



Standard Specification for Compacted Mineral-Insulated, Metal-Sheathed, Base Metal Thermocouple Cable¹

This standard is issued under the fixed designation E 585/E 585M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification establishes requirements for compacted, mineral-insulated, metal-sheathed, base metal thermocouple cable,² with at least two thermoelements.³

1.2 This specification describes the required material, processing and testing requirements, and also the optional supplementary testing and quality assurance and verification choices.

1.3 The material of construction includes standard base metal thermoelements, austenitic stainless steel or other corrosion resistant sheath material, and either magnesia (MgO) or alumina (Al₂O₃) insulation.

1.4 The values stated in inch-pound units or SI (metric) units may be regarded separately as standard. The values stated in each system are not the exact equivalents, and each system shall be used independently of the other.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 The following documents of the latest issue form a part of this specification to the extent specified herein. In the event of a conflict between this specification and other specifications referenced herein, this specification shall take precedence.

2.2 ASTM Standards:

A 213/A 213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes⁴

A 249/A 249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes⁴

A 269 Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service⁴

A 632 Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service⁴

B 163 Specification for Seamless Nickel and Nickel Alloy Condenser and Heat-Exchanger Tubes⁵

B 167 Specification for Nickel-Chromium-Iron Alloy (UNS N06600, N06601, and N06690) Seamless Pipe and Tube⁵

B 516 Specification for Welded Nickel-Chromium-Iron Alloy (UNS N06600, UNS N06603, UNS N06025, and UNS N06045) Tubes⁵

E 220 Method for Calibration of Thermocouples by Comparison Techniques⁶

E 230 Specification for Temperature—Electromotive Force (EMF) Tables for Standardized Thermocouples⁶

E 235 Specification for Thermocouples, Sheathed, Type K, for Nuclear or for Other High-Reliability Applications⁶

E 344 Terminology Relating to Thermometry and Hydrometry⁶

E 608 Specification for Metal-Sheathed Base-Metal Thermocouples⁶

E 780 Test Method for Measuring the Insulation Resistance of Sheathed Thermocouple Material at Room Temperature⁶

E 839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Material⁶

E 1652 Specification for Magnesium Oxide and Aluminum Oxide Powder and Crushable Insulators used in the Manufacture of Metal-Sheathed Platinum Resistance Thermometers and Noble Metal Thermocouples⁶

2.3 ANSI Standard:

B46.1 Surface Texture⁷

3. Terminology

3.1 *Definitions*—The definitions given in Terminology E 344 shall apply to this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *adjacent thermoelement configuration, n*—thermoelement configuration within a multi-pair cable where two or more positive thermoelements are immediately adjacent to one another around the circular pattern and two or more negative thermoelements are also immediately adjacent to one another

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² The terms “metal sheathed thermocouple cable” or “cable” will be used to describe the subject description.

³ “Wire” is also used to describe “thermoelements.”

⁴ *Annual Book of ASTM Standards*, Vol 01.01.

⁵ *Annual Book of ASTM Standards*, Vol 02.04.

⁶ *Annual Book of ASTM Standards*, Vol 14.03.

⁷ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

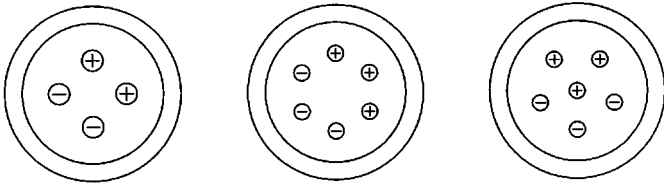


FIG. 1 Examples of Adjacent Configurations

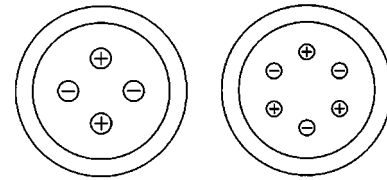


FIG. 2 Examples of Alternating Configurations

around the circular pattern as shown in Fig. 1 (compare with alternating thermoelement configuration in Fig. 2).

3.2.1.1 *Discussion*—By default, a multi-pair cable with a thermoelement in the center must be considered an adjacent configuration.

