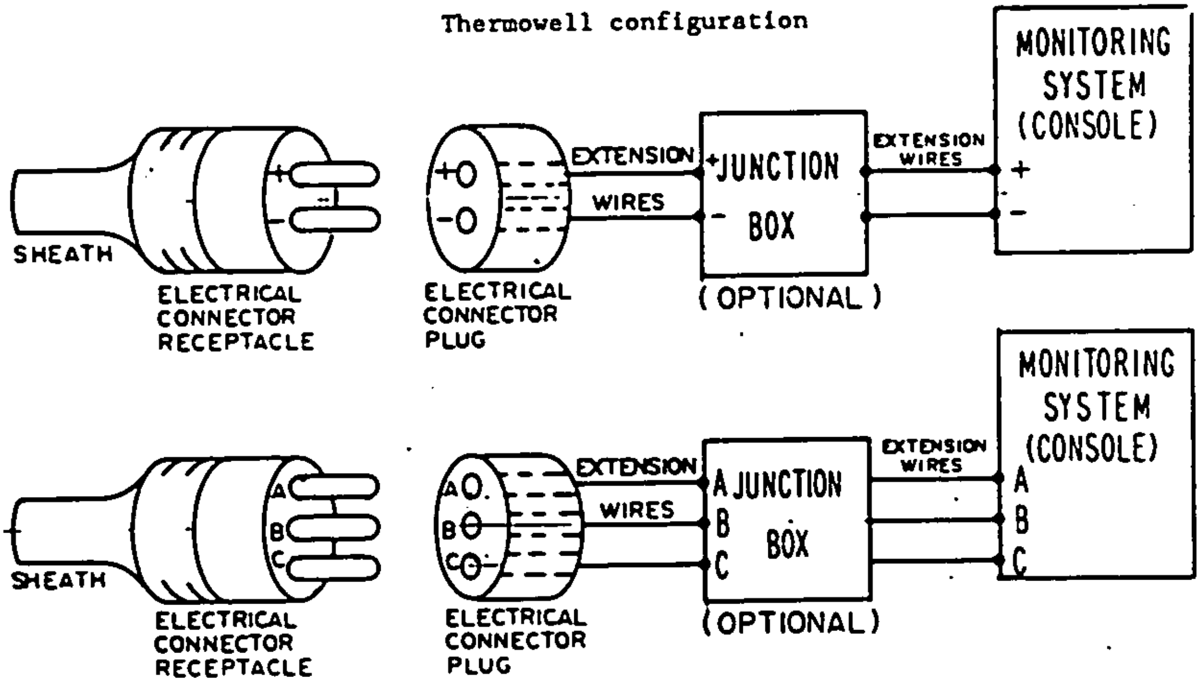
FIGURE 6. Embedded configuration and typical installation.



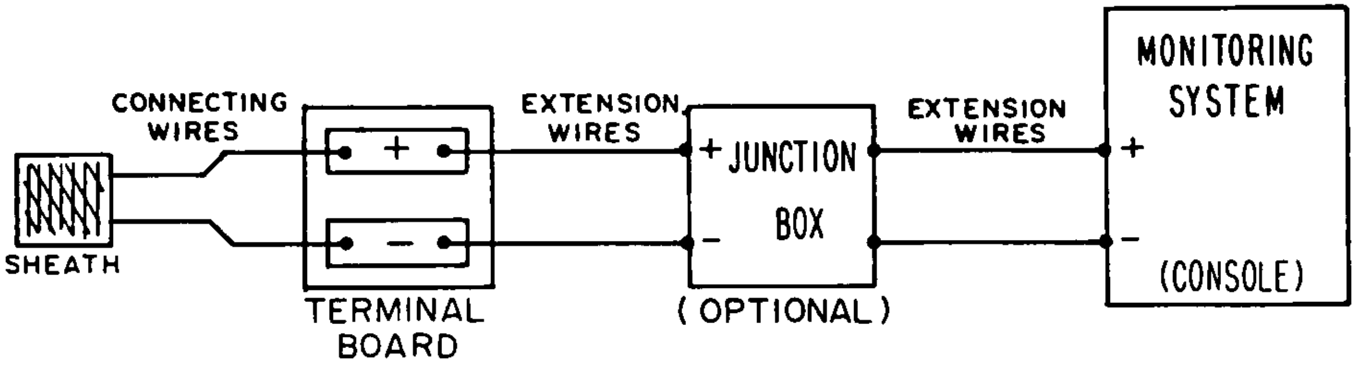
Thermowell configuration

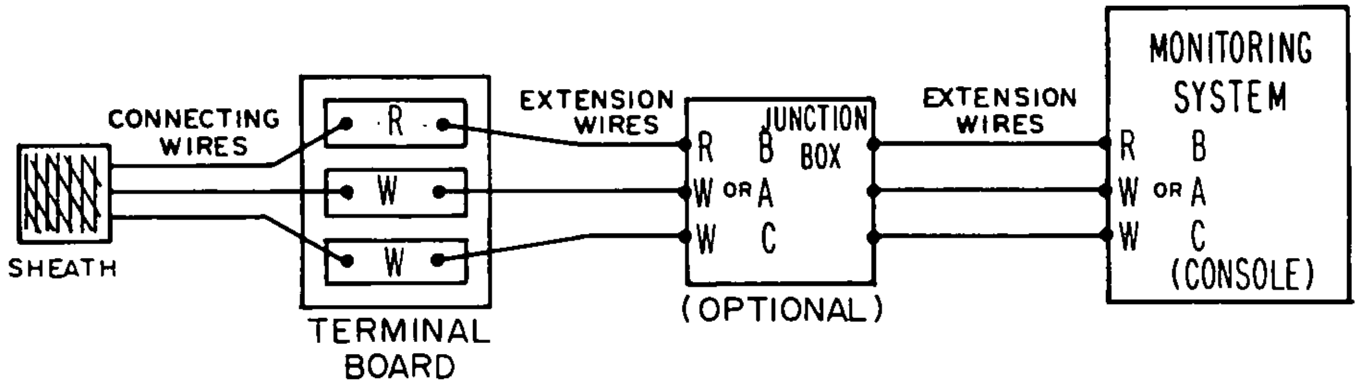


Bare bulb configuration

SH 132316724

FIGURE 7. Installation of extension wires.

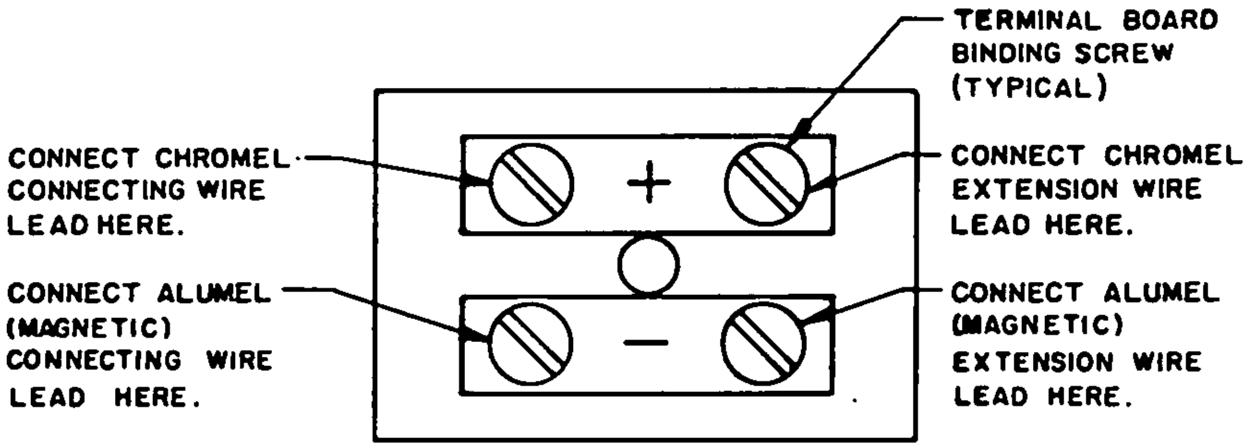




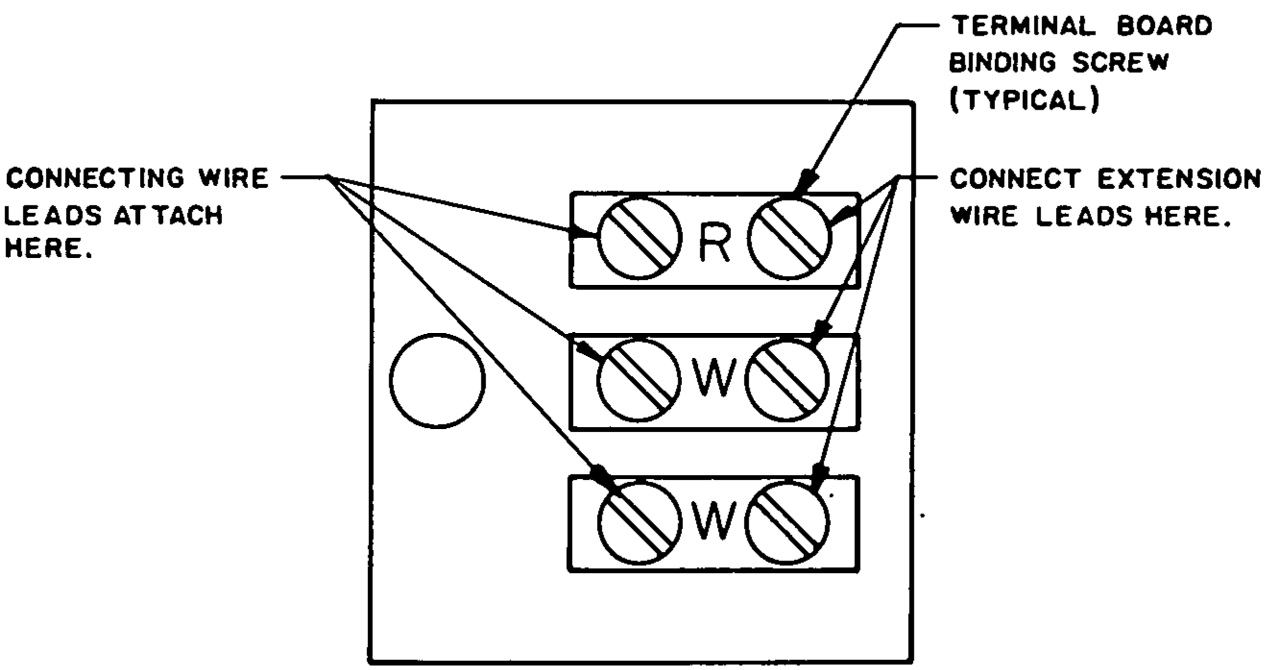
Embedded configuration.

SH 132316724

FIGURE 7. Installation of extension wires - Continued.



Terminal board for thermocouple sensor.



Terminal board for resistance thermometer.

SH 132316725

FIGURE 8. Installation of terminal board connecting wires and extension wires.

