7.3.4.2 Thickness

The minimum thickness of tape or of the sheath or tube before corrugation shall be as shown in Table 7-13.

Table 7-13
Minimum Thickness of Metal for Corrugated Armor

Calculated Diameter of Cable Under Armor*		Aluminum		Copper		Steel	
inches	mm	mils	mm	mils	mm	mils	mm
0–2.180	0– 55.37	22	0.56	..	...	..	...
2.181–3.190	55.40– 81.03	29	0.74	..	...	..	...
3.191–4.200	81.05–106.70	34	0.86	..	...	..	...
0–2.365	0– 60.07	..	...	17	0.43	..	...
2.366–3.545	60.10– 90.04	..	...	21	0.53	..	...
3.546–4.200	90.07–106.70	..	...	25	0.64	..	...
0–1.905	0– 48.39	..	...	..	...	16	0.41
1.906–3.050	48.41– 77.47	..	...	..	...	20	0.51
3.051–4.200	77.50–106.70	..	...	..	...	24	0.61

* See Appendix C for minimum diameter calculation.

7.3.4.3 Flexibility

The armored cable shall be capable of being bent around a mandrel having a diameter of 14 times the cable diameter. The armor shall show no evidence of openings, splits, or cracks visible to the unaided eye. The test shall be conducted in accordance with ANSI/NEMA WC 53/ICEA T-27-581 “Method for Flexibility Test for Continuously Corrugated Armor.”

7.3.5 Galvanized Steel Wire Armor for Submarine Cables

Zinc-coated low-carbon-steel wire shall be used for the armoring of submarine cables. For wire armor for special uses such as on dredge, borehole, vertical riser, shaft and buried land cables, see Divisions II and III (7.4 and 7.5). All tests shall be made prior to application of the wire to the cable.

7.3.5.1 Physical Requirements

The zinc-coated wire shall be uniform in diameter and free from cracks, splints or other flaws.

The zinc-coated wire shall have a tensile strength of not less than 50,000 psi (345 MPa) and not more than 70,000 psi (483 MPa). The tensile strength shall be tested in accordance with ASTM E 8.

The zinc-coated wire shall have an elongation of not less than 10 percent in 10 in. (254 mm). The elongation shall be the permanent increase in length of a marked section of the wire originally 10 in. (254 mm) in length and shall be determined after the specimen has fractured.

The zinc-coated wire shall withstand, without fracture, the minimum number of twists specified in Table 7-14. This test shall be made on a sample of wire having an initial length of 6 in. (152 mm) between jaws of a standard torsion machine or equivalent with one head of the machine movable horizontally. The effective speed of rotation shall not exceed 60 rpm.

Table 7-14
Number of Twists (Torsion Test)

Nominal Wire Diameter mils	Nominal Wire Diameter mm	Minimum Number of Twists
238–166	6.05–4.22	7
165–110	4.19–2.79	10
109– 65	2.77–1.65	14

7.3.5.2 Galvanizing (Zinc Coating) Tests

The zinc coating shall be applied by either the hot-dip or the electro-galvanizing process.

The weight of zinc coating shall be determined before the wire is applied to the cable. The wire shall have a minimum weight of coating per square foot of uncoated wire surface in accordance with Table 7-15. The zinc coating shall be tested for weight by a stripping test in accordance with ASTM A 90.

Table 7-15
Minimum Weights of Zinc Coating

Size and Nominal Diameter of Coated Wire			Minimum Weight of Zinc Coating per Area of Exposed Surface	
Size (BWG*)	Diameter mils	Diameter mm	Ounces per Square Foot	Grams per Square Meter
4	238	6.05	1.00	305
5	220	5.59	1.00	305
6	203	5.16	1.00	305
8	165	4.19	0.90	275
10	134	3.40	0.80	244
12	109	2.77	0.80	244
14	83	2.11	0.60	183

* Birmingham Wire Gauge.

The zinc coating shall remain adherent when the wire is wrapped at a rate of not more than 15 turns per minute in a closed helix of at least two turns around a cylindrical mandrel of the diameter specified in Table 7-16.

