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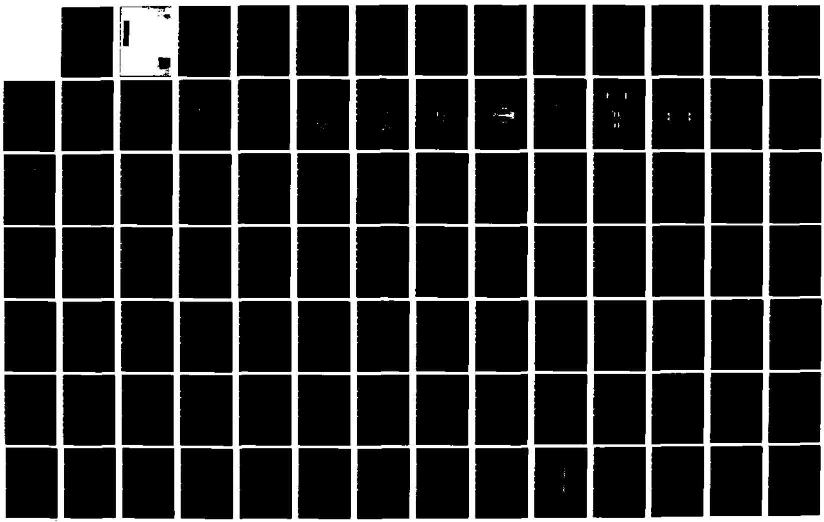

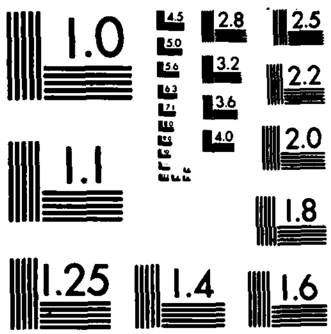
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Cable testing	Sonar cable
	Transducer cable

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Comments were solicted from sonar system and cable manufacturers, Transducer Repair Facilities, Navy Laboratories, NAVSEA engineers, and private and Naval shipyards regarding the adequacy of Navy underwater cables in meeting existing and future Navy sonar system requirements. These inquiries have resulted in a number of recommended revisions to the underwater cable specifications detailed in MIL-C-915; as well as recommended additional cable designs to be incorporated in the subject specification.

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RECOMMENDATIONS FOR THE REVISION OF MIL-C-915 OUTBOARD CABLE SPECIFICATIONS

1. INTRODUCTION

1.1. General

The primary objective of this study has been to offer recommendations for the revision and addition to the Navy's MIL-C-915 electrical cable specification in the areas of underwater electrical cables used in conjunction with sonar systems.

Comments on the MIL-C-915 specification were solicited from Navy laboratories, Naval Sea Systems Command (NAVSEA) engineers, private and Naval shipyards, transducer repair facilities, and cable and sonar system manufacturers. These comments were combined with the capabilities of the manufacturers who fabricate the desired cables and, as a result, recommendations are offered in this report to update the applicable portions of the MIL-C-915 cable specification to meet NAVSEA's current and future sonar system cable needs.

Appendix A gives a listing of personnel contacted during the first phase of the study and Appendix B is a copy of the form sent for comment. The report gives an overview of how outboard sonar cables are installed and terminated on submarines and surface ships. It discusses the environmental, mechanical, and electrical design requirements of outboard sonar cables. The main body of the report discusses those areas of cable design where revisions and additions to the MIL-C-915 cable specifications are felt to offer improvements to the existing cables. Appendix C provides a copy of MIL-C-915 and the appropriate cable specification sheets covered in this report.

The sonar system electrical cables discussed in this report are primarily located outside the submarine pressure hull and the hull of surface ships. The Navy outboard cable types are listed in Table 1. The hydrophones and transducers which use these cables are listed in Table 2. Prior to discussing possible revisions to the outboard MIL-C-915 cable specification sheets [1], a review of how these cables are supported and protected and terminated is felt to be in order.

Table 1 - Navy sonar outboard cables

CABLE TYPE	SPECIFICATION SHEET
DSS-2	MIL-C-915/8
DSS-3	MIL-C-915/8
DSS-4	MIL-C-915/8
FSS-2	MIL-C-915/8
7SS-2	MIL-C-915/8
2SWF-3	MIL-C-915/48
2SWF-3	MIL-C-915/48
2SWF-4	MIL-C-915/48
2SWF-7	MIL-C-915/48
TSP-11	MIL-C-915/22
TSP-31	MIL-C-915/22
DSWS-4	MIL-C-915/7
S2S	MIL-C-915/61
RG-8/U	G.E. Dwg 7094511
RG-12A/U(MOD)	MIL-C-17/22
RG-27/U	MIL-C-17/23
RG-28/U	MIL-C-17/28
RG-58A/U	MIL-C-17/29
RG-59/U	MIL-C-17/33
RG-64A/U	MIL-C-17/56
RG-130/U	MIL-C-17/56
24 Shielded Conductor Harness	Raytheon 430679
66 Conductor Cable	GE191E-CA-0033
10 Pair Cable	Sangamo 820742
66 Conductor Cable	Sangamo 820026
9 Pair Cable	Sangamo 867484
	Sangamo 2196
	Massa C30732-2
	Massa C320829-501
8 to 1 Harness	GE C77C705423
8 to 1 Harness	GE 77D603108
8 to 1 Harness	EDO 42892
Towed-Array Harness	EDO 57026
10 Conductor Harness	EDO 60372-1
48 Conductor Harness	EDO 58112-1
	EDO 60379-1
1PR-16	EBDiv CPG 1000/3
1TR-16	EBDiv CPG 1000/4
1Q-16	EBDiv CPG 1000/16
3PR-16	EBDiv CPG 1000/20
7PR-16	EBDiv CPG 1000/18
1 Shielded Twisted Pair	Belden Corp. No. 8428

Table 2 - Cables used on Navy sonar transducers and hydrophones.

TRANSDUCER	CABLE TYPE	CABLE LENGTH (FT)	TRANSDUCER CONNECTOR	SYSTEM
AT-177	TSP-11 & RG-64A/U	65	Stuffing Tube	AN/SQS-1, 10, 10A, 11, 11A
AT-177A	TSP-11 & RG-64A/U	65	Stuffing Tube	AN/SQS-1, 10, 10A, 11, 11A
AT-177A-CU326	TSP-11 & RG-64A/U	65	Stuffing Tube	AN/SQS-1, 10, 10A, 11, 11A
AT-177B	TSP-11 & RG-64A/U	65	Stuffing Tube	AN/SQS-1, 10, 10A, 11, 11A
AT-186	DSS-3	125	Stuffing Tube	AN/UQC-1
AT-186A	DSS-3	125	Stuffing Tube	AN/UQC-1
AT-186B	DSS-3	125	Stuffing Tube	AN/UQC-1
AT-186C	DSS-3	125	Stuffing Tube	AN/UQC-1
AT-200	DSS-3	65	Stuffing Tube	AN/UQN-1, 4
AT-200A	DSS-3	65	Stuffing Tube	AN/UQN-1, 4
AT-200B	DSS-3	65	Stuffing Tube	AN/UQN-1, 4
AT-200C	DSS-3	65	Stuffing Tube	AN/UQN-1, 4
AT-200D	DSS-3	65	Stuffing Tube	AN/UQN-1, 4
AT-200G	DSS-3	80	MIL-C-24217	AN/UQN-1, 4
AT-200G	DSS-3, 1PR-16	180	MIL-C-24217	AN/UQN-1, 4; AN/BQQ-6
AT-217	DSS-3	30	MIL-C-24217	AN/BQN-1
AT-299	DSS-3	65	MIL-C-24217	AN/BQS-2, 3
AT-388	FSS-2	55	MIL-C-24217	AN/BQS-2, 3
AT-349	TSP-11	65	Stuffing Tube	AN/SQS-10, 10A
AT-354	TSP-11	65	Stuffing Tube	AN/SQS-11, 11A
AT-359B	RG-8/U, RG-59/U	17	Stuffing Tube	AN/UQS-1B, 1D
AT-360	DSS-3	50	Stuffing Tube	AN/UQN-2
AT-385	DSS-3	80	Stuffing Tube	AN/BQC-1, 1A, 1B
DT-30	DSS-2	35	Stuffing Tube	AN/UQR
DT-69A	FSS-2	50	Stuffing Tube	AN/BQR-3A
DT-70	FSS-2	50	Stuffing Tube	AN/BQR-3A
DT-85	DSS-3	100	Stuffing Tube	AN/BQR-4
DT-95	DSS-3	100	Stuffing Tube	AN/BQR-4A
DT-143	DSS-3	50	Stuffing Tube	AN/UQR
DT-168	DSS-3	125	Stuffing Tube	AN/BQR-2, 2A, 2B, 2C, 2D
DT-168B	DSS-3	125	Stuffing Tube	AN/BQS-4, AN/BQR-2, 2A, 2B
DT-168A	DSS-3	125	Stuffing Tube	AN/BQS-4, AN/BQR-2, 2C, 2D
DT-170	RG-59/U	17	Stuffing Tube	AN/UQS-1, 1B, 1D
DT-171	FSS-2	50	Stuffing Tube	AN/BQR-3A
DT-171A	FSS-2	31	Stuffing Tube	AN/BQR-3A
DT-241	DSS-3	150	Cable Gland	OMA/BQM-1
DT-241A	DSS-3	300	Cable Gland	OMA-BQM-1
DT-242	DSS-3	150	Cable Gland	OMA/BQM-1
DT-242A	DSS-3	300	Cable Gland	OMA/BQM-1
DT-242B	DSS-3	150	Cable Gland	OMA/BQM-1
DT-242C	DSS-3	300	Cable Gland	OMA/BQM-1

(continued)

TRANSDUCER	CABLE TYPE	CABLE LENGTH (FT)	TRANSDUCER CONNECTOR	SYSTEM
DT-276	DSS-3	125	Cable Gland	AN/BQR-7, 7B
DT-280	DSS-3	100, 200, 300*	Cable Gland	AN/BQQ-3, AN/BQH-2
DT-280A	DSS-3	100, 200, 300*	Cable Gland	AN/BQQ-3, AN/BQH-2
DT-280B	DSS-3	100, 200, 300*	Cable Gland	AN/BQQ-3, AN/BQH-2
DT-282	DSS-3	70	Cable Gland	AN/BQG-2, 2A, 4
DT-282A	DSS-3	70	Cable Gland	AN/BQG-2, 2A, 4
DT-282B	DSS-3	70	Cable Gland	AN/BQG-2,
DT-282C	DSS-3	70	Cable Gland	AN/BQG-2,
DT-282D	DSS-3	50	Cable Gland	AN/BQG-2,
DT-283	S2S	70	Cable Gland	AN/BQG-2
DT-283A	S2S	70	Cable Gland	AN/BQG-2
DT-305	2SWF-4	100	MIL-C-22539	AN/BQS-8, 8A, 10, 14
DT-308	2SWF-4	40	MIL-C-22539	AN/BQS-8, 8A, 10, 14
DT-339	FSS-2	50	Cable Gland	AN/BQR-3A
DT-365	FSS-2	50	Cable Gland	AN/BQS-15XN1
DT-369	FSS-2	200	Cable Gland	AN/BQH-5
DT-372	Raytheon #430679	110	Special Harness	AN/BQR-19
DT-393	DSS-3	125	Special Harness	
DT-506	FSS-2	150	Special Harness	AN/BQA-8, 8A
DT-506	FSS-2	300	Special Harness	AN/BQA-8, 8A
DT-511	2SWF-4	100	MIL-C-24217	AN/WLR-9
DT-511A	2SWF-4	100	MIL-C-24217	AN/WLR-9
DT-512	2SWF-7	160	MIL-C-24217	AN/WLR-9
DT-512A	2SWF-7	160	MIL-C-24217	AN/WLR-9
DT-513	FSS-2	150	Cable Gland	AN/BQA-8, 8A
DT-513	FSS-2	250	Cable Gland	AN/BQA-8, 8A
DT-513A/B	FSS-2	150	Cable Gland	AN/BQA-8, 8A
DT-513A/B	FSS-2	250	Cable Gland	AN/BQA-8, 8A
DT-531	FSS-2	150	Cable Gland	AN/BQA-8, 8A
DT-531	FSS-2	250	Cable Gland	AN/BQA-8, 8A
DT-532	DSS-3	125	Cable Gland	AN/BQR-21
DT-537	FSS-2	70	Cable Gland	AN/SQQ-23
DT-538	FSS-2	100	Cable Gland	AN/SQQ-23
DT-539	FSS-2	150	Cable Gland	AN/BQS-3
DT-544	2SWF-7, 7PR-16	160	Cable Gland	AN/WLR-12; AN/BQQ-6
DT-574	1PR-A20E	50	Cable Gland	AN/BQQ-6
DT605	2SWF-4	40	Cable Gland	AN/BQS-8, 10, 14
DT-611	1PR-A20E	100	Cable Gland	AN/BQR-21

(continued)

TRANSDUCER	CABLE TYPE	CABLE LENGTH (FT)	TRANSDUCER CONNECTOR	SYSTEM
HS-18	DSS-3	100	Stuffing Tube	DUUG-1
HS-18E	DSS-3	100	Stuffing Tube	DUUG-1
HS-18E(BTD)	DSS-3	100	Stuffing Tube	DUUG-1
HS-18G(MI)	DSS-3	75	Stuffing Tube	DUUG-1
HS-18G	DSS-3	100	Stuffing Tube	DUUG-1
HS-18H	DSS-3	100	Stuffing Tube	DUUG-1
HS58DO-300	DSS-3, 1PR-16	35	MIL-C-24217	AN/BQN-13, AN/BQQ-6
MX-1905	RG-8/U	17	MIL-C-24217	AN/UQS-1, 1B, 1D
TR-107	TSP-31	60	MIL-C-24217	**
TR-108	TSP-31	60	MIL-C-24217	†
TR-110	DSS-3	65	MIL-C-24217	AN/SQM-1, AN/UQM-1
TR-111	DSS-3	65	MIL-C-24217	AN/SQM-1, AN/UQM-1
TR-112	DSS-3	65	MIL-C-24217	AN/SQM-1, AN/UQM-1
TR-113	DSS-3	65	MIL-C-24217	AN/SQM-1, AN/UQM-1
TR-114	TSP-31	60	MIL-C-24217	††
TR-114A	TSP-31	60	MIL-C-24217	AN/SQS-4, 30, 30A, 30B, 40(V), 50, 30B, 30C, 44(V), Hull
TR-115	TSP-31	60	MIL-C-24217	§
TR-115A	TSP-31	60	MIL-C-24217	AN/SQS-4, 29, 29(A), 39(V), 49, 29B, 29C, 43(V), Hull
TR-116	TSP-31	60	MIL-C-24217	**
TR-116	TSP-31	60	MIL-C-24217	**
TR-117	TSP-31	60	MIL-C 24217	†
TR-117A	TSP-31	60	MIL-C-24217	†
TR-122	DSS-3	80	Cable Gland	AN/BQC-1, 1A, 1B
TR-122A	DSS-3	80	Cable Gland	AN/BQC-1, 1A, 1B
TR-122B	DSS-3	80	Cable Gland	AN/BQC-1, 1A, 1B
TR-126	DSS-2	75	Cable Gland	AN/WQM
TR-127	DSS-2	75	Cable Gland	AN/WQM
TR-128	DSS-2	75	Cable Gland	AN/WQM
TR-129	DSS-2	75	Cable Gland	AN/WQM
TR-131	TSP-31	60	Cable Gland	§
TR-132	TSP-31	60	Cable Gland	**
TR-133	TSP-31	60	Cable Gland	§
TR-134	TSP-31	60	Cable Gland	††
TR-139	TSP-31	125	Cable Gland	AN/SQS-4, (Mod 1, Submarine) 49
TR-141	RG-28/U, DSWS-4	125	Stuffing Tube	AN/BQS-4
TR-141A	DSWS-4	125	Stuffing Tube	AN/BQS-4
TR-141B	DSWS-4	125	Stuffing Tube	AN/BQS-4
TR-143	RG-12A/U(MOD)	135	Cable Gland	AN/BQN-3
TR-145	DSS-3	250	Cable Gland	AN/BQN-4
TR-146	DSS-3	50	Cable Gland	AN/SQN-8