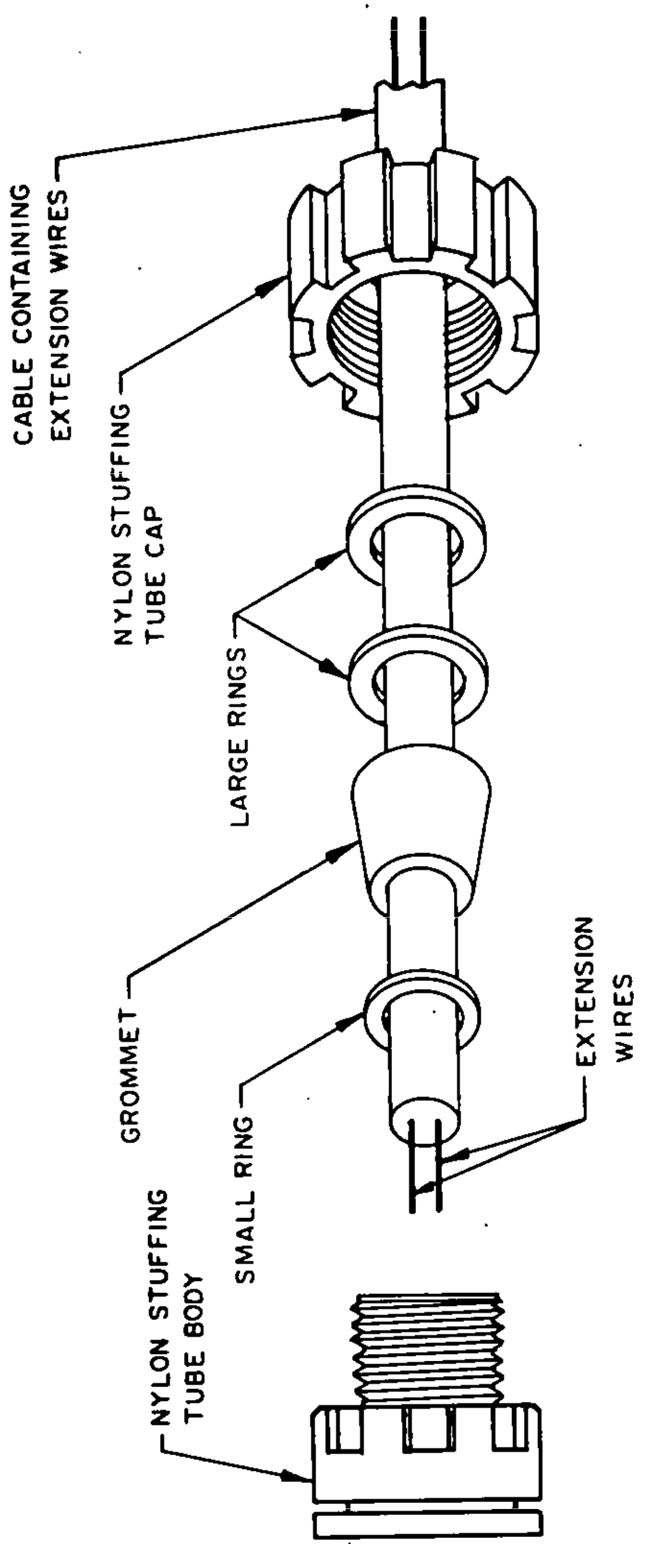


FIGURE 9. Stuffing tube components and installation method.

SH 132316726

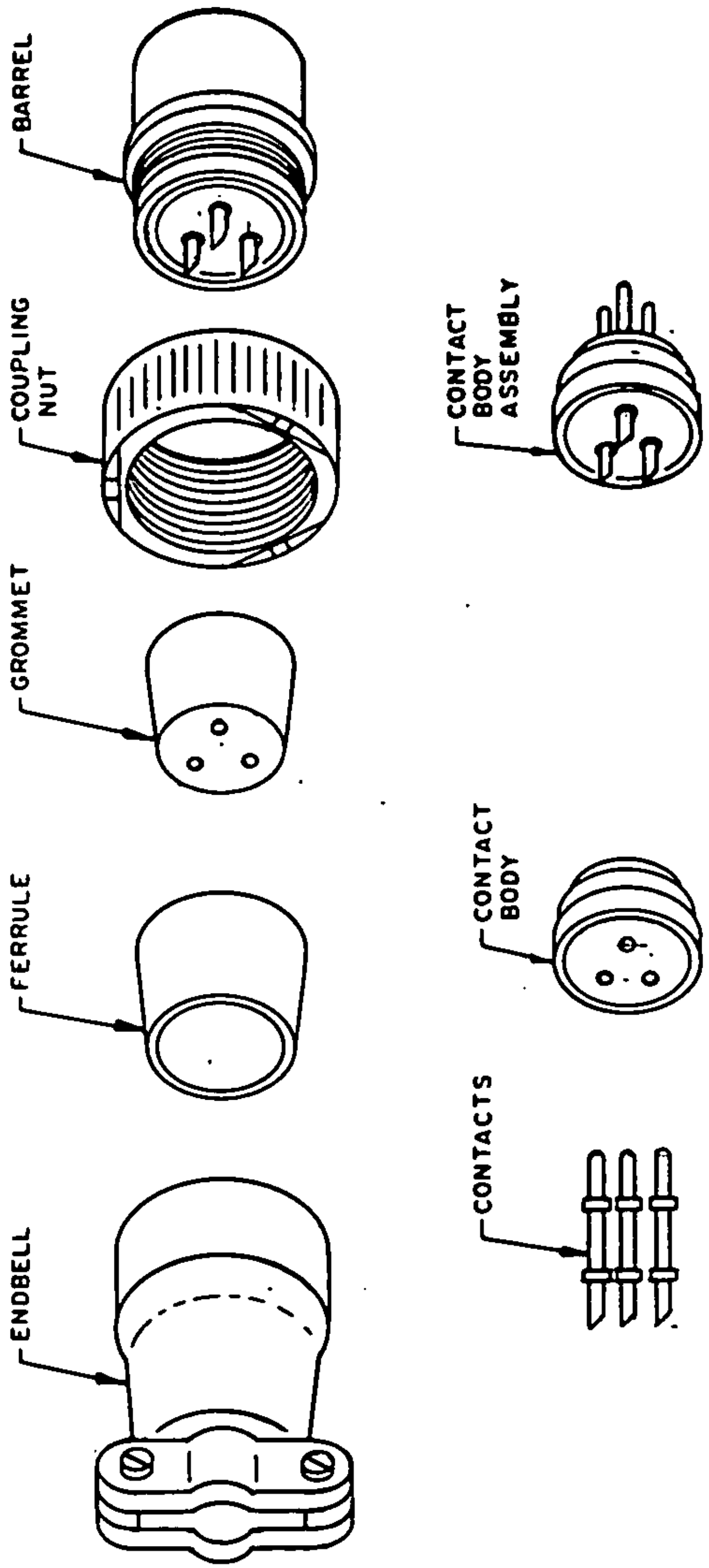
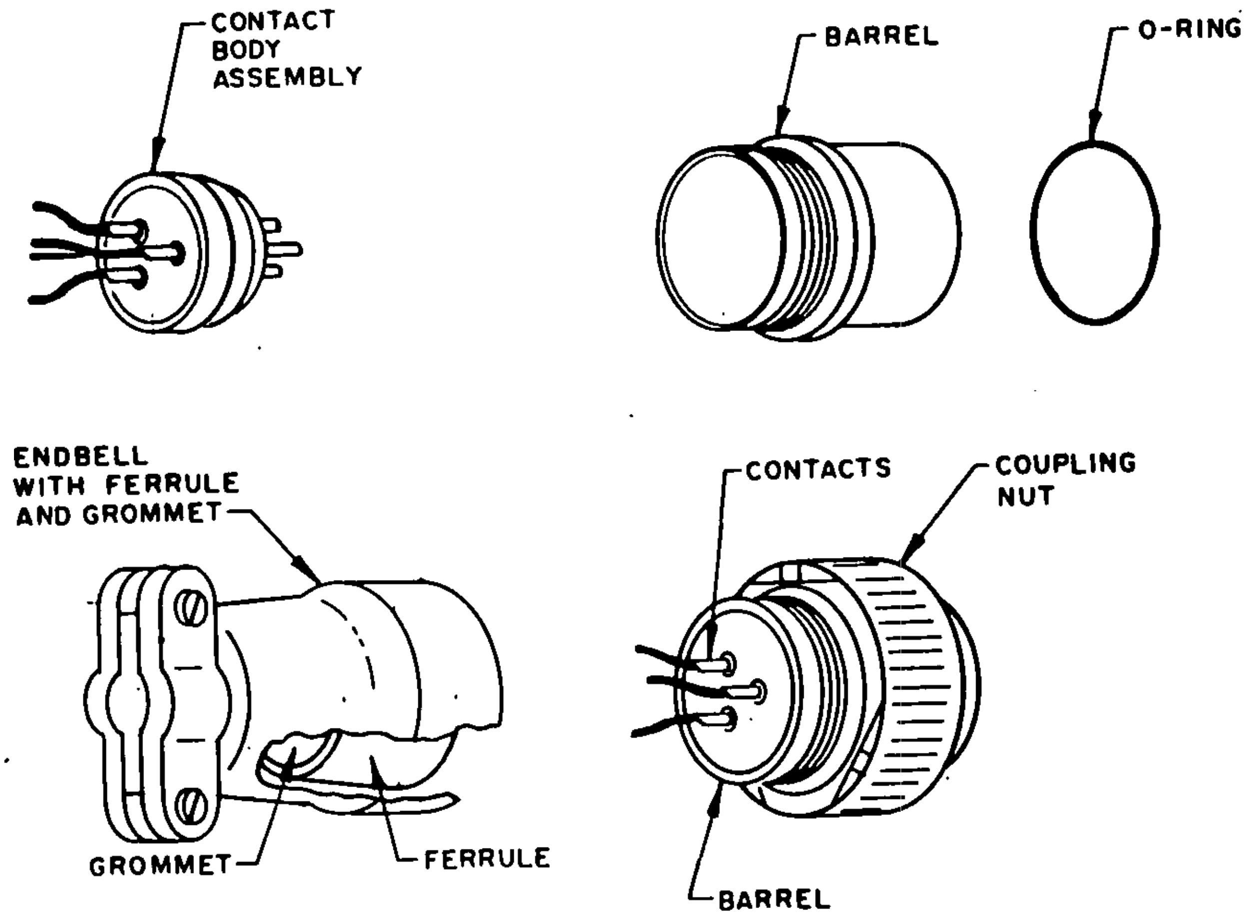


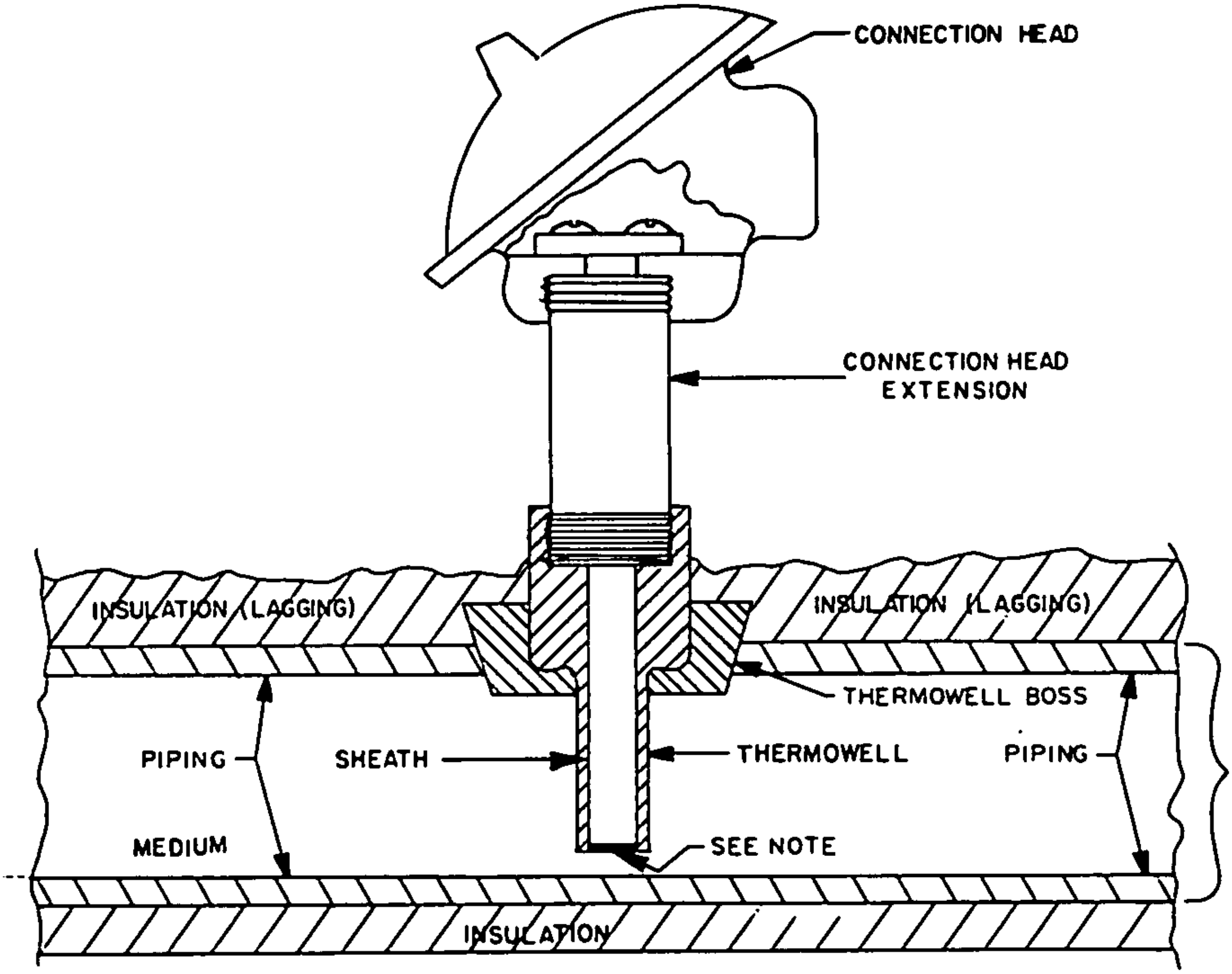
FIGURE 10. Installation of electrical connectors.