3.2.2 *alternating thermoelement configuration, n*—thermoelement configuration within a multi-pair cable where positive thermoelements and negative thermoelements alternate around the circular pattern as shown in Fig. 2 (compare with adjacent thermoelement configuration in Fig. 1).

3.2.2.1 *Discussion*—In an alternating thermoelement pattern, there are never two or more positive thermoelements nor two or more negative thermoelements immediately adjacent to one another.

3.2.3 *lot, n*—a quantity of finished mineral-insulated, metal-sheathed thermocouple cable manufactured from tubing from the same heat, wire from the same spool and heat, and insulation from the same batch then assembled and processed together under controlled production conditions to the required final outside diameter.

3.2.4 *raw material, n*—tubing, insulation, and wires used in fabrication of the sheathed thermocouple cable.

4. Significance and Use

4.1 *Thermocouple Cable may be Used as Follows:*

4.1.1 Sheathed thermocouple cable for use in manufacturing thermocouples (see Specification E 608).

4.1.2 Sheathed thermocouple cable for use as extension cable in extremely harsh environments.

5. Ordering Information and Basis for Purchase

5.1 The purchasing documents shall specify the following options:

5.1.1 The total length of finished thermocouple cable and the length of each piece of finished thermocouple cable.

5.1.2 The type and quantity of thermoelements, the thermoelement configuration (see 3.2.1 and 3.2.2), and the tolerance on initial values of emf versus temperature if other than standard (see 6.2). Consult individual manufacturers for the number of thermoelements limited by cable size.

5.1.3 The kind of sheath material (see 7.3) and whether it shall be seamless or welded and drawn. Note that other sheath material may be used with purchaser and producer agreement.

5.1.4 The nominal outside diameter of the sheath (see 6.3).

5.1.5 The kind of ceramic insulation (see 7.2). Note that other insulation composition and impurity levels may be used with purchaser and producer agreement.

5.1.6 The intended operating temperature range of the cable (see 9.8).

5.1.7 The kind of end seal applied to the open ends, prior to shipment (see 11.1).

5.1.8 Supplementary testing or material requirements (see Supplementary Requirements).

5.1.9 The quality assurance or verification program requirements or both (see Appendix X1).

5.1.10 Any deviations from this specification or the referenced documents.

6. General Requirements

6.1 *Mineral-Insulated, Metal-Sheathed Thermocouple Cable*—Cable shall be in accordance with this specification (see Fig. 3). This figure describes a cable with two thermoelements, but more than two thermoelements may be specified.

6.2 *Tolerances on Initial Values of Emf versus Temperature*—The standard tolerances of Specification E 230 apply unless otherwise stated in the ordering information.

6.3 *Dimensions*—The dimensional and tolerance requirements for sheath diameter and wall thickness, thermoelement diameter, and insulation thickness depicted in Fig. 3 shall be based on nominal sheath outside diameters. The preferred cable sizes are listed in Table 1. For any nominal sheath size, the outside diameter tolerance, *A*, shall be ± 0.025 mm [0.001 in.] or ± 1 %, whichever is greater. The wall thickness, *B*, shall be at least 10 % of the nominal sheath outside diameter and shall be uniform within 20 %. The thermoelement diameters, *D*, shall be at least 15 % of the nominal sheath outside diameter if 2 thermoelements are included, at least 12 % of the nominal sheath outside diameter if 4 thermoelements are included, or at least 9 % of the nominal sheath outside diameter if 6 thermoelements are included. The insulation thickness, *C*, either thermoelement to thermoelement or thermoelement to inside surface of the sheath, shall be at least 10% of the inside diameter of the sheath. The inside sheath diameter is equal to Diameter *A* minus 2 times dimension *B*. Dimensions shall be measured per Test Methods E 839. The purchaser need only specify the outside diameter and number of thermoelements in the ordering documents.

6.4 *Materials*—The thermocouple cable shall be fabricated from component parts specified in Section 7.

6.5 *Insulation Resistance at Room Temperature*—The minimum electric insulation resistance between thermoelements and between each thermoelement and the sheath (at room temperature) shall be as specified in Table 2, for the voltages noted. The values of insulation resistance, given in megohms, shall apply to the supplied lengths. See Test Methods E 780 and E 839.