(continued)

TRANSDUCER	CABLE TYPE	CABLE LENGTH (FT)	TRANSDUCER CONNECTOR	SYSTEM
TR-155A	DSS-3	15	Cable Gland	AN/BQS-6, 6A, 6B, 11, 12, 13
TR-155B	DSS-3	15	Cable Gland	AN/BQS-6, 6A, 6B, 11, 12, 13
TR-155C	DSS-3	15	Cable Gland	AN/BQS-6, 6A, 6B, 11, 12, 13
TR-155D	DSS-3	15	Cable Gland	AN/BQS-6, 6A, 6B, 11, 12, 13
TR-155E	DSS-3	18	Cable Gland	AN/BQS-6, 6A, 6B, 11, 12, 13
TR-155F	DSS-3	18	Cable Gland	AN/BQQ-5, 5A, 5B
TR-155G	DSS-3	18	Cable Gland	AN/BQQ-5, 5A, 5B
TR-164	DSS-3	250	Stuffing Tube	AN/BQN-4A
TR-167B	7SS-2, 3PR-16	250	MIL-C-22539	AN/BQH-1A, 1B; AN/BQQ-5
TR-167C	7SS-2, 3PR-16	150	MIL-C-22539	AN/BQH-1A, 1B; AN/BQQ-6
TR-170	GI #91E-CA-0033	30	MIL-C-22539	AN/SQA-10; AN/SQS-31B, 31C, 45(V)
TR-170A	GI #91E-CA-0033	30	MIL-C-22539	AN/SQA-10; AN/SQS-31B, 31C, 45(V)
TR-170B	GI #91E-CA-0033	30	MIL-C-22539	AN/SQA-10; AN/SQS-31B, 31C, 45(V)
TR-171	GI #91E-CA-0033	30	MIL-C-22539	AN/SQA-10; AN/SQS-32B, 32C, 46(V)
TR-171A	GI #91E-CA-0033	30	MIL-C-22539	AN/SQA-10; AN/SQS-32B, 32C, 46(V)
TR-171B	GI #91E-CA-0033	30	MIL-C-22539	AN/SQS-10; AN/SQS-32B, 32C, 46(V)
TR-173(TD)	RG-58A/U	25	MIL-C-22539	AN/SQQ-14
TR-177(SC)	SANGAMO #820742	50	MIL-C-22539	AN/SQS-23
TR-183	TSP-31	60	MIL-C-22539	§
TR-183A	TSP-31	60	MIL-C-22539	§
TR-184	TSP-31	60	MIL-C-22539	††
TR-184A	TSP-31	60	MIL-C-22539	††
TR-185	TSP-31	60	MIL-C-22539	†
TR-185A	TSP-31	60	MIL-C-22539	†
TR-186	TSP-31	60	MIL-C-22539	**
TR-188	SANGAMO #829026	30	MIL-C-22539	AN/SQA-10; AN/SQS-29B, 29C, 43(V)
TR-188A	GI #91E-CA-0033	30	MIL-C-22539	AN/SQS-10; AN/SQS-29B, 29C, 43(V)
TR-186A	TSP-31	60	MIL-C-22539	**
TR-189	SANGAMO #829026	30	MIL-C-22539	AN/SQS-10; AN/SQS-30B, 30C, 44(V)
TR-189A	GI #91E-CA-0033	30	MIL-C-22539	AN/SQS-10; AN/SQS-30B, 30C, 44(V)
TR-191(SC)	MASSA #C30829-501	50	MIL-C-22539	AN/SQS-23
TR-191A(SC)	Massa #C30829-501	50	MIL-C-22539	AN/SQS-23
TR-192	DSS-3, DSS-4	65	MIL-C-22539	AN/UQN-1, 4
TR-192A	DSS-3, DSS-4	65	Stuffing Tube	AN/UQN-1, 4
TR-192B	DSS-3, DSS-4	65	Stuffing Tube	AN/UQN-1, 4

(continued)

TRANSDUCER	CABLE TYPE	CABLE LENGTH (FT)	TRANSDUCER CONNECTOR	SYSTEM
TR-193	DSS-3	150	Stuffing Tube	AN/UQC-1
TR-193A	DSS-3	150	Cable Gland	AN/UQC-1
TR-193B	DSS-3	30	Cable Gland	AN/UQC-1
TR-193B	DSS-3	150	Cable Gland	AN/UQC-1
TR-194(MC)	Massa #C30732-2	26	Cable Gland	AN/SQA-10; AN/SQS-29B, 29C
TR-195(MC)	Massa #C30732-2	26	Cable Gland	AN/SQA-10, AN/SQS-30B, 30C 44(V)
TR-196	TSP-11, RG-27/U, RG-130/U	50	Cable Gland	AN/SQS-17
TR-197(SC)	Massa #C30829-501	50	Cable Gland	AN/SQS-23
TR-198(SC)	GE #C77C705425	118	Cable Gland	AN/SQS-26AXR
TR-203(SC)	Edo #42892	105	Cable Gland	AN/SQS-26BX
TR-204	TSP-31	85	Cable Gland	AN/SQS-36
TR-205	Belden No. 8428	100	Cable Gland	AN/WQM-3
TR-205A		100	Cable Gland	AN/WQM-3
TR-208(SC)	Massa #C30289-501	50	Cable Gland & Joy Connector	AN/SQS-23
TR-208A(SC)	Massa #C30289-501	50	Cable Gland & Joy Connector	AN/SQS-23
TR-208A(SC)	Massa #C30289-501	100	Cable Gland & Joy Connector	AN/SQS-23
TR-212	2SWF-4	100	MIL-C-22539	AN/BQS-8, 8A, 10, 14
TR-213	DSS-3	90	MIL-C-22539	AN/BQS-8, 8A, 10, 14
TR-214	DSS-3	75	MIL-C-22539	AN/BQS-8, 8A, 10, 14
TR-215	FSS-2	22	MIL-C-22539	AN/BQS-8, 8A, 10, 14
TR-216	DSS-3	75	MIL-C-22539	AN/BQS-8, 8A, 10, 14
TR-217	DSS-3	75	MIL-C-22539	AN/BQS-8, 8A, 10, 14
TR-217A	DSS-3	75	MIL-C-22539	AN/BQS-8, 8A, 10, 14
TR-225	Belden NO. 8428	100	MIL-C-22539	AN/WQM-3
TR-227(SC)	GE #77D603108	118	MIL-C-22539	AN/SQS-26CX
TR-229(FTC)	Edo #57026	650	MIL-C-22539	AN/SQS-35
TR-229(FTC)	Edo #60372-1 & Edo #581[illegible]-1	5 7	MIL-C-22539	AN/SQS-38
TR-230(FTC)	Edo #5702[illegible]	650	MIL-C-22539	AN/SQS-35(V)
TR-231	Edo #60369-1 (Pigtail)	2	MIL-C-22539	AN/SQS-38
TR-232	DSS-3, 1PR-16	30	Cable Gland	AN/WQC-2; AN/BQQ-6
TR-232	DSS-3, 1PR-16	175	Cable Gland	AN/WQC-2; AN/BQQ-6
TR-233	DSS-3, 1PR-16	30	Cable Gland	AN/WQC-2; AN/BQQ-6
TR-233	DSS-3, 1PR-16	175	Cable Gland	AN/WQC-2; AN/BQQ-6

(continued)

TRANSDUCER	CABLE TYPE	CABLE LENGTH (FT)	TRANSDUCER CONNECTOR	SYSTEM
TR-237	Sangamo #867484	50	Cable Gland & Joy Connector	AN/SQS-4, 29, 29A, 30, 30A, 39(V), 29B, 29C, 30B, 30C, 43(V), 45(V), Hull, 51, 52
TR-238	Sangamo #867484	50	Cable Gland & Joy Connector	AN/SQS-4, 31, 31A, 32, 32A 41(V), 42(V), 31B, 31C, 32B, 32C, 45(V), 46(V), Hull
TR-242	FSS-2	50	MIL-C-24217	AN/BQS-15; AN/BQQ-6
TR-255	Sangamo #2196	150	MIL-C-24217	AN/SQS-4, MOD 1 & 2 (Submarine), 40, 50
TR-256	DSS-3	125	MIL-C-24217	AN/UQN-1, 4; AN/BQQ-6
TR-281	DSS-3	175	MIL-C-24217	AN/BQS-15
TR-282	DSS-3	175	MIL-C-24217	AN/BQS-15
TR-297	DSS-3	100	D.G. O'Brien	AN/UQN-1, 4; AN/BQQ-6
TR-298	DSS-3	100	C17C1001G12	AN/UQN-1, 4; An/BQQ-6
TR-302	2SWF-3	150	MIL-C-24217	AN/BQN-17
TR-316	FSS-2	22	MIL-C-22539	AN/BQS-10, 14, 18
TR-317	SPECIAL	22	Cable Gland	AN/BQQ-5
TR-318	(2 Cond. SHIELDED)		Cable Gland	AN/BQQ-5
TR-321	7SS-2	125	MIL-C-22539	AN/BQH-IC

* - Length as requested
** - AN/SQS-4,32, 32A, 42(V), 52, 23B, 32C, 46(V), Hull
† - AN/SQS-4, 31B, 31C, 45(V), Hull, 31, 31A, 41(V), 51
†† - AN/SQS-4, 30, 30A, 30B, 40(V), 40, 30B, 30C, 44(V), Hull
§ - AN/SQS-4, 29, 29A, 39(V), 49, 29B, 29C, 43(V), Hull

(TD) - Test Transducer
(SC) - Stave Cable
(MC) - Main Cable
(FTC) - Faired Tow Cable

1.2. Submarine Outboard Cables

Submarine sonar outboard cables run from the submarine pressure hull to components located between the pressure hull and submarine superstructure including ballast tanks (see Fig. 1). The cables are supported and protected under the ship superstructure in type 316 stainless steel cable troughs and inverted steel angle iron [2]. The large cable banks are housed in the cable troughs and the multiple (1 to 3) cable runs are located in the angle iron (see Fig. 2). The outboard sonar system cables are terminated at the hydrophones and transducers in cable glands in which the cables are directly rubber-molded to the cable gland which is mounted to the component housing (see Fig. 3). The cables are also terminated with pressure-proof electrical connectors. The MIL-C-24231 [3] type conectors , the MIL-C-24217 [4], and the NAVSEA Drawing 815-1197170 type connector [5] (Figs. 4, 5, and 6 respectively) are primarily used to terminate cables at outboard sonar system components. The cables are sealed to the connector plugs by molding a neoprene or polyurethane rubber boot to the cable jacket and to the plug shell or sleeve.

The outboard cables are terminated at the submarine pressure hull with hull penetrators (hull fittings). Three basic types of sonar system hull penetrators are used. They are the electrical conector type, the cable stuffing tube, and the molded hull penetrator type. The MIL-C-24231 connector penetrators are fitted with electrical connectors on the outboard side of the hull. Multiple connector penetrators (Fig. 7) and single connector penetrators (Fig. 8) are used to service submarine sonar systems.

Cable stuffing tube type hull penetrators are also used at the submarine pressure hull. Figure 9 shows the TR-155 transducer cable stuffing tube type hull penetrator installed in the attack class submarine sonar spheres. There are 1241 hull penetrators of this type installed in each submarine. The hull penetrator is detailed in Ref. 6. Also, a few submarines fabricated prior to 1960 employ a multiple cable stuffing tube type hull penetrator depicted in Fig. 10. These penetrators are detailed in Refs. 7 and 8.

A third type of hull penetrator is one in which the cables are directly molded to hull penetrator body. Figure 11 shows a polyethylene-molded boot hull penetrator which services the Trident submarine sphereical and line-array hydrophones. The penetrator is detailed in Ref. 9. Figure 12 shows still another neoprene boot molded hull penetrator which will be used to penetrate the sonar sphere on attack class submarines using the TR-155 transducers. In this design, the outboard cable is directly molded to the penetrator body and terminated to contacts hermetically sealed to the body. A molded rubber plug mates to the penetrator on the inboard side of the sphere.

Outboard sonar cables may also pass through ballast tank bulkheads. Multiple cable stuffing tube type penetrators as shown in Fig. 13 and detailed in Ref. 10 are used to seal the cables.

Also, on a few occasions, outboard sonar cables that exit inboard from hull penetrators are also required to pass through inboard bulkheads using single-cable bulkhead stuffing tubes which are also detailed in Ref. 10.

