



STANDARD FOR
TELECOMMUNICATIONS CABLE
FILLED, POLYOLEFIN INSULATED,
COPPER CONDUCTOR
TECHNICAL REQUIREMENTS

Approved by

AMERICAN NATIONAL STANDARDS INSTITUTE

MAY 26, 1995

Publication # ANSI/ICEA S-84-608-1994

© 1995 by

INSULATED CABLE ENGINEERS ASSOCIATION, Inc.

Copyrighted by the ICEA
Contents may not be reproduced
in any form without permission of the
INSULATED CABLE ENGINEERS ASSOCIATION, INC.

Copies of this publication maybe obtained from:

INSULATED CABLE ENGINEERS ASSOCIATION, INC.
Post Office Box 440
South Yarmouth, Massachusetts 02664
Telephone: (508) 394-4424

STANDARD FOR
TELECOMMUNICATIONS CABLE
FILLED, POLYOLEFIN INSULATED,
COPPER CONDUCTOR
TECHNICAL REQUIREMENTS

Published By
Insulated Cable Engineers Association, Inc.
Post Office Box 440
South Yarmouth, Massachusetts 02664, U.S.A.

Second Edition

© 1995 by ICEA

Approved July 15, 1994 by
INSULATED CABLE ENGINEERS ASSOCIATION, Inc.

Approved by 9/27/94 by ANSI ASC C-8

Approved May 26, 1995 by
AMERICAN NATIONAL STANDARDS INSTITUTE

DEDICATION

In recognition of his forty years of contribution to the Wire and Cable Industry and in particular for his vision in recognizing in 1984 a need for a true Industry standard, his perseverance in organizing a broad based user/manufacturer technical forum, and his leadership in the preparation of this document until his retirement in 1987, this Standard is gratefully dedicated to:

E.D. (ED) METCALF

FOREWORD

ICEA Standards are published in the public interest and are intended to promote product uniformity and quality throughout the industry. Existence of an ICEA publication does not in any respect preclude the manufacture or use of products not conforming to the Standard.

The user of this Standard is cautioned to observe any applicable health or safety regulations and rules relative to the manufacture and use of cable made in conformity with this Standard. This Standard hereafter assumes that manufacture, testing, installation, and maintenance of cables defined by this Standard will be performed only by properly trained personnel using suitable equipment and employing appropriate safety precautions.

Questions of interpretation of ICEA Standards can only be accepted in writing at Headquarters by the Secretary, and the reply shall be provided in writing.

Suggestions for improvements in this Standard are welcome and should be sent to ICEA at the address on Page ii.

S-84-608 was the first standard developed by the Telecommunications Wire and Cable Standards Technical Advisory Committee whose membership consisted of technical experts from the manufacturing, user, and general interest segments of the industry. It was first approved and published as an ANSI (American National Standards Institute) standard on June 30, 1989. It and its companion standard, S-85-625 published in April, 1990, were patterned after an existing ICEA Standard, S-56-434. When these two standards were completed, some of the details contained in S-56-434 were not included. The most significant of these included: (1) Requirements for 16 AWG conductors, (2) Unitized color coding including both full-count and mirror image coding schemes and, (3) Provision for spare and service pairs.

This latest revision now includes those details and, in addition, the performance requirements and construction details have been updated to reflect current technologies and applications. It was approved by ICEA on July 15, 1994. With publication of this revision and the subsequent review and revision of its companion Standard, S-85-625, the need for S-56-434 will no longer exist. It is intended that S-56-434 will be discontinued. The members of the ICEA Communications Cable Section, Working Group 647, who participated in this project were:

J. S. Tyler, Chairman
A. G. Dwyer
J-H. Walling

D. K. Baker
T. McLaughlin
T. Hardin

V. B. Mascarenhas
L. Lisker

**TELECOMMUNICATIONS WIRE AND CABLE STANDARDS
TECHNICAL ADVISORY COMMITTEE**

Committee Chairman: N. J. Baer of Essex Group
Committee Vice-Chairman: Chi-Than Nguyen of Bell Canada

Individuals Who Participated in the Revision of This Standard:

Adamson, J. of Southwestern Bell
Allcock, E. of Independent Cable
Baker, D. of Independent Cable
Baker, D. K. of Superior TeleTec
Brasseaux, J. of BellSouth Telecomm.
Brown, D. of AMERITECH
Christensen, J. of Bellcore
Dwyer, A. G. of AT&T
Gurney, E. A. of GTE Telephone Operations
Hardin, T. G. of AT&T
Hessler, G. J. of USDA-REA
Hitchcock, R. E. of Bellcore
Hore, L. M. of Bellcore
Johnsen, R. of Alcatel
Kaminski, V. of Bell Atlantic
Kress, K. of Cincinnati Bell
Lange, W. E. of Alcatel
Lisker, L. S. of American Insulated Wire
Maddali, P. V. of NYNEX
Mascarenhas, V. B. of Alcatel Canada Wire
McKay, M. C. of US WEST
McLaughlin, T. of General Cable
Silva, M. of Independent Cable
Tyler, J. S. of Essex Group
Walling, J-H of Northern Telecom
Whipple, P. H. of Bellcore

CONTENTS:	SECTION	PAGE
1.	<u>GENERAL</u>	
	1.1 PURPOSE	1
	1.2 SCOPE	1
	1.3 UNITS AND TOLERANCES	2
	1.4 REFERENCES	2
	1.5 QUALITY ASSURANCE	2
	1.6 SAFETY CONSIDERATIONS	2
2.	<u>CONDUCTORS</u>	
	2.1 REQUIREMENTS	3
	2.2 FACTORY JOINTS	3
3.	<u>CONDUCTOR INSULATION</u>	
	3.1 INSULATION MATERIALS	4
	3.1.1 Propylene/Ethylene Copolymer	4
	3.1.2 High-Density Polyethylene	4
	3.1.3 Medium-Density Polyethylene	4
	3.2 INSULATION TYPE	4
	3.2.1 Solid	4
	3.2.2 Foam	4
	3.2.3 Foam-Skin	4
	3.3 INSULATION DIMENSIONS, COLORS, AND SPLICES	4
	3.4 INSULATION PHYSICAL REQUIREMENTS	5
	3.4.1 Insulation Adhesion	5
	3.4.2 Elongation	5
	3.4.3 Compression	6
	3.4.4 Cold Bend	6
	3.4.5 Shrinkback	6
	3.4.6 Thermal Oxidative Stability	6
	3.5 TWIST LENGTH AND COLOR CODING	7
4.	<u>CORE CONSTRUCTION</u>	
	4.1 CORE LAYUP	7

CONTENTS:	SECTION	PAGE
	4.2 BINDERS	9
	4.3 SPARE PAIRS	10
	4.4 CORE WRAP	11
	4.5 FILLING COMPOUND	11
	4.5.1 Type Filling Compound	12
	4.5.2 Adequacy of Fill	12
	4.6 FLOODING COMPOUND	12
	4.7 WATER SWELLABLE MATERIALS	12
5.	<u>INTERNAL SCREENS</u>	
	5.1 DESCRIPTION	12
	5.2 SCREEN MATERIAL	12
	5.2.1 Film Adhesion	13
	5.2.2 Film Delamination	13
	5.3 SERVICE PAIRS	13
6.	<u>SHIELDS</u>	
	6.1 SHIELDING SYSTEMS	13
	6.2 SHIELD MATERIALS	14
	6.2.1 8-mil Bare Aluminum Tape	14
	6.2.2 8-mil Coated Aluminum Tape	14
	6.2.3 5-mil Copper Tape	14
	6.2.4 5-mil Copper Clad Alloy Steel Tape	14
	6.2.5 5-mil Copper Clad Stainless Steel Tape	15
	6.2.6 6- and 7-mil 194 Copper Alloy Tape	15
	6.2.7 6-mil Bare Steel Tape	15
	6.2.8 6-mil Coated Steel Tape	16
	6.3 SHIELD APPLICATION	16
	6.3.1 Shield Corrugation	16
	6.3.2 Shield Overlap	16
	6.3.3 Shield Splices	17
	6.4 CORRUGATION EXTENSIBILITY	17

CONTENTS:	SECTION	PAGE
7.	<u>POLYETHYLENE INNER AND OUTER JACKET</u>	
7.1	INNER JACKET	18
7.1.1	Material and Test Requirements	18
7.1.2	Inner Jacket Thickness Requirement	18
7.2	OUTER JACKET	19
7.2.1	Raw Material	19
7.2.2	Outer Jacket Thickness Requirement	19
7.2.3	Completed Cable Material Requirements	21
7.2.4	Shrinkback	22
7.2.5	Sheath Adherence-Unbonded	22
7.2.6	Sheath Adherence-Bonded	22
8.	<u>ELECTRICAL REQUIREMENTS</u>	
8.1	DC RESISTANCE	23
8.2	DC RESISTANCE UNBALANCE	23
8.3	MUTUAL CAPACITANCE	23
8.3.1	Final Product 100% Testing	24
8.4	CAPACITANCE DIFFERENCE	24
8.5	PAIR-TO-PAIR CAPACITANCE UNBALANCE	24
8.6	PAIR-TO-GROUND CAPACITANCE UNBALANCE	24
8.7	ATTENUATION	24
8.8	UNIT CROSSTALK	25
8.8.1	Crosstalk Qualification Test	26
8.9	BETWEEN-COMPARTMENT CROSSTALK FOR SCREENED CABLES	27
8.9.1.	Requirements for all Applications	28
8.9.2	Requirements for T-1C and Similar Applications	28
8.9.3	Qualification Test Procedure	28
8.10	SCREEN INTEGRITY DIRECT CAPACITANCE TEST	28
8.11	INSULATION RESISTANCE	28

CONTENTS:	SECTION	PAGE
	8.12 CONDUCTOR-TO-CONDUCTOR DC PROOF TEST	29
	8.13 CORE-TO-SHIELD DC PROOF TEST	29
	8.14 CORE-TO-SCREEN DC PROOF TEST	29
	8.15 SHIELD RESISTANCE	29
	8.16 CONTINUITY OF METALLIC CABLE ELEMENTS	30
9.	<u>MECHANICAL REQUIREMENTS</u>	
	9.1 COMPOUND FLOW	30
	9.2 WATER PENETRATION	30
	9.3 CABLE BEND TEST	30
	9.3.1 Cold Bend Test	31
	9.3.2 Hot Bend Test	31
	9.4 CABLE IMPACT	31
	9.5 JACKET NOTCH TEST FOR STEEL SHIELDED CABLE	31
	9.6 CABLE TORSION - QUALIFICATION REQUIREMENT	32
10.	<u>GENERAL REQUIREMENTS</u>	
	10.1 IDENTIFICATION AND MARKING	33
	10.1.1 Manufacturer Identification	33
	10.1.2 Year of Manufacture	33
	10.1.3 Alternate Identification	33
	10.1.4 Jacket Marking	33
	10.1.5 Length Marking	34
	10.1.6 Defective Pair Marking	34
	10.1.7 Communication Cable Identifier	35
	10.2 END SEALING	35
	10.3 THERMAL WRAP	35
	10.4 INFORMATION ACCOMPANYING THE REEL	36
	10.5 OPTIONAL REQUIREMENTS	36
	10.5.1 Physical Reel Protection	36
	10.5.2 Pulling Eyes	36

CONTENTS:	SECTION	PAGE
	Table 1: Specifications Referenced in This Standard	37
	Figure 1: Forming of Steel Tape Overlap	40
	Figure 2: Minimum Extensibility (EXT) for Aluminum	41
	Figure 3: Minimum Extensibility (EXT) for Steel	42
	Figure 4: Sheath Adherence Sample Preparation	43
	Figure 5: Sample Preparation for Notch Test	44
	Appendix A: Test Procedure for Wicking	45
	Test Procedure for Hygroscopicity	45
	Figure A-1	46
	Appendix B: Adhesion Between Screen Aluminum and Coating	47
	Appendix C: Standard Internally Screened (IS) Cable Pair Counts	48
	Appendix D: Metallic Tape Splice Breaking Strength, Percent Retention	49

ICEA STANDARD FOR
FILLED, POLYOLEFIN INSULATED, COPPER CONDUCTOR
TELECOMMUNICATIONS CABLE
TECHNICAL REQUIREMENTS

SECTION 1 GENERAL

- 1.1 PURPOSE:** The purpose of this Standard is to establish generic technical requirements that may be referenced by individual telecommunications cable specifications covering products intended for normal outside plant use. The parameters covered provide material, construction, and performance requirements that are applicable to filled, polyolefin insulated and jacketed cables of all pair counts, including a variety of shield and jacket combinations and optional compartmental screening.

Because this Standard does not cover all details of individual cable design, it cannot be used as a single document for procurement of product. It is intended to be used in conjunction with an individual product specification that provides complete design details for the specific cable type and designates the applicable performance requirements. Such individual cable specifications may be prepared either by the user or the manufacturer. The specification designated for procurement is at the option of the user.

- 1.2 SCOPE:** This Standard covers mechanical and electrical requirements for filled, polyolefin insulated, copper conductor telecommunications cable. It provides alternative choices for type of insulation, type of filling compound, core lay-ups, color code, sheath design (shielding materials, single or double jackets, and jacket thicknesses), and screened or non-screened core.

This Standard is arranged in Sections covering one specific area of cable requirement and may be referenced as complete Sections or as individual paragraphs.