6.6 *Minimum Insulation Density*—The minimum density of the compacted electric insulation shall be 70 % of the maximum theoretical density which is 3580 kg/m^3 [0.129 lb/in.^3] for

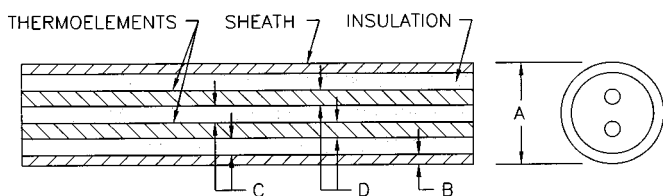


FIG. 3 Sheathed Thermocouple Material Construction
(See Table 1)

TABLE 1 Dimensions of Metal Sheathed Thermocouple Cable in SI (Metric) and Inch-Pound Units

Preferred Sizes—Nominal Outside Diameter, A, in millimetres [inches]	
Diameter	
millimetres	inches
0.50	0.020
...	0.032
1.00	0.040
1.50	0.062
2.00	...
...	0.093
3.00	0.125
4.50	0.188
6.00	0.250
8.00	0.375

TABLE 2 Room-Temperature Insulation Resistance Requirements in SI (Metric) and Inch-Pound Units

Nominal Sheath Outside Diameter	Applied Voltage, min, V, dc	Insulation Resistance, min, MΩ
Less than 0.80 mm [0.030 in.]	50	1000
0.80 to 1.45 mm [0.030 to 0.057 in.]	50	5000
Larger than 1.45 mm [0.057 in.]	500	10 000

MgO, and 3970 kg/m³[0.144 lb/in.³] for Al₂O₃.⁸ See also Supplementary Requirement S6.2.

6.7 *Sheath Condition*—The sheath shall be free of visible surface contaminants and oxidation. The sheath shall be in the fully annealed state for Type E, J, K, and N thermocouple material. For Type T material, the sheath shall be annealed to the extent that the thermoelements will permit. Tests for proving conformance are in Supplementary Requirement S2 or S9.

6.8 *Sheath Integrity*—The sheath of the finished thermocouple cable shall exclude gases and liquids. There shall be no holes, cracks, or other void defects that penetrate through the sheath wall. Tests for proving conformance to this requirement are in Supplementary Requirement S3.

6.9 Quality verification requirements are specified on an optional basis. The purchaser may require material traceability, as desired (see Appendix X1).

6.10 The tests as specified in the body of the specification are the minimum to determine if the specification requirements have been met. Additional optional supplementary requirements are listed in the Supplementary Requirements section

and may be included in the purchasing order requirements, as desired by the purchaser.

7. Material Requirements

7.1 Thermoelements:

7.1.1 The thermoelements shall be solid wire, round in cross section.

7.1.2 The thermoelements shall only be of thermoelectric types: E, J, K, N, or T. All wire used for fabrication shall meet the supplemental cleanliness requirements of Specification A 632, except that no acetone shall be used as a cleaning agent.

7.1.3 The emf versus temperature relationship shall meet the initial calibration tolerance of 6.2.

7.2 Insulation:

7.2.1 The insulation shall only be magnesia (MgO) or alumina (Al₂O₃) and shall meet the compositional requirements specified in 7.2.1.1 or 7.2.1.2.

7.2.1.1 The magnesia, if used, shall be electrically fused with a 99.4 % minimum mass content of magnesia. All impurity concentrations in the magnesia shall be less than 0.6% by mass. The total iron impurity concentration expressed as Fe₂O₃ shall not exceed 0.04% by mass. The sulfur content shall be less than 0.005% by mass, and the carbon content shall not exceed 0.02% by mass. Magnesia powders and crushable insulators conforming to Specification E 1652 satisfy these requirements.

7.2.1.2 The alumina, if used, shall be alpha alumina with a minimum mass content of 99.5 % alumina. All impurity concentrations in the alumina shall be less than 0.5% by mass. Sulfur shall not exceed 0.005% by mass while carbon shall not exceed 0.02% by mass. Alumina powders and crushable insulators conforming to Specification E 1652 satisfy these requirements.