SH 132316727



SH 132316727

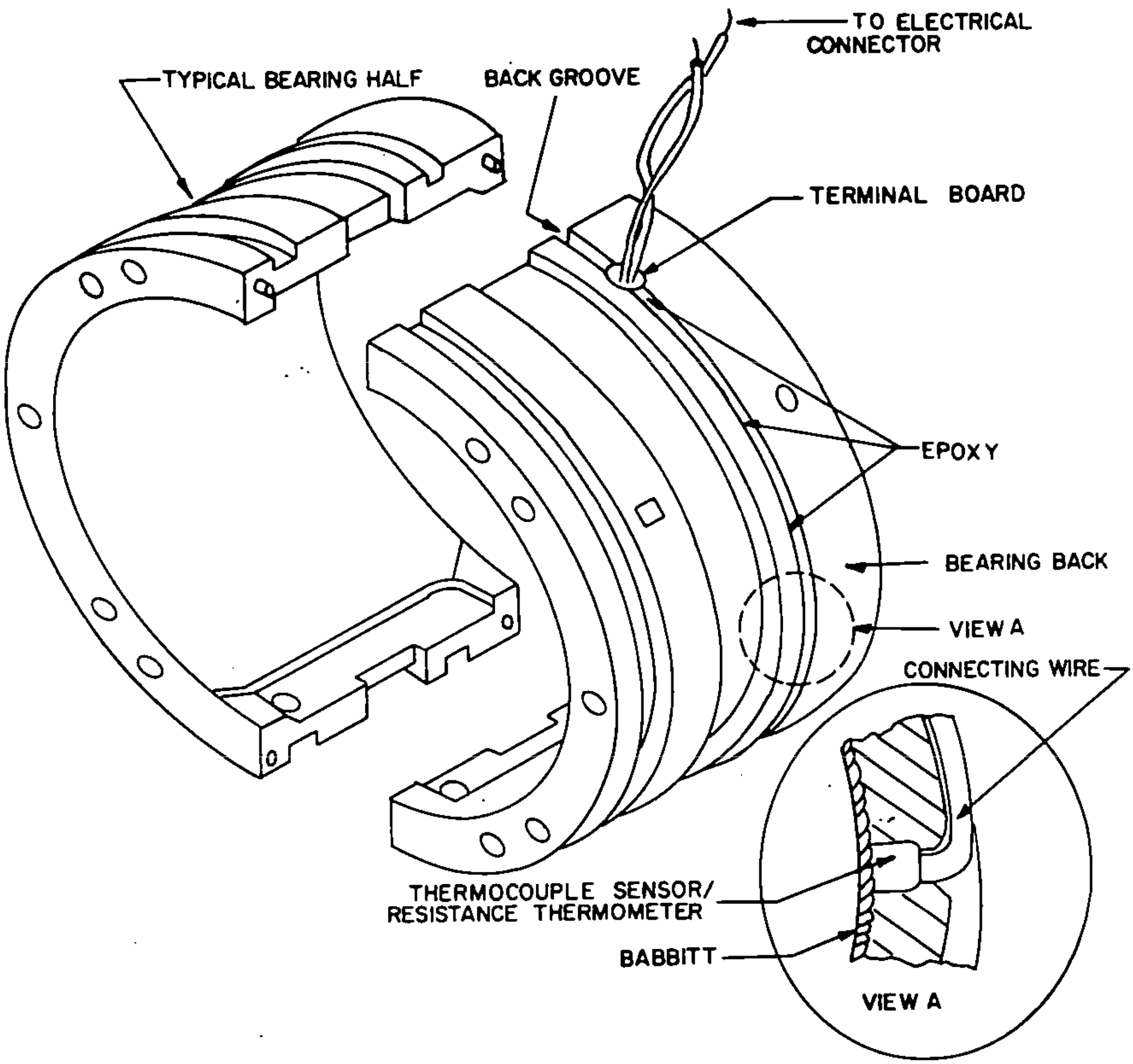
FIGURE 10. Installation of electrical connectors - Continued.



NOTE: Tip "bottoming" on thermowell

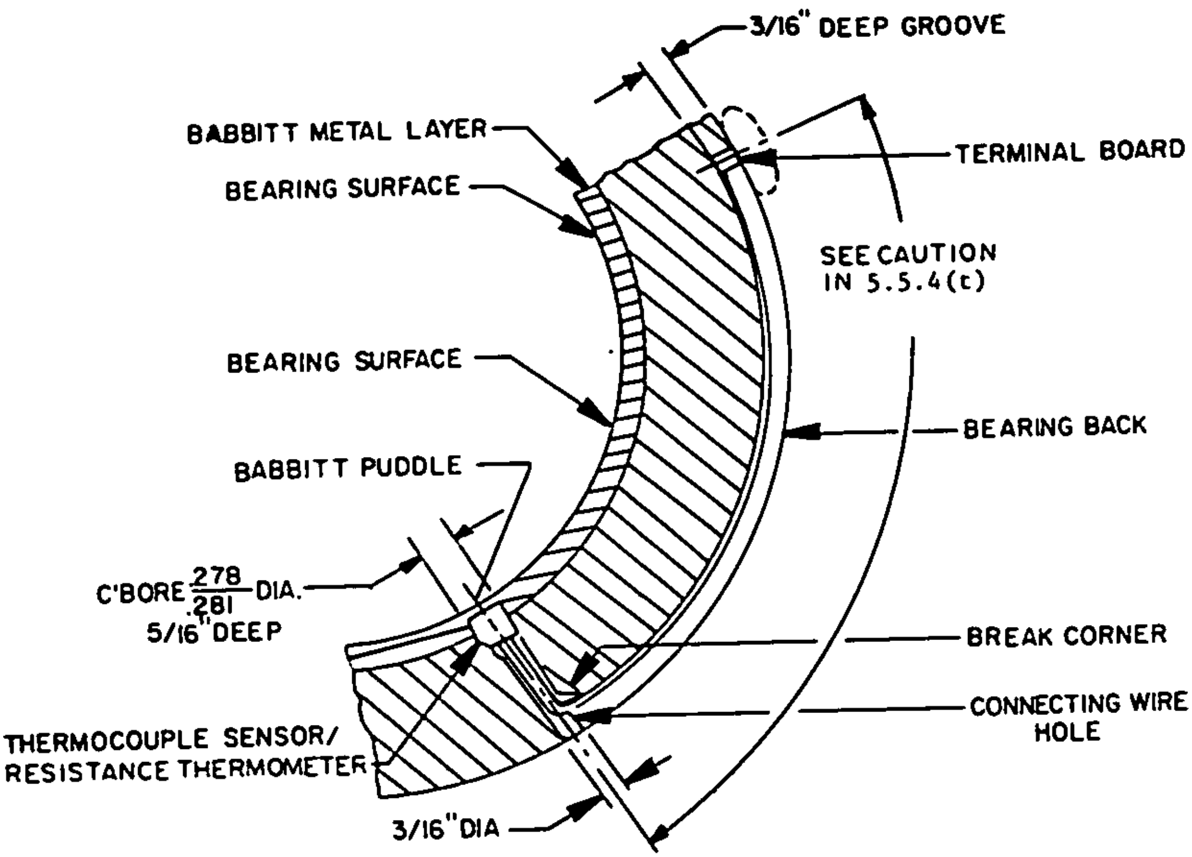
SH 132316728

FIGURE 11. Thermowell configuration in piping system.



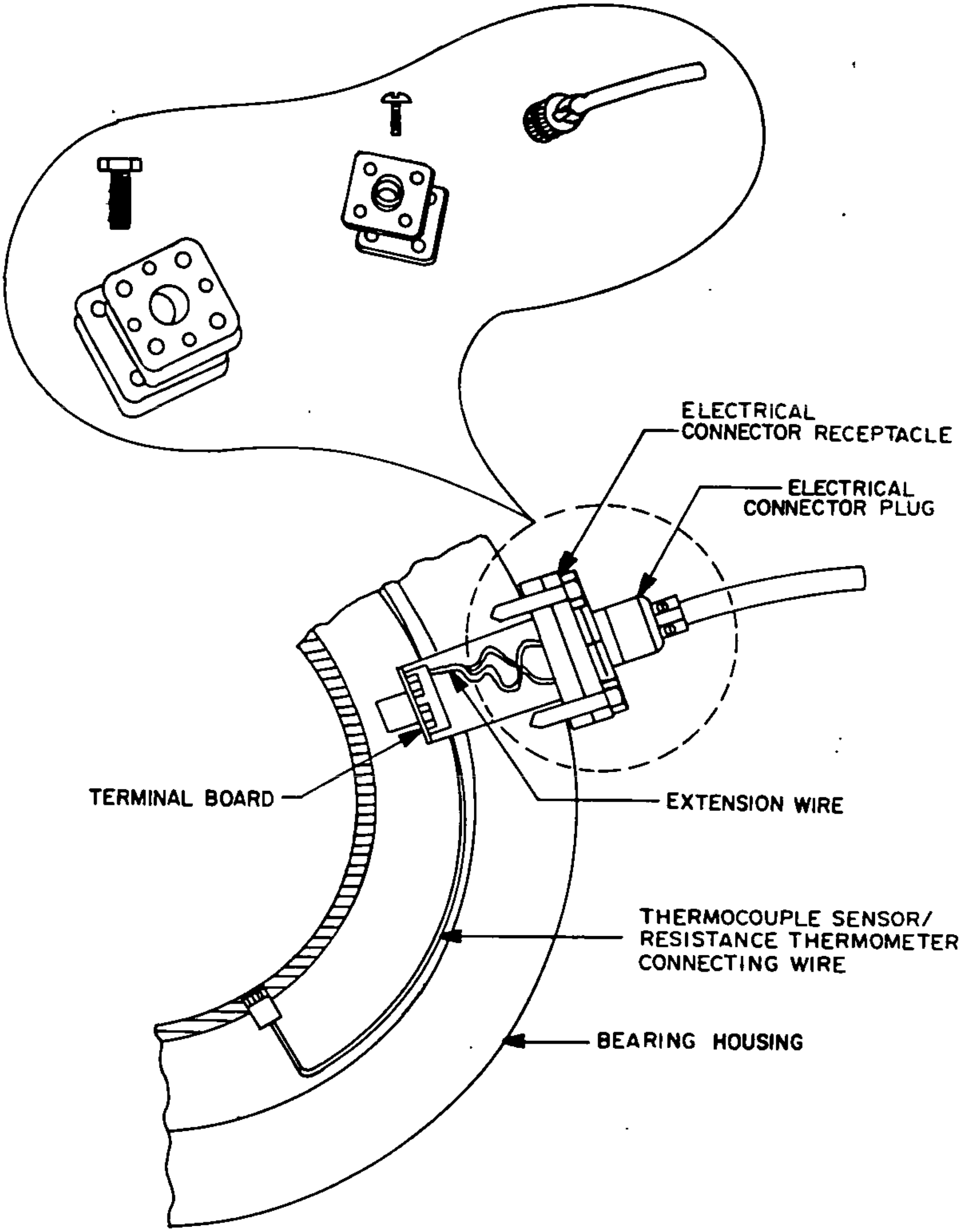
SH 132316729

FIGURE 12. Construction of typical bearing.