Sections of this Standard where the user must specify a particular option are listed below:

- 3.2 Insulation Type
- 4.1.3 Color Code, Super-Units (Multi-Units)
- 4.5.1 Type Filling Compound
- 5.3.3 Color Code, Service Pairs
- 6.1 Shielding Systems
- 7.1 Inner Jacket
- 7.2.1 Outer Jacket (Material Type)

- 1.3 **UNITS AND TOLERANCES:** U.S. customary units, except for temperature, are specified throughout this Standard. Approximate International System of Units (SI) equivalents and Fahrenheit temperatures are included for information only. Unless otherwise specified, the rounding-off method of ASTM E 29 shall be used for determining conformance with requirements.
- 1.4 **REFERENCES:** All documents referenced herein shall be as listed in Table 1 with issues and/or dates as indicated.
- 1.5 **QUALITY ASSURANCE:** It is the responsibility of the manufacturer to establish a quality assurance system consistent with ANSI/ASQC Q90 and Q94, or an alternate system acceptable to the user. When the user wishes to require a specific quality assurance program or special testing procedures, agreement between the user and the manufacturer should be reached before the order is placed.

Requirements provided in this Standard are of two types, qualification and product performance. Qualification requirements are intended to be proof of adequate design and processing and shall be repeated as needed for verification. Product performance requirements are those which shall be met by every length of delivered cable as assured by quality control methods. The following tests shall be performed on all reels of completed cable. The term "completed cable" refers to a continuous length of cable resulting from the last jacketing operation.

Properties that shall be tested on 100 percent of the cable lengths produced are listed below by paragraph number:

1. Jacket Thickness per Paragraph 7.1.2 and Paragraph 7.2.2
 2. Average Mutual Capacitance per Paragraph 8.3 and Paragraph 8.3.1
 3. Conductor-to-Conductor DC Proof Test per Paragraph 8.12
 4. Core-to-Shield DC Proof Test per Paragraph 8.13
 5. Core-to-Screen DC Proof Test per Paragraph 8.14
 6. Continuity of metallic cable elements per Paragraph 8.16
- 1.6 **SAFETY CONSIDERATIONS:** Materials in the cable shall present no dermal or environmental hazards as defined by current industry standards or applicable federal or state laws and regulations.

The user of this Standard is cautioned to observe any applicable health or safety regulations and rules relative to the manufacture and use of cable made in conformity with this Standard. This Standard hereafter assumes that manufacture, testing, installation, and maintenance of cables defined by this Standard will be performed only by properly trained personnel using suitable equipment and employing appropriate safety precautions.

SECTION 2 CONDUCTORS

- 2.1 REQUIREMENTS:** Each conductor shall be a solid wire of commercially pure annealed copper and shall meet the quality requirements of ASTM B 3 except that requirements for "Dimensions and Permissible Variations" are not applicable and elongation requirements are superseded by this Standard. The conductor sizes shall be 16, 19, 22, 24, 26, and 28 American Wire Gauge (AWG) per ASTM B 258. The following nominal diameters are stated for reference only:

Conductor Size (AWG)	Nominal Diameter	
	Inch	(mm)
16	0.0508	(1.290)
19	0.0359	(0.912)
22	0.0253	(0.643)
24	0.0201	(0.511)
26	0.0159	(0.404)
28	0.0126	(0.320)

When tested in accordance with ASTM E 8, the minimum conductor elongation in final cable shall be:

Conductor Size (AWG)	Minimum Elongation(%)
16	24
19	22
22	20
24	16
26	12
28	8

- 2.2 FACTORY JOINTS:** Prior to insulating, factory joints in conductors may be either butt brazed, using a silver alloy solder and nonacid flux, or butt welded. Joints in uninsulated conductors shall be free from lumps and sharp projections. Subsequent to insulating, solder sleeves may also be used. The tensile strength of any conductor containing a joint shall not be less than 90% of the strength of an adjacent length of conductor outside the joint area.

SECTION 3 CONDUCTOR INSULATION

- 3.1 INSULATION MATERIAL:** Base resin(s) used for conductor insulation shall be one or more of the three insulating grade polyolefin materials listed under Paragraphs 3.1.1, 3.1.2, and 3.1.3. The polyolefin shall consist of 100% virgin material as defined in ASTM D 883. The insulation shall contain a stabilization system sufficient to pass the Thermal Oxidative Stability Test of Paragraph 3.4.6 B. Insulation for all conductors in a single length of cable shall be the same.
- 3.1.1** A propylene/ethylene copolymer (polypropylene) conforming to ASTM D 4101, Class PP 200 B 40003 E11.
- 3.1.2** A high-density polyethylene conforming to ASTM D 1248, Type III, Class A, Category 4 or 5, Grade E9.
- 3.1.3** A medium-density polyethylene conforming to ASTM D 1248, Type II, Class A, Category 4 or 5, Grade E4.
- 3.2 INSULATION TYPE:** Type of conductor insulation shall be either solid, foam, or foam-skin as defined in Paragraph 3.2.1, 3.2.2, or 3.2.3. Specific type of insulation required for any product shall be designated by the individual product specification that provides cable construction details.
- 3.2.1** Solid. Insulation shall be colored solid polyolefin material. Solid insulation shall be capable of meeting all applicable requirements of this Standard.
- 3.2.2** Foam. Insulation shall be colored cellular polyolefin material. Foam insulation shall be capable of meeting all applicable requirements of this Standard.
- 3.2.3** Foam-Skin. Insulation shall consist of an inner layer of natural polyolefin foam material covered by a continuous outer layer of colored solid polyolefin insulation. Foam-skin insulation shall be capable of meeting all applicable requirements of this Standard.
- 3.3 INSULATION DIMENSIONS, COLORS, AND SPLICES:** The insulation shall be as uniform and smooth as is consistent with good commercial practice. The nominal diameter of the insulation shall be such that all applicable electrical requirements of this Standard are met. Eccentricity of the insulation shall be determined in accordance with the procedure of ASTM D 4565 and shall not exceed the following requirements:

Conductor Size (AWG)	Eccentricity	
	Inch	(mm)
16	0.004	(0.10)
19	0.004	(0.10)
22	0.003	(0.08)
24	0.002	(0.05)
26	0.002	(0.05)
28	0.002	(0.05)

The insulation shall be uniformly colored as specified under type requirements of Paragraph 3.2 using the following ten colors:

RING	TIP
Blue (BL)	White (W)
Orange (O)	Red (R)
Green (G)	Black (BK)
Brown (BR)	Yellow (Y)
Slate (S)	Violet (V)

Colors of the insulation are specified in terms of the Munsell Color System of ASTM D 1535 and shall comply with ANSI/EIA-359-A, "EIA Standard Colors for Color Identification and Coding".

Splices in the insulated conductors shall be reinsulated with a non-hygroscopic, dielectric material. There shall be no exposed conductor at the splice. Insulated splices in finished cable shall be capable of meeting all applicable electrical requirements of this Standard.

3.4 INSULATION PHYSICAL REQUIREMENTS: Unless otherwise specified, insulation taken from each gauge size of completed cable shall meet the applicable requirements listed under this Section.

3.4.1 Insulation Adhesion. Adhesion of the insulation to the conductor shall be such that a maximum force of 6 (27), 5 (22), 4 (18), 3 (13), 2.5 (11), and 2 (9) lbf (N), respectively, for 16, 19, 22, 24, 26, and 28 AWG is required to strip insulation from the conductor when tested in accordance with ASTM D 4565 at $23 \pm 2^{\circ}\text{C}$ ($73 \pm 4^{\circ}\text{F}$) and a rate of travel of 2 ± 1 inches (51 ± 25 mm) per minute.

3.4.2 Elongation. Elongation of the insulation removed from the conductor shall not be less than 300% when tested in accordance with ASTM D 4565. The minimum length of unclamped specimen shall be 2.0 inches (51 mm). The

minimum speed of jaw separation shall be 1.0 inch (25 mm) per minute per inch (25 mm) of unclamped specimen. The temperature of specimens and surroundings shall be $23 \pm 2^{\circ}\text{C}$ ($73 \pm 4^{\circ}\text{F}$).

- 3.4.3 Compression.** Foam and foam-skin insulated conductors, when tested in accordance with ASTM D 4565, shall withstand the compression requirements specified below using a rate of approach not to exceed 0.02 inch (0.51 mm) per minute.

Conductor Size (AWG)	Minimum Compressive Force for 2 inch (51 mm) Sample	
	lbf	(N)
16	160	(712)
19	160	(712)
22	110	(489)
24	85	(378)
26	45	(200)
28	45	(200)

- 3.4.4 Cold Bend.** Insulated conductors shall show no cracks when tested in accordance with ASTM D 4565, when observed with normal or corrected-to-normal vision. The test temperature shall be $-40 \pm 2^{\circ}\text{C}$ ($-40 \pm 4^{\circ}\text{F}$) with a mandrel diameter of three times the outside diameter of the insulated conductor.
- 3.4.5 Shrinkback.** Insulation shrinkback shall not exceed 3/8 inch (10 mm) when tested at $115 \pm 1^{\circ}\text{C}$ ($239 \pm 2^{\circ}\text{F}$) in accordance with ASTM D 4565. All changes in insulation length which occur from the time the samples are cut shall be included.
- 3.4.6 Thermal Oxidative Stability.** Insulation of the completed cable shall be capable of meeting the following requirements:
- A. Qualification Requirement.** Qualification testing to predict lifetime performance of this product is presently under review. Until such requirements are included in this Standard, specific test requirements may be included in individual product specifications.
 - B. Product Performance Requirement.** A sample length of cable shall be preconditioned in a forced air circulating oven, conforming to ASTM D 5423, Type II, for 14 days at $70 \pm 1^{\circ}\text{C}$ ($158 \pm 2^{\circ}\text{F}$). Insulation specimens removed from the sample shall meet a minimum oxidative induction time of 20 minutes for solid and 60 minutes for foam or foam-skin when tested in

accordance with ASTM D 4565. Test temperature shall be $200 \pm 1^{\circ}\text{C}$ ($392 \pm 2^{\circ}\text{F}$). The copper conductors shall be removed from the insulation before testing. Pan material for the tests shall be aluminum.

Alternately, the foam and foam-skin insulation may be tested at $210 \pm 1^{\circ}\text{C}$ ($410 \pm 2^{\circ}\text{F}$) and shall meet a minimum oxidative induction time of 25 minutes. In case of dispute, the 200°C test shall be used as the referee method.

- 3.5 **TWIST LENGTH AND COLOR CODING:** Insulated conductors shall be formed into pairs using twist lengths that will ensure that the finished cables shall be capable of meeting the finished cable electrical requirements of this Standard. The average twist length of any pair in the finished cable shall not exceed 6.5 inches (165 mm).

Insulated conductors shall be formed into pairs in accordance with the following color code and pair designations:

Pair Number	Conductor		Pair Number	Conductor	
	Ring	Tip		Ring	Tip
1	Blue	White	14	Brown	Black
2	Orange	White	15	Slate	Black
3	Green	White	16	Blue	Yellow
4	Brown	White	17	Orange	Yellow
5	Slate	White	18	Green	Yellow
6	Blue	Red	19	Brown	Yellow
7	Orange	Red	20	Slate	Yellow
8	Green	Red	21	Blue	Violet
9	Brown	Red	22	Orange	Violet
10	Slate	Red	23	Green	Violet
11	Blue	Black	24	Brown	Violet
12	Orange	Black	25	Slate	Violet
13	Green	Black			

- 3.5.1 In cables having more than 25 pairs, the pair color code of 3.5 above shall be repeated and each group of 25 pairs shall be distinguished by colored binders in accordance with Paragraph 4.2.2.

SECTION 4 CORE CONSTRUCTION

- 4.1 **CORE LAYUP:** Unless otherwise specified by the manufacturer, or the individual cable product specification referencing this Standard, core layups shall be as follows:
- 4.1.1 In cables having 25 pairs or less, the twisted pairs shall be assembled in layers to form a substantially cylindrical core. Adjacent layers may be cabled in the

same direction or in opposite directions. Cables having 25 pairs or less may also be composed of subgroups in lieu of the concentric layer construction.

- 4.1.2 In cables having more than 25 pairs, the twisted pairs shall be grouped, each group being bound by threads or tape. Each group shall contain not more than 25 pairs, excluding spare or service pairs. When desired for lay-up reasons, the basic 25-pair groups may be divided into two or more subgroups called units. Each unit in a particular 25-pair group shall be bound with binder threads or binder tapes of the colors indicated in the Table below for its particular 25-pair group. The pair count shall be consecutive from 1 to 25 as given in Paragraph 3.5 through the units in a group.

Group No.	Color of Binders*	Group Pair Count
1	White-Blue	1-25
2	White-Orange	26-50
3	White-Green	51-75
4	White-Brown	76-100
5	White-Slate	101-125
6	Red-Blue	126-150
7	Red-Orange	151-175
8	Red-Green	176-200
9	Red-Brown	201-225
10	Red-Slate	226-250
11	Black-Blue	251-275
12	Black-Orange	276-300
13	Black-Green	301-325
14	Black-Brown	326-350
15	Black-Slate	351-375
16	Yellow-Blue	376-400
17	Yellow-Orange	401-425
18	Yellow-Green	426-450
19	Yellow-Brown	451-475
20	Yellow-Slate	476-500
21	Violet-Blue	501-525
22	Violet-Orange	526-550
23	Violet-Green	551-575
24	Violet-Brown	576-600

* Use of the white binder in cables of 100 pair or less is optional.