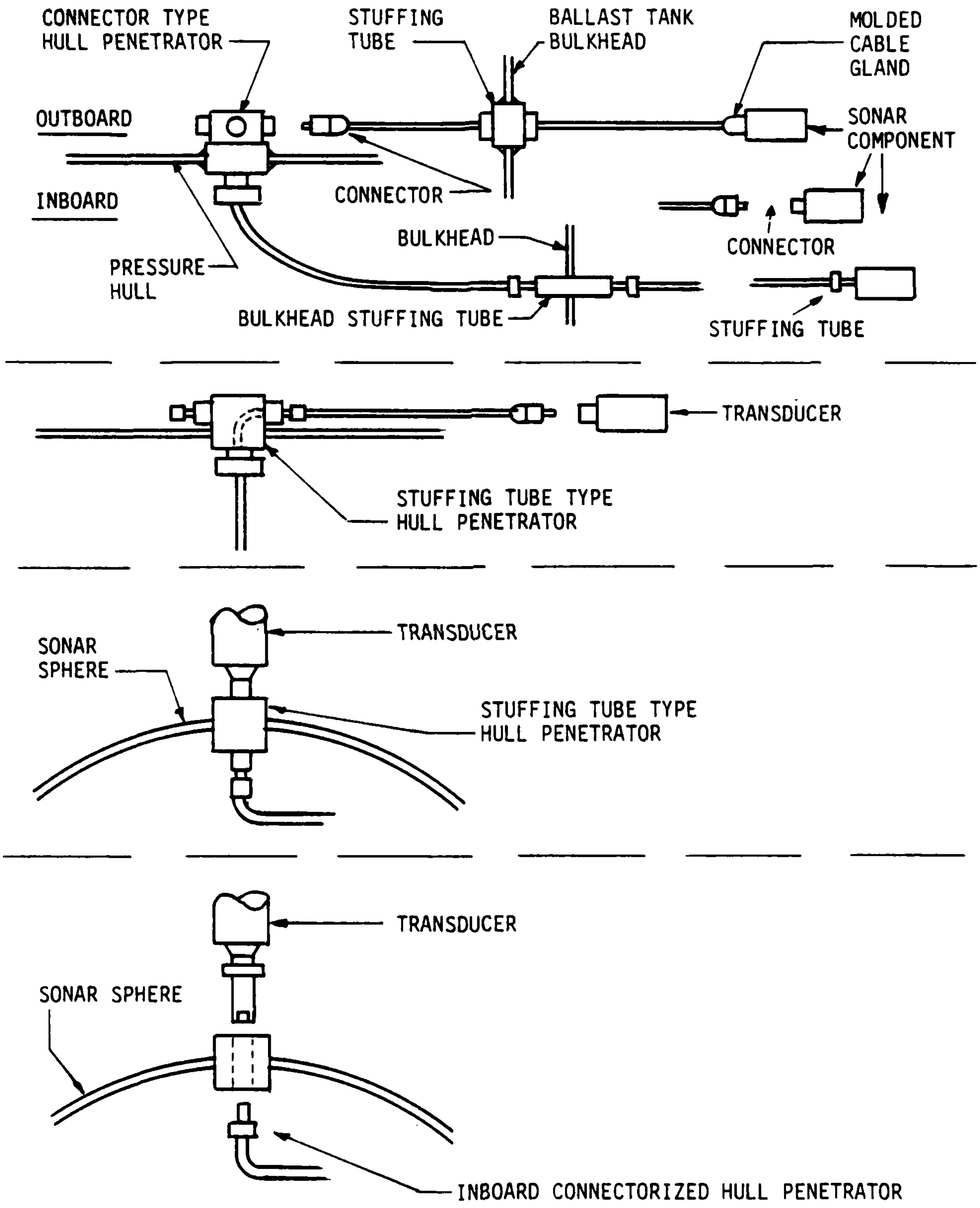

Fig. 1 - Submarine sonar system outboard cable runs.

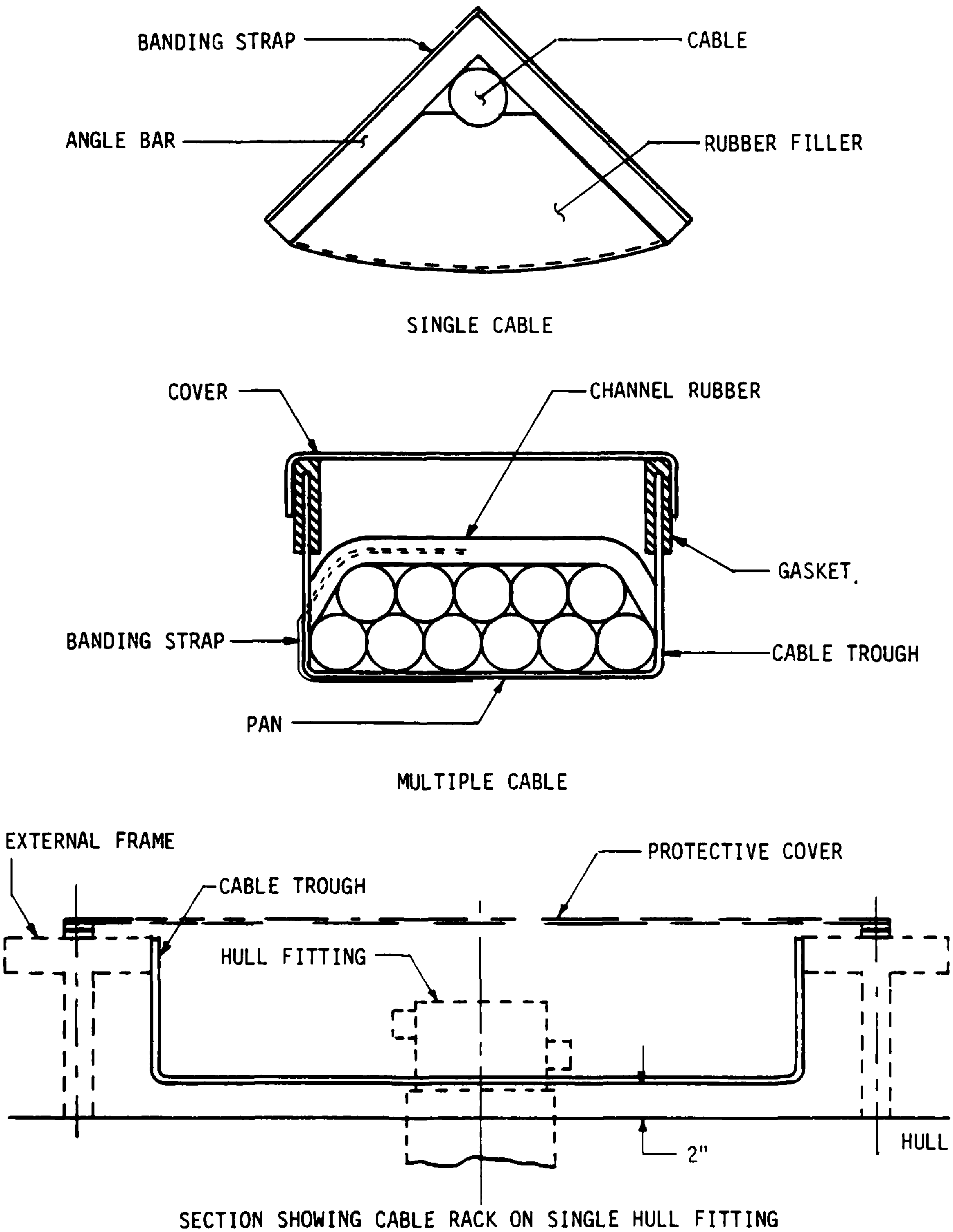

Fig. 2 - Submarine outboard cable support and protection methods.

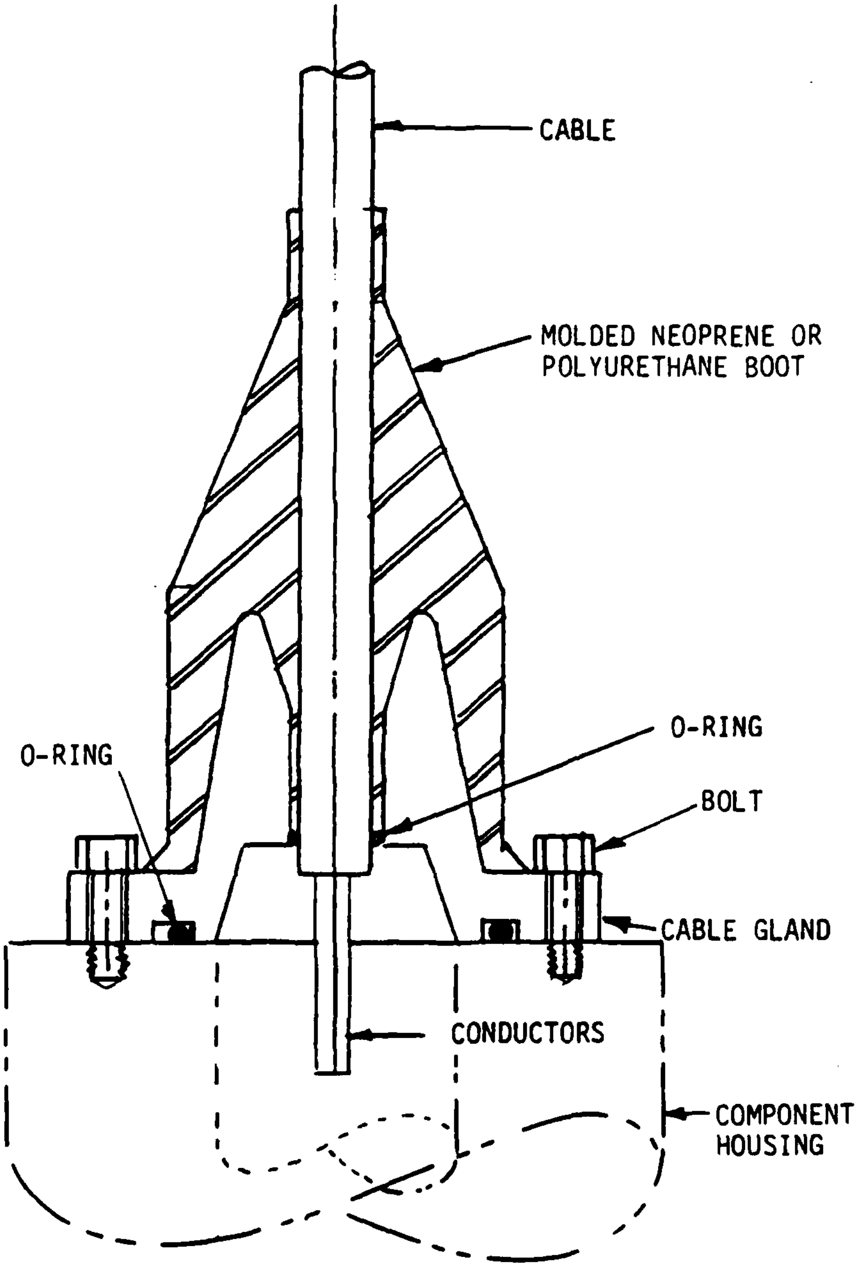

Fig. 3 - Sonar system component cable gland.

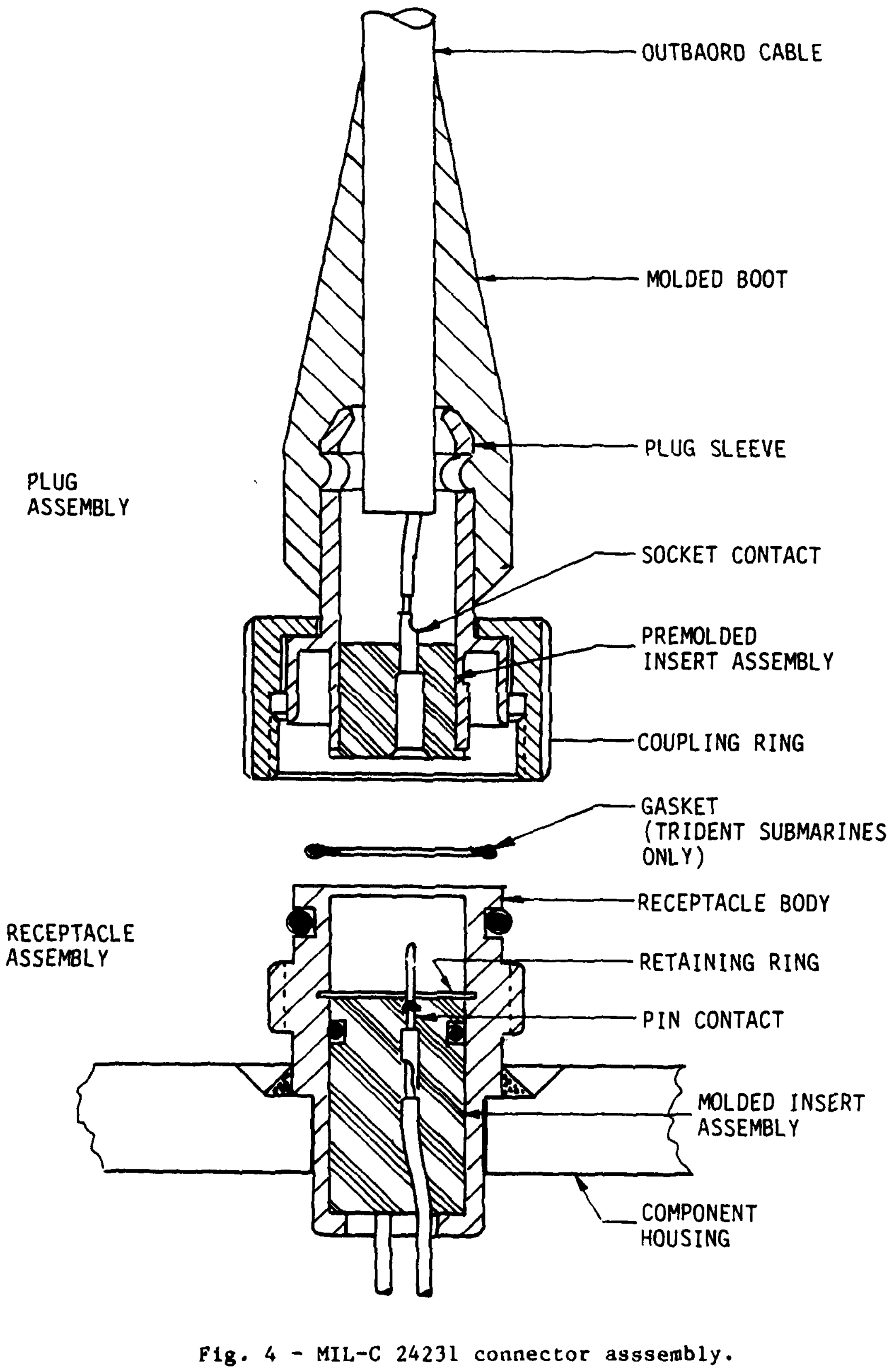

Fig. 4 - MIL-C 24231 connector asssembly.