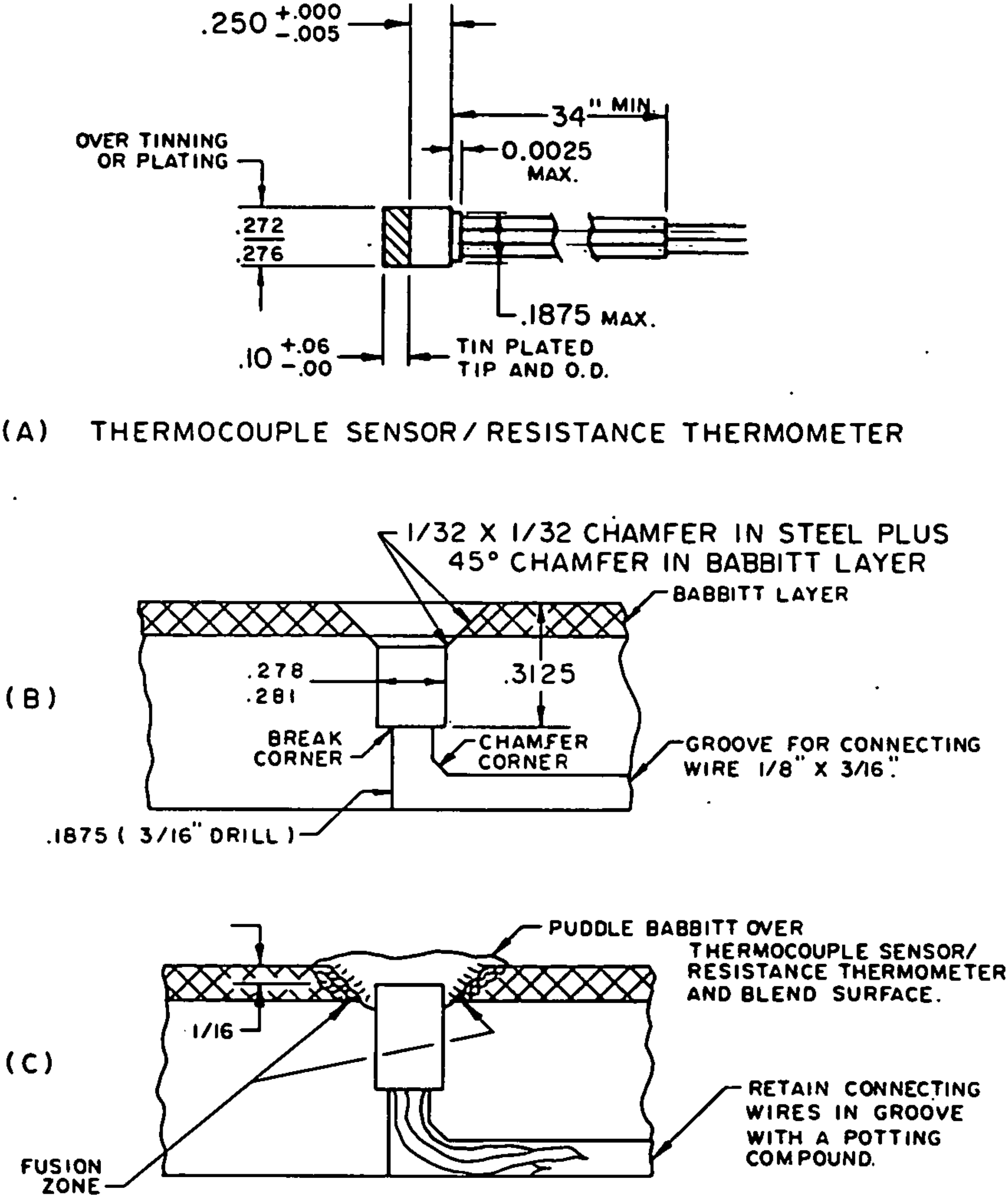
SH 132316730

FIGURE 13. Placement of embedded thermocouple sensor/resistance thermometer in a bearing.



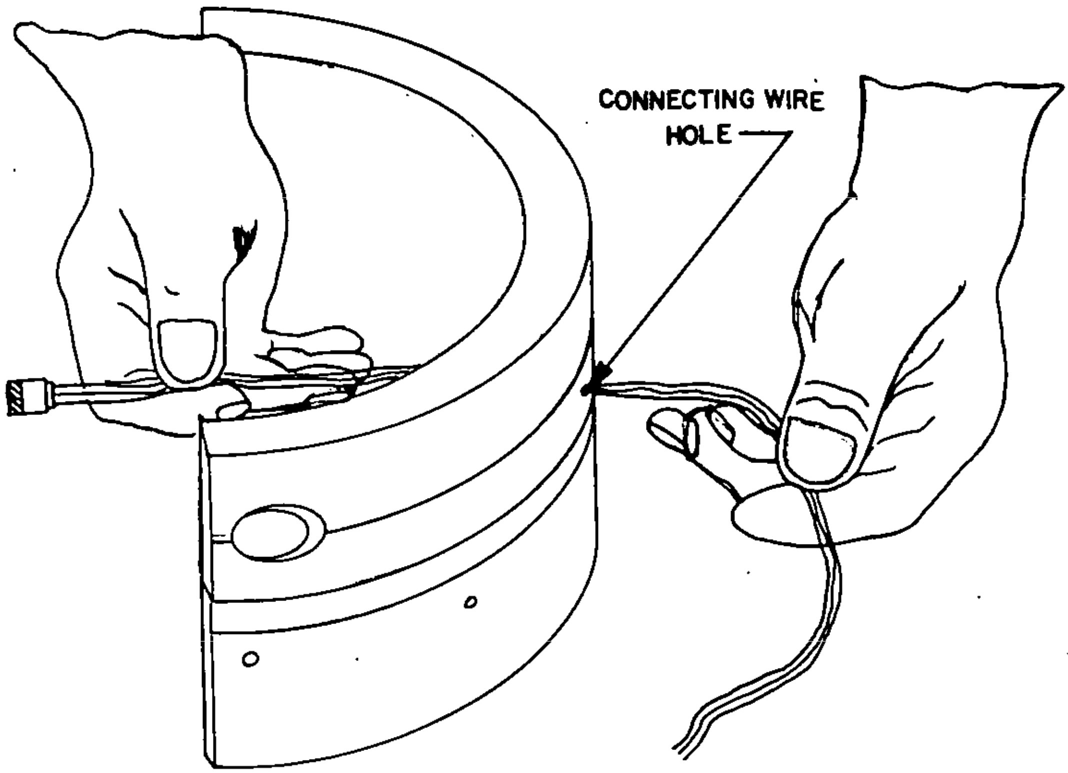
SH 132316731

FIGURE 14. Connecting wire connections.



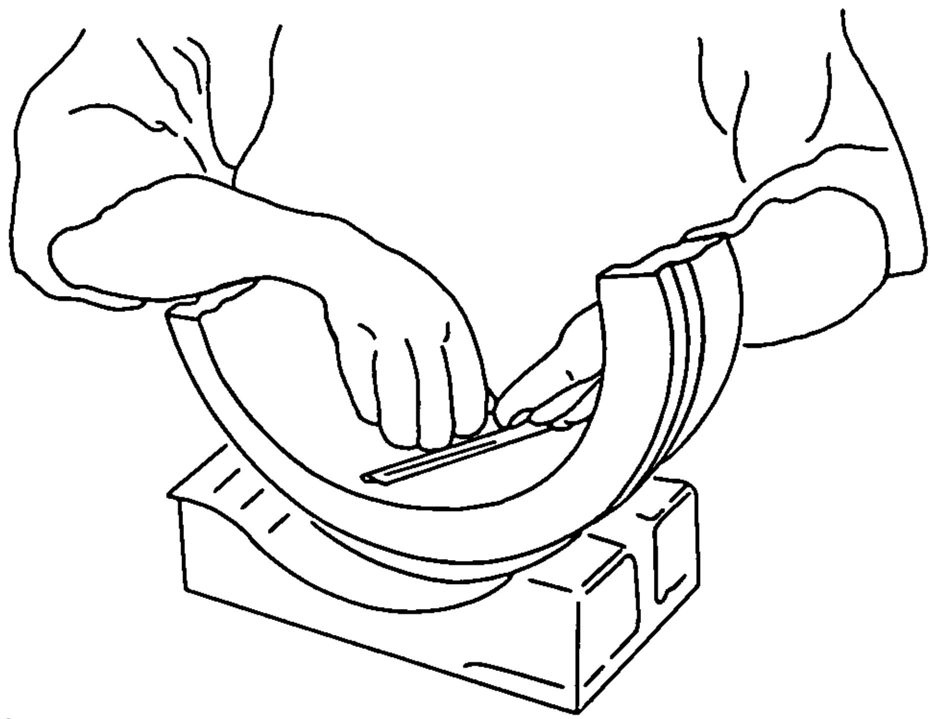
SH 132316732

FIGURE 15. Typical thermocouple sensor/resistance thermometer installation in a bearing.



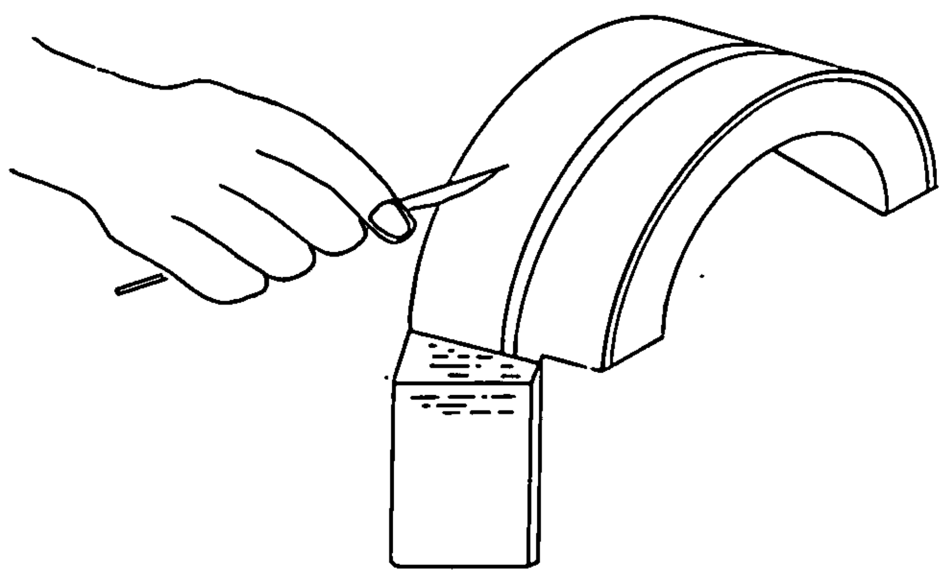
SH 132316733

FIGURE 16. Placement of connecting wires through the bearing.



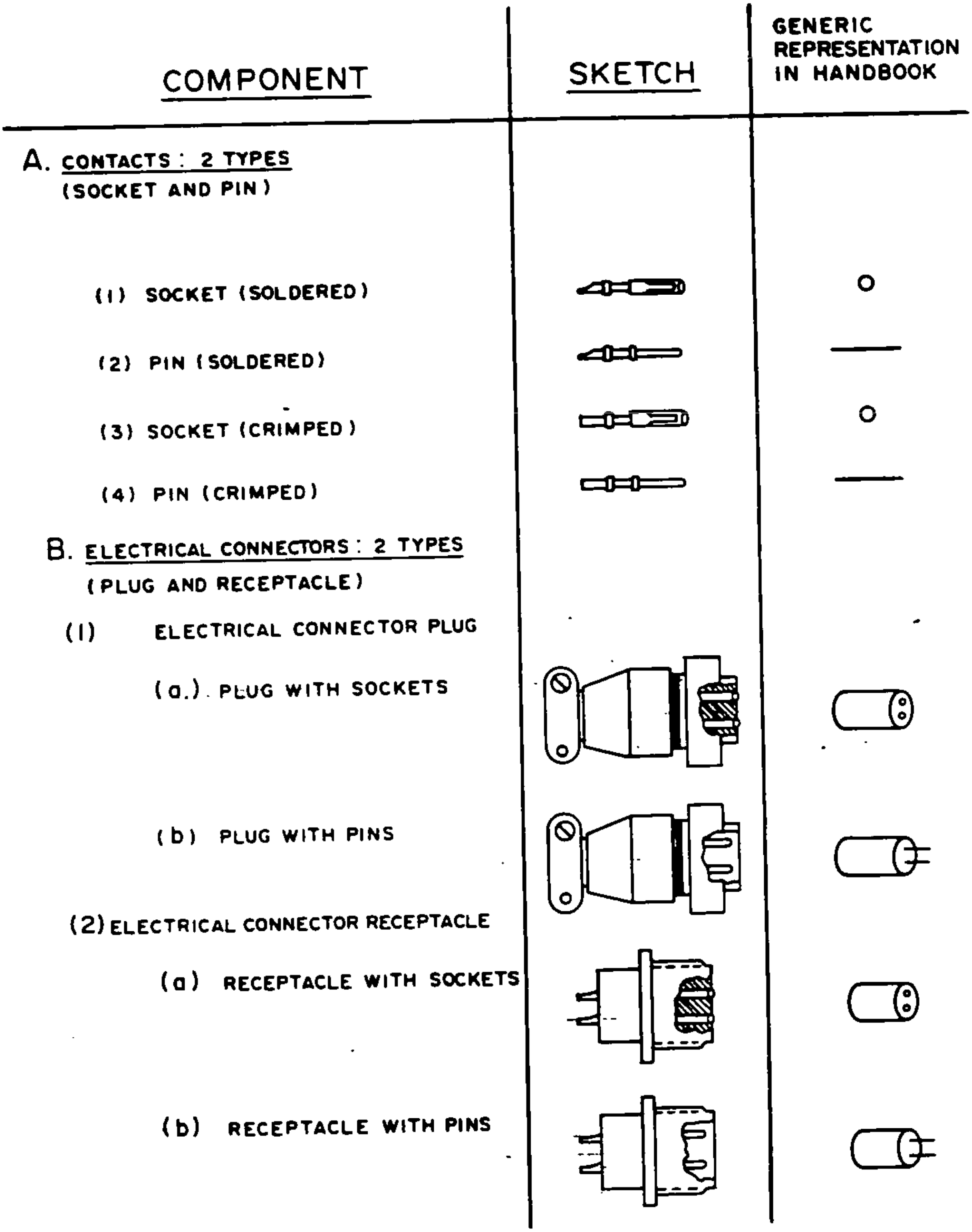
SH 132316734

FIGURE 17. Smooth puddled surface flush with babbitt surface of bearing.