- 4.1.3 When desired for manufacturing reasons, two or more 25-pair groups may be bound together with threads or tapes to form super-units (multi-units).

- 4.1.3.1 Super-unit binders shall be of the color shown below.

Pair Numbers	Color of Binders	Abbreviation
1-600	White	W
601-1200	Red	R
1201-1800	Black	BK
1801-2400	Yellow	Y
2401-3000	Violet	V
3001-3600	Blue	BL
3601-4200	Orange	O
4201-4800	Green	G
4801-5400	Brown	BR
5401-6000	Slate	S

- 4.1.3.2 Alternately, when agreed to by the purchaser and the manufacturer, cables having more than 900 pairs may be assembled with a "mirror-image" color code. With this type of color code, the cable is assembled from super-units. Within each super-unit, the binders identifying the 25-pair groups shall be the same as for cables with the same number of pairs as given in Paragraph 4.1.2. For a super-unit with a given number of pairs, the super-units are identically color coded except for the colors of the super-unit binders. Each super-unit will have two colors for the super-unit binder or binders. The first color defines a super-unit's position within a layer, and the second color defines its layer within the cable. To indicate the layer, all super-units within a given layer shall have a common binder color. The color shall be yellow for super-units in the outermost layer, black for super-units in the next layer, then yellow, then black, etc., going toward the center of the cable core. To indicate its location within a layer, one super-unit in the center of the cable core and one super-unit in each layer shall have green as its second binder color. The green bound super-unit serves as a marker and establishes the starting point for counting within any layer. The green bound super-unit is flanked by red bound super-units, then blue bound super-units, then red, then blue, etc. In any cable having more than one layer of super-units, no super-unit shall be farther than one super-unit from its position relative to the super-units of adjacent layer(s).

- 4.2 BINDERS: All binders shall be of a nonwicking and nonhygroscopic dielectric material. Nonwicking and nonhygroscopic are defined in Appendix A. If required for manufacturing reasons, a binder may be applied over the core, core wrap, or metallic shield(s). Binders for units shall be polyolefin tapes. Binders for super-units and the core shall be polyolefin or

polyester tapes or threads. Unit and super-unit binders shall meet the color requirements for insulation in Paragraph 3.3.

- 4.2.1 The binders shall be colored to indicate the sequence of groups for pair identification. Binders shall be applied with a lay length of not more than 4 inches (100 mm).
- 4.2.2 The colors of the binders and their significance with respect to pair count shall be as shown in Paragraph 4.1.2 or 4.1.3.2.
- 4.2.3 Unless otherwise permitted by the user, color binders shall not be missing for more than 300 feet (90 m) from any 25-pair group or from any subgroup used as part of a super-unit. At any cable cross-section, no adjacent 25-pair groups and no more than one subgroup of any super-unit may have missing binders. In no case shall the total number of missing binders exceed three. Missing super-unit binders are not permitted for any distance.
- 4.2.4 **Binder Shrinkback (Raw Material):** Binder tape or thread used for binding units shall not exceed 10% shrinkback. Tape or thread used for binding multiunits shall not exceed 13% shrinkback. The following test procedure shall be used:

Cut 3.0-inch (76-mm) specimens and measure their length to the nearest 0.01 inch (0.2 mm). Place the specimens on a 0.25-inch (6.4-mm) bed of talc in a petri dish and place in a circulating air oven maintained at $115 \pm 2^{\circ}\text{C}$ ($239 \pm 4^{\circ}\text{F}$). After 18 hours, remove, cool to room temperature and remeasure the length to the nearest 0.01 inch (0.2 mm).
- 4.3 **SPARE PAIRS:** In cables of 600 pair and greater, spare pairs may be included at the option of the manufacturer or user. Spare pairs may be used to replace defective pairs containing either a short, cross, or open so as to guarantee the nominal pair count of good, working pairs.
 - 4.3.1 The number of spare pairs included may be up to 0.5% of the cable's nominal pair count, but in no case shall the number of spare pairs exceed 15.
 - 4.3.2 When included, the spare pairs shall be color coded in accordance with Table below. The spare pairs may be placed within groups and under the group binders or in the interstices between groups or super-units in the outer layer of the cable core.

Color Code for Spare or Service Pairs

Spare/Service Pair Number	Tip Conductor	Ring Conductor
1	White (W)	Red (R)
2	White (W)	Black (BK)
3	White (W)	Yellow (Y)
4	White (W)	Violet (V)
5	Red (R)	Black (BK)
6	Red (R)	Yellow (Y)
7	Red (R)	Violet (V)
8	Black (BK)	Yellow (Y)
9	Black (BK)	Violet (V)
10	Yellow (Y)	Violet (V)
11	Blue (BL)	Orange (O)
12	Blue (BL)	Green (G)
13	Blue (BL)	Brown (BR)
14	Blue (BL)	Slate (S)
15	Orange (O)	Green (G)
16	Orange (O)	Brown (BR)
17	Orange (O)	Slate (S)
18	Green (G)	Brown (BR)

- 4.4 **CORE WRAP:** The cable core shall be completely covered with one or more layers of nonhygroscopic and nonwicking dielectric material. Nonhygroscopic and nonwicking are defined in Appendix A. This dielectric core wrap may be replaced with, laminated to, or covered by a water swellable material which is designed to block water ingress into the cable. In this case the requirements of Appendix A are waived.

The core wrap shall be applied with an overlap. It shall provide a sufficient heat barrier to prevent visible deformation of conductor insulation or adhesion between insulated conductors caused by heat transfer during subsequent operations.

The core wrap shall provide adequate dielectric strength to meet the core-to-shield dc proof test requirement of Paragraph 8.13.

- 4.5 **FILLING COMPOUND:** Filling compound shall be applied in a manner to fill the voids and interstices under the core wrap. The filling material shall be a homogeneous, uniformly mixed compound meeting all requirements of this Standard. It shall contain a suitable antioxidant to provide long-term stability.

The compound shall be as colorless as required to maintain pair, unit and group identification and shall be free from foreign matter. The filling compound shall be compatible with the insulation, jacket, and shield coating when tested in accordance with ASTM D 4568 at a temperature of $80 \pm 1^{\circ}\text{C}$ ($176 \pm 2^{\circ}\text{F}$).

- 4.5.1 **Type Filling Compound.** The following types of filling compound are included in this Standard:

PEPJ - Polyethylene/Petroleum Jelly
ETPR - Extended Thermoplastic Rubber
EPW - Extended Petroleum Wax
ATG - Absorbant Thixotropic Gel

Type of filling compound and minimum compound flow temperature as listed in Paragraph 9.1 shall be specified by the individual product specification. Filling compounds and flow test temperatures other than those designated in Paragraph 9.1 may be specified by the user.

- 4.5.2 **Adequacy of Fill.** Tests for determining adequacy of fill and water penetration are provided in Paragraphs 8.4 and 9.2, respectively.

- 4.6 **FLOODING COMPOUND:** A flooding compound may be provided as a moisture barrier. The flooding compound shall be compatible with the jacket and shield coating when tested in accordance with ASTM D 4568 at a temperature of $80 \pm 1^{\circ}\text{C}$ ($176 \pm 2^{\circ}\text{F}$). The flooding compound shall have adhesive properties capable of meeting the Sheath Adherence-Unbonded requirement of Paragraph 7.2.5.

- 4.7 **WATER SWELLABLE MATERIALS:** Water swellable materials designed to block the ingress of water may be used within the interstices of the cable. When used the requirements of Appendix A are waived.

SECTION 5 INTERNAL SCREENS

- 5.1 **DESCRIPTION:** When required by the product specification, an internal separator screen(s) shall be included in the cable construction that will provide two core compartments capable of meeting the crosstalk requirements of Paragraph 8.9.
- 5.2 **SCREEN MATERIAL:** The internal screen(s) shall be an electrically continuous aluminum alloy material meeting the requirements of Paragraph 6.2.1 except the metal thickness shall not be less than 0.0036 inch (0.09 mm). The aluminum screen(s) shall be coated or enveloped with an insulating film capable of meeting the dc proof test requirement of Paragraph 8.14. There shall be no channels or air pockets under the coating where water could run or accumulate.

When two resin-coated tapes are to be joined, the coating shall be removed prior to making the splice. After joining, the splice shall be coated with a dielectric material and shall contain no voids.

- 5.2.1 **Film Adhesion:** Adhesion of the film to aluminum shall be tested per Appendix B both at $23 \pm 2^{\circ}\text{C}$ ($73 \pm 4^{\circ}\text{F}$) after water aging and at $80 \pm 1^{\circ}\text{C}$ ($176 \pm 2^{\circ}\text{F}$) in the as-received condition (without water aging). When tested at $23 \pm 2^{\circ}\text{C}$ ($73 \pm 4^{\circ}\text{F}$) in accordance with Appendix B, Paragraphs C and E, the adhesion values of the samples tested shall be 3.0 lbf/inch (525 N/m) minimum. When tested at $80 \pm 1^{\circ}\text{C}$ ($176 \pm 2^{\circ}\text{F}$) in accordance with Appendix B, Paragraphs D and E, the average adhesion values of the samples tested shall be 0.9 lbf/inch (158 N/m) or higher with no value less than 0.5 lbf/inch (88 N/m).
- 5.2.2 **Film Delamination:** The coated screen material shall be capable of being aged at $80 \pm 1^{\circ}\text{C}$ ($176 \pm 2^{\circ}\text{F}$) and tested in accordance with ASTM D 4568 without delamination of the film from the aluminum tape.
- 5.3 **SERVICE PAIRS:** Service pairs may be provided for voice order, fault locate and pressure check.
 - 5.3.1 The number of service pairs normally provided shall be one per twenty five carrier pairs plus two for cable sizes up to and including 400 pairs, subject to a minimum of four service pairs. Standard pair counts for Internally Screened (IS) cables are given in Appendix C.
 - 5.3.2 For cable sizes above 400 pairs, the number of service pairs required shall be provided as agreed to by the user and manufacturer.
 - 5.3.3 The color code of the service pairs shall be as shown in Paragraph 3.5 or 4.3.2. The service pairs shall be located either all on one side of the screen or equally divided between the two sides. When divided, the color sequence shall be repeated on each side of the screen.

SECTION 6 SHIELDS

- 6.1 **SHIELDING SYSTEMS:** The shielding system may consist of single tape or dual tape construction as listed below. The type of shielding system required for each individual cable shall be specified by the product specification and shall be identified as one of the following types:

Single Tape Types

8-mil Bare Aluminum
 8-mil Coated Aluminum
 5-mil Copper
 5-mil Copper Clad Alloy Steel
 5-mil Copper Clad Stainless Steel
 6- and 7-mil 194 Copper Alloy

Dual Tape Types

8-mil Bare Aluminum & 6-mil Bare Steel
 8-mil Bare Aluminum & 6-mil Coated Steel
 8-mil Coated Aluminum & 6-mil Bare Steel
 8-mil Coated Aluminum & 6-mil Coated Steel

6.2 SHIELD MATERIALS: The shielding material specified by the product specification shall meet the applicable raw material requirements of this Section. It shall be electrically continuous throughout the cable.

6.2.1 8-mil Bare Aluminum Tape. The aluminum tape shall be Alloy 1060, 1100, 1145, or 1235 and shall conform to ASTM B 736. The tape shall be nominally 0.008 inch (0.20 mm) thick with a minimum thickness of 0.007 inch (0.18 mm).

6.2.2 8-mil Coated Aluminum Tape. Bare aluminum tape meeting the requirements of Paragraph 6.2.1 shall be coated on one or two sides with a protective resin material in accordance with ASTM B 736, Type I, Class 2. One- or two-side coated tape may be used as specified by the product specification.

The minimum thickness of the coating shall be 0.0015 inch (0.038 mm).

6.2.3 5-mil Copper Tape. The 5-mil copper tape shall conform to ASTM B 694. The tape shall be nominally 0.005 inch (0.13 mm) thick with a minimum thickness of 0.0046 inch (0.12 mm).

6.2.4 5-mil Copper Clad Alloy Steel Tape. The 5-mil copper clad alloy steel tape must be in the fully annealed condition and the copper component must conform to the requirements of ASTM B 224-80 and the alloy steel component must conform to the requirements of ASTM A 505-87, with a cladding ratio of 16/68/16.

6.2.4.1 The electrical conductivity of the clad tape must be a minimum of 28 percent of the International Annealed Copper Standard (IACS) when measured per ASTM B 193-87.