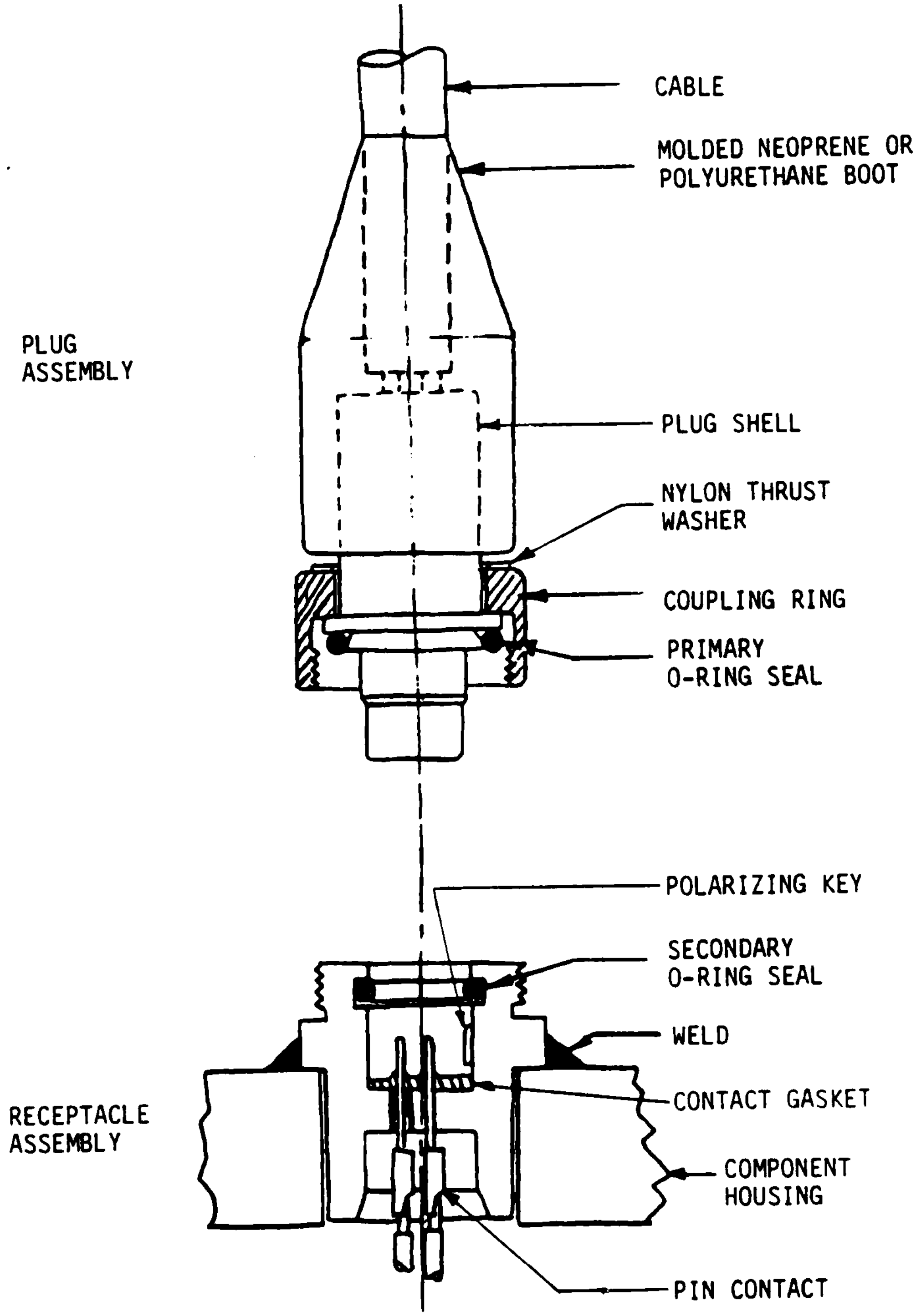

Fig. 5 - MIL-C24217 connector assembly.

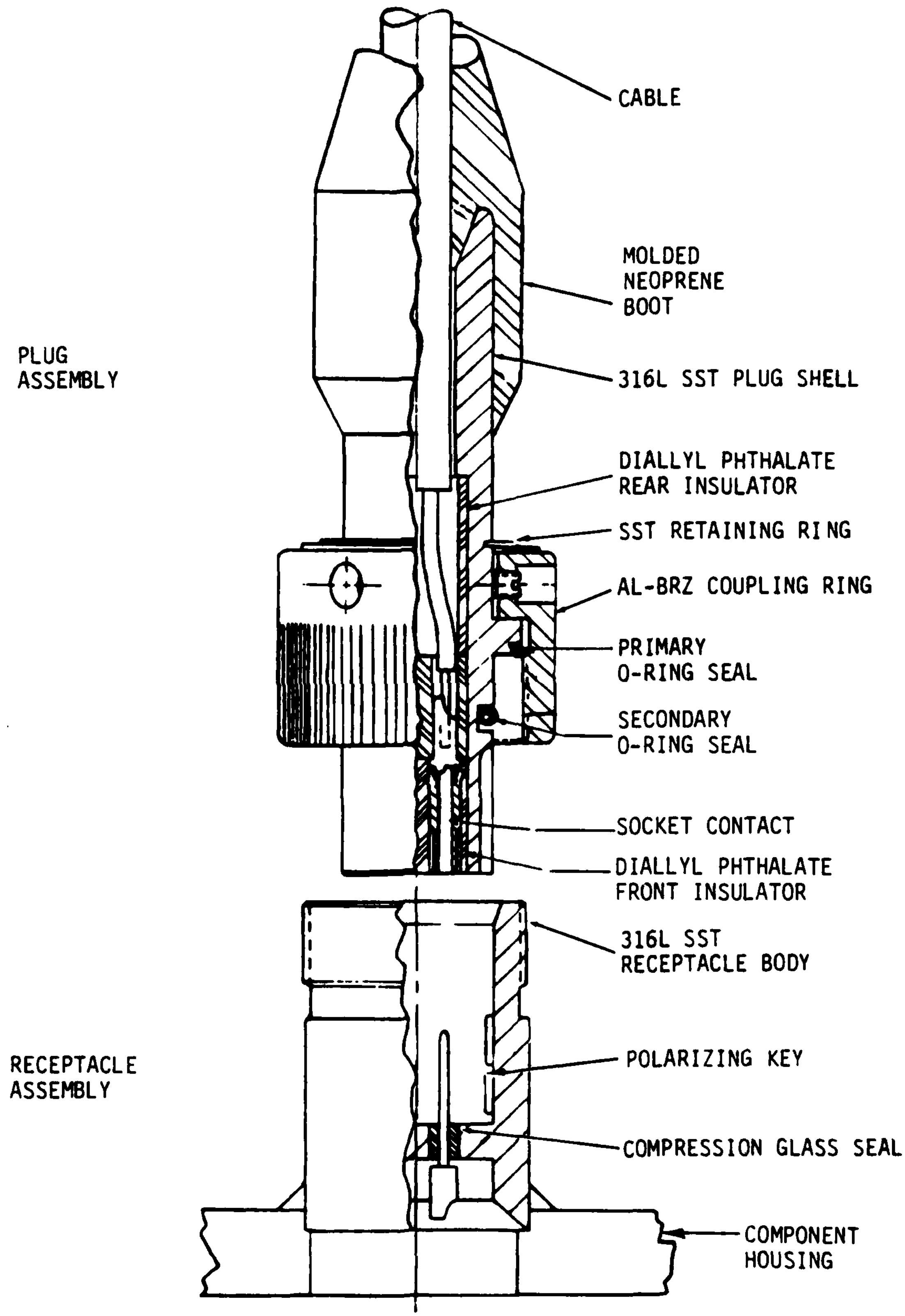

Fig. 6 - NAVSEA dwg 815-1197170 connector assembly.

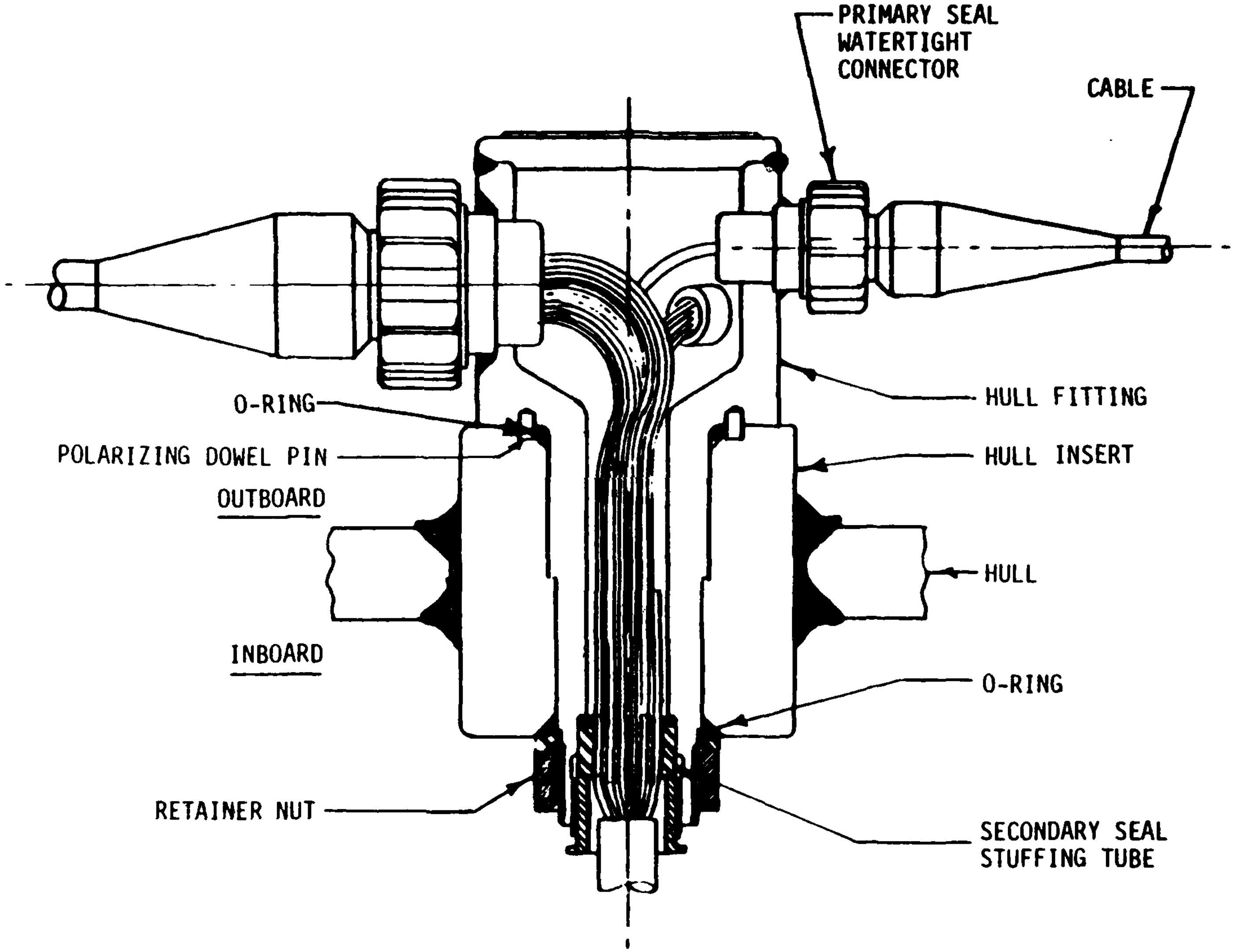

Fig. 7 - MIL-C-24231 multiple connector hull penetrator.

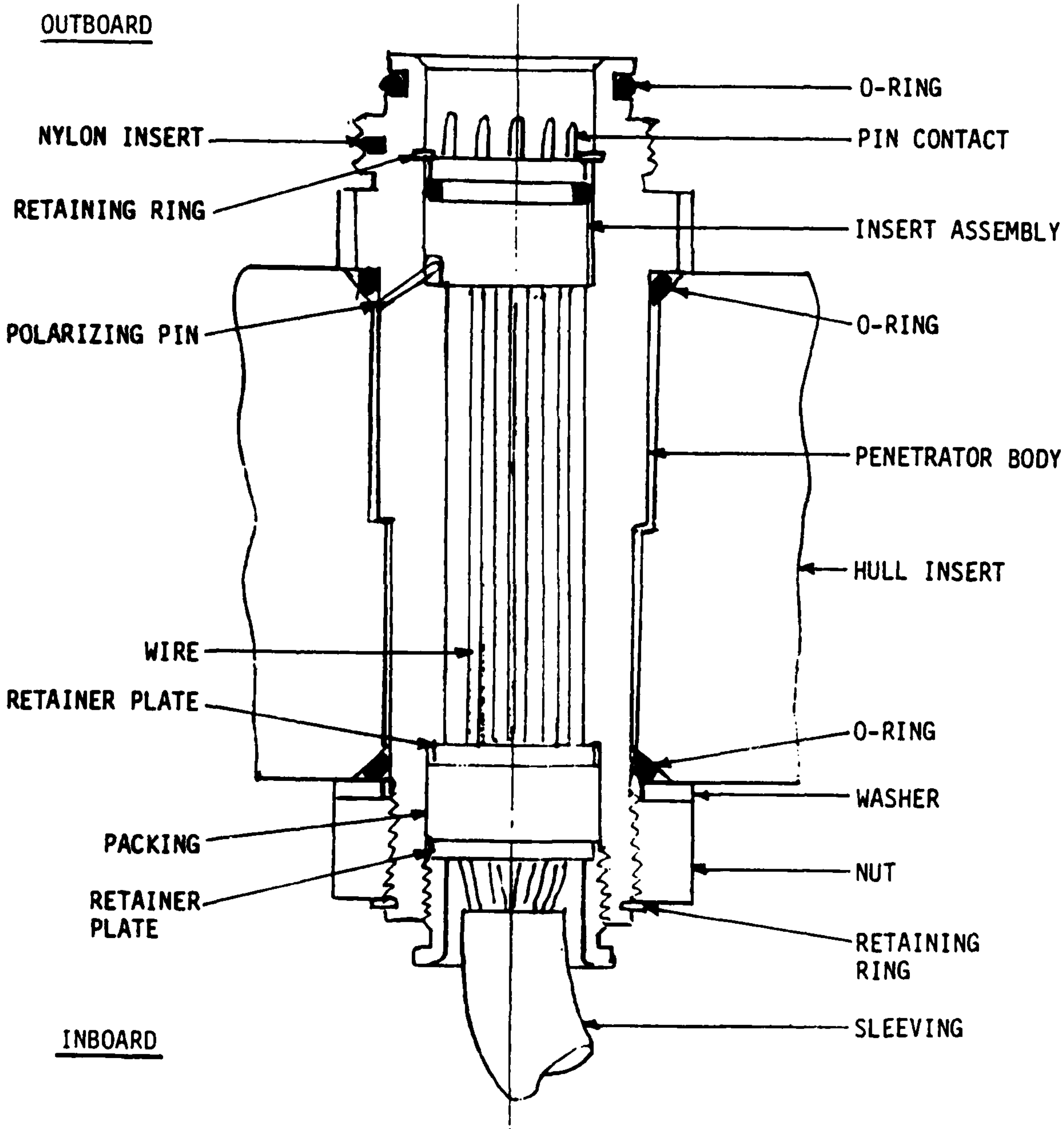

Fig. 8 - MIL-C-24231 single connector hull penetrator.