The zinc coating shall be considered as meeting this requirement if, when the wire is wrapped about the specified mandrel, the coating does not flake, and none of it can be removed from the wire by rubbing it with the fingers. Loosening or detachment during the adherence test of superficial, small particles of zinc formed by mechanical polishing of the surface of zinc-coated wire shall not constitute failure.

Table 7-16
Mandrel Diameter for Adherence of Coating Tests

Wire Diameter mils	Wire Diameter mm	Mandrel Diameter
less than 134	less than 3.40	2 times wire diameter
134 & larger	3.40 & larger	3 times wire diameter

7.3.5.3 Size of Armor Wire

The size of armor wire for submarine cables shall be in accordance with Table 7-17. If the service requirements are exceptionally severe, larger sizes of armor wire may be required. Diameter tolerances for the armor wire sizes are given in Table 7-18.

Table 7-17
Size of Galvanized Steel Armor for Submarine Cable

Calculated Diameter of Cable Under Bedding*		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
0–0.750	0–19.05	12	109	2.77
0.751–1.000	19.08–25.40	10	134	3.40
1.001–1.700	25.43–43.18	8	165	4.19
1.701–2.500	43.21–63.50	6	203	5.16
2.501 & larger	63.53 & larger	4	238	6.05

* See Appendix C for minimum diameter calculation.

Table 7-18
Tolerances in Diameter

Nominal Diameter of Coated Wire		Tolerance	
mils	mm	mils	mm
65 through 108	1.65 through 2.75	±3	±0.08
109 through 165	2.77 through 4.20	±4	±0.10
166 through 238	4.22 through 6.25	±5	±0.13

7.3.5.4 Lay

The length of lay of the armor wires of Division I cables shall be not less than seven nor more than twelve times their pitch diameter for all constructions except for dredge cable. For dredge cable, see 7.4.2. Successive layers of jute and armor shall be laid in opposite directions. The direction of lay of the armor wires shall be so chosen that birdcaging of the cable being armored shall be reduced to a minimum.

7.3.6 Bedding over Cable Cores to Be Metallic Armored

7.3.6.1 Unsheathed or Unjacketed Cores

When an unsheathed and unjacketed cable core, is to have a flat steel tape or round wire armor applied, it shall be protected by suitable tape (compound-filled or equivalent) plus other bedding having a thickness in accordance with Table 7-19. When an interlocked metal tape armor or a continuously corrugated armor is to be applied, only a suitable tape bedding is required.

A compound-filled tape is a fabric cloth treated on one or both sides with a non-conducting compound. When used, a tape shall be applied helically and overlapped not less than 10 percent of its width. (For cores having a diameter smaller than 0.300 in. (7.62 mm), serving(s) of jute or equivalent yarns may be substituted for the tape.)

When flat steel tape, interlocked tape, or round wire armor will remain unjacketed, and the cable is intended for use in below-grade or potentially wet environments, cores having beddings of tapes or jute yarn or other roving shall be run through a hot asphalt compound or equivalent saturant. When intended for installation in permanently dry indoor above-grade locations, saturant compounds need not be applied to the core beddings.

When the armor will have an outer protective jacket, the cable core, with or without metallic shield tape and/or beddings, does not require exposure to saturant compounds.

The nominal thickness of the bedding shall be in accordance with Table 7-19. The thickness shall be determined by the use of a diameter tape and shall be considered as one-half of the difference in measurements under and over the bedding.

Table 7-19
Thickness of Bedding under Metallic Armor for Unsheathed and Unjacketed Cores

Calculated Diameter of Cable Under Bedding*		Under Flat Steel Tape Armor		Under Round Wire Armor	
		Nominal Bedding Thickness		Nominal Bedding Thickness	
inches	mm	mils	mm	mils	mm
0.450 & less	11.43 & less	30	0.76	80	2.03
0.451–0.750	11.46–19.05	45	1.14	80	2.03
0.751–1.000	19.08–25.40	45	1.14	95	2.41
1.001–2.500	25.43–63.50	65	1.65	110	2.79
2.501 & larger	63.53 & larger	65	1.65	125	3.18

* See Appendix C for minimum diameter calculation.