- 6.2.4.2 The tape must be nominally 0.005 in. (0.13 mm) thick with a minimum thickness of 0.0045 in. (0.11 mm).
- 6.2.5 5-mil Copper Clad Stainless Steel Tape. The 5-mil copper clad stainless steel tape must be in the fully annealed condition and must conform to the requirements of ASTM B 694-86, with a cladding ratio of 16/68/16.
- 6.2.5.1 The electrical conductivity of the copper clad alloy steel tape must comply with the requirement specified in Paragraph 6.2.4.1 of this specification.
- 6.2.5.2 The thickness of the copper clad alloy steel tape must comply with the requirements specified in Paragraph 6.2.4.2 of this specification.
- 6.2.6 6- and 7-mil 194 Copper Alloy Tape. The 194 copper alloy tape shall conform to ASTM B 694. 6-mil tape shall be used for cables with an overall jacket diameter greater than 0.60 inch (15 mm). 7-mil tape shall be used for cables of 0.60-inch (15-mm) diameter and smaller. The minimum tape thicknesses shall be as shown below:

Nominal Thickness 194 Copper Alloy Tape	Minimum Thickness	
	inch	(mm)
6-mil	0.0055	(0.14)
7-mil	0.0065	(0.17)

- 6.2.7 6-mil Bare Steel Tape. The steel tape shall be nominally 0.006 inch (0.15 mm) thick with a minimum thickness of 0.0055 inch (0.14 mm) and shall be one of the following materials:

Black plate steel per ASTM A 625
 Tin-plated steel per ASTM A 624
 Terne coated steel per ASTM A 308
 Electrolytic chrome coated steel (ECCS) per ASTM A 657
 Tin-plated electrolytic chrome coated steel (ECCS)
 per ASTM A 624 and A 657

The steel shall have a maximum tensile strength of 60,000 psi (414 MPa) and a minimum elongation of 15% for a 2.0-inch (51-mm) specimen length when tested in accordance with ASTM A 370. Steel composition shall be certified on a basis of heat analysis and shall be as follows:

Element	Maximum Percent (Weight)
Carbon	0.13
Manganese	0.60
Phosphorus	0.02
Sulfur	0.05

- 6.2.8 **6-mil Coated Steel Tape.** Steel tape meeting the requirements of Paragraph 6.2.7 shall be coated on one or two sides with a protective resin material which shall meet the bonding-to-metal, heat sealability, lap-shear, and moisture resistance requirements of ASTM B 736, Type I, Class 2. One- or two-side coated tape may be used as specified by the product specification.

The minimum thickness of the coating shall be 0.0015 inch (0.038 mm).

- 6.3 **SHIELD APPLICATION:** The cable shield(s) shall be longitudinally applied over the core wrap for a single jacketed construction and over the inner jacket for a double jacketed construction. The shield(s) may be either flat or corrugated as designated by the product specification.

When a dual shield (aluminum and steel) construction is specified by the product specification, the aluminum tape shall be applied over the core wrap for a single jacketed construction and over the inner jacket for a double jacketed construction. The steel tape shall be applied directly over the aluminum tape.

- 6.3.1 **Shield Corrugation.** Shields shall be corrugated at right angles to the longitudinal axis of the cable. The corrugation profile shall be approximately sinusoidal. The reduction in shield thickness due to the corrugation and application process shall not exceed 10% for aluminum or copper bearing shields and 5% for steel. The shield(s) shall not split, crack, or tear as the result of corrugating and forming.

- 6.3.2 **Shield Overlap.** All single tape shields applied over wrapped cores (or inner jacket for double jacketed cables) with a diameter of 0.75 inch (19 mm) or less shall have an edge overlap of at least 1/8 inch (3 mm). All shields applied over wrapped cores (or inner jacket for double jacketed cables) greater than 0.75 inch (19 mm) in diameter shall have a minimum overlap of 3/16 inch (5 mm).

When a dual tape shielding system consisting of aluminum and steel tapes is provided, the edges of the inner aluminum tape may overlap but not coincidental with the steel shield. If the aluminum tape does not overlap, the gap between the edges of the formed aluminum tape shall not exceed 0.2 inch (5 mm) plus 4% of the total circumference as measured over the core wrap or inner jacket, when used.

The outer steel tape shall be formed with a minimum overlap of 1/8 inch (3 mm) where the diameter over the inner aluminum shield is 0.75 inch (19 mm) or less. For diameters greater than 0.75 inch (19 mm), the minimum overlap shall be 3/16 inch (5 mm). The overlap shall be formed to minimize notching of the outer jacket. An acceptable example is shown in Figure 1. Other shapes of the formed edge may be used.

- 6.3.3 Shield Splices.** The breaking strength of any section of shield containing a splice shall not be less than 80% of the breaking strength of an adjacent section of shield of equal length without a splice when tested in accordance with Appendix D. For aluminum or copper bearing tapes, a 3-foot (0.9-m) section of shield containing a splice shall have a resistance not greater than 110% of the resistance of an adjacent section of shield of equal length without a splice.

When two resin-coated tapes are to be joined, the coating shall be removed prior to making the splice. After joining the tapes, the splice shall be coated with a dielectric material and shall contain no voids.

- 6.4 CORRUGATION EXTENSIBILITY:** Corrugated metal from the completed cable, when tested as defined in the following procedure, shall elongate without breaking to the minimum percent extensibility shown in Figure 2 for aluminum or Figure 3 for steel. The test is limited to tape materials listed below with tensile loads in lbf per inch (N/mm) width of specimen as specified:

Shield Tape Metal	Tensile Load Limits	
	lbf/inch	(N/mm)
Aluminum	52 to 55	(9.1 to 9.6)
Steel	176 to 180	(30.8 to 31.5)

- A. For this test, a straight sided specimen, approximately 5.0 inches (127 mm) long (perpendicular to the corrugations) and 0.25 inch (6.4 mm) to 0.5 inch (12.7 mm) wide shall be formed without deforming the sample. The gauge length shall be indicated by markings applied to the specimen before removing from the cable.
- B. Tension shall be applied to the specimen. Within the specified load range, the specimen shall elongate without breaking until:

$$P = \frac{(L2 - L1)}{L1} \times 100$$

where:

P = Minimum extensibility, percent
 L1 = Initial gauge length, inches (mm)
 L2 = Final gauge length, inches (mm)

Gauge length L1 and L2 shall be determined from measurements made directly on the specimen. The indicated gauge length shall remain entirely outside of the clamped portion of the specimen during the test.

- C. The pulling direction shall be perpendicular to the corrugation crests. The strain rate shall not exceed 1.0 inch (25 mm) per minute per inch (25 mm) of gauge length. The minimum gauge length shall be 1.0 inch (25 mm). Additional length shall be provided as required for clamping.
- D. The requirement is fulfilled if the first specimen tested in accordance with the above demonstrates the minimum required extensibility. The test need not proceed to breaking of the specimen. If the first specimen fails to meet the requirement, two additional specimens may be tested in accordance with the above. If both specimens achieve the minimum extensibility, the requirement is fulfilled.

SECTION 7 POLYETHYLENE INNER AND OUTER JACKET

- 7.1 **INNER JACKET:** A polyethylene inner jacket shall be provided over the core wrap and under the shield(s) when required by the product specification. The jacket shall be free from holes, splits, blisters, or other imperfections and shall be as smooth as is consistent with good commercial practice. Repair of holes or other imperfections in the jacket is not permitted without approval of the user.
- 7.1.1 **Material and Test Requirements.** The inner jacket material and test requirements shall be as specified for the outer jacket under Paragraph 7.2, except that either black or natural polyethylene may be used. In the case of natural polyethylene, the requirements for absorption coefficient and the inclusion of furnace black are waived.
- 7.1.2 **Inner Jacket Thickness Requirement.** The inner jacket thickness at any point shall not be less than 0.032 inch (0.8 mm). The thickness shall be determined from measurements on 2-inch (51-mm) samples taken not less than 1 foot (0.3 m) from either end of the cable. The average shall be determined from 4 readings taken approximately 90° apart on any cross

section of the sample. The maximum and minimum points shall be determined by exploratory measurements. The maximum thickness minus the minimum thickness at any cross section shall not exceed 40% of the average jacket thickness at that cross section.

- 7.2 OUTER JACKET: A black polyethylene outer jacket shall be provided over the cable shield(s). The jacket shall be free from holes, splits, blisters, or other imperfections and shall be as smooth as is consistent with good commercial practice. Repair of holes or other imperfections in the jacket is not permitted without approval of the user.

- 7.2.1 Raw Material. The jacket compound shall be a polyethylene material of one of the three types listed below and shall be capable of meeting all finished cable jacket requirements specified in Paragraph 7.2.3. The raw material shall contain an antioxidant to provide long term stabilization and a $2.60 \pm 0.25\%$ concentration of furnace black to provide ultraviolet shielding. Both the antioxidant and furnace black shall be compounded into the polyethylene before jacket extrusion.

Type L1. Material in conformance with the requirements of ASTM D 1248, Type I, Class C, Category 4 or 5, Grade J3. This type generally corresponds to a composition that incorporates low-density polyethylene as the base resin.

Type L2. Material in conformance with the requirements of ASTM D 1248, Type I, Class C, Category 4 or 5, Grade J3. This type generally corresponds to a composition that incorporates linear low-density polyethylene as the base resin.

Type M. Material in conformance with the requirements of ASTM D 1248, Type II, Class C, Category 4 or 5, Grade J4. This type generally corresponds to a composition that incorporates medium-density polyethylene as the base resin.

- 7.2.2 Outer Jacket Thickness Requirement. In a completed cable, when continuous thickness measurements are made during manufacture, the minimum jacket thickness at any point and the minimum average thickness at any cross section shall meet the requirements in the following table. If jacket thickness is determined by end measurement, the minimum thickness at any point and the minimum average thickness at any cross section shall be increased over the values in the table by 0.010 inch (0.25 mm). The minimum point shall be determined by exploratory measurements. The minimum average thickness at any cross section shall be determined from four readings including the minimum point, taken approximately 90° apart. The thickness measurement shall exclude any polyethylene that has formed into the corrugations.

Average Diameter (D) Over Core Wrap or Inner Jacket, If Applicable inch (mm)	Minimum Jacket Thickness inch (mm)	Minimum Average Thickness inch (mm)
Less than 1.29 (32.8)	0.039 (1.0)	0.047 (1.2)
1.29 (32.8) to 3.00 (76)	0.014D + 0.021 (0.014D + 0.53)	0.017D + 0.025 (0.017D + 0.64)
More than 3.00 (76)	0.063 (1.6)	0.076 (1.9)

The maximum thickness at any cross section shall not be greater than 155% of the minimum thickness. The eccentricity of the jacket shall not exceed 43% and shall be calculated as follows:

$$\frac{\text{Max. Thickness} - \text{Min. Thickness}}{\text{Average Thickness}} \times 100$$

7.2.3 Completed Cable Jacket Material Requirements. Samples of jacket removed from completed cable shall meet all of the following material requirements:

Property	Units	Method	Jacket Material			
			L1	L2	M	
Density	g/cc	ASTM D 1505, clean sample	Min. Max.	0.920 0.940	0.925 0.945	0.940 0.955
Ultimate Elongation, Minimum	percent	ASTM D 638, Die V for samples < 1.5 inches OD, 0.5-inch/minute speed, 1.0-inch jaw separation; Die IV for samples ≥ 1.5 inches OD 2-inch/minute speed, 2.5-inch jaw separation; all samples cut perpendicular to cable axis with no metal seam impressions within gauge length.		400	400	400
Yield Strength, Minimum	psi (MPa)	See Ultimate Elongation		1000 (6.9)	1200 (8.3)	1600 (11.9)
Absorption Coefficient, Minimum	ABS/mm	ASTM D 3349, clean sample		400	400	400
Oxidative Stability, Minimum	minutes	*ASTM D 3895, aluminum pan, unhomogenized clean sample		20	20	20
Stress Crack Resistance	hours	Prepare with clean samples per ASTM D 4565, samples cut perpendicular to cable axis, no metal seam impression in sample, Test per ASTM D 1693, Condition A for Types L1 and L2, Condition B for Type M; no failures allowed.		48	48	48

Test Procedure Notes:

- Test methods designating "clean sample" require that any residual flooding or bonding compounds be removed from the surface of the sample by other than chemical means. Those not so designated shall include these materials if they cling to the jacket.
- Requirements for absorption coefficient of the raw material may be substituted for tests on completed cable by agreement with the user.
- The Stress Crack Resistance requirement applies to cables having an outside diameter of 1.2 inches (30.5 mm) or greater.

- d) Jackets should be removed from aluminum or steel bonded sheath constructions in accordance with the Procedure provided under Paragraph 9.5 C.

7.2.4 Shrinkback. Samples of jacket removed from the completed cable, when tested in accordance with ASTM D 4565, shall meet a shrinkback requirement of less than 5% resulting from exposure for 4 hours in an oven at a temperature of $100 \pm 1^\circ\text{C}$ ($212 \pm 2^\circ\text{F}$). As an exception to ASTM D 4565, 4 specimens, 2 inches (51 mm) long (parallel to the cable axis) and 0.25 inch (6.4 mm) wide, shall be cut from the jacket. One of the specimens shall be cut from a portion of the jacket lying directly over the outer shield overlap and the other three shall be taken at successive 90 degree increments to the overlap.

7.2.5 Sheath Adherence - Unbonded. Cables that do not require bonding between the shield and outer jacket shall be capable of meeting the following sheath adherence requirement:

A cable sample 12.0 ± 0.5 inches (305 ± 13 mm) long shall have the gripping fixtures of a tensile tester clamped to only the polyethylene jacket at one end and to the core and outer metal shield at the other end, as shown in Figure 4. The metal-jacket interface shall be not less than 60°C (140°F) during the test and the jaw speed shall not exceed 10 inches (254 mm) per minute.

The force required to initiate slippage between the jacket and underlying shield shall be a minimum of 8.0 lbf/inch (1.4 N/mm) of circumference. The diameter over the underlying shield shall be used to determine circumference.

7.2.6 Sheath Adherence - Bonded. Cables that require a bond between a coated metal shield and outer jacket shall be capable of meeting the following sheath adherence requirement when tested in accordance with ASTM D 4565:

For cables having a bonded steel sheath, tests shall be made at 18°C to 27°C (64°F to 81°F) and at $60 \pm 2^\circ\text{C}$ ($140 \pm 4^\circ\text{F}$). The bond shall have a minimum strength of 10 lbf/inch (1.7 N/mm) of specimen width when measured at 18°C to 27°C (64°F to 81°F) and 7 lbf/inch (1.2 N/mm) of specimen width at $60 \pm 2^\circ\text{C}$ ($140 \pm 4^\circ\text{F}$) for two of three samples.