7.3 Sheath Material:

7.3.1 The sheath material may be seamless or welded and drawn tubing of austenitic stainless steel, or heat-resistant nickel-chrome-iron alloy.

7.3.2 The producer's customary tubing specification shall be applicable for the sheath material. See Supplementary Requirement S8.

7.3.3 A nickel-chrome-iron sheath, as in Specifications B 163, B 167, or B 516, is recommended for fresh water service. There are high molybdenum stainless steels that are specifically made for use in salt water, such as type 316 and proprietary alloys.

7.3.4 Alternate heat-resistant tubing materials may be specified for the sheath by the producer, provided the annealing requirements imposed by 6.7 are satisfied.

7.3.5 Each piece of tubing used in the fabrication of thermocouple material shall meet the supplemental cleanliness requirements of Specification A 632, except that acetone may not be used as a cleaning agent.

8. Processing Requirements

8.1 The producer is responsible for all processing of all component materials to ensure that the overall requirements of this specification are met. The producer is also responsible for the quality of the finished product.

⁸ *Handbook of Chemistry and Physics*, Chemical Rubber Publishing Co., No. 76 (1995) edition.

TABLE 3 Standard Tests

Section	Test	Test Piece
9.1.1, 9.6	Dimensional inspection	Sample ^A
9.1.2, 9.7	Insulation resistance at room temperature	Sample ^A
9.1.3, 9.8	Calibration	Sample ^A
9.1.4, 9.9	Electrical continuity	Sample ^A

^A Each finished thermocouple material length shall be tested.

9. Quality Verification and Test Requirements

9.1 The following tests are required for all thermocouple cable furnished under this specification:

- 9.1.1 Dimensional inspection,
- 9.1.2 Insulation resistance at room temperature,
- 9.1.3 Calibration, and
- 9.1.4 Electrical continuity.

9.2 *Documentation*—Certificate of conformance in accordance with Section 10.

9.3 Optional testing is defined in the Supplementary Requirements section. If the purchaser desires that these tests be performed in whole, or in part, he shall so state on the purchasing documents.

9.4 A quality assurance or verification program or both, is defined in Appendix X1. The purchaser may choose this program or any part thereof, as an optional requirement.

9.5 *Standard Tests*—The producer shall perform inspection tests in accordance with Table 3. Sampling shall be performed from each lot. A lot shall not be greater than 150 m [500 ft] of finished thermocouple cable prior to cutting to shipping lengths.

9.6 *Dimensional Inspection*—The producer shall measure a sample of finished thermocouple cable to determine conformance to 6.3 for the following: outside diameter, thermoelement diameter, and sheath wall thickness. Dimensions shall be measured per Test Methods E 839. The purchaser may specify measurement of the insulation thickness. See Supplementary Requirement S6.

9.7 *Insulation Resistance at Room Temperature*—The insulation resistance of each length of cable shall be tested to determine conformance to Table 2 and 6.5.

9.8 *Calibration*—Compliance with the tolerances on initial values of emf versus temperature shall be demonstrated by calibration of a sample of finished cable. The sample shall be fabricated into a thermocouple and calibrated with the general procedures outlined in Method E 220. The tolerances on initial values of emf versus temperature are defined in Specification E 230. The calibration shall be performed in order of increasing temperature at temperatures that represent the minimum, intermediate, and maximum intended operating conditions of the finished cable. If this information is not furnished by the purchaser, calibration shall be performed at the temperatures specified in Table 4. The actual temperature of the heat source used for calibration may deviate up to 25 °C [45 °F] from the calibration temperature specified. The purchaser may specify other calibration temperatures; see Supplementary Requirement S5.

9.9 *Electrical Continuity*—The continuity of each thermoelement of each length of finished thermocouple cable shall be verified, using the producer's routine techniques.

TABLE 4 Calibration Temperatures for Standard Thermocouples

NOTE—When the material is used below 0 °C, the allowable error shall be agreed upon between the producer and the purchaser.

Thermocouple Type	Nominal Calibration Temperature	
	°C	°F
K,J,E,N	300	600
	500	900
	700	1250
T	100	200
	200	400
	300	600

10. Certification and Reports

10.1 A certificate of conformance covering the completed mineral-insulated, metal-sheathed thermocouple cable and the data taken during the testing by the producer shall be provided to the purchaser upon request. The certificate shall state that the product has been manufactured from materials specified in the purchase order, that the material was tested in accordance with this specification, that the results are in accordance with this specification, and that the test data and certifications are on file at the producer's facility. It is suggested that these records be retained for a minimum of 3 years.