7.3.6.2 Jacketed Cores or Sheathed Non-jacketed Cores

When a jacketed core is to be armored, any suitable tape or serving of jute or other roving may be used as a bedding if necessary.

When a core with an unjacketed sheath is to have a flat steel tape or round wire armor, it shall be protected with a suitable bedding having a thickness in accordance with Table 7-19. When an interlocked tape or continuously corrugated armor is to be applied, any suitable separator tape may be used over the core.

When the applied flat steel tape, interlocked tape, or round wire armor will remain unjacketed, and the cable is intended for installation in below-grade or potentially wet environments, the metallic sheath and all bedding layers applied over the sheath or core jacket shall be run through a hot asphalt or tar compound, or equivalent saturant. When intended for installation in a permanently dry indoor above-grade location, a cable core bedding does not require exposure to saturant compounds.

7.3.7 Outer Servings

7.3.7.1 Over Metallic Sheath (Without Armor or Jacket)

When specified for mechanical protection of the metallic sheath, the sheathed cable shall be run through hot asphalt or equivalent saturant and served with one (or two if specified) closely wound lay of No. 16/3 impregnated jute yarn, or plied jute, or other servings of equivalent thickness. If two servings are used, they shall be closely wound and applied with opposite directions of lay. Each serving may be run through hot asphalt or equivalent saturant. For either one or two servings, the outer serving shall be further coated with some suitable material if required to prevent sticking of adjacent turns of the cable when wound on a reel.

The nominal thickness of the single and double servings applied over metallic sheathed cable for mechanical protection shall be as given in Table 7-20.

Table 7-20
Thickness of Servings over Metallic Sheath (Without Metallic Armor)

Calculated Diameter of Cable Under Serving*		Nominal Thickness of Serving One Serving		Two Servings	
inches	mm	mils	mm	mils	mm
1.000 or less	2.540 or less	65	1.65	95	2.41
1.001–2.50	25.43–63.50	65	1.65	110	2.79
2.501 & larger	63.53 & larger	65	1.65	125	3.18

* See Appendix C for minimum diameter calculation. The thickness of servings over the metallic sheath of a flat twin cable shall be based on the calculated major core diameter.

7.3.7.2 Over Metallic Armored Cables

When an outer serving is required, the armored cable shall first be run through hot asphalt or equivalent coating, then served with a layer of No. 16/3 impregnated jute, or plied yarn, or other servings of equivalent thickness, applied with a close lay. The cable shall then be run through hot asphalt or equivalent saturant and finished by running through some suitable material if required to prevent sticking of adjacent turns of the cable when wound on a reel.

The direction of lay of the serving shall be opposite to that of the underlying armor.

7.3.8 Crosslinked Jackets over Metallic Sheaths and Armors

A crosslinked jacket, when used, shall be one of the following materials extruded over the metallic sheath or armor and shall meet the applicable requirements of Section 7:

Neoprene, Heavy Duty Black
Nitrile-butadiene/Polyvinyl Chloride, Heavy Duty
Chlorosulfonated Polyethylene, Heavy Duty
Chlorinated Polyethylene, Heavy Duty, Crosslinked
Low Smoke Halogen Free, Thermoset Type I or II

A separator in accordance with 7.1.19 shall be permitted to be used over the armor.

The minimum thickness of the crosslinked jacket shall be not less than that specified in Table 7-21.

The crosslinked jacket over a sheath or an armor shall not have irregularities as determined by the procedure given in ANSI/NEMA WC 53/ICEA T-27-581. The methods to be used are:

Method A for Neoprene.
Method B for Nitrile-butadiene/PVC, Chlorosulfonated Polyethylene and Low Smoke Halogen Free, Thermoset Type I or II.
Method C for Crosslinked Chlorinated Polyethylene.