For cables having a bonded aluminum sheath, the adhesion shall be 3.5 lbf/inch (0.6 N/mm) minimum at the same test temperatures specified above.

SECTION 8 ELECTRICAL REQUIREMENTS

- 8.1 DC RESISTANCE:** The maximum dc resistance of any conductor in a completed length of cable and the average resistance of all conductors in a Quality Control lot shall not exceed the requirements listed below. Measurement shall be in accordance with ASTM D 4566. As used in this Standard, lot average is defined as the average of all individual measurements performed on cable(s) comprising a Quality Control lot.

Conductor Size (AWG)	OHMS PER SHEATH-MILE (km) Corrected to 20°C (68°F)	
	Individual	Lot Average
16	23.2 (14.3)	22.2 (13.8)
19	45.0 (28.0)	44.0 (27.3)
22	91.0 (56.6)	88.5 (55.0)
24	144.0 (89.5)	140.0 (87.0)
26	232.0 (144.2)	225.0 (139.8)
28	385.0 (239.2)	373.0 (231.8)

- 8.2 DC RESISTANCE UNBALANCE:** When tested in accordance with ASTM D 4566, the resistance unbalance between the two conductors of any pair in a completed cable shall not exceed 5.0% for 16, 19, 22, 24, and 26 AWG and 6.0% for 28 AWG when measured at or corrected to 20°C (68°F). The average resistance unbalance of all pairs of a cable under test shall not exceed 1.5% for 16, 19, 22, 24, and 26 AWG and 2.5% for 28 AWG. The average resistance unbalance of all pairs in a Quality Control lot shall not exceed 1.1% for 16, 19, 22, 24 and 26 and 1.8% for 28 AWG.
- 8.3 MUTUAL CAPACITANCE:** The average mutual capacitance of all the pairs of any length of cable and the individual mutual capacitance of any pair shall meet the following requirements at 1 kHz with all other conductors, screen, and shield(s) grounded. Measurements shall be made in accordance with ASTM D 4566 at or corrected to $23 \pm 2^\circ\text{C}$ ($73 \pm 4^\circ\text{F}$).

MUTUAL CAPACITANCE nF/mile (nF/km)		
No. of Pairs	Average of All Pairs	Maximum Any Pair
12 or less	83 ± 7 (52 ± 4)	94 (58)
13 or More	83 ± 4 (52 ± 2)	92 (57)

- 8.3.1 Final Product 100% Testing.** For cables larger than 100 pairs, if the average mutual capacitance for the first 100 pairs tested from randomly selected groups is between 80 and 85 nF/mile (50 and 53 nF/km), the remainder of the pairs need not be tested.
- 8.4 CAPACITANCE DIFFERENCE:** For completed cables having 75 pairs or more, the percent difference in average mutual capacitance for the innermost and outermost pairs shall not exceed 2%. Measurement shall be made in accordance with ASTM D 4566 at or corrected to $23 \pm 2^{\circ}\text{C}$ ($73 \pm 4^{\circ}\text{F}$) except that the sample size shall not be less than 5 outer pairs and 5 inner pairs. This test is required to determine if the core is adequately filled throughout the cable cross section.
- 8.5 PAIR-TO-PAIR CAPACITANCE UNBALANCE:** When measured in accordance with ASTM D 4566, the pair-to-pair capacitance unbalance between any two pairs of a cable at 1 kHz shall not exceed 80 pF/kft (145 pF/km) at or corrected to $23 \pm 2^{\circ}\text{C}$ ($73 \pm 4^{\circ}\text{F}$). For cables of more than 12 pairs, the maximum rms pair-to-pair unbalance of all pairs shall not exceed 25 pF/kft (45 pF/km).
- 8.6 PAIR-TO-GROUND CAPACITANCE UNBALANCE:** When measured at 1 kHz in accordance with ASTM D 4566, the pair-to-ground capacitance unbalance of the completed cable at or corrected to $23 \pm 2^{\circ}\text{C}$ ($73 \pm 4^{\circ}\text{F}$) shall not exceed the following requirements:

CAPACITANCE UNBALANCE-TO-GROUND pF/kft(pF/km)				
AWG	No. of Pairs	Lot Average	Cable Average	Individual Pair
16 to 26	12 or Less	---	---	800(2625)
16 to 26	13 or More	120(394)	175(574)	800(2625)
28	All Sizes	155(509)	225(738)	800(2625)

- 8.7 ATTENUATION:** The average attenuation of all pairs of a completed cable having more than 12 pairs shall not exceed the values in the following table when measured in accordance with ASTM D 4566. For cables of 12 pairs or less, the average attenuation shall not exceed a value increased by 10% over the requirements in the table. Requirements shall be met at 772 kHz only unless the 150 kHz requirements are specified by the user.

AVERAGE ATTENUATION AT 20°C (68°F) dB/kft (dB/km)				
Conductor Size (AWG)	Solid		Foam or Foam-Skin	
	150 kHz	772 kHz	150 kHz	772 kHz
16	-- --	2.1 (6.8)	-- --	2.6 (8.4)
19	1.3 (4.3)	2.8 (9.2)	1.4 (4.6)	3.2 (10.5)
22	1.8 (5.9)	4.0 (13.1)	2.0 (6.6)	4.5 (14.8)
24	2.4 (7.9)	5.0 (16.4)	2.7 (8.9)	5.6 (18.4)
26	3.6 (11.8)	6.5 (21.3)	3.8 (12.5)	7.1 (23.3)
28	5.0 (16.4)	8.6 (28.2)	5.5 (18.0)	9.0 (29.5)

- 8.8 **UNIT CROSSTALK:** The power sum crosstalk of a pair, when measured between pairs within each unit of completed cable and determined in accordance with the qualification procedure covered in Paragraph 8.8.1, shall be equal to or greater than the requirements listed below for Equal Level Far End and Near End Crosstalk.

EQUAL LEVEL FAR END CROSSTALK (FEXT) REQUIREMENTS Power Sum in dB/kft (dB/305 m)										
Frequency (MHz)	Mean Power Sum					Worst Pair Power Sum				
	(AWG)					(AWG)				
	16 & 19	22	24	26	28	16 & 19	22	24	26	28
0.150	65	63	63	61	59	59	57	57	57	57
0.772	51	49	49	47	45	45	43	43	43	43
1.600	44	43	42	41	40	39	37	37	37	37
3.150	39	37	37	35	33	33	31	31	31	31
6.300	33	31	31	29	27	27	25	25	25	25

NEAR END CROSSTALK (NEXT) REQUIREMENTS Power Sum in dB/kft (dB/305 m)										
Frequency (MHz)	Mean Power Sum					Worst Pair Power Sum				
	(AWG)					(AWG)				
	16 & 19	22	24	26	28	16 & 19	22	24	26	28
0.150	58	58	58	58	58	53	53	53	53	53
0.772	47	47	47	47	47	42	42	42	42	42
1.600	43	43	43	43	43	38	38	38	38	38
3.150	38	38	38	38	38	33	33	33	33	33
6.300	34	34	34	34	34	29	29	29	29	29

- 8.8.1 Crosstalk Qualification Test: Selection of pairs for qualification testing shall exclude any T-carrier service pairs provided in a screened cable. Pair-to-pair crosstalk shall be measured at five frequencies (0.150, 0.772, 1.600, 3.150, and 6.300 MHz) between all pair combinations within a 50-pair unit having a specific twist length design. Crosstalk measurements on one unit may be assumed to apply to the entire cable so long as all units have the same twist length design.

One cable of at least 1000 feet (305 m) shall be selected at random from each of five different manufacturing batches. If the maximum cable reel length is less than 1000 feet (305 m), it may be used as long as it is over 500 feet (152 m). The values of power sum crosstalk calculated for the length of cable measured shall be corrected to the reference length of 1000 feet (305 m) using the following equations:

$$NEXT \text{ in dB / kft (dB / 305 m) } = next + 10 \cdot \log \left[\frac{1 - 10^{-\frac{aL}{5}}}{1 - 10^{-\frac{a}{5}}} \right]$$

$$FEXT \text{ in dB/kft (dB/305 m) } = fext + 10 \log L$$

where:

- a = Average attenuation in dB/kft (dB/305 m) at the measurement frequency
- L = Cable length in kilofeet
- next = Measured value of NEXT in dB
- fext = Measured value of FEXT in dB

Each of these cables shall be measured for far-end (FEXT) and near-end (NEXT) crosstalk using all pair and frequency combinations within groups of 50 consecutive pairs. Power sum calculations for each pair at each frequency shall then be made. It is recommended that a set of power sums for the individual pairs of cable be plotted on probability paper to check the normality of the distribution of power sums.

The 50 pairs measured shall be members of the same 50-pair multiunit where these exist in a design. If no 50-pair multiunits are present, adjacent units shall be chosen to make up a 50-pair group. In this case, the 50-pair group must consist of a whole number of units; it may contain no partial units. If the same twist length assignments are used throughout all units in a cable, then the results for any one 50-pair group shall be taken to characterize the design. Otherwise, tests shall be made on each unique 50-pair unit design and the results for the worst 50-pair group taken as the performance of the overall cable.

The average mean and average worst pair of the five cables shall meet or exceed the requirements of this Standard. If the sample averages for the first set of five cables fail to meet these requirements, two additional, independent sets of five cables each should be selected and tested. Failure of either of the additional sets is cause for investigation into process control methods.

- 8.9 BETWEEN-COMPARTMENT CROSSTALK FOR SCREENED CABLES:** When tested in accordance with Paragraph 8.9.3, the completed cable shall meet the requirements of Paragraphs 8.9.1 or 8.9.2 as required by the product specification.
- 8.9.1 Requirements for All Applications.** Near-end power sum crosstalk (NEXT) between pairs on opposite sides of the compartment screen shall be determined in accordance with the procedure of Paragraph 8.9.3. All cables shall have no pair with less than 70 dB power sum coupling loss when measured at 772 kHz.
- 8.9.2 Requirements for T-1C and Similar Applications.** When cables are to be used with T-1C Carrier or other systems requiring similar high frequency performance, the between-compartment power sum coupling loss shall be not less than 78 dB at 1600 kHz.
- 8.9.3 Qualification Test Procedure.** The between-compartment near-end power sum crosstalk (NEXT) shall be measured at the frequencies specified in Paragraph 8.9.1 or 8.9.2 between all combinations of pairs selected as discussed below.

Four cables of at least 1000 feet (305 m) shall be selected at random for measurement. Two cables shall be the smallest production pair size and two cables shall be the largest production pair size. If the maximum cable reel length is less than 1000 feet (305 m), it may be used as long as it is over 750

feet (229 m). The values of power sum crosstalk calculated for the length of cable measured shall be corrected to the reference length of 1000 feet (305 m) using the NEXT length correction equation in Paragraph 8.8.1.

If the cable contains 100 pairs or less, each pair on one side of the screen shall be measured against each pair on the other side. If the cable contains more than 100 pairs, the unit or units selected for measurement on the first side shall be shown to have the worst crosstalk to the other side of the screen. The 50 pairs selected on the first side of the screen shall be members of the same 50-pair multiunit where these exist in the design. If no 50-pair multi units are present, adjacent units shall be chosen to make up a 50-pair group and must consist of a whole number of units.

The 50 pairs selected on the second side of the screen shall be selected equally from every 25-pair group so that all groups are represented. Each twist length shall appear at least twice in the selected 50-pair group.

Power sum calculations for each pair at each frequency shall then be made. The pair having the lowest power sum crosstalk shall meet or exceed the requirements. If any sample of the first set of four cables fails to meet the requirement, two additional independent sets of four cables should be selected and tested. Failure of either set of the additional cables is cause for investigation into process control methods.

8.10 SCREEN INTEGRITY DIRECT CAPACITANCE TEST: The direct capacitance between compartments of screened cables shall be tested as follows:

- A. For cables of less than 100 pairs, the direct capacitance between: (1) all conductors on one side of the screen electrically connected together and (2) all conductors on the other side of the screen, similarly connected, shall be measured at any frequency between 5 and 1000 Hz. The screen and shield shall be guarded. The direct capacitance shall not exceed the requirements provided by the product specification.
- B. For cables of 100 pairs and larger, the direct capacitance measured between the shield and all the pairs connected together in a selected unit in the cable outside layer shall not exceed the requirements provided by the product specification when measured at a frequency between 5 and 1000 Hz. All other units and the cable screen shall be guarded during the test. The unit selection for this test shall be as specified in the product specification.

8.11 INSULATION RESISTANCE: Each insulated conductor of a completed cable shall have an insulation resistance greater than 1.0 gigohm·mile (1.6 gigohm·km) when tested in accordance with ASTM D 4566. The tests shall be made with all conductors, other than the one under test, and the screen (if present) grounded to the shield(s).