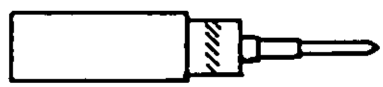
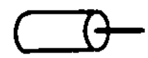
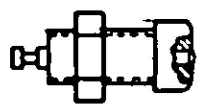
SH 132316735

FIGURE 18. Filling cavity containing thermocouple sensor/resistance thermometer connecting wires with potting mixture.



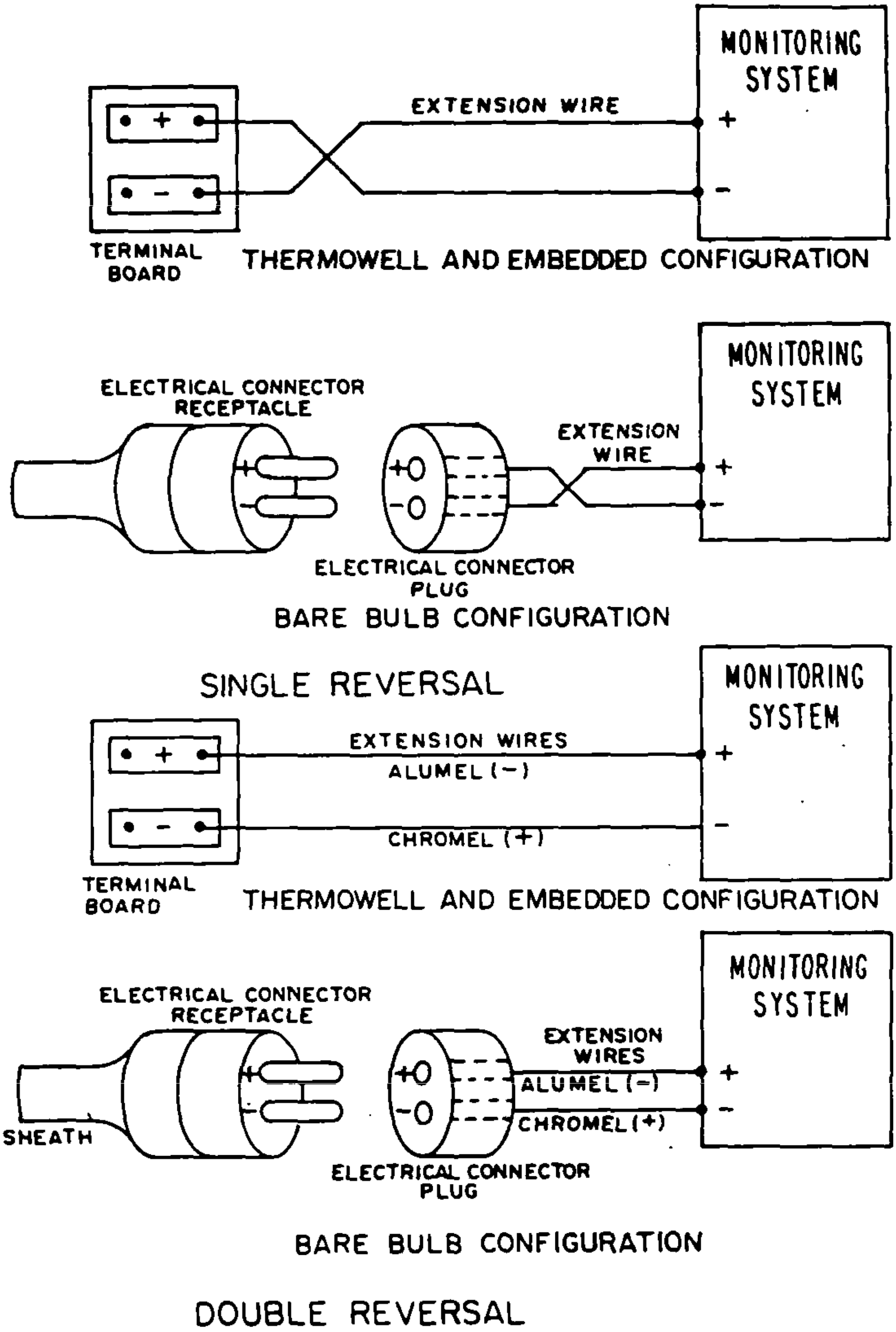
SH 132316736

FIGURE 19. Configurations for electrical connectors.

COMPONENT	SKETCH	GENERIC REPRESENTATION IN HANDBOOK
(c) TEST POINT PLUG		
(d) TEST POINT JACK		

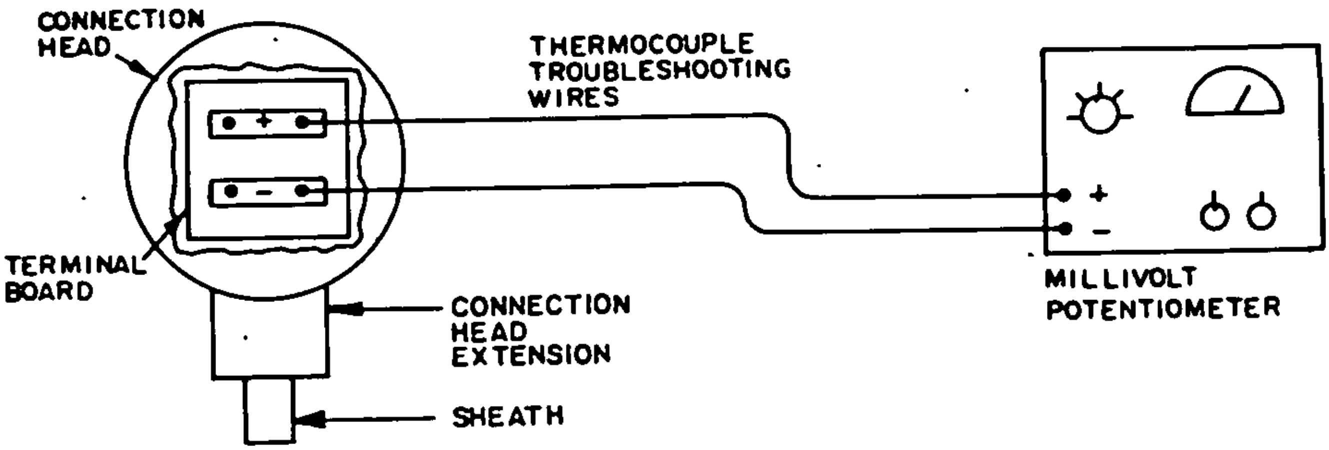
SH 132316736

FIGURE 19. Configurations for electrical connectors - Continued.

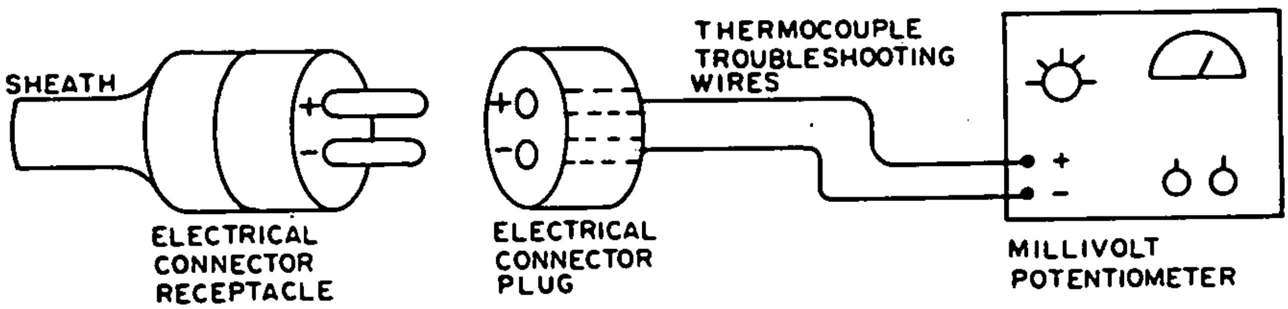


SH 132316737

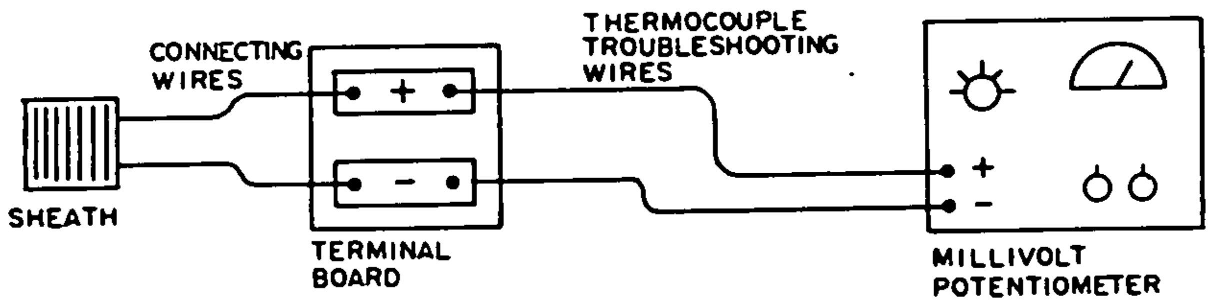
FIGURE 20. Reversal of wire.



Troubleshooting wire configuration.