The test voltage for a given thickness shall not be less than indicated in Table 7-21.

7.3.9 Thermoplastic Jackets over Metallic Sheaths or Armors

Thermoplastic jackets, when used, shall be one of the following materials extruded over the metallic sheath or armor and shall fit tightly thereto:

Polyvinyl chloride meeting the requirements given in Section 7, except that the cold bend requirements shall be as stated below, or

Chlorinated polyethylene meeting the requirements given in Section 7, except that the cold bend requirements shall be as stated below, or

Polyethylene meeting the requirements given in Section 7 for low & linear low density, or medium density, or high-density material or

Low Smoke Halogen Free (LSHF) (thermoplastic) meeting the requirements given in Section 7

The minimum thickness of the thermoplastic jacket over metallic sheaths or armors shall be not less than that specified in Table 7-21.

Table 7-21
Thickness of Extruded Crosslinked Jackets and Extruded Thermoplastic Jackets over Metallic Sheaths and Armors

Calculated Diameter of Cable* Under The Jacket		Jacket Thickness Over Sheath or Flat Tape and Round Wire Armor		AC Spark Test Voltage for Nonconducting Jackets		Jacket Thickness Over Interlocked or Corrugated Armor		AC Spark Test Voltage for Nonconducting Jackets	
inches	mm	mils	mm	Method B (kV)	Method C (kV)	mils	mm	Method B (kV)	Method C (kV)
0.750 or less	19.05 or less	40	1.02	2.0	4.0	40	1.02	2.0	4.0
0.751–1.500	19.08–38.10	50	1.27	2.5	5.0	40	1.02	2.0	4.0
1.501–2.250	38.13–57.15	65	1.65	3.0	6.5	50	1.27	2.5	5.0
2.251–3.000	57.18–76.20	75	1.91	3.5	7.5	60	1.52	3.0	6.0
3.001 & larger	76.23 & larger	90	2.29	4.5	9.0	70	1.78	3.5	7.0

* See Appendix C for minimum diameter calculation.

The tightness of a polyethylene jacket over a sheath shall be tested in accordance with Section 9. No movement of the 2-in. (50.8 mm) ring shall take place within a period of one minute following the application of a force to the upper end of the sample. (See 9.7)

The thermoplastic jacket over a sheath or an armor shall not have irregularities as determined by the procedure given in ANSI/NEMA WC 53/ICEA T-27-581. The methods to be used are:

Method B for Thermoplastic Chlorinated Polyethylene and Low Smoke Halogen Free
Method C for Polyvinyl Chloride and for Polyethylene

The test voltage for a given thickness shall not be less than indicated in Table 7-21.

When required, the manufacturer shall submit evidence that when similar thermoplastic jacketed cable has been subjected to the same cold bend test with the same frequency as required for the underlying core and at a test temperature of minus 10°C or colder, the jacket shall show no cracks visible to the normal unaided eye. (See Section 9)

7.4 Division II

The requirements of Division I pertaining to quality of materials, design, and construction apply also to the borehole, dredge, shaft, and vertical riser cables except as expressly set forth in the following sections for the respective types of cable, or as otherwise modified.

7.4.1 Borehole Cable (Suspended at One End Only)

7.4.1.1 Armor

Galvanized round steel wire shall be used for borehole cable.

The size of the armor wire shall be as given in Table 7-22. The tensile safety factor [based on 50,000 psi (345 MPa)] shall be not less than five. If the required tensile safety factor is not maintained, the next larger size wire given in the table should be used.

The length of lay of the armor wires shall be not less than seven nor more than twelve times their pitch diameter. The armor shall be applied closely without appreciable space between the wires.

Table 7-22
Size of Galvanized Steel Armor Wire for Borehole Cable

Calculated Diameter of Cable Under Bedding*		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
0.750 or less	19.05 or less	12	109	2.77
0.751–1.000	19.08–25.40	10	134	3.40
1.001–1.700	25.43–43.18	8	165	4.19
1.701–2.500	43.21–63.50	6	203	5.16
2.501 & larger	63.53 & larger	4	238	6.05

* See Appendix C for minimum diameter calculation.