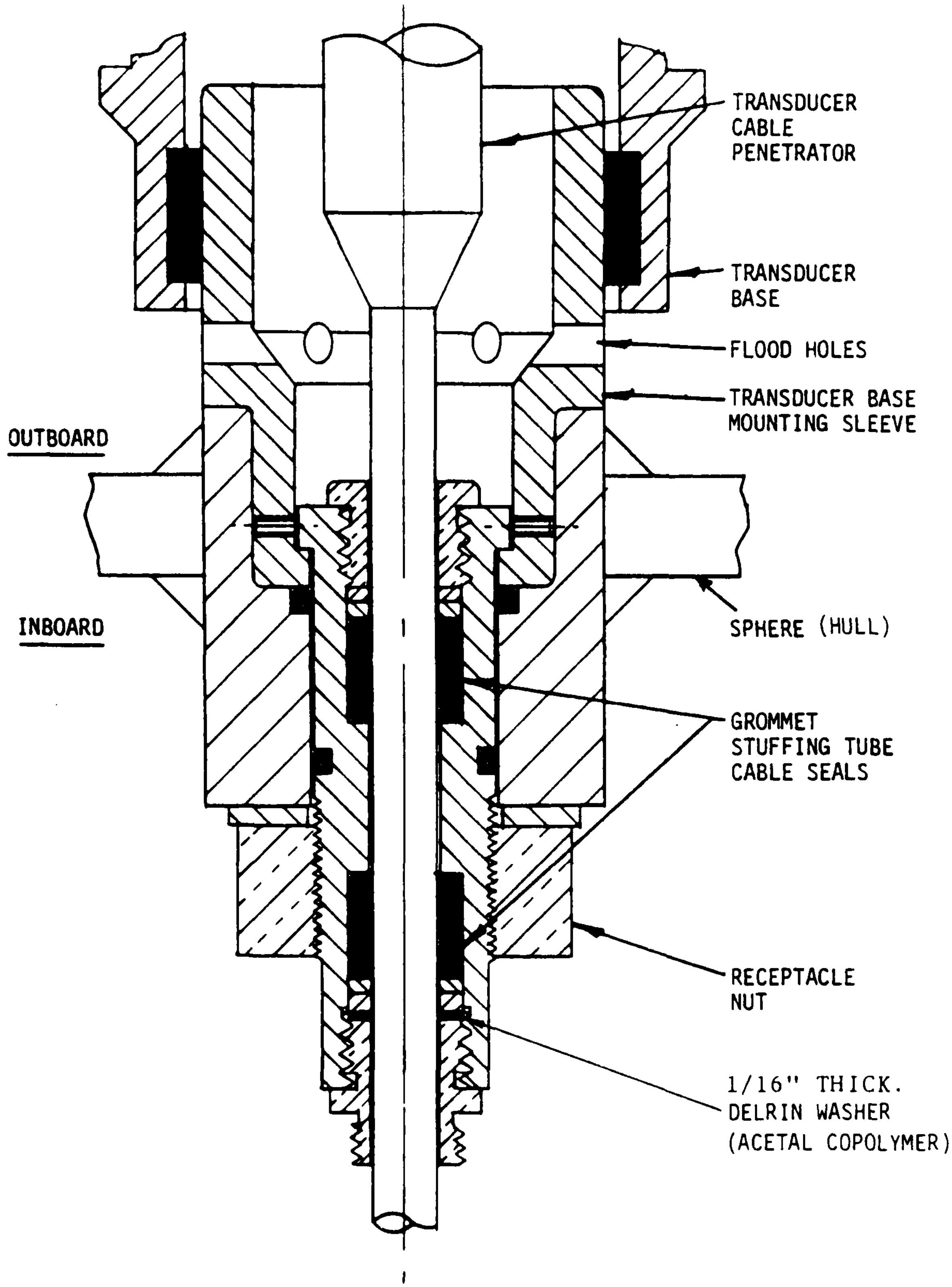

Fig. 9 - TR-155 transducer cable stuffing tube hull penetrator.

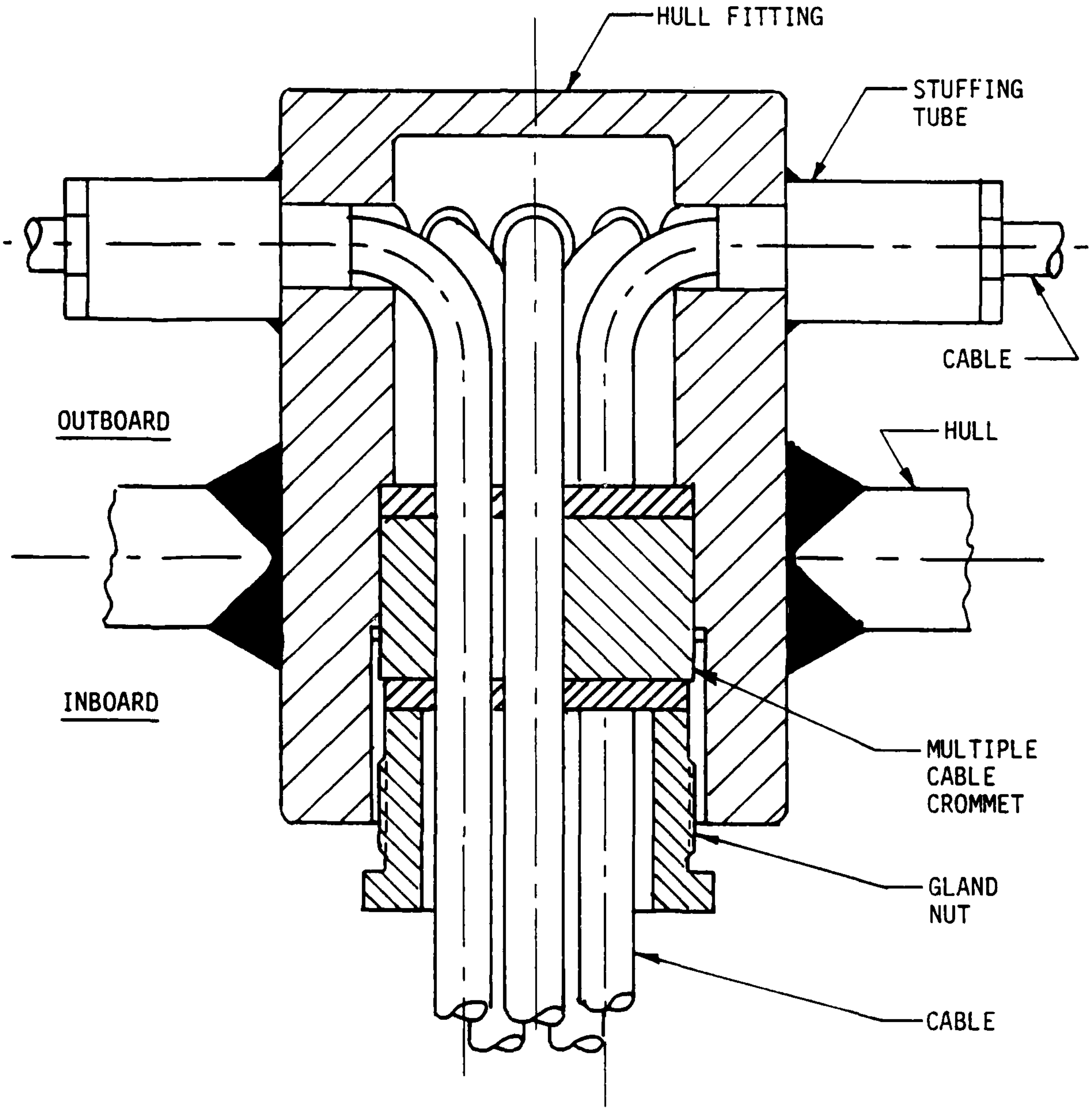

Fig. 10 - Multiple stuffing tube type cable hull penetrator.

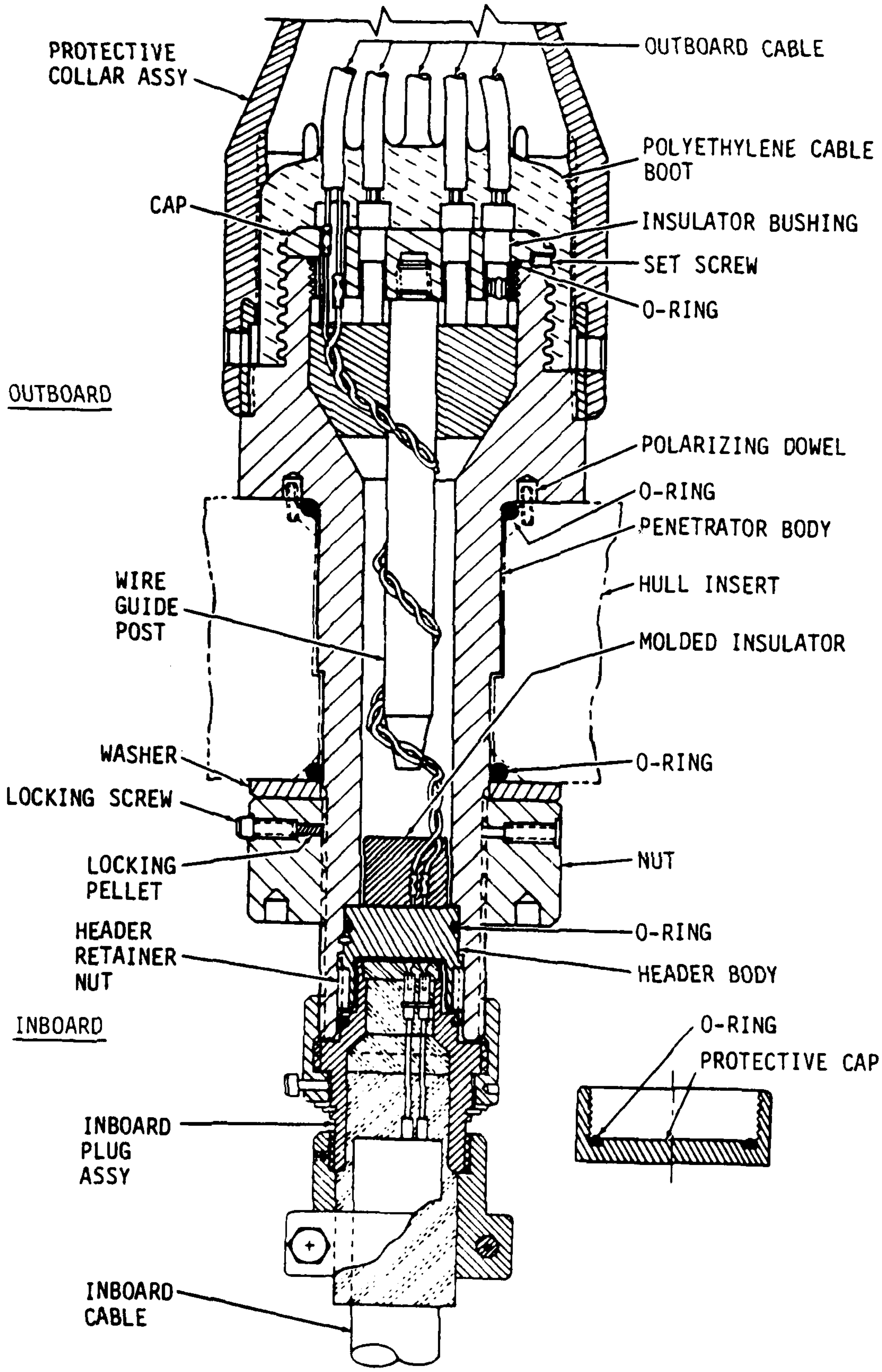

Fig. 11 - Trident polyethylene molded boot hull penetrator.

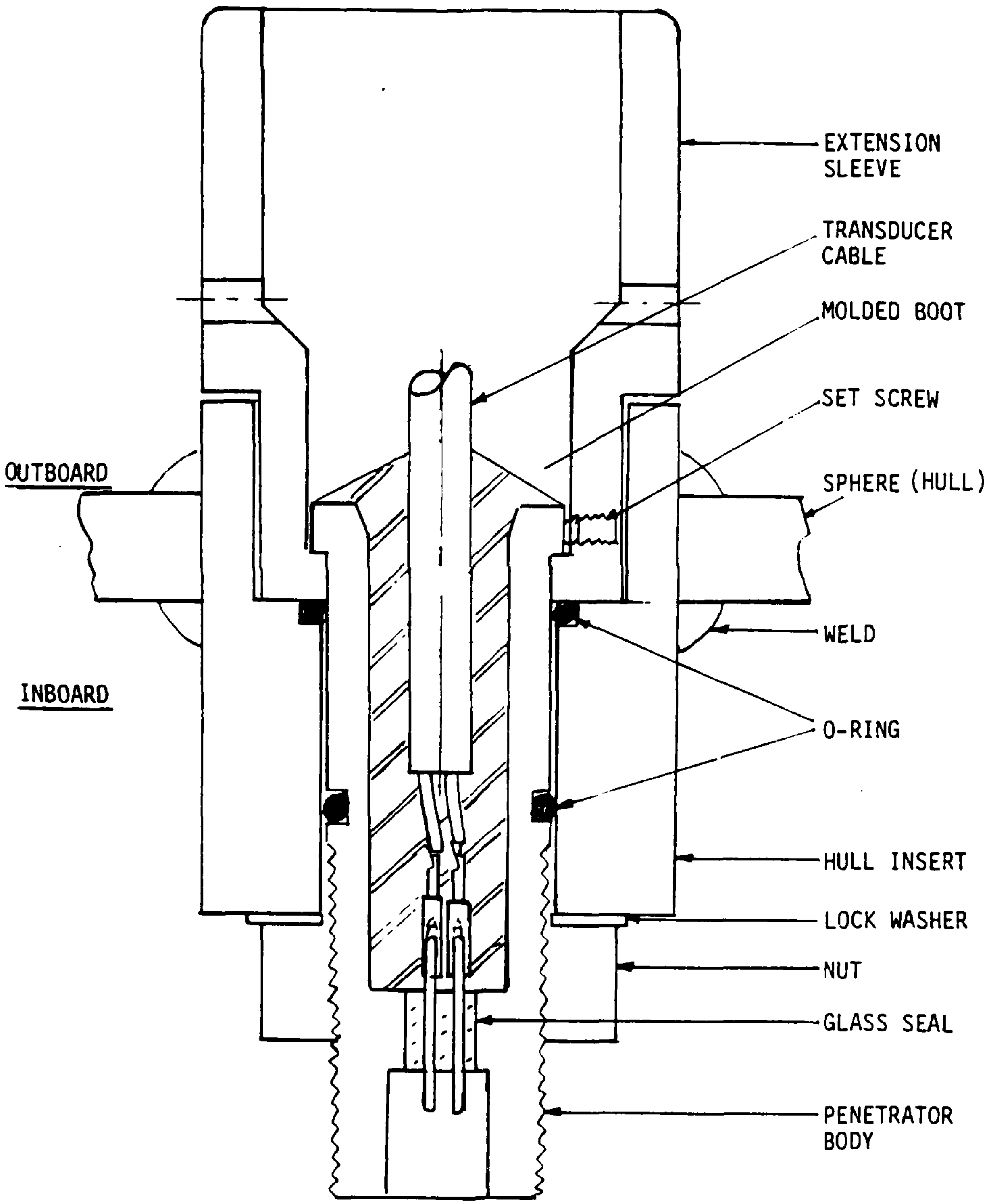

Fig. 12 - Connectorizd TR-155 transducer hull penetrator.