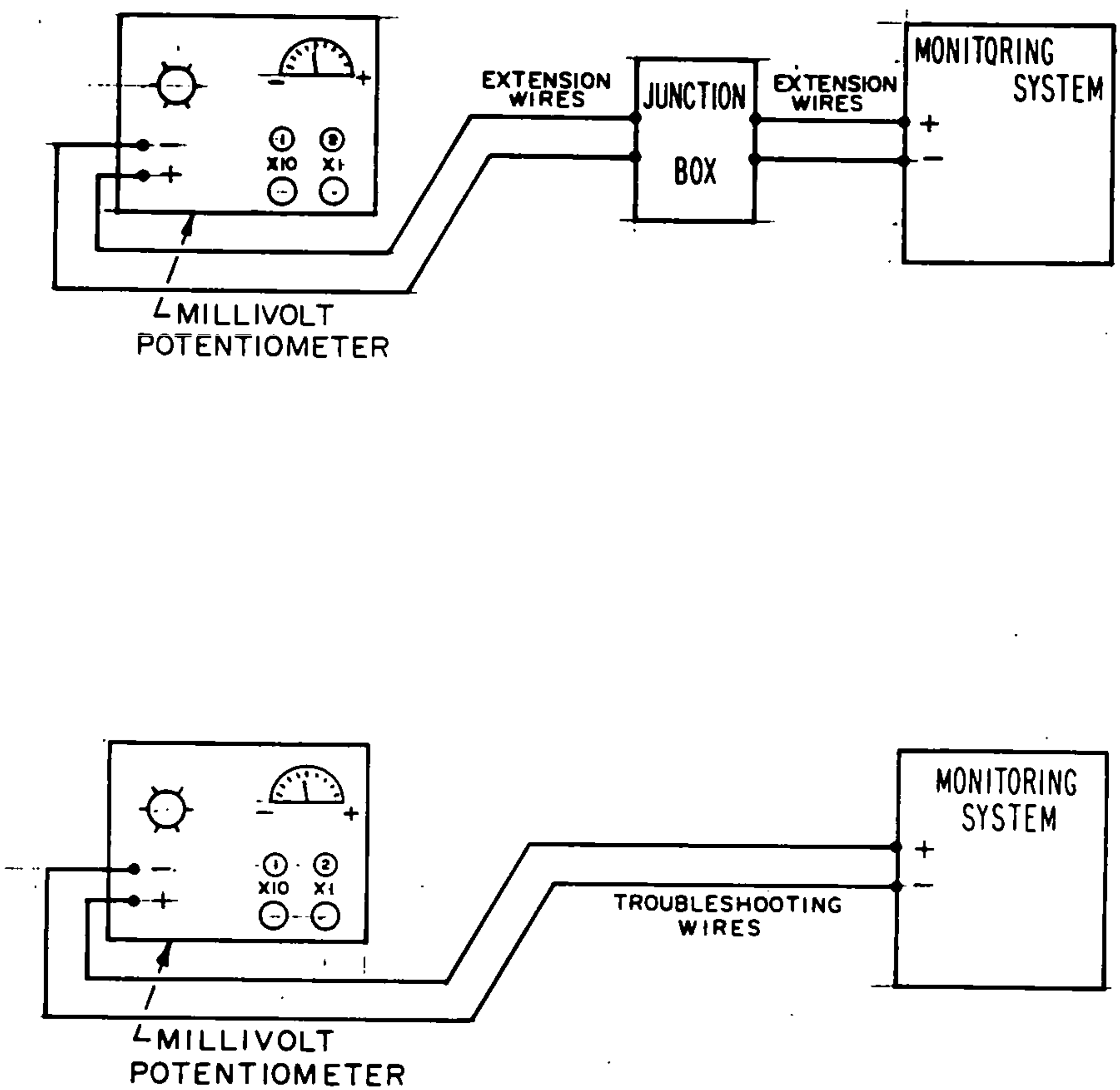
Bare bulb configuration.



Embedded configuration.

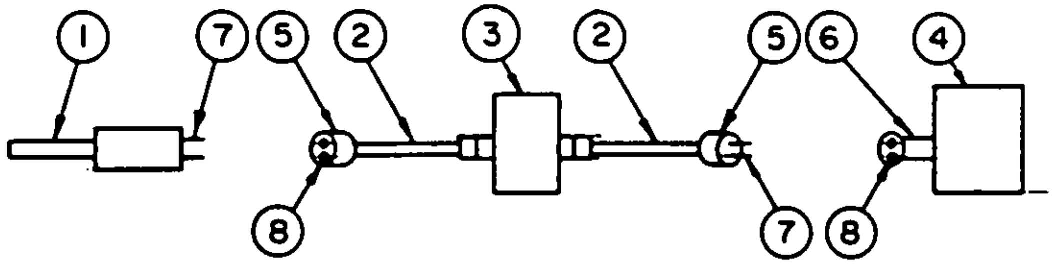
SH 132316738

FIGURE 21. Thermocouple sensor check.

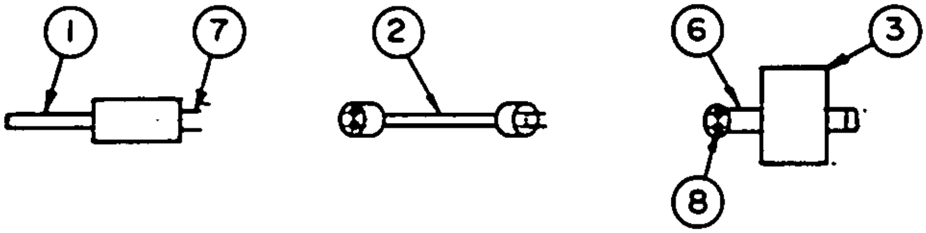


SH 132316739

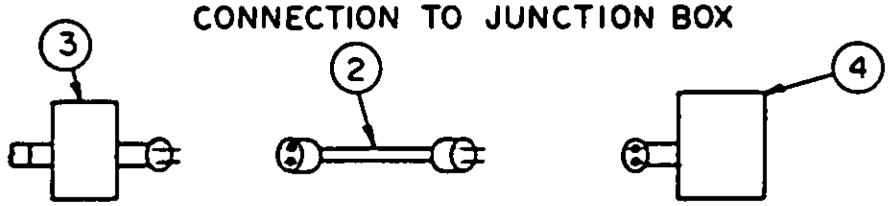
FIGURE 22. Thermocouple sensor monitoring system check.



THERMOCOUPLE SENSOR OR RESISTANCE THERMOMETER
CONNECTION TO MONITORING SYSTEM



THERMOCOUPLE SENSOR OR RESISTANCE THERMOMETER
CONNECTION TO JUNCTION BOX

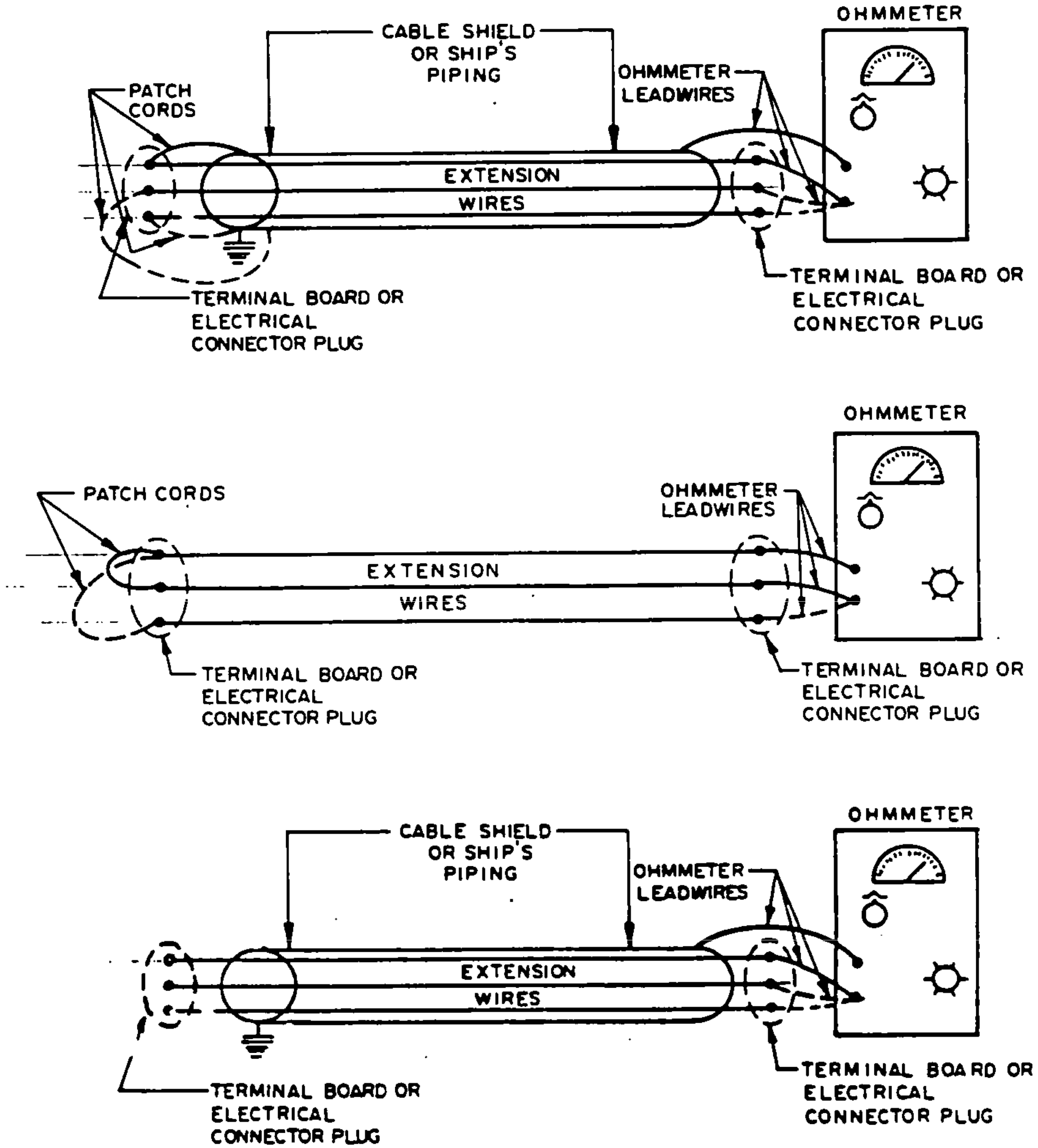


JUNCTION BOX TO MONITORING SYSTEM

ITEM DESIGNATORS: 1 THERMOCOUPLE SENSOR
2 EXTENSION WIRE
3 JUNCTION BOX
4 MONITORING SYSTEM
5 PLUG
6 RECEPTACLE
7 PIN
8 SOCKET

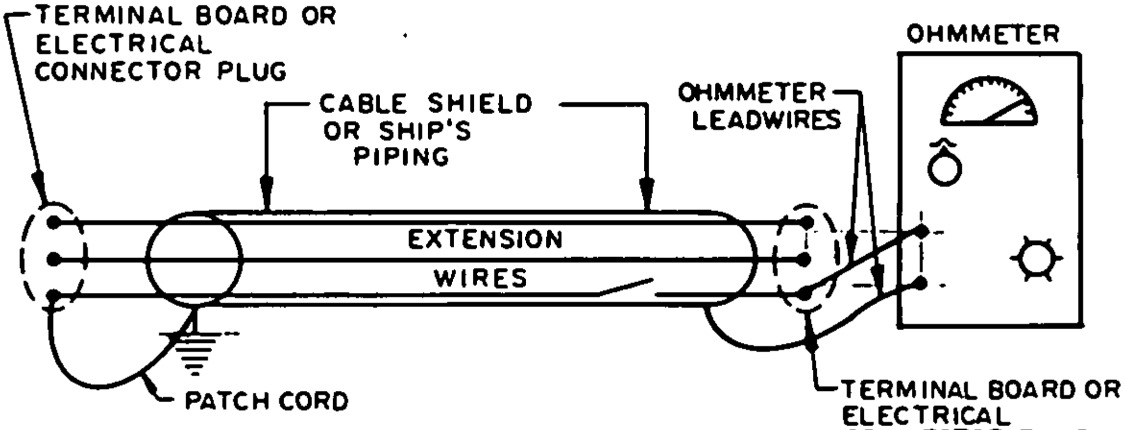
SH 132316740

FIGURE 23. Order to perform extension wire continuity check.