7.4.1.2 Wire Band Serving

Where wire band servings over the armor are required for cable suspended vertically from one end, No. 12 BWG (109 mils) (2.77 mm) wire or flat strap punch-lock clamps shall be used. The length of the serving band and the spacing of the band throughout the length of the cable shall be in accordance with Table 7-23.

Table 7-23
Spacing and Length of Band Servings

Calculated Diameter Over the Armor Wire*		Maximum Band Spacing		Length of Band	
inches	mm	feet	meters	inches	mm
0–1.500	0–38.10	50	15.2	3	76
1.501–2.500	38.13–63.50	35	10.7	4	102
2.501 & larger	63.53 & larger	25	7.6	4	102

* See Appendix C for minimum diameter calculation.

The bands shall be applied sufficiently tight to prevent their movement along the cable during installation handling.

7.4.2 Dredge Cable

7.4.2.1 Armor

Galvanized round steel wire shall be used for dredge cable and shall be applied with a short lay. The pitch ratio limits shall be in accordance with Table 7-24.

Table 7-24
Pitch Ratio of Galvanized Wire Armor for Dredge Cable

Calculated Diameter Over the Armor Wires*		Minimum Pitch Ratio
inches	mm	
0–2.500 or less	0–63.50 or less	2.5
2.501 & larger	63.53 & larger	3.0

* See Appendix C for minimum diameter calculation.

The pitch ratio is taken as the quotient resulting from dividing the length of lay of the armor wires by the pitch diameter of the armor wires. Where unusual service conditions exist, it may be desirable to modify the above pitch ratio. If so, it should be defined before the cable design is finalized.

The size of the armor wires shall be as given in Table 7-25.

Table 7-25
Size of Galvanized Steel Armor Wire for Dredge Cable

Calculated Diameter of Cable Under Bedding*		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
1.700 or less	43.18 or less	12	109	2.77
1.701–2.500	43.21–63.50	10	134	3.40
2.501 & larger	63.53 & larger	8	165	4.19

* See Appendix C for minimum diameter calculation.

7.4.3 Shaft Cable

If the shaft cable is suspended from one end during installation and thereafter, galvanized round steel wire armor shall be used and the cable shall be suspended by the armor wires.

7.4.3.1 Tape or Wire Armor for Clamped Cables

When shaft cable is clamped to the shaft structure or wall, the metallic coverings used (either tape or wire) shall comply with the applicable requirements of 7.3.

7.4.3.2 Wire Armor for Vertically Suspended Cables

The size of the armor wires for cables suspended at one end shall be as given in Table 7-26, but the tensile safety factor shall be not less than five [based on 50,000 psi (345 MPa)].

Wire band servings in accordance with 7.4.1.2 shall be applied.

Table 7-26
Size Of Galvanized Steel Armor Wire for Shaft Cable and Vertical Riser Cable

Calculated Diameter of Cable Under Bedding*		Nominal Size of Armor Wire		
inches	mm	BWG	mils	mm
1.000 or less	25.40 or less	12	109	2.77
1.001–1.700	25.43–43.18	10	134	3.40
1.701–2.500	43.21–63.50	8	165	4.19
2.501 & larger	63.53 & larger	6	203	5.16

* See Appendix C for minimum diameter calculation.

7.4.4 Vertical Riser Cable

Vertical riser cable is for installation within buildings and is suspended at one end only.

7.4.4.1 Armor

Galvanized round steel wires shall be used for vertical riser cables.

7.4.4.2 Size of Armor Wire

For non-sheathed cables, the armor wires shall be sized in accordance with Table 7-26 for shaft cable. The tensile safety factor [based on 50,000 psi (345 MPa)] shall be not less than seven. If the required tensile safety factor is not maintained, the next larger size wire given in the table should be used. Wire band servings in accordance with 7.4.1.2 shall be applied.