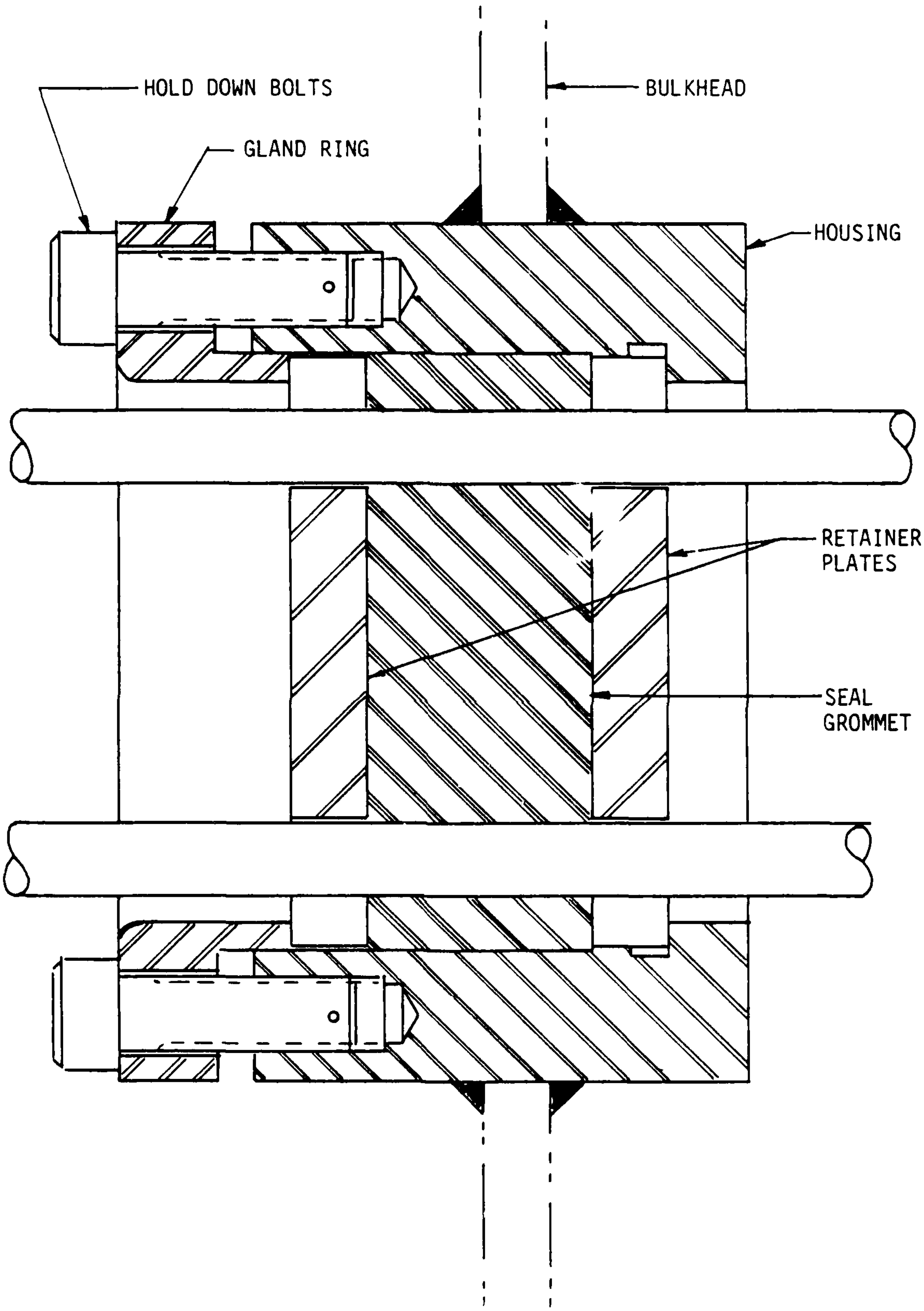

Fig. 13 - Multiple cable ballast tank bulkhead stuffing tube penetrator.

1.3. Surface Ship Outboard Cables

Surface ship sonar outboard cables run from the ship's hull to transducers located in a bulkhead housing below the ships hull. For instance, the SQS-53C transducer system has 72 staves housed in a circular pattern. There are eight transducer elements per stave. As seen in Fig. 14, the trunk cable runs through a stuffing tube located in the hull. The eight twisted pair trunk cable is terminated at a molded rubber cable junction from which eight cables breakout and run to individual molded rubber connectors located a few feet from the transducers. The molded rubber transducer connector assembly is shown in Fig. 15.

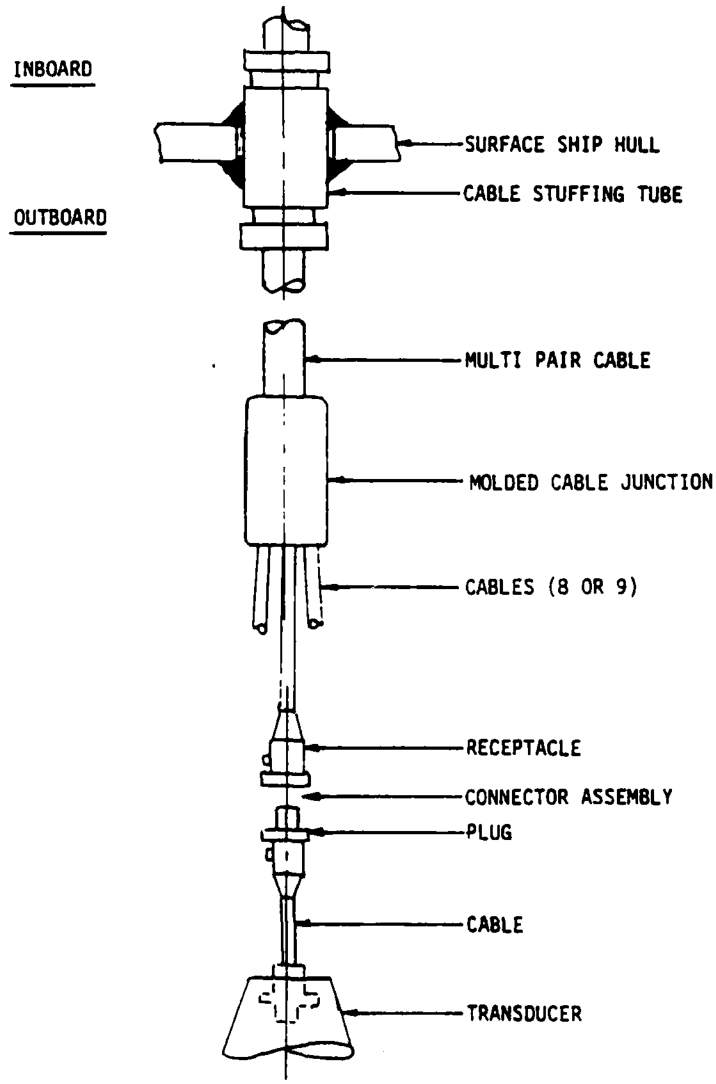

Fig. 14 - Typical surface ship sonar cable harness assembly.

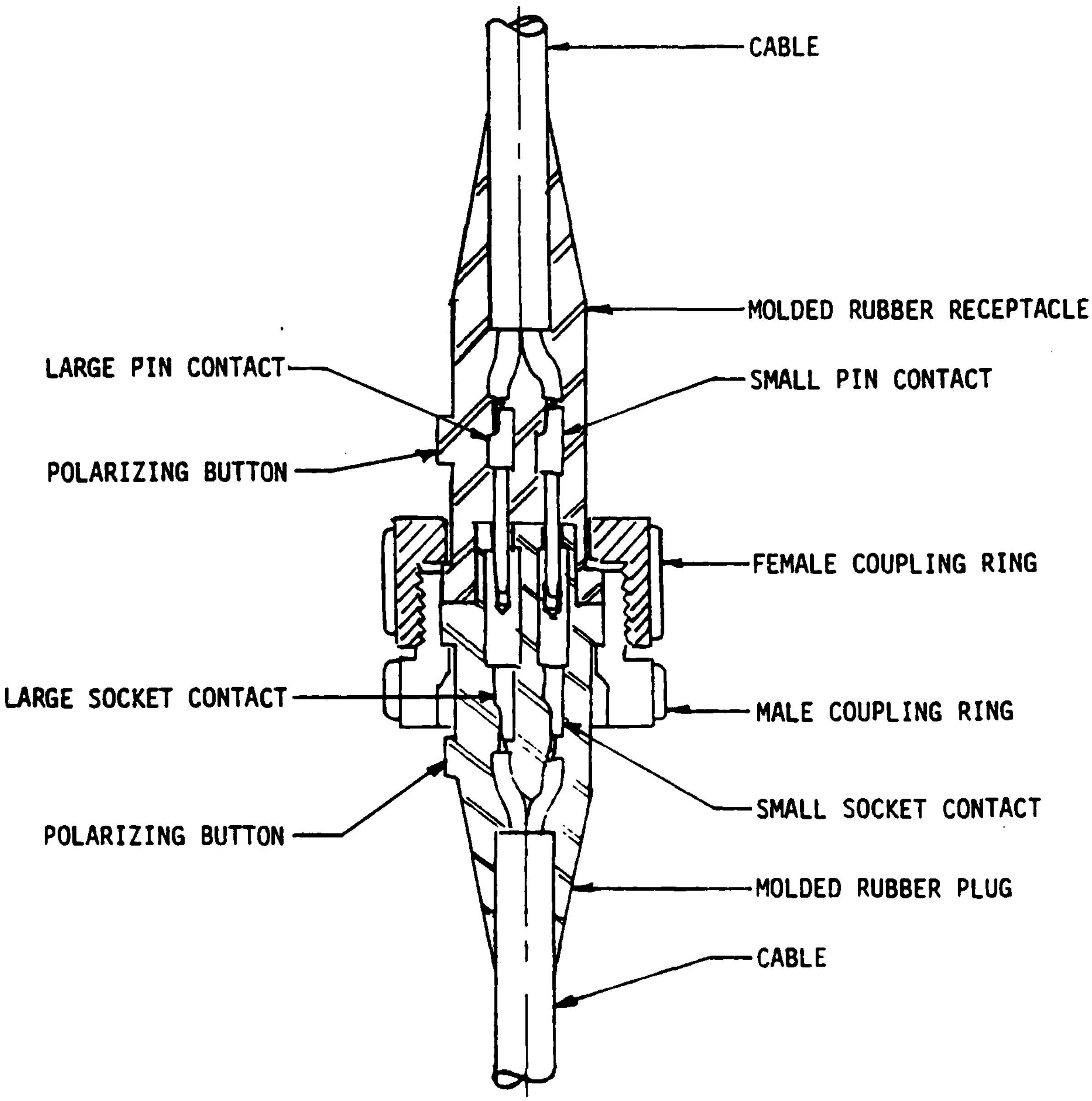

Fig. 15 - Surface ship outboard connector assembly.

2. OUTBOARD CABLE DESIGN REQUIREMENTS

Sonar system outboard cables installed on submarines are subject to the following electrical, mechanical, environmental, and termination requirements.

2.1. Environmental

Submarine outboard cables can be totally or partially submerged in seawater. The seawater temperatures fluctuate between 29°F (-1.7°C) and 85°F (29°C). The air temperature in arctic conditions can reach -40°F (-40°C) while the temperature under the superstructure is said to reach +140°F (60°C) in tropical waters. Thermal shock conditions of -40°F (-40°C) to +29°F (1.7°C) can be observed when a submarine dives in arctic conditions while the thermal shock encountered in tropical waters can range from +140°F (60°C*) to +29°F (-1.7°C). when the submarine dives.

Cables located above the waterline can be subject to fuel oil mixed with seawater when the ship is docked at tenders, Naval bases, or shipyards.

Cable jacket resistance to water permeation, resistance to damage at low temperatures once installed, and flexing at low temperatures during installation are the most severe environmental conditions to which the outboard cables are subjected.

2.2. Mechanical

Submarine outboard cables are primarily subject to mechanical stress during fabrication of harnesses, termination to transducers and hydrophones, and installation at shipyards and hydrostatic pressure when in service.

The cable jacket material must be resistant to abrasion and cut-through to withstand damage when terminating cables to sonar components and installing the cables aboard ships.

The cables must be impact and puncture resistant to remain undamaged from falling objects during construction. Weld splatter resistance is also a desirable (but not too easily obtainable) goal.

The cables must also be capable of withstanding shock (MIL-S-901) and vibration (MIL-STD-167) conditions. However, this is accomplished by utilizing proper cable support and protection methods.

The cables must be designed to allow for small cable bend radii to facilitate installation in space-limited areas such as is found in the area around the hull penetrators and sonar system components.

In many cases, the cables are directly wired and molded to cable glands

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* This temperature has been questioned; 85 - 90°F (29.4 - 32.2°C) may be more accurate, 140°F (60°C) could possibly be seen at dockside.

must be capable of withstanding axial tensile loads resulting from lifting the sonar components by the cable (despite warnings forbidding this practice). Cable installation on the ship is performed by laying the cables in troughs as opposed to "pulling" them from the hull penetrator to the outboard component. Therefore, axial cable strength at installation is not a major requirement.

One of the major requirements for the outboard cables is that they must be capable of being sealed in stuffing tube hull penetrators. Once installed in the stuffing tubes, the assembly must not allow internal and external seawater leakage past the stuffing tube assembly at 1000 psi (6.895 MPa) hydrostatic pressure. Also, the cable should not move axially in the tube greater than 1/8 in. (3.18 mm) at maximum pressure. While it is understood that stuffing tubes are being replaced in new designs, their continued use on existing designs is anticipated for many years. Also, the cables must be capable of being sealed in ballast tank bulkhead penetrators which also use a stuffing tube design. However, in this application, only a 25 psi (172 Pa) hydrostatic pressure test is required.