- 8.12 CONDUCTOR-TO-CONDUCTOR DC PROOF TEST:** The insulation between each conductor and all other conductors, in each completed cable, shall withstand the following dc voltages when tested in accordance with ASTM D 4566:

Conductor Size (AWG)	DC Test Voltage (kV)	
	Foam or Foam-Skin	Solid
16	6.0	8.5
19	4.5	7.0
22	3.6	5.0
24	3.0	4.0
26	2.4	2.8
28	1.5	2.0

- 8.13 CORE-TO-SHIELD DC PROOF TEST:** The dielectric material(s) between all conductors and the shield(s), in each completed cable, shall withstand the following dc voltages when tested in accordance with ASTM D 4566:

Conductor Size (AWG)	DC Test Voltage (kV)		
	Single Jacketed		Double Jacketed
	Foam or Foam-Skin	Solid	
16	10	15	20
19	10	15	20
22	10	15	20
24	10	15	20
26	10	15	20
28	5	5	20

- 8.14 CORE-TO-SCREEN DC PROOF TEST:** In each length of screened cable, the insulation between all conductors and the screen shall withstand a minimum dc potential of 5 kV when tested in accordance with ASTM D 4566. In constructions where the divider screen and shield are a single configuration, this test may be omitted because of the core-to-shield dc proof test requirement.
- 8.15 SHIELD RESISTANCE:** The maximum dc resistance of the single aluminum shield in a completed cable or dual aluminum-steel shields in all completed cables when measured at or corrected to 20°C (68°F) shall not exceed the value given by the following equation:

$$R \text{ (Ohms/kft)} = 0.75/D$$

$$[R \text{ (Ohms/km)} = 62.5/D]$$

where:

R = Maximum shield resistance in Ohms/kft (Ohms/km)

D = Nominal diameter over the outer shield in inches (mm)

- 8.16 **CONTINUITY OF METALLIC CABLE ELEMENTS.** All conductors, metallic screens, and shields of a completed cable shall be electrically continuous when tested in accordance with ASTM D 4566.

SECTION 9 MECHANICAL REQUIREMENTS

- 9.1 **COMPOUND FLOW:** The completed cable shall be capable of meeting the compound flow test of ASTM D 4565 when exposed for a period of 24 hours to a minimum test temperature of $65 \pm 1^\circ\text{C}$ ($149 \pm 2^\circ\text{F}$) or $80 \pm 1^\circ\text{C}$ ($176 \pm 2^\circ\text{F}$) as specified by the individual product specification (see Paragraph 4.5.1). The cable jacket(s) and shield(s) may be slit to relieve pressure created by expansion at elevated temperatures.

A glass dish shall be placed under the end of the cable to collect any dripping compound. It shall be weighed before and after the test. There shall be no more than 0.5 grams of material in the dish after 24 hours at the test temperature.

- 9.2 **WATER PENETRATION:** The completed cable shall be capable of meeting the following test requirement:
- A. A 3-foot (0.9-m) sample of cable shall be stabilized at $23 \pm 2^\circ\text{C}$ ($73 \pm 4^\circ\text{F}$) and tested in accordance with ASTM D 4565.
 - B. A perpendicular tube shall be filled with a 0.2-gram sodium fluorescein per liter water solution at a static head of not less than 3.0 feet (0.91 m) and not more than 3.3 feet (1.0 m) or equivalent continuous pressure without creating an air lock. The pressure (or static head) shall be maintained for one hour. During this time, no water may leak through the open cable end.
 - C. If the first sample fails, one additional 3-foot (0.9-m) sample taken from the adjacent 6 feet (1.8 m) of cable may be tested using the same static head. If the second sample passes, the cable is acceptable.
- 9.3 **CABLE BEND TEST:** The completed cable shall be capable of meeting the Wire and Cable Bending Test requirements of ASTM D 4565 after being

conditioned as described below. Prior to visual examination at room temperature, the cable shall pass the core-to-shield dc proof test of Paragraph 8.13 and, when a screen is present, the core-to-screen dc proof test of Paragraph 8.14.

- 9.3.1 Cold Bend Test: The completed cable shall be conditioned at $-20 \pm 2^{\circ}\text{C}$ ($-4 \pm 4^{\circ}\text{F}$) for a minimum of 4 hours.
- 9.3.2 Hot Bend Test: The completed cable shall be conditioned at $60 \pm 1^{\circ}\text{C}$ ($140 \pm 2^{\circ}\text{F}$) for a minimum of 4 hours.
- 9.4 CABLE IMPACT: The completed cable shall meet the following cold impact requirement when tested in accordance with ASTM D 4565, using a 1-pound (0.45-kg) weight dropped from a height of 3 feet (0.9 m). The sample shall be conditioned at $-20 \pm 2^{\circ}\text{C}$ ($-4 \pm 4^{\circ}\text{F}$) for a minimum of 4 hours and tested at the conditioned temperature.

Neither the inner nor the outer surface of the jacket(s) shall show evidence of cracking when examined with normal or corrected-to-normal vision. The cable shall be allowed to stabilize at room temperature prior to inspection of the impacted area.

- 9.5 JACKET NOTCH TEST FOR STEEL SHIELDED CABLE: One sample of outer jacket removed from steel shielded cable shall meet a minimum elongation requirement of 400% when tested in accordance with the following procedure:
- A. Cut a circumferential sheath sample from the cable which is 1.125 ± 0.125 inches (28.6 ± 3.2 mm) wide. Remove the core and aluminum shield from the cut sample.
 - B. On the sample, cut the cable jacket and steel shield longitudinally opposite (180 degrees from) the location of the overlap of the steel shield.
 - C. If the shield is bonded, the jacket shall be removed from the steel as follows:
 - a) Hold the steel overlap area firmly with flat-jawed pliers (e.g., modified gas pliers) or a vise. Taking care not to bend or damage the overlap area, carefully separate the longitudinal cut in the cable sheath to approximately the distance of one cable diameter.
 - b) All steel shall be removed by directing hot air at the steel side of the sample with a heat gun while peeling the steel from the jacket. If this procedure is properly followed, the sample will be no more than warm to the touch after the steel has been removed.

- D. Allow the sample to stabilize at room temperature. A dumbbell-shaped tensile bar, per ASTM D 638 Type IV, shall then be die-cut from each sample. The notch area shall be centered in and bisect the tensile bar.
- E. The sample with a gauge length of 1.0 inch (25 mm) and with the notch area centered between the jaws shall be clamped in a tensile testing machine as shown in Figure 5. The jaw separation for various cable sizes shall be as shown. The use of self-aligning grips is preferred.
- F. The sample shall be pulled at a minimum crosshead speed of 2 inches (51 mm) per minute at 18°C to 27°C (64°F to 81°F).
- G. The minimum elongation (gauge length increase) before the sample starts to break or tear shall be 400%.
- H. If the sample slips in or breaks at the jaws before the requirement is met, the test is invalid and it shall be repeated on a new sample. However, if the jacket begins to neck outside the jaws, it is acceptable for the necking to progress between the jaws as the test proceeds.
- I. If the sample fails, two adjacent samples shall be prepared and tested as described above, and both shall meet the requirement. If either, or both, adjacent samples fail, the cable may be tested in accordance with Paragraph 9.6. If the cable meets the requirements of Paragraph 9.6, it is acceptable.

9.6 CABLE TORSION - QUALIFICATION REQUIREMENT: All cables with a steel shield shall be capable of meeting the following qualification torsion test:

The gauge length of the cable test sample shall be 60 ± 2 inches (1520 ± 50 mm). The test shall be performed at 18°C to 27°C (64°F to 81°F) with the sample conditioned in this temperature range for at least 24 hours prior to testing.

The sample shall be straightened and one end fixed in a vise or other holding device. The other end shall be rotated. The rotation shall be opposite to the overlap in the steel sheath. The sample shall not bend while being twisted. Bonded and Unbonded cables of 2.0 inches (51 mm) outside diameter and larger shall be rotated through at least 360 degrees. Cables having an outside diameter of less than 2.0 inches (51 mm) shall be rotated through the number of degrees calculated from the equation:

$$\phi = 540 - 90 (OD_1)$$

$$[\phi = 540 - 3.5 (OD_2)]$$

where: ϕ = angle of rotation in degrees
 OD_1 = outside diameter of cable, inches
 OD_2 = outside diameter of cable, mm

The center 36 inches (914 mm) of the sample shall not split.

SECTION 10 GENERAL REQUIREMENTS

- 10.1 IDENTIFICATION AND MARKING: All lengths of cable shall have internal identification and jacket markings as specified in this Section.
- 10.1.1 Manufacturer Identification: The manufacturer's identification may be colored threads or tapes applied longitudinally. Colors used for each manufacturer shall be as assigned by the Underwriters Laboratories, Inc. or the Canadian Standards Association. As an alternate, a colored core binder or core wrap binder may be used for manufacturer's identification.
- 10.1.2 Year of Manufacture. One (or more) year of manufacture markers shall be placed over or under the core wrap. The marker shall be colored non-hygroscopic and non-wicking thread or tape. The color of the year marker shall indicate the last digit of the year in which the cable is sheathed in accordance with the following schedule:

Color	Year	Color	Year
Blue	1	White	6
Orange	2	Red	7
Green	3	Black	8
Brown	4	Yellow	9
Slate	5	Violet	0

As an alternate, a printed tape may be used to identify the year of manufacture. This tape shall be non-hygroscopic and nonwicking and shall have the year of manufacture printed on it.

- 10.1.3 Alternate Identification. A single printed tape may be used to identify the manufacturer and year of manufacture. The tape shall be non-hygroscopic and non-wicking.
- 10.1.4 Jacket Marking. The outer surface of the jacket shall be indented or durably surface printed in white ink with the following information:

- a) Manufacturer's Name
- b) Year of Manufacture
- c) Pair Count
- d) AWG Identification
- e) Cable Code (if used)
- f) Sequential Length Marking (see 10.1.5)
- g) Communications Cable Identifier (see 10.1.7)

Markings for items a) through e) shall be spaced at equal intervals to and alternating with the sequential length marking. Characters shall be dimensioned and spaced to produce good legibility and shall be approximately 1/8 inch (3 mm) or larger in height. An occasional illegible or missing marking is permissible. The markings shall have no adverse effect on the electrical characteristics of the cable. If the white marking fails to meet any of the previous requirements, the cable may be remarked with a yellow marking. The remarking shall meet all of the original requirements.

- 10.1.5 Length Marking. All cables shall have durable, sequentially numbered white length markings at regular intervals along the outside of the jacket. The numbers shall be legible. An occasional illegible marking is permitted if there is a legible marking on either side of it.

Length markings shall appear at intervals not to exceed 2 feet (0.6 m) and the word "FEET" shall appear after each length marking. If specified by the user, length markings shall be provided in meters and shall appear at intervals not to exceed 1 meter (3.28 feet). The word "METER" shall appear after each length marking.

The accuracy of the length marking shall be such that the actual length of any cable section is never less than the length indicated by the marking and never more than 1 percent greater than the length indicated by the marking.

The height of the markings shall be a minimum of 3/32 inch (2.4 mm) for cables having diameters up to 1.25 inches (32 mm) and a minimum of 1/8 inch (3.2 mm) for cables that are larger.

If the white marking fails to meet any of the previous requirements, the cable may be remarked with a yellow marking. This marking shall meet all of the original requirements.

- 10.1.6 Defective Pair Marking: Both ends of each length of cable containing defective pairs shall be permanently marked, in red. The red marking shall completely encircle the cable jacket and shall be located within 1 foot (300 mm) of the end of the cable. The marking shall be at least 4 inches (100 mm) in width.

- 10.1.7 **Communication Cable Identifier:** Direct-buried communications cables shall be legibly marked in compliance with Rule 350.G of the National Electrical Safety Code (NESC).
- 10.2 **END-SEALING:** The cable ends shall be sealed so as to prevent the escape of filling compound and the entry of moisture during shipping, handling, and storage prior to placement.
- 10.3 **THERMAL WRAP:** When specified, a thermal protective wrap shall be securely applied over the outer convolutions of the cable on each reel. It shall be applied prior to exposure to solar heating. The wrap shall be weather resistant and shall limit solar heating of the cable.

Thermal wrap material shall meet the following qualification test:

- A. Tests shall be performed on two 18-inch (460-mm) lengths of cable removed sequentially from the same 25-pair, 22-gauge jacketed cable.
- B. Place the two samples on a thermal insulating material such as wood. Tape thermocouples to the jackets of each sample. Cover one sample with the thermal reel wrap.
- C. Expose the samples to a radiant heat source capable of heating the uncovered jacket to a minimum of 71°C (160°F). A 600-watt photoflood lamp at a height of 15 inches (380 mm) above the wrapped sample meets this requirement.
- D. After one hour of exposure of each sample, the temperature difference between the jacket with the wrap and the jacket without the wrap shall be equal to or greater than 17°C (31°F).

The wrap shall be capable of remaining in place until the cable is installed and shall be labeled "Do Not Remove Wrap Until Cable Is To Be Placed" or an equivalent statement.

10.4 INFORMATION ACCOMPANYING THE REEL: Each reel of cable shall be stenciled and/or labeled clearly to indicate the following information:

Customer Order Number
 Manufacturer's Name
 Factory Reel Number
 Year of Manufacture
 Manufacturer's Code and Pair Size of Cable
 Gauge of Conductors
 Length of Cable
 Inner and Outer Sequential Length Marking
 Total Weight of Cable and Reel

All packing slips, invoices, tags, and other material attached to the reel and made a part of shipment must either be weatherproof or contained within a weatherproof pouch.

If the supply reel is to be recycled, each reel shall be clearly and permanently labeled or stenciled with a unique manufacturer's reel or serial number.

10.5 OPTIONAL REQUIREMENTS: The following optional items shall be provided when specifically ordered by the user.

10.5.1 Physical Reel Protection. When specified, lags or other suitable physical reel protection shall be securely applied over the cable to prevent physical damage to the cable during shipment.