For sheathed cables, the armor wires for vertical riser cable for indoor installation shall be in accordance with Table 7-22 for borehole cable, but with a tensile safety factor of not less than four. Wire band servings in accordance with 7.4.1.2 shall be applied.

7.5 Division III

7.5.1 Buried Land Cables

Division III gives details of construction of round wire armor for sheathed and non-sheathed buried land cables requiring greater longitudinal strength than that provided by flat tape armor, but not the strength of the regular armor required for submarine service. The requirements of Division I pertaining to quality of materials, design, and construction apply also to these buried round wire armored cables except as set forth in the following sections.

7.5.1.1 Armor

The size of armor wire and the thickness of a jute or equivalent bedding shall be in accordance with Table 7-27.

The length of lay of the armor wires shall be not less than three nor more than twelve times their pitch diameter. This lay shall be used such that the armor will be applied closely without appreciable space between wires.

A serving as specified in 7.3.7.2 shall be applied over the armor.

Table 7-27
Thickness of Bedding and Size of Armor Wire (Division III)

Calculated Diameter of Cable Under Bedding*		Minimum Thickness of Bedding		Nominal Size of Armor Wire		
inches	mm	mils	mm	BWG	mils	mm
0–0.750	0–19.05	45	1.14	14	83	2.11
0.751–1.000	19.08–25.40	65	1.65	12	103	2.77
1.001–1.700	25.43–43.18	80	2.03	10	134	3.40
1.701–2.500	43.21–63.50	80	2.03	8	165	4.19
2.501 & larger *	63.53 & larger	95	2.41	6 **	203	5.16

* See Appendix C for minimum diameter calculation.
** For cable diameters over 2.500 in. (63.50 mm) where greater strength is desired than is obtainable with the No. 6 BWG wires or where the required number of wires exceeds the capacity of the armoring machine, a No. 4 BWG (238 mils or 6.05 mm diameter) wire size may be used.

Section 8
Assembly, Fillers, and Cable Identification

8.1 Assembly Of Multiple-Conductor Cables

Multiple-conductor cables shall be assembled in accordance with Section 8 unless otherwise modified by Section 7.

Conductors in a multiple-conductor cable, with an overall covering, shall be cabled with a length of lay not to exceed values calculated from the factor given in Table 8-1. The direction of lay may be changed at intervals throughout the length of the cable. The intervals need not be uniform. In a cable in which the direction of lay is reversed:

a. Each area in which the lay is right- or left-hand for a minimum of five complete twists (full 360° cycles) shall have the conductors cabled with a length of lay that is not greater than the values calculated from the factor given in Table 8-1, and
b. The length of each lay-transition zone (oscillated section) between these areas of right- and left-hand lay shall not exceed 1.8 times the maximum length of lay values calculated from the factor given in Table 8-1.
c. The length of lay of the conductors in a multi-conductor cable shall be determined by measuring, parallel to the longitudinal axis of the cable, the pitch of each successive convolution of one conductor. When the direction of lay is reversed, the beginning and end of area reversal shall be defined on either side by the last convolution that does not exceed the maximum lay requirement on either side of the reversed area.

If the direction of lay is not reversed in a cable containing layers of conductors, the outer layer of conductors shall have a left-hand lay, and the direction of lay of the conductors in the inner layers shall be governed by the cabling machine.

If the direction of lay is not reversed in a single layer cable, the conductors shall have a left-hand lay.

A left-hand lay is defined as a counterclockwise twist away from the observer.

8.1.1 With a Common Covering

The length of lay of the individual conductors in a cable with a common covering shall not exceed the value calculated from the factor given in Table 8-1.

8.1.2 Without a Common Covering

The length of lay of the individual conductors in a 2, 3, or 4 conductor cable without a common covering shall not exceed 60 times the largest conductor diameter. The largest conductor is the insulated conductor having the largest calculated overall diameter.

Table 8-1
Conductor Multiplying Factors

Number of Conductors In Cable	Multiplying Factors Based On Calculated Diameter
2	30 times largest conductor
3	35 times largest conductor
4	40 times largest conductor
5 or more	15 times assembled cable diameter