The cables must be capable of being flexed in-service in a few applications. In this case the capability of being flexed at low temperature is required (flexing endurance).

Cable diameters and allowable fabrication tolerances are important considerations in cable design. Cable overall diameter and tolerances must be closely held to allow for proper design of cable stuffing tubes. Large tolerances on diameter would not allow for proper sealing and retention of the cable by the rubber grommet in the stuffing tube. Also, small tolerances on cable diameter assist in designing mold clamps for cable retention in neoprene rubber boot molds where high molding pressures are require.

Cable roundness and circularity is also an important consideration in cable stuffing tube and mold termination designs.

Uniformity of cable jacket thickness is an important cable design consideration as the jacket provides the desired protection from the seawater operational environment.

The cable interstices (valleys) should be filled with an elastomeric filler to assist in providing a round cable cross section. A circular cross section is required for a proper fit in the mold when terminating the cable. The fillers also prevent undue stress on the cable jacket when the cable is subjected to external hydrostatic pressure.

Cables that are terminated at each end with pressure-proof connectors need not be internally water blocked as the water barrier is provided at the connector receptable. Cables which pass through stuffing tubes should be waterblocked to prevent water leakage past the stuffing-tube cable seal. The conductor strand, cable valleys, and shield valleys are filled with an elastomeric compound which prevents the flow of water through voids which would otherwise exist in the cable. It should be noted that these internally waterblocked cables are only effective when used in conjunction with stuffing tube. If a cable jacket is damaged, then water has been found to flow to the cable terminations.

A braided cable shield is not required for tensile strength purposes on Size 3 (DSS-3 for example) and larger cables; it is necessary on the Size 2 cables (DSS-2 for example) [15].

2.3. Electrical

Electrical tests associated with outboard sonar system cables include insulation resistance, voltage withstand, conductor resistance, mutual capacitance, capacitance, characteristic impedance, capacitance unbalance, and attenuation.

Insulation resistance (IR) is of primary importance in cable design and use. Unacceptable insulation resistance is the usual reason for removing a cable harness assembly from a submarine. Insulation resistance is measured conductor-to-conductor, conductor-to-shield, and shield-to-water. Acceptable insulation resistance readings must be maintained from ship overhaul to overhaul (5 - 7 years). The major problems with insulation resistance requirements for outboard cables in the past two decades have centered around unacceptable insulation resistance readings from shield-to-water. MIL-C-915, Rev. A, did not require an insulation material over the shield. Consequently, the IR readings, shield-to-water, dropped to unacceptable levels once installed on submarines. The neoprene cable jacket is an acceptable cable jacketing material but a poor insulator due to its poor water permeation properties and low volume resistivity. Later revisions of the MIL-C-915 cable specification required a synthetic rubber insulation over the shield (butyl rubber) prior to extruding the neoprene jacket on the cable. This type of construction solves the IR problem but introduces others that are discussed later in the report. Low IR readings, conductor-to-conductor and conductor-to-shield, have not been problems associated with cable designs. They usually can be attributed to the connectors located at the end of the cable.

Voltage withstand has not been noted as a problem in outboard cable design. However, most cables are rated at 600 V rms and in a few sonar systems (TR-155) the operating voltage is approximately 1200 V rms. The specifications must be changed where applicable to accomodate these requirements.

Conductor resistance is a standard test conducted by the cable manufacturer prior to shipment for quality conformance purposes to assure proper copper conductor size, material, and absence of broken conductor strands.

Capacitance, capacitance unbalance, characteristic impedance and attenuation are special requirements associated with shielded twisted pair cables. Cables presently available in the MIL-C-915 specification meet current sonar system electrical requirements.

In recent years NAVSEA has determined that SS-type outboard cables do not require overall shielding of conductors to satisfy sonar system electrical requirements. Overall shields are still required in multi-twisted pair cables such as the SWF types.

2.4. Cable Termination

Cable termination is one of the least considered design parameters in cable harness design. Outboard sonar system cables are sealed to connectors or cable glands with neoprene or polyether polyurethane rubber boots. The cable constituents must be able to withstand 180°F (80°C) polyurethane molding temperatures for a six-hour period or 300°F (149°C) neoprene molding temperatures for a ½- to one-hour period. Also, the cable jacket material must be capable of being bonded to the polyurethane or neoprene rubber boots to provide the desired cable seal. Cable termination manufacturers have noted many problems in the past decade with the two-layer jacketed outboard cables. The pressures and temperatures involved with injection, transfer, or compression molding neoprene boots to connector and glands causes the outer jacket (which is not suitably bonded to the inner jacket) to bunch up the mold, thus resulting in an unacceptable component. Consequently, cable termination fabricators have insisted on the use of a single-jacketed cable. However, compression rubber molding can be accomplished by using a cable clamp at the cable exit point of the mold. Problems have also been noted with removing conductor and shield strand sealants which are required to properly separate the conductors and shields. For termination, bonding of the conductor insulation to the cable belt material has also caused cable termination problems.

3. RECOMMENDATIONS

The following recommendations are offered as a result of this study.

1. The requirement for an overall braided shield on outboard cables should be deleted from sonar system specifications with the exception of multi-twisted pair cables. (Section 4.1)

2. The use of chlorosulfonated polyethylene (Hypalon) should be deleted as a MIL-C-915/8 cable jacket material. (Section 4.2)

3. DSS-2, TSS-2, and TSS-4 cables should not be used in tactical submarine and surface ship applications. (Section 4.3)

4. A specification sheet should be prepared for unshielded DSS-, TSS-, FSS-, 5SS-, and 7SS-type cables. (Section 4.4)

5. The conductor insulations on the 2SWF-type cables detailed in MIL-C-915/48 should be replaced with a high temperature material such as TFE Teflon, FEP Teflon or TEFZEL. A twenty shielded twisted pair cable, designated 2SWF-20, should be added to the MIL-C-915/48 cable specification sheet. Consideration should be given to deleting the 2SWF-3 cable from the MIL-C-915/48 specification sheet. (Section 4.5)

6. Ethylene propylene rubber should be specified as the inner layer jacket material on MIL-C-915/8 cables. (Section 4.6)

7. The SS cable specification sheets should be revised to increase the conductor-to-conductor working voltage at 1500 V rms. (Section 4.7)

8. The MIL-C-915/8 specification sheet should be revised to have the specification sheet capacitance test agree with the test specified in the body of the MIL-C-915 specification. (Section 4.8)

9. The SS-type MIL-C-915 cable specification sheets should be revised to require an ASTM D413-76 180-degree peel test for the inner and outer cable jackets. (Section 4.9)

10. The open-end hydrostatic pressure test for SS-type MIL-C-915 cables should be changed to require the test to be conducted at 1000 psi. Also, the DSS-3 cable should be tested in an 815-1197218 NAVSEA drawing hull fitting. (Section 4.10)

11. The Electric Boat Division (General Dynamic Corp.) CPG 1000/3 (1PR-16), CPG 1000/16 (1Q-16), CPG 1000/18 (7PR-16), and CPG 1000/20 (3PR-16) specification sheets should be added to the MIL-C-915 specification. (Section 4.11)

12. The Naval Ship Engineering Center Procurement Specification for 1PR-A20E-type cable should be added to the MIL-C-915 specification. (Section 4.12)

13. Cables which deviate in construction from the MIL-C-915-type cables should not be given the cable designations of the specification. (Section 4.13)

14. The SS-type cable specification sheets should be revised to note the requirement for conductor strand sealants. NAVSEA should also issue a directive noting the solvents to be used in removing the sealant from the strands prior to soldering or crimping the conductor. (Section 4.14)

15. A cable-breaking strength test is not recomended at this time for the SS-type MIL-C-915 cables. (Section 4.15)

16. The butyl-jacketed cable and butyl rubber termination system should only be suitable for use on the AN/BQR-21 sonar system. (Section 4.16)

17. Cable manufacturing quality control testing should be upgraded to assure overall cable diameters as specified, as well as desired ease of stripping cables for termination purposes. (Section 4.17)

18. NAVSEA should prepare a general directive specifying minmum acceptable insulation resistance requirments for all cables, harnesses, hydrophones and transducers used on outboard sonar systems. The minimum insulation resistance requirements as noted in Table 6 are recommended. (Section 4.18)

19. An RG-12A (Modified) specification sheet should be prepared and added to MIL-C-23020. (Section 4.19)

20. MIL-C-17 coaxial cables which must be used outboard on sonar systems should be heavy-duty-jacketed with MIL-C-915 neoprene rubber. (Section 4.20)

21. Sonar system hydrophones and transducers should be fitted with pressure-proof connectors in all cases where the component design permits their use. (Section 4.21)

22. Cable specification sheets should be added to MIL-C-915 which cover cables used on sonar system cable harnesses. (Section 4.22)

23. A military specification should be prepared to cover outboard cable harness asemblies used on submarine and surface ship sonar systems. (Section 4.23)

24. Consideration should be given to investigate the feasibility of using oil-filled cable harness assemblies for use in tactical submarine sonar system applications. (Section 4.24)

4. DISCUSSION OF RECOMMENDED CHANGES

The following is a discussion of recommendations which are felt to be justified as a result of the coments received from personnel responding to the inquiries of this study.

4.1. Deletion of Overall Cable Shield

MIL-C-915 outboard cables required a braided shield to be placed over the conductors on the DSS-, TSS-, FSS-, 7SS, and DSWS-type cables. Most sonar systems no longer require an overall shield on the outboard cables. Outboard cables used on the Trident submarines are not required to be shielded [11]. In 1974, a NAVSEA letter [12] noted that cable shields were not to be connected electrically at the connector for the AN/BQA-8, AN/BQR-2, AN/BQR-7, AN/UQC-1, AN/BQH, AN/UQN-1 and 4, and AN/WQC-2 sonar systems. Also, a 1982 memorandum [13] notes that the shield is no longer required on the SSN 685 when used in conjunction with the DT-276 hydrophones on the AN/BQQ-5 sonar system. The deletion of the shield requirement in the outboard cable is significant in the design. The need for a shield insulation layer over the shield can be deleted, thus allowing a thicker jacket which increases the physical protection for the conductors. Shield-to-water insulation resistance requirements would be unnecessary. This requiremnt has caused the replacement of many outboard cables over the past two decades. Cable costs will be reduced with the deletion of the braided shield. It is possible to use fewer electrical hull penetrators if the cable shield is not carried through a contact in the hull penetrator. This was demonstrated in the Trident submarine spherical and line-array sonar system. Eighty-seven hull penetrators would have been required to service the 1044 hydrophones if a shielded cable was used. The elimination of the cable shield resulted in 58 hull penetrators being used. The shield elimination also eliminates an internal leakage path should the cable jacket be damaged, reduces cable terminaton costs at the hull penetrator plug connector, and increases the reliability of the cable terminaton due to the elimination of one terminated contact.

Shielding is not necessary to meet mission profile requirements for cable crush or flexural abrasion resistance per Ref. 15. Deletion does reduce tensile strength but not below that required by mission profile for DSS-3, DSS-4, and FSS-2 cables.

The elimination of the braided shield negates the need for an inner and outer jacket layer. Butyl rubber has primarily been used in the past. It does not bond well to the arctic neoprene outer layer. As a result, cable termination manufacturers have had considerable difficulty in terminating these cables as the outer layer tends to "bunch up" in the mold when injecting the neoprene rubber in the mold at high pressures and temperatures. This has been cited as a major problem with sonar system suppliers. It should be noted, however, that this problem could be eliminated with the use of ethylene prooylene rubber in the inner layer as the material bonds well to the neoprene outer layer and is a satisfactory shield insulation material. It is noted, however, in other sections of this report that the shield may perform a useful function in preventing DSS-3 cable axial movement in the TR-155 transducer stuffing tube type sonar sphere hull penetrator.

4.2. Deletion of Hypalon Jacket on SS Cables

The MIL-C-915/8 cable specification sheet should be revised to delete the use of chlorosulfonated polyethylene (Hypalon) as a cable jacket material. The material is not currently being used by any of the qualified suppliers as a cable jacket material for these type cables. The material is said not to meet the low temperature flexibility requirements in the specification. The use of a single-cable jacket outer material (neoprene) minimizes the possibility of cable termination problems in bonding rubber sealing boots to the cable jacket.

4.3. Deletion of DSS-2, TSS-2, and TSS-4 Cables on Tactical Submarine Applications

DSS-2 and TSS-2 cables have minimum jacket thickness of 0.050 in. (1.27 mm). The TSS-4 cable has a minimum jacket thickness of 0.055 in. (1.40 mm). While these cables may be suitable for use in closely controlled research and development environments, they are not recommended for installation on tactical submarine and surface ship applications. The protection of outboard cables during installation in shipyards, at best, is most difficult. It is certainly a heavy-duty application. Table 3 gives recommended cable jacket thicknesses for light, medium, and heavy-duty applications for neoprene cable jackets as per MIL-C-3432. The heavy-duty cable jacket thicknesses should be followed in all future Navy outboard cable designs. The MIL-C-915/8 specification sheet should be reviewed to note that the subject cables are not suitable for tactical submarine and surface ship outboard applications. Also, DSS-2 does not meet the mission profile requirements for tensile strength [15].

Table 3 - Recommended sheath thicknesses - polychloroprene.

	SHEATH WALL THICKNESS (NOMINAL IN.)		
CORE DIAMETER (IN.)	LIGHT DUTY*	MEDIUM DUTY*	HEAVY DUTY*
0.125 and Under	0.020	0.027	0.035
0.126 to 0.155	0.022	0.031	0.040
0.156 to 0.219	0.024	0.039	0.045
0.220 to 0.234	0.026	0.039	0.078
0.235 to 0.290	0.031	0.047	0.078
0.291 to 0.300	0.031	0.047	0.094
0.301 to 0.430	0.050	0.063	0.094
0.431 to 0.540	-	0.070	0.094
0.541 to 0.640	-	0.078	0.109
0.641 to 0.740	-	0.094	0.125
0.741 to 0.850	-	0.109	0.141
0.851 to 1.100	-	0.125	0.156
1.101 to 1.320	-	0.156	0.172
1.321 to 1.550	-	0.172	0.188
1.551 to 1.820	-	-	0.203

(continued)

(Table 3 continued)

NOTE: Double-layer sheaths shall be used on cables whose sheath wall thickness, as specified, is 0.109 in. or over. Such double-layer sheaths should be applied in two concentric layers so cured or vulcanized that they are strongly bonded together; the outer layer to be at least 50% of the total thickness. A reinforcement consisting of an open braid, or two layers applied in reverse directions of seine twine, or the equivalent, shall be provided between the layers of the sheath.