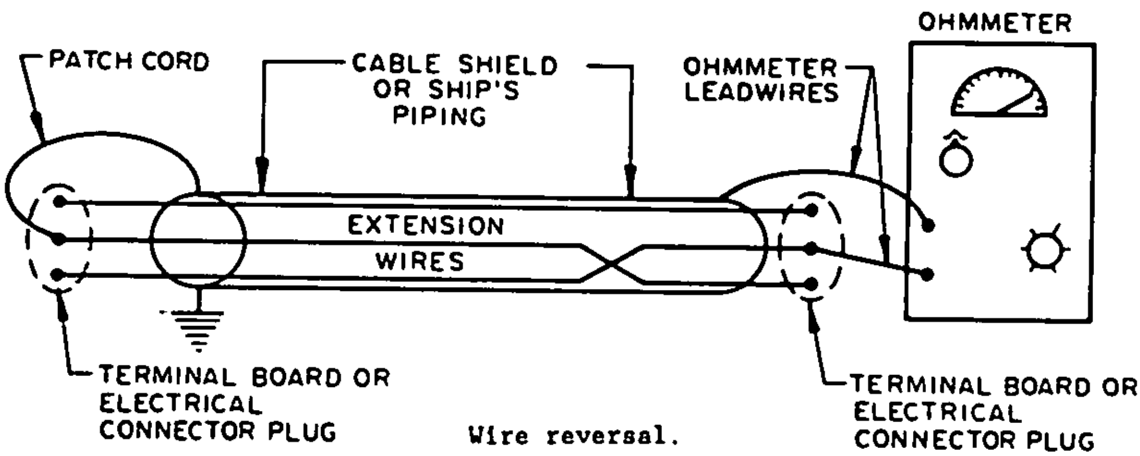


SH 132316741

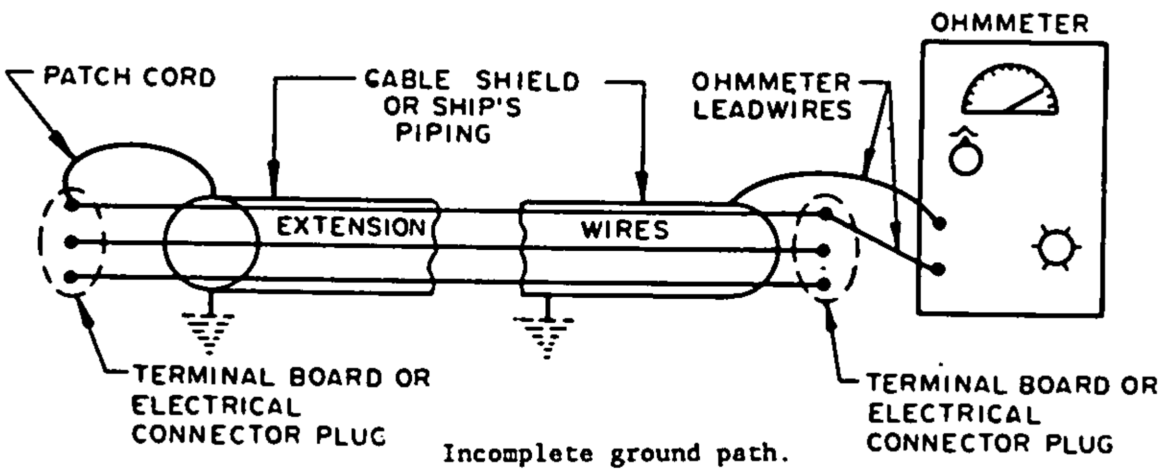
FIGURE 24. Extension wire continuity check.



Broken wire.



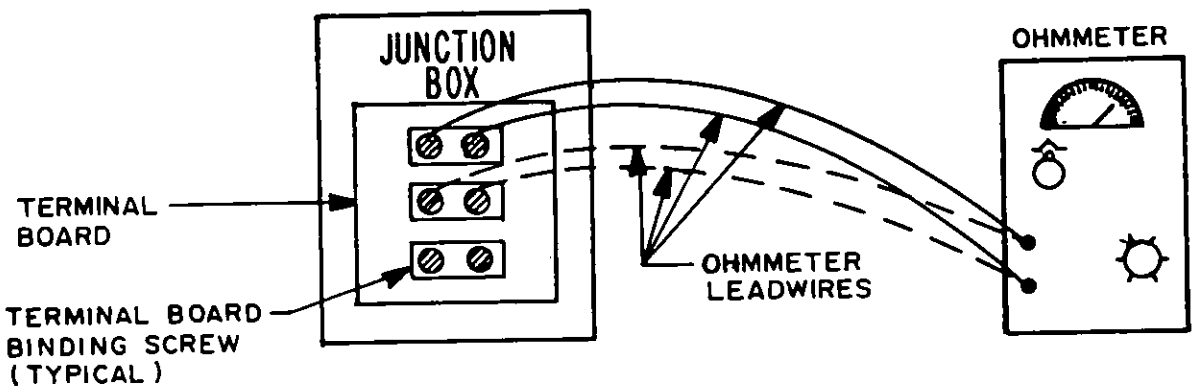
Wire reversal.



Incomplete ground path.

SH 132316742

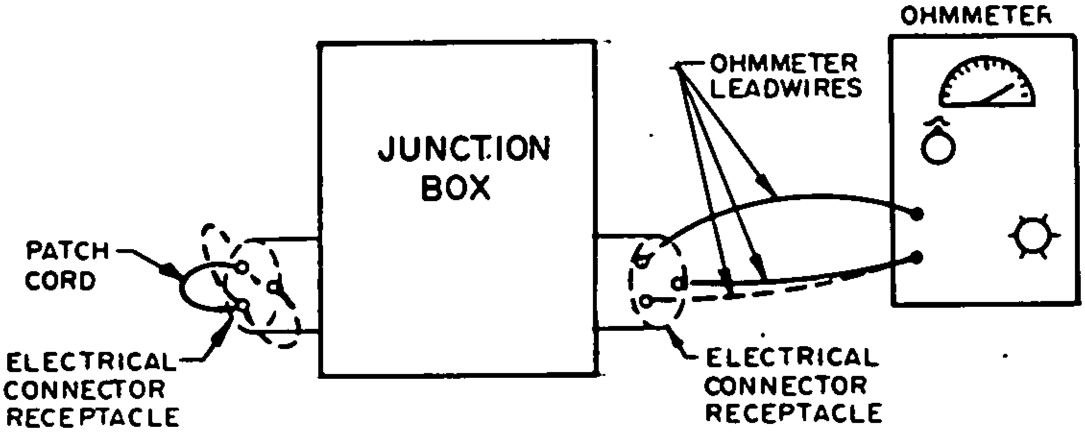
FIGURE 25. Reasons for discontinuity, three-wire configuration.



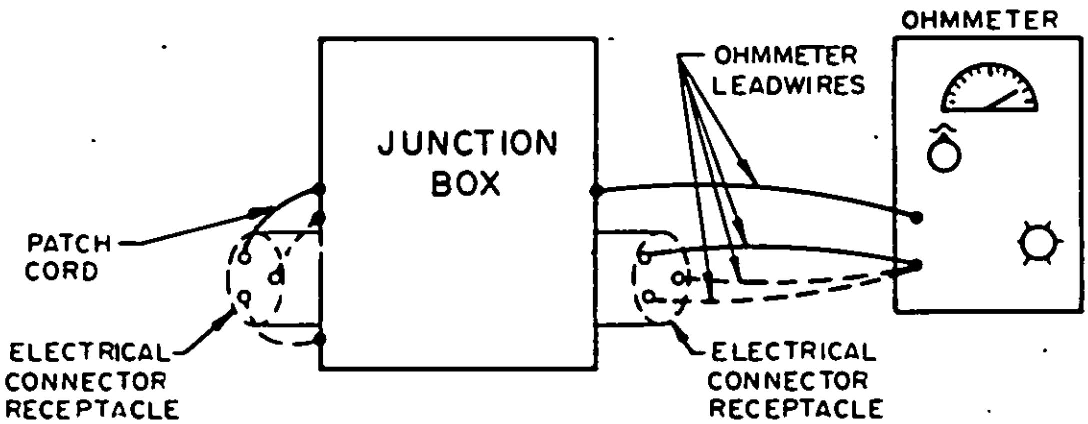
Stuffing tube cable entrance configuration.

SH 132316743

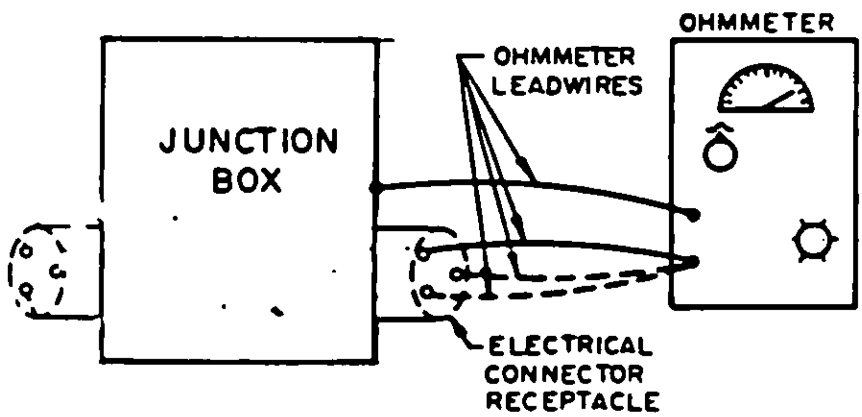
FIGURE 26. Junction box three-wire continuity check.



Electrical connector cable entrance configuration.



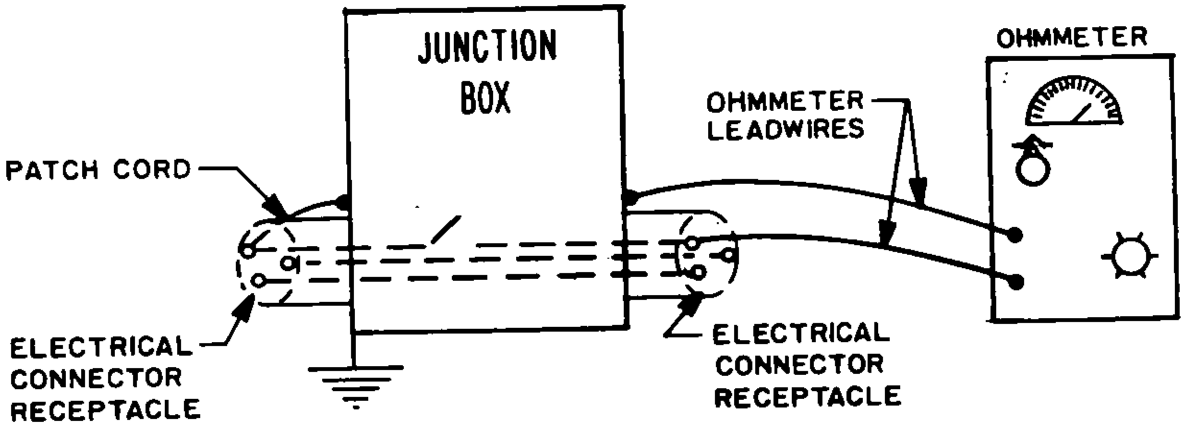
Electrical connector cable entrance configuration.



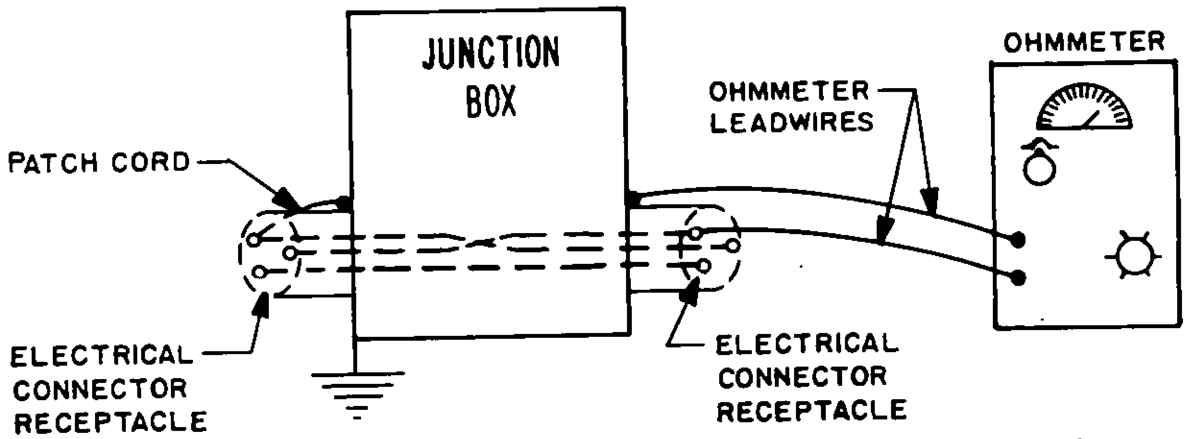
Electrical connector cable entrance configuration.