11. Packaging, Marking, and Shipping

11.1 *Sealing*—All open ends of mineral-insulated, metal-sheathed thermocouple cable shall be sealed when processing allows and especially before shipment, in order to prevent entry of moisture inside the cable. Seal welding and epoxy seals are examples of techniques used for sealing.

11.2 *Cleaning Prior to Packaging*—The outer sheath shall be cleaned free of grease, oil, dirt, and other foreign substances.

11.3 The method of packaging of completed cable shall be per producer's usual practice, unless otherwise requested by the purchaser.

11.4 Each individual length of product shall be marked with the producer's name, unique lot identification number, cable diameter, type of thermoelements, kind of sheath, quantity of thermoelements, kind of insulation, and the purchaser's order number.

11.5 Each shipping container shall be legibly marked with at least the following information:

- 11.5.1 Producer's name and address,
- 11.5.2 Length of each piece of finished thermocouple cable and quantity of cables in the package,
- 11.5.3 Purchaser's order number,
- 11.5.4 Nominal diameter of material,
- 11.5.5 Sheath type,
- 11.5.6 Insulation type, and
- 11.5.7 Quantity of thermoelements and type of each thermoelement.

12. Keywords

12.1 sheathed thermocouple material; thermocouple; thermoelement

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Optional Elevated-Temperature Insulation Resistance

S1.1 *Requirements*—If this optional requirement is specified, the electrical resistance between thermoelements and between each thermoelement and sheath, when in an ungrounded condition, shall be as agreed upon between the purchaser and the producer.

S1.2 *Test Method*—Compliance with these requirements shall be demonstrated on a sample from each lot. The method for testing will also be a matter for agreement between the purchaser and the producer. See Test Methods E 839.

S2. Sheath Condition and Flexibility

S2.1 If this optional requirement is specified, the annealed sheath condition shall be demonstrated on one sample selected from each lot.

S2.1.1 Close wind the selected section of the sheathed thermocouple cable three full turns on a mandrel twice the sheath diameter. Check continuity and insulation resistance, each thermoelement to sheath and thermoelement to thermoelement before and after bending. The following is cause for rejection of the lot of material: a reduction in the insulation resistance by a factor of 10 or more, an open thermoelement, a short between the thermoelements, or a short between any thermoelement and the sheath.

S2.1.2 Cut the center turn from the section and examine under 30× magnification. Any visual evidence of sheath cracking shall be cause for rejection of the lot.

S3. Sheath Integrity Tests

S3.1 Inspect in accordance with one of the following tests from 8.1 of Test Methods E 839:

- S3.1.1 Fast Sheath Integrity Test Using Water,
- S3.1.2 Basic Sheath Integrity Test Using Water,
- S3.1.3 Sheath Integrity Mass Spectrometer Method, and
- S3.1.4 Dye Penetrant Method.

S4. Surface Finish

S4.1 If this optional requirement is specified, the outside surface of all finished thermocouple cable shall have a bright appearance with a finish no rougher than 0.81 μm [32 μin.] rms. A visual comparison made with roughness standards in accordance with ANSI B46.1 shall be acceptable.

S5. Calibration of Sample Thermocouple at Other Temperatures

S5.1 The purchaser may specify calibration tests at other temperatures in addition to, or instead of, the temperatures specified in Table 4. The upper-use temperature of both the sheath and the thermoelements should be taken into consider-

ation. For more information, see ASTM MNL 12.⁹

S6. Requirements for Measuring Insulation Thickness, Insulation Compaction Density, and Insulation Retention

S6.1 *Insulation Thickness Measurement*—The dimension C of Fig. 3 shall be determined with a microscope having at least a 60× magnification and a 2.5-mm [0.100-in.] reticle graduated in 0.02-mm [0.001-in.] increments. Sampling frequency shall be as agreed upon between the purchaser and producer.