* per MIL-C-3432C as follows:

Light-Duty Cables: Light-duty cables are intended for use in test equipment in short lengths, or for interconnection of major components. They are intended to withstand any severe flexing and frequent manipulation. Light-duty cables should not be used where they will be stepped on, run over by vehicles, beaten, or subjected to severe impacts. Light-duty cables are suitable for lightweight portable tools or small motor and generator leads where flexibility, rather than long life is essential.

Medium-Duty Cables: Medium-duty cables are intended to withstand the same usage as heavy-duty cables with the exception that they should not be used wehre they will be run over by vehicles or be subjected to severe impacts. They are intended to be a substitute for all uses of heavy-duty cables when the reduction in weight would be advantageous to the equipment in which they are used. Medium-duty cables are suitable for small portable tools, sound equipment, radio receivers, and motor leads which do not require the heavier, sturdier, heavy-duty cables.

Heavy-Duty Cables: Heavy-duty cables are intended for use where they will be subjected to extreme service impacts or will be run over by heavy vehicles, such as trucks, tanks, or the like. They are designed to withstand severe flexing and mechanical abuse, over long periods of time, without deterioration. Heavy-duty cables are suitable for portable tools, extension lamps, charging cables, and control cables.

4.4. Preparation of Unshielded Outboard Cables Specification Sheet

As outboard sonar system cables no longer require an overall shield, a MIL-C-915 cable specification sheet should be prepared for the DSS-, TSS-, FSS-, and 7SS-type cables in which the overall shield is deleted. These cables could be used in new sonar system applications and on replacement systems where the cables do not pass through stuffing tubes. The current MIL-C-915/8 cable specification sheet should remain active at this time as the overall shield has been found to be beneficial in cases where the cables pass through stuffing tubes because the shield assists in preventing inboard axial cable creep due to hydrostatic pressure cycling resulting from changes in operating depth. The new cables could be designated DSU, TSU, FSU, and 7SU. It is noted that Code 2713 of the David W. Taylor Naval Ship Research and Development Center (DTNSRDC), Bethesda, MD, has been tasked by NAVSEA in past years to develop unshielded cables; this work should be continued. A specification sheet which can be considered for the SU cable constructions is shown in Appendix A.

4.5. Changes to the 2SWF Cable Specification Sheet

The 2SWF cables specified in MIL-C-915/48 are required to have nylon over the polyethylene conductor insulation. This insulation combination is not suitable when considering 300°F (149°C) neoprene molding temperatures to terminate and seal the cables in connectors. Consideration should be given to changing the conductor insulation to TFE Teflon, FEP Teflon, or TEFZEL.

A twenty shielded twisted pair cable designated 2SWF-20 should be added to the MIL-C-915/48 cable specification sheet. This type cable is currently being used on a towed array designated STASS (AN/BQR-25) developed by the Naval Underwater Systems Center (NUSC), New London, CT.

Consideration should be given to deleting the 2SWF-3 cable from the MIL C-915/48 specification sheet. A 2SWF-4 cable is currently detailed which has four shielded twisted pair cables. The 2SWF-3 and 4 have the same cable diameter (0.600 - 0.625 in./15.2 - 15.9 mm). This 2SWF-4 cable can be used where the 2SWF-3 cable is required because rubber molds used to terminate the cables will not have to be redesigned.

4.6. Material Callout for Inner Jacket Layer of SS Cables

The MIL-C-915/8 cable specification sheet should be revised to require an ethylene propylene synthetic rubber (EPR) insulation over the overall shield in lieu of butyl rubber as is currently used by one cable supplier. The EPR will provide satisfactory insulation resistance between the shield and the seawater. Also the EPR rubber is more easily bonded to the neoprene outer jacket layer thus eliminating current cable terminaton problems. The currently used butyl rubber does not bond well to the neoprene outer jacket.

4.7. Increase in SS-Type Cable Working Voltages

Consideration should be given to increasing the allowable working voltage in SS-type MIL-C-915 cables to 1500 V conductor-to-conductor (V rms). A number of current sonar system applications are said to require cables that function at these voltages. It is felt that this change will not require a change in presently used insulation materials.

4.8. Revision to DSS-3 Cable Capacitance Test

The capacitance test specified for DSS-3 cable in specification sheet MIL-C-915/8D does not agree with the test specified in the body of MIL-C-915, paragraph 4.9.2., as the capacitance of a single conductor to other conductors, shield, or ground is being tested; the title "Mutual Capacitance" should also be changed to "Conductor Capacitance."

4.9. Inner and Outer Cable Jacket Bonding Test

A rubber-to-rubber adhesion test should be added to the MIL-C-915 SS-type cable specification sheets for determining the bond strength between the inner and outer cable jacket layers. As noted in other sections of this report, it has been noted that insufficient bond strength between the butyl rubber inner layer and neoprene outer layer on SS-type cables prevents proper termination of the cables during transfer molding operations. It has also been noted that the cable termination problem does not occur when ethylene propylene rubber is used as the inner jacket layer material. Two samples of DSS-3 cable jacket material provided by the Okonite Company were tested in 180-degree peel in accordance with ASTM D413-76. The bond strength was found to be 8.4 and 7.7 psi of width (1.4 N/mm).

This test or a similar one is recommended to be added, where applicable, to the MIL-C-915 specification sheet. The required bond strength can be determined by NAVSEA following discussions with cable manufacturers and Navy cable engineeers at the DTNSRDC. The cable tests can be conducted by NAVSEA's Cable Test Facility at Naval Ships Systems Engineering Station, Philadelphia, PA.

4.10 Revision to Open-End Hydrostatic Pressure Testing of SS-Type Cable

The open-end hydrostatic pressure test for SS-type MIL-C-915 cables should be changed to require the test to be conducted at 1000 psi (6.895 MPa). The current requirement is 500 psi (3.448 MP). Also, the stuffing tube used for conducting the test for the DSS-3 cable should be changed from the MIL-S-24235 tubes to the hull-fitting stuffing tube design detailed on NAVSEA Drawing 815-1197218, "Hull Fitting for AN/BQQ-1 Sonar, Sym. 538." This hull-fitting is used in conjunction with the TR-155 transducers used at the sonar sphere on attack class submarines. While it is noted that this hull fitting has been redesigned to provide a connectorized hull penetrator, it is likely tha many years will pass before this hull penetrator design is totally implemented in the fleet. A 1/8 in. (3.18 mm) maximum axial cable movement in the stuffing tube at maximum hydrostatic pressure should also be specified in the test paragraph. NAVSEA should supply the test stuffing tube assembly to the cable manufacturers on the Qualified Products List.

4.11. Addition of Trident Submarine Polyurethane Jacketed Outboard Cable Specification Sheets

Polyurethane rubber-jacketed outboard cables were designed by the Electric Boat Division in conjunction with NAVSEA for use on Trident submarines. See Table 4 for the cables used on Trident sonar systems. The number 16 AWG conductors in these cables are insulated with a nominal 0.010-in. (0.25 mm) layer of TEFZEL. The polyurethane cable jacket material is a B.F. Goodrich Estane 58300 or 58863 or Mobay Chemical Company TEXIN 985A. The cables are not internally waterblocked. These cables should be added to the MIL-C-915 specification sheets to facilitate Navy procurement of these cables for use by the Trident Refit Facilities. The cables could also be used on other Navy outboard systems where termination of the cables with neoprene rubber is not required. The cables are terminated with MIL-M-24041 polyurethane rubber on the Trident submarines. Specifications sheets that can be considered for the above noted cable constructions are shown in Appendix A.

Table 4 - Trident polyurethane-jacketed outboard cables.

CABLE TYPE	EB DIVISION SPECIFICATION	DESCRIPTION
1 PR-16	CPS 1000/3	1 Twisted Pair
1 TR-16	CPS 1000/14	1 Twisted Triad
1 Q-16	CPS 1000/16	1 Twisted Quad
3 PR-16	CPS 1000/20	3 Twisted Pair
7 PR-16	CPS 1000/18	7 Twisted Pair

4.12. Addition of Trident Submarine Polyethylene-Jacketed Outboard Cable Specification Sheet

A polytheylene-jacketed cable designated 1 PR-A20E was designed by the Electric Boat Divison, NAVSEA, and NUSC (New London Laboratory) for use on the Trident AN/BQQ-6 spherical and line array sonar systems. The cable is used in conjunction with the DT-574 hydrophones. This cable is a twisted pair, non-waterblocked and is directly molded to the polyethylene encapsulated hydrophone. Over 150,000 ft (45.7 km) of this cable is used on each Trident submarine. The cable is presently detailed on a Naval Ship Engineering Center Procurement Specification. It should be added to the specification sheets of MIL-C-915 to facilitate Navy procurements of this cable for use by the Trident Refit Facilities. The NAVSEA specification sheet for this cable is shown in Appendix A.

4.13. Designation of Special Sonar System Cables

In the past years transducer manufacturers have procured cables with certain deviations from the MIL-C-915 specification. These cables have been stamped with MIL-C-915 designations such as DSS-3. When these cables are replaced, they may be substituted with the standard MIL-C-915 cables in the Navy supply system. Problems could result from improper replacement of the cable. Sonar cables which are required to deviate from the standard MIL-C-915 constructions should be designated as a special cable or, preferably, a new cable specification sheet should be added to MIL-C-915 if the NAVSEA (Code 5422) agrees with its use.

4.14 Conductor Strand and Braid Sealant and Solvents for SS Cables

The SS-type cable specification sheets of MIL-C-915 should be revised to note the requirement for conductor strand sealants. It is recognized that cable manufacturers use proprietary strand sealants in their cable constructions and that the material is made known to NAVSEA cable specification custodians. However, purchasers of the cable should be made aware that a sealant is no longer being supplied for the shielding braid. Conversely, cable purchasers should also be made aware that a sealant is no longer being supplied for the shielding braid. In past years, some suppliers provided a braid sealant in their cable constructions. Cable suppliers should also be required to provide recommended cleaning solvents for removing the conductor strand sealants from the strands to allow proper soldering and crimping of the cable conductors. This information should also be supplied to users by NAVSEA (Code 5422) in official Navy directives.

4.15. Cable-Breaking Strength Test

A number of personnel contacted in this study have recommeded that a cable-breaking strength test be added to the SS-type cables in MIL-C-915. The Texas Research Institute (TRI) conducted a cable strength study for the Naval Research Laboratory's Underwater Sound Reference Detachment (NRL-USRD) under the Sonar Transducer Reliability Improvement Program (STRIP) [15]. The report suggests that the type DSS-2 cable may pull up an attached weight (transducer/hydrophone) of 54 lbs (240 N). Also, the cable may be used as a hand hold aboard ship and be subjected to 198 lbs (880 N). The study test results indicate that the smaller size DSS-2 cable did not meet the 880 N tensile strength requirement. The single- and double-jacketed DSS-3 and FSS-2 cables did pass the test. As a result of these findings, a cable-breaking strength test is not felt to be required for the MIL-C-915/8 SS-type cables which have an overall shield in their cable constructions. The DSS-2 and TSS-2 cables which do not meet the 880 N breaking strength requirement are not recommended for use in tactical submarine applications in other sections of this report (Section 4.3). Cable damage due to axial pulling has not been reported as a problem in submarines and surface ships in the past two decades. As a result, the need for an approximate 200 lbs (44.96 N) cable-breaking strength requirement should be questioned - especially in the proposed design of unshielded DSU-, TSU-, FSU-, and 7SU-type cables. A strength member located in the cable jacket is not felt to be required for submarine and surface ship sonar system applications. It is recognized, however, that special sonar system applications such as hydrophones dropped from helicopters and towed sonar arrays require special cable designs with steel or Kevlar strength members. These are special designs and, therefore, required special cable construction.

4.16. Limiting the Use of Butyl-Jacketed Outboard Cable

A special butyl rubber jacketed cable and butyl rubber termination system was designed by the Naval Weapons Systems Center (NWSC), Crane, IN, for use on the AN/BQR-21 sonar system. This cable and terminaton system should not be encouraged for use on existing and future sonar system designs due to the rigorous quality control procedures which must be followed in molding and bonding the butyl rubber to the butyl cable jacket and the metal cable glands mounted on the hydrophones or the transducers.

4.17. Cable Manufacturing Quality Control

Discussions with cable users does not indicate major quality control problems with SS-type MIL-C-915 cable manufacturers. Over or undersize cable diameters and bonding of the conductor insulation to the cable belt were noted, however, by some users as being a past or current problem. With regard to the cable diameter, which is important when the cables are placed in stuffing tubes for sealing and in molds for cable termination, perhaps a detailed method could be established in the specification for determining the overall cable diameter - such as go, no go gauges, a pi tape (recommended method), micrometer, etc. Also, it is most difficult to check the undesired bonding of materials within the cable which causes difficulty in separating cable conductors from the cable belt. This problem must be controlled during the manufacturing process as only the ends of the cable can be checked following manufacture - and the problem may not be located at the ends of the cable.

4.18. Sonar System Insulation Resistance Requirements

It is recomended that NAVSEA prepare a general directive which specifies minimum acceptable insulation resistance requirements for all cables, harnesses, hydrophones, and transducers used outboard on submarines and surface ships. It is seen from a review of cable and harness specifications and submarine post sea trial requirements that some formal standardization would be of value. Tables 5 and 6 note insulation resistance requirements for the SSN 688 and Trident submarines following installation and the deep dive trials. The requirements vary from 10 to 200 MΩ . It is recommended that the minimum insulation resistance requirements of Table 7 be considerd as a standard. It will be noted that insulation resistance requirements decrease from the fabrication of the bulk cable to the fabrication of the transducer or hydrophone with mated cable harness. The required insulation resistance values also decrease from the time the sonar system is initially installed on the ship until the ship is brought in for overhaul.

Table 5 - SSBN726 (Trident) class submarine sonar system insulation resistance requirements.

SYSTEM	TRANSDUCER TYPE	CABLE TYPE CABLE TYPE	CONDUCTOR TO GROUND megohms)
Spherical/ line	DT-574	1PR-A20E	50
AN/WLR-12 Active Emission	DT-544	7PR-16	50
AN/BQS-15 HF Pro- jector	TR-242	1Q-16	10
AN/BQH-1B Depth/Sound Speed	TR167B	3PR-16	5
Emerg Comms	TR-122	1PR-16	10
AN/BQN-13 Distress Beacon	HS058D0300	1PR-16	10
Depth Sounder	TR-297	1PR-16	10
AN/WQC-2 HF Comms	TR-233	1PR-16	30
AN/WQC-2 LF Comm	TR-232	1PR-16	30
AN/BQS-15	DT-365	3PR-16 1PR-16 