10.5.2 Pulling Eyes: When specified, pulling eyes shall be installed with the capability of sustaining a load in lbf (N) equal to values determined by multiplying the nominal pair count by the factor shown below, up to 17,000 lbf (75.6 kN), maximum.

Conductor Size (AWG)	Load Factor	
	lbf/Pair	(N/Pair)
16	45.0	(200)
19	22.1	(100)
22	11.0	(50)
24	6.6	(30)
26	4.4	(20)
28	2.8	(12)

Table 1
Specifications Referenced in This Standard

SPECIFICATION AND ISSUE DATE	TITLE
ANSI/ASQC Q90-1987	Quality Management and Quality Assurance Standards - Guidelines for Selection and Use
ANSI/ASQC Q94-1987	Quality Management and Quality System Elements - Guidelines
ANSI C2-1993	National Electrical Safety Code
ANSI/EIA-359-A-84	EIA Standard Colors For Color Identification and Coding
ASTM A 308-88	Specification for Steel, Sheet, Cold-Rolled, Long Terme Coated
ASTM A 370-91a	Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A 624-90 ASTM A 624M-90	Specification for Tin Mill Products, Electrolytic Tin Plate, Single-Reduced
ASTM A 625-85	Specification for Single-Reduced Black Plate
ASTM A 625M-85	Specification for Tin Mill Products, Black-Plate, Single Reduced, Metric
ASTM A 657-87	Specification for Tin Mill Products, Black Plate, Electrolytic Chromium-Coated, Single and Double Reduced
ASTM B 3-90	Specification for Soft or Annealed Copper Wire
ASTM B 193-87	Test Method for Resistivity of Electrical Conductor Materials
ASTM B 258-81(1991)	Specification for Standard Nominal Diameters and Cross- Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors

Table 1 (Continued)
Specifications Referenced in This Standard

SPECIFICATION AND ISSUE DATE	TITLE
ASTM B 694-86	Specification for Copper, Copper Alloy and Copper-Clad Stainless Steel Sheet and Strip for Electrical Cable Shielding
ASTM B 736-92a	Specification for Aluminum, Aluminum Alloy and Aluminum-Clad Steel Cable Shielding Stock
ASTM D 150-92	Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials
ASTM D 257-91	Test Methods for DC Resistance or Conductance of Insulating Materials
ASTM D 638-91 ASTM D 638M-91a	Test Methods for Tensile Properties of Plastics
ASTM D 883-91	Terminology Relating to Plastics
ASTM D 903-49(1983)	Test Method for Peel or Stripping Strength of Adhesive Bonds
ASTM D 1248-84(1989) ^{e1}	Specification for Polyethylene Plastics Molding And Extrusion Materials
ASTM D 1505-90	Test Method for Density of Plastics by the Density-Gradient Technique
ASTM D 1535-89	Method for Specifying Color by the Munsell System
ASTM D 1693-70(1988) ^{e1}	Test Method for Environmental Stress-Cracking of Ethylene Plastics
ASTM D 1765-91a	Classification System for Carbon Blacks Used in Rubber Products

Table 1 (Continued)
Specifications Referenced in This Standard

SPECIFICATION AND ISSUE DATE	TITLE
ASTM D 3349-93	Test Method for Absorption Coefficient of Carbon Black Pigmented Ethylene Plastic Film
ASTM D 3895-80(1986) ^{e1}	Test Method for Oxidative Induction Time of Polyolefins By Thermal Analysis
ASTM D 4101-82(1988)	Specification for Propylene Plastic Injection and Extrusion Materials
ASTM D 4565-90a	Methods of Testing Physical and Environmental Performance Properties of Insulations and Jackets for Telecommunications Wire and Cable
ASTM D 4566-90	Methods of Testing Electrical Performance Properties of Insulations and Jackets for Telecommunications Wire and Cable
ASTM D 4568-93	Test Methods for Evaluating Compatibility Between Cable Filling and Flooding Compounds and Polyolefin Cable Materials
ASTM D 5423-93	Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation
ASTM E 8-91 ASTM E 8M-91	Methods for Tension Testing of Metallic Materials
ASTM E 29-90	Recommended Practice for Indicating Which Places of Figures are to be Considered Significant in Specified Limiting Values

NOTE: The dash number indicates date of the last revision. A number in parentheses indicates the year of last reaffirmation by the committee with jurisdiction for the standard.

Figure 1. Forming of Steel Tape Overlap

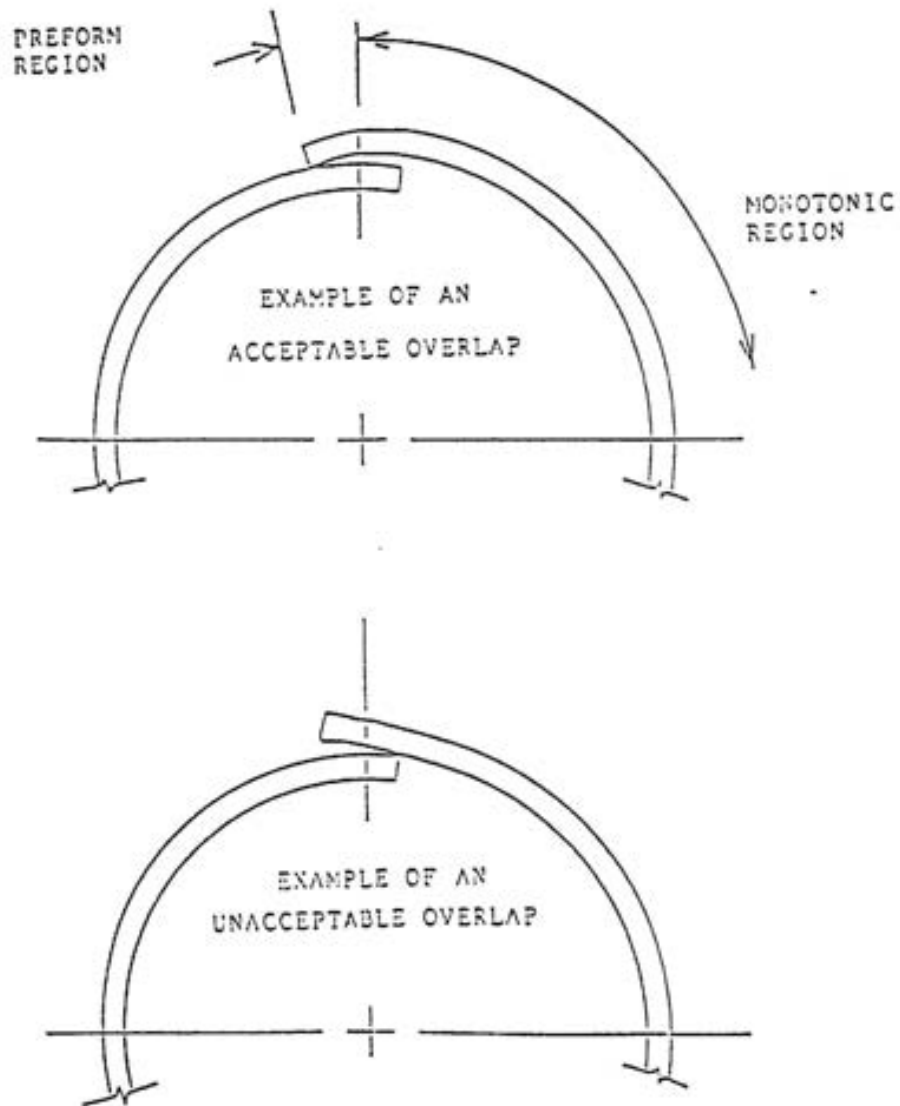


Figure 2. Minimum Extensibility (EXT) for Aluminum

EXT ≥ 2%	FOR D < 0.6 inch (15 mm)
EXT ≥ (5.10 × D) - 1.65	FOR 0.6 ≤ D < 2.73 inches
[EXT ≥ (0.24 × D) - 1.65	FOR 15 ≤ D < 69 mm]
EXT ≥ 15%	FOR D ≥ 2.73 inches (69 mm)

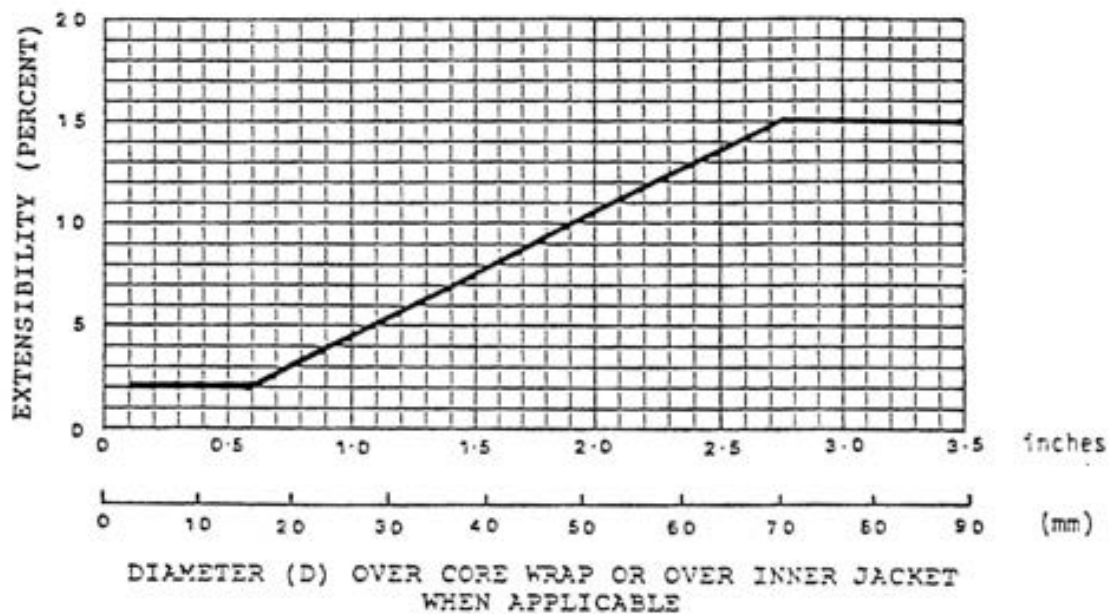


Figure 3. Minimum Extensibility (EXT) for Steel

$$\begin{aligned} \text{EXT} &\geq (8 \times D) - 1.0 && \text{FOR } D \leq 1.62 \text{ inches} \\ \text{[EXT} &\geq (0.315 \times D) - 1.0 && \text{FOR } D \leq 41 \text{ mm}] \\ \text{EXT} &\geq 12\% && \text{FOR } D > 1.62 \text{ inches (41 mm)} \end{aligned}$$