S6.2 *Compaction Density Measurement*—If this optional requirement is specified, the test method for determining compaction density shall be agreed upon between the purchaser and the producer.

S6.3 *Insulation Retention Requirement*—If this optional requirement is specified, the test method and the acceptance levels for minimum insulation retention shall be agreed upon between the purchaser and the producer.

S7. Analysis of the Insulating Material

S7.1 If this optional requirement is specified, a certified analysis of the composition of the insulating material as supplied to the thermocouple cable producer shall be furnished to the purchaser. The thermocouple cable producer shall be responsible for maintaining the purity within the specified limits in the finished thermocouple material.

S8. Special Requirements for the Sheath

S8.1 If this optional requirement is specified, standard sheath materials shall be austenitic stainless steels as specified in Specifications A 213, A 249, A 269, and A 632 or Ni-Cr-Fe alloy. Unless otherwise specified, the thermocouple cable producer's normal specification will apply.

NOTE S8.1—The supplemental cleanliness requirements (S3) of Specification A 632 shall apply to all material supplied to this specification, except that acetone may not be used as the cleaning agent.

S8.2 *Additional Requirements*—The purchaser shall specify the name of the material and the grade. The purchaser may also specify any other options called for by the ASTM specifications.

S8.3 *Deviations*—This specification may be used for material not herein specified but any and all specifications and deviating requirements shall be agreed upon by the purchaser and the producer in the purchasing documents.

S9. Metallurgical Structure of the Sheath

S9.1 If this optional requirement is specified:

S9.1.1 A section from the sample thermocouple shall be examined for grain size of the sheath.

⁹ *Manual on the Use of Thermocouples in Temperature Measurement, ASTM MNL-12, Fourth Edition, ASTM, April 1993. (Revision of STP 407B.)*

S9.1.2 A section from the sample thermocouple shall be examined for cracks or localized wall thinning in the sheath.

S9.1.3 The test methods and the acceptance levels shall be

agreed upon between the purchaser and the producer. Specification E 235 may be used as a guide.

APPENDIX

(Nonmandatory Information)

X1. QUALITY ASSURANCE OR REQUIREMENTS QUALITY VERIFICATION, OR BOTH

X1.1 Scope

X1.1.1 This appendix shall apply only when the requirement is specified by the purchaser in the inquiry, contract, or purchase order. This appendix has been prepared as a guide for the purchaser, to determine what specific requirements should be covered by the purchaser's quality assurance documents.

X1.1.2 If specified, the producer shall be responsible for observing the requirements of the purchaser's quality assurance and verification program specifications during the manufacturing and testing of the sheathed thermocouple material. This may also include the verification of all raw materials used in their manufacture.

X1.2 Identification and Documentation

X1.2.1 Identification and documentation shall make it possible to trace any finished thermocouple material length back through production and testing to the raw materials used in that length. The producer shall identify all raw materials and thermocouple material through all phases of production, storage, and shipment. For this, the producer shall use the identification methods submitted to the purchaser for approval (and approved by the purchaser), for positive identification by labeling, tagging, and coding.

X1.3 Test Procedures

X1.3.1 All tests shall be performed in accordance with written test procedures prepared in accordance with the purchaser's quality assurance and verification program specification.

X1.3.1.1 The purchaser shall state in the ordering documents whether he will accept the producer's standard test procedures, or whether specific test procedures for the purchase order shall be prepared and submitted to the purchaser for approval.

X1.3.1.2 If the test procedures shall be submitted to the purchaser for approval, the producer shall itemize and specify the test procedure required, referencing the appropriate sections of this specification and the supplementary requirements of this specification.

X1.3.1.3 If the procedures shall include raw material procurement, then the purchaser shall so state in the ordering documents.

X1.4 Documentation

X1.4.1 All documentation shall be submitted in accordance with purchaser's quality assurance and verification program specification. It is suggested that the documentation include the following:

X1.4.1.1 The certifications covering all raw materials,

X1.4.1.2 The in-process certifications and results, and

X1.4.1.3 Certifications and test results for all routine tests stated in this specification.

X1.5 In-Process Surveillance

X1.5.1 Any in-process surveillance by the purchaser shall be determined by agreement between the purchaser and the producer and shall be covered by the purchase documents.

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