SH 132316743

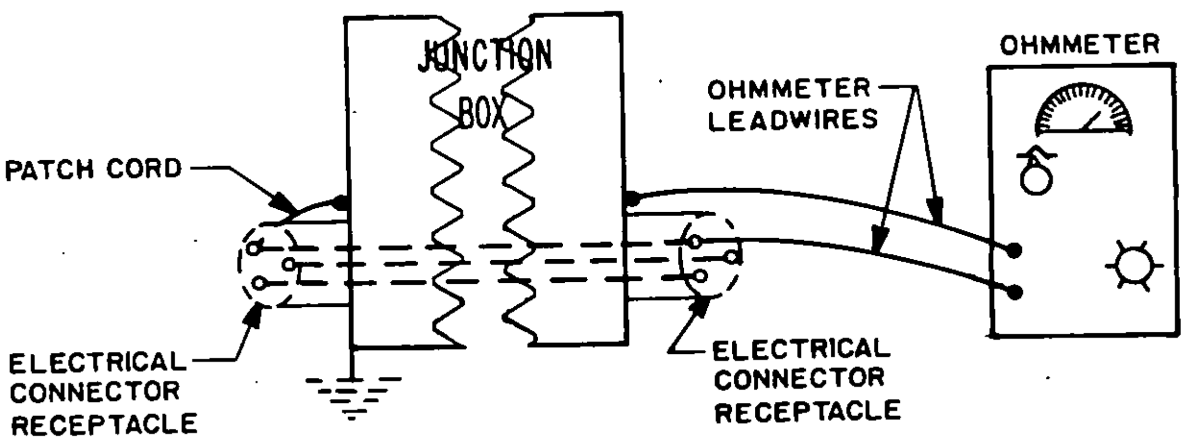
FIGURE 26. Junction box three-wire continuity check - Continued.



Broken wire.



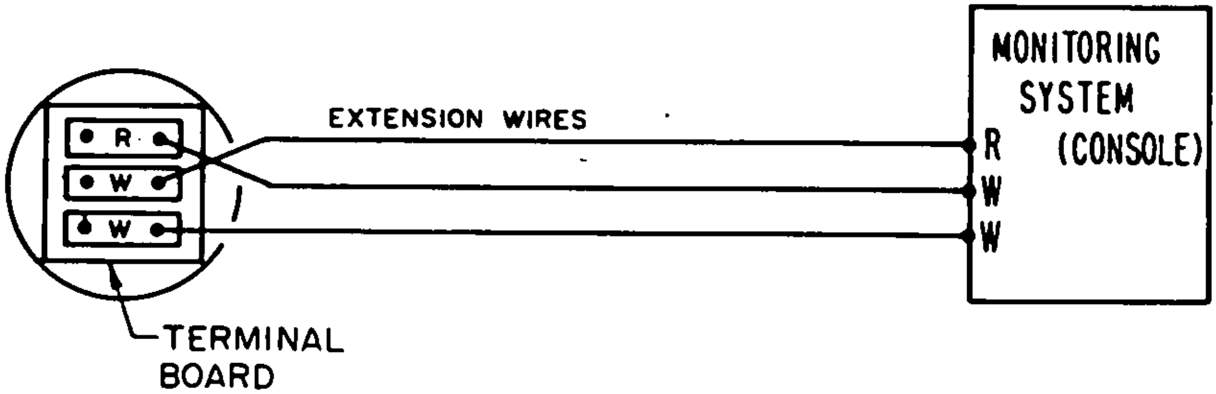
Wire reversal.



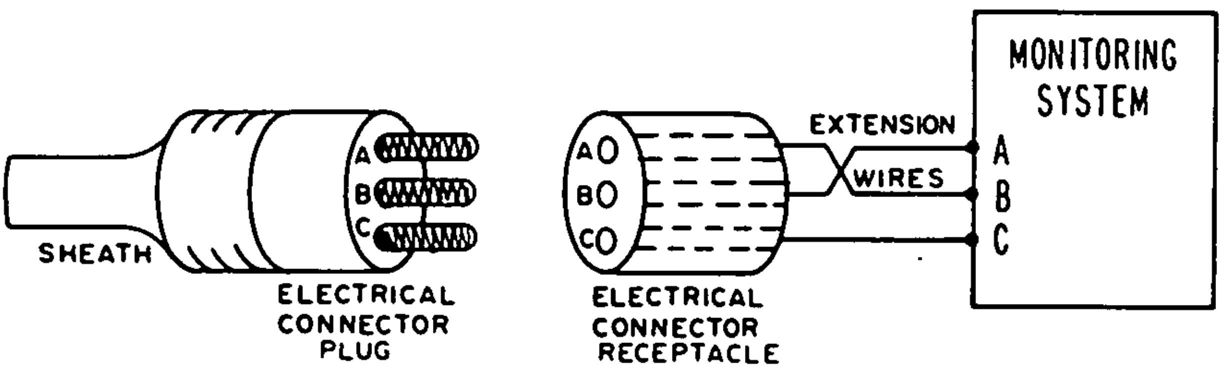
Incomplete ground path.

SH 132316744

FIGURE 27. Reasons for discontinuity, two-wire configuration.



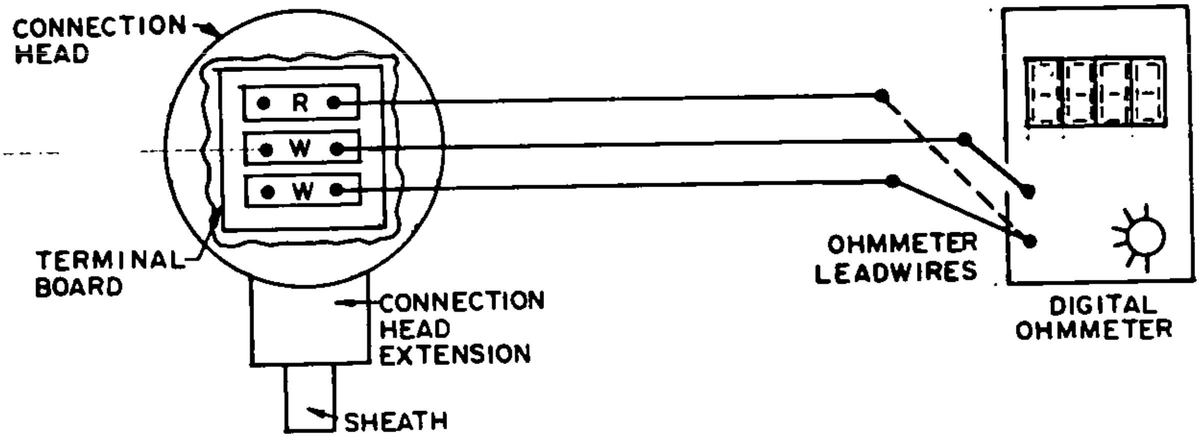
Thermowell and embedded configurations.



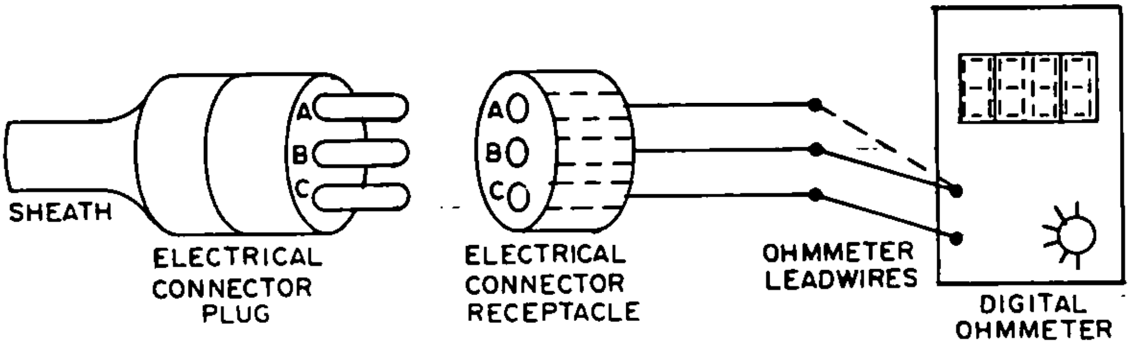
Bare bulb configuration.

SH 132316745

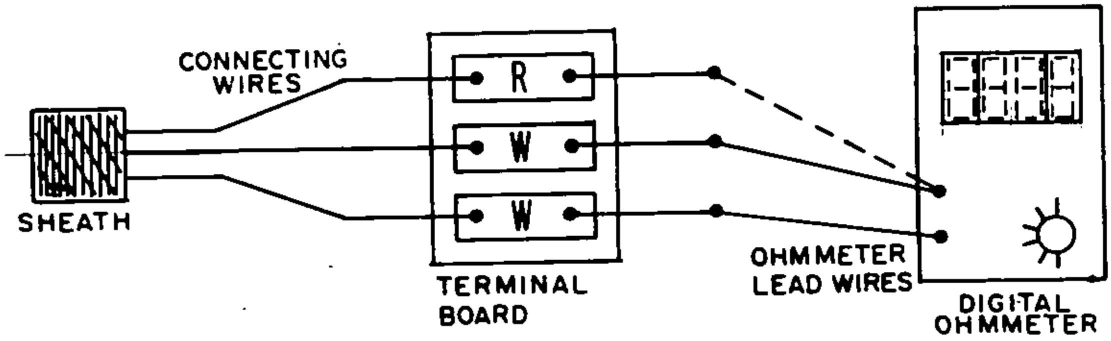
FIGURE 28. Single reversal of wire.



Thermowell configuration.



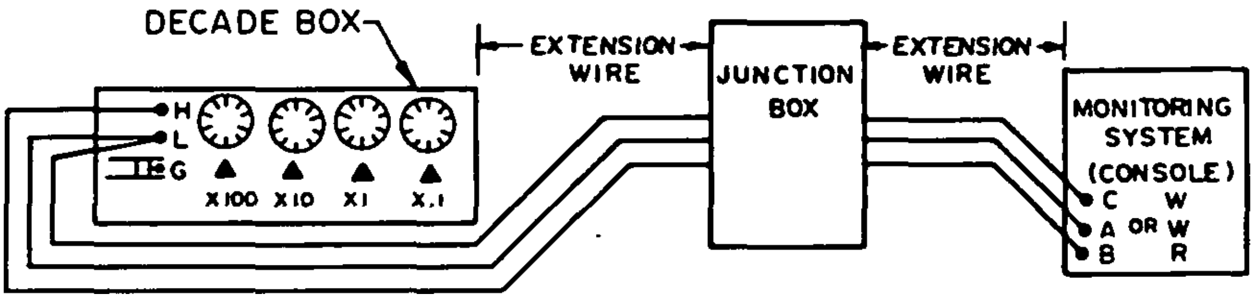
Bare bulb configuration.

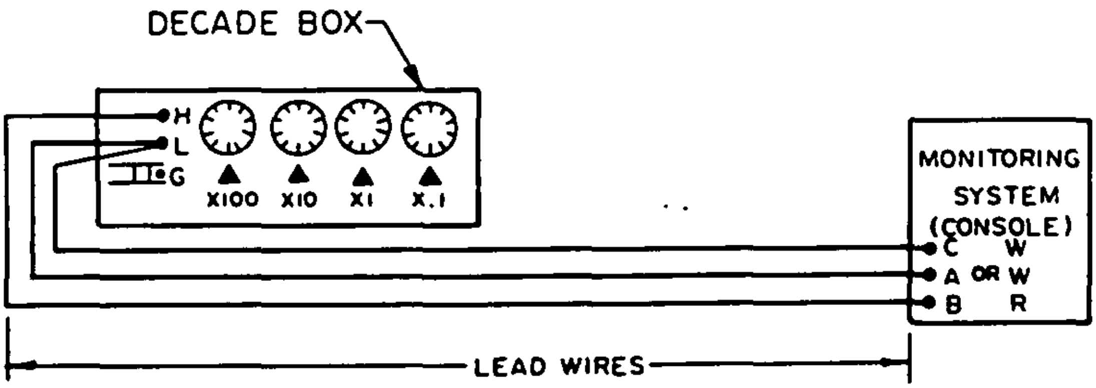


Embedded configuration.

SH 132316746

FIGURE 29. Resistance thermometer check.





SH 132316747

FIGURE 30. Resistance thermometer monitoring system check.

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER MIL-HDBK-298(SH)

2. DOCUMENT TITLE Selection, Installation And Troubleshooting Of Resistance Thermometers And Thermocouple Sensors

3a. NAME OF SUBMITTING ORGANIZATION

4. TYPE OF ORGANIZATION *(Mark one)*

- [ ] VENDOR
- [ ] USER
- [ ] MANUFACTURER
- [ ] OTHER *(Specify)*: ______

b. ADDRESS *(Street, City, State, ZIP Code)*

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional

b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional

c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional

8. DATE OF SUBMISSION *(YYMMDD)*

(TO DETACH THIS FORM, CUT ALONG THIS LINE.)

DD FORM 1426 82 MAR

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