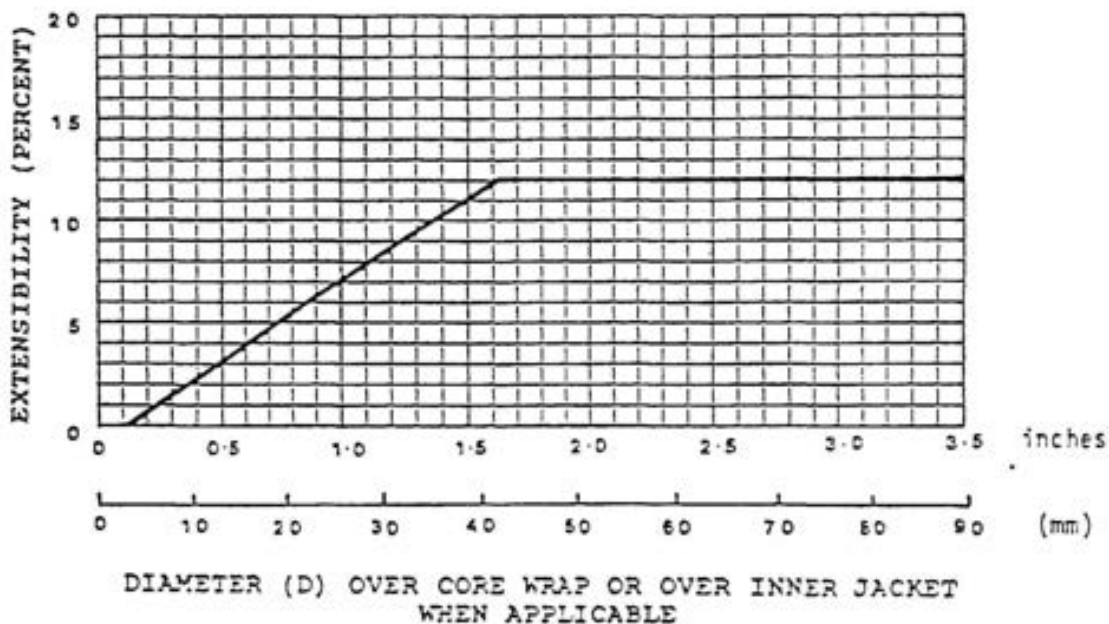


Figure 4. Sheath Adherence Sample Preparation

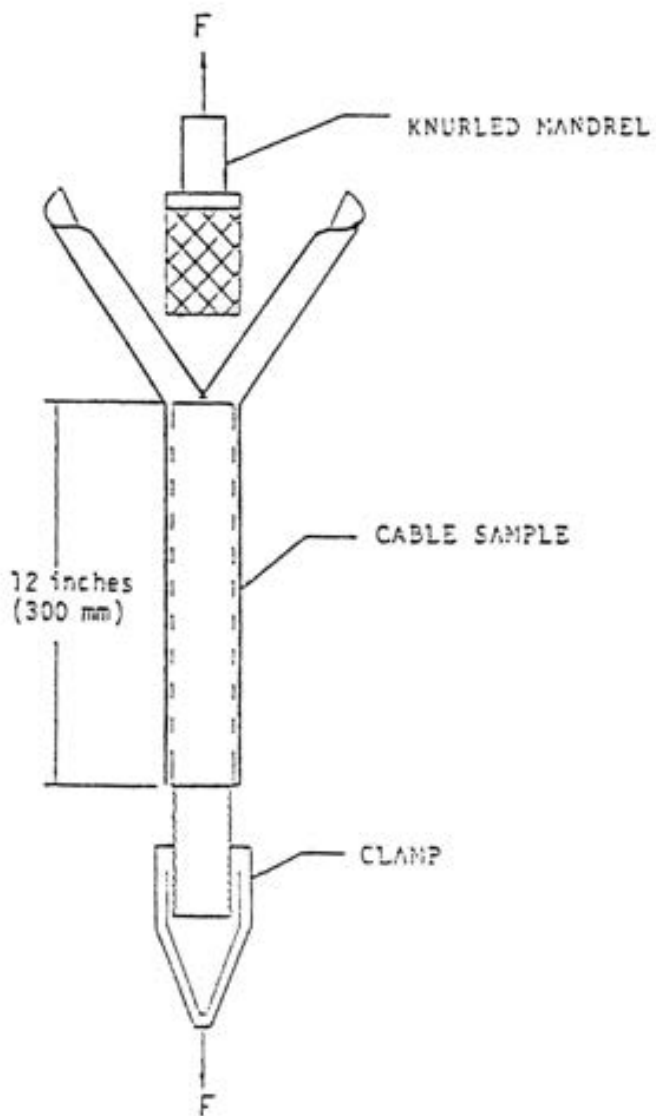
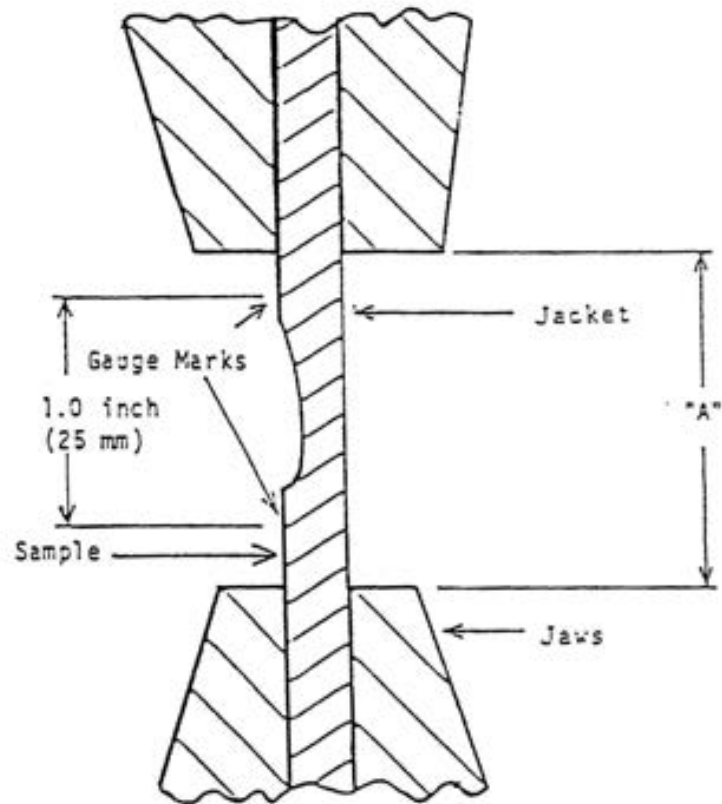


Figure 5. Sample Preparation for Notch Test



<u>Cable Diameter</u>	<u>"A" Dimension</u>
< 1.25 inches (32 mm)	1.5 inches (38 mm)
≥ 1.25 inches (32 mm)	2.5 inches (64 mm)

APPENDIX A

TEST PROCEDURE FOR WICKING

1. EQUIPMENT

- 1.1 Beaker: 500 to 1000 ml.
- 1.2 Laboratory Stand: with movable crossbar.
- 1.3 Weight: 3/4 to 7/8 ounce (23 to 27 g), lead sinker type (3).
- 1.4 Fluorescein Dye Solution: 0.1 g/liter of water.
- 1.5 Filter paper 1 in (25 mm) square: (3 pieces).

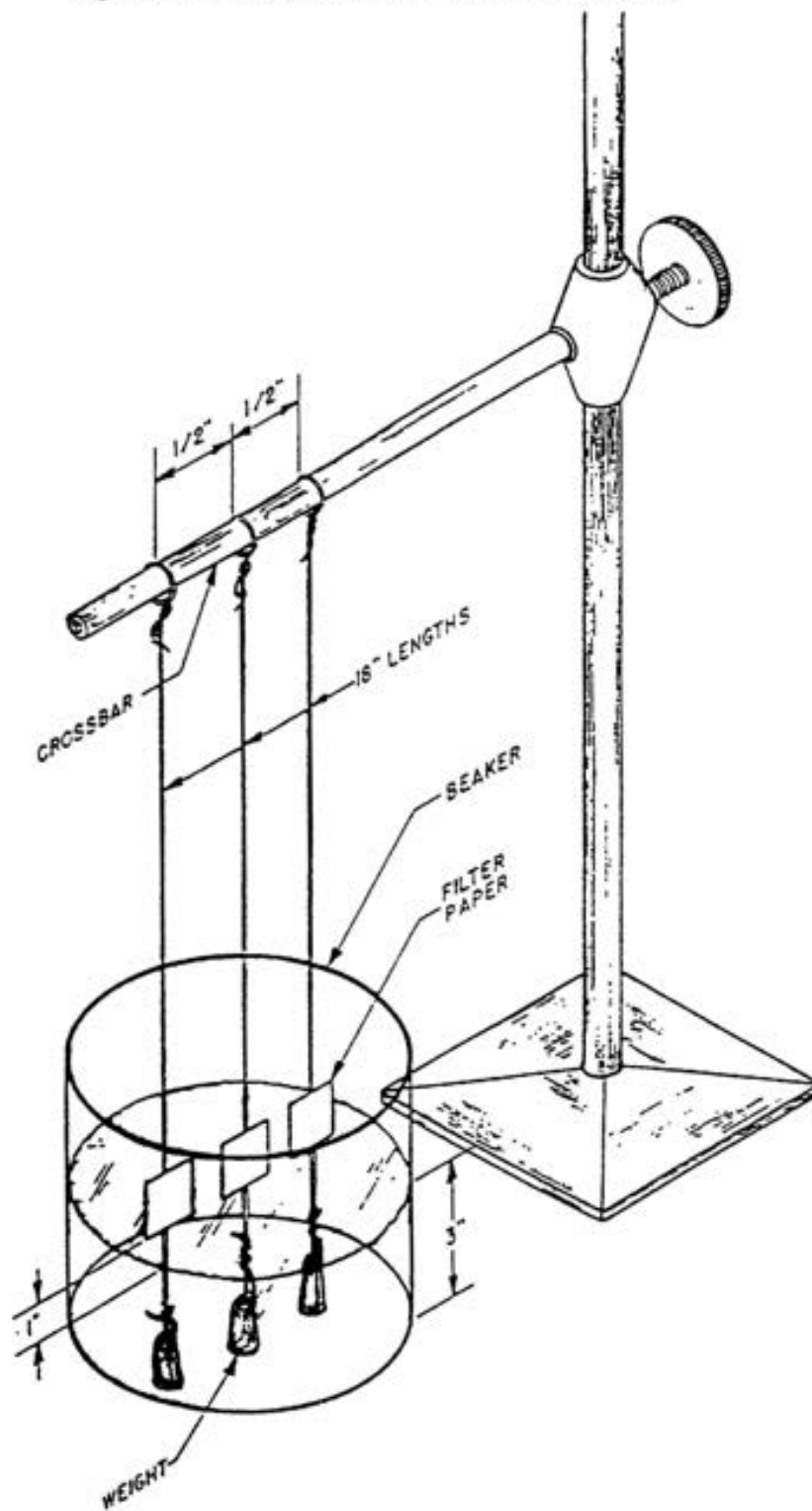
2. PROCEDURE

- 2.1 Cut three (3) 18 in (460 mm) lengths of material to be tested and attach lead sinker type weights to one end of each sample.
- 2.2 Attach the opposite end of each sample length to the crossbar with approximately 0.5 in (13 mm) space between samples. See Figure A-1.
- 2.3 Attach one section of filter paper to each sample with a paper clip, approximately 3 in (76 mm) above the weight.
- 2.4 Fill the beaker with the Fluorescein solution to a depth of about 3 in (76 mm).
- 2.5 Position the crossbar with attached, hanging samples in place directly over the filled beaker. Lower crossbar so that the weighted sample end enters the solution positioning the bottom of the filter paper 1.0 in (25 mm) above the surface. Record time of entry.
- 2.6 The sample shall be considered "nonwicking" if the solution does not wick and wet the lower edge of the filter paper within 6 hours.

TEST PROCEDURE FOR HYGROSCOPICITY

The material is considered to nonhygroscopic when a dry sample of the material is placed in an environment of $65 \pm 5\%$ Relative Humidity and $20 \pm 2^{\circ}\text{C}$ ($68 \pm 4^{\circ}\text{F}$) for 3 hours, and the amount of moisture gained does not exceed 1% by weight.

Figure A-1. WICKING TEST CONFIGURATION



APPENDIX B

ADHESION BETWEEN SCREEN ALUMINUM AND COATING

- A. **OUTLINE OF METHOD:** Adhesion between the coating and aluminum is to be measured at 23°C (73°F) (as received plus water aging) and at 80°C (176°F) per ASTM D 903 with the following modifications.
- B. **SAMPLE PREPARATION:** Take samples having a dimension of about 6 inches (152 mm) along the length of the material and score the aluminum with a sharp blade midway of the 6-inch (152-mm) length (score line is parallel to cut ends of material). Since the film on the unscored side is the one to be tested, prepare enough material to produce three good samples for each side of the coated aluminum. Cut the scored material into 1-inch (25-mm) wide strips by 6 inches (152 mm) long. A suitable sample cutter is JDC-50 supplied by Thwing-Albert Instrument Company, 10960 Dutton Road, Philadelphia, Pennsylvania 19154.

Flex the end of the sample along the scored line until the aluminum has completely separated along this line. Elongate the sample with a smooth, steady pull until there is a slight gap between the two pieces of metal.

Beginning at the gap in the metal, peel back the coating from one section until sufficient metal has been bared.

A total of six samples, three from each side, are needed.

- C. **WATER AGING AT 23°C (73°F):** Immerse samples completely in distilled or deionized water at $60 \pm 1^\circ\text{C}$ ($140 \pm 2^\circ\text{F}$) for 7 days. Equilibrate to ambient conditions for 24 hours before further testing.
- D. **HIGH TEMPERATURE CONDITIONING:** Place test samples in an environmental chamber during the initial temperature equilibrium (approximately 5 minutes). After placing each sample in the jaws of the testing machine, re-equilibrate at test temperature for 3 minutes before performing the adhesion test.
- E. **ADHESION TEST:** Perform the test at 2 inches (51 mm) per minute jaw separation speed without the use of weights on the sample or an alignment plate. Disregard the initial 0.25-inch (6.4-mm) peel length when determining the peel force for each sample. Average the six values.

APPENDIX C

Standard Internally Screened (IS) Cable Pair Counts		
Carrier Pair Count	Service Pairs	Total Pair Count
24	4	28
50	4	54
100	6	106
150	8	158
200	10	210
300	14	314
400	18	418

APPENDIX D

METALLIC TAPE SPLICE BREAKING STRENGTH, PERCENT RETENTION

1. **OUTLINE OF METHOD:** The percent retention of the breaking strength of a splice in metallic tape before corrugating shall be determined by comparing breaking strengths of a welded section of flat shield material with the breaking strengths of adjacent unwelded material. In the absence of a tensile tester capable of gripping a full width of shield material, the following test procedures apply.
2. **APPARATUS:** Calibrated tensile tester capable of performing tensile test per ASTM A 370.
3. **SAMPLE SELECTION AND PREPARATION**
 - 3.1 Tape samples shall be selected from actual shielding or armoring material (coated and uncoated). The splice operator(s) shall utilize the same shield preparation, weld procedures (voltage, number, placement, etc.), equipment, and material used during normal production. The coating (when applicable) shall be reapplied before performing the test.
 - 3.2 The sample shall be of sufficient length to allow taking a tensile sample on both the welded and adjacent unwelded section. The tape sample shall be cut into a welded and unwelded section. Each section shall then be slit into widths suitable to the gripping capabilities of the tensile tester. The slits shall be made parallel to the sides of the metallic tape and in such a manner as not to slit through or disturb the individual welds.
4. **TEST PROCEDURE:**
 - 4.1 Test all tape samples representing the entire width of the welded tape and accumulate the results.
 - 4.2 Do the same for the unwelded tape section.
 - 4.3 Then make the following calculation:

$$\% \text{ Retention of Breaking Strength} = \frac{\Sigma(F_1)}{\Sigma(F_2)} \times 100$$

Where: F_1 = breaking strength of welded tape samples

F_2 = breaking strength of unwelded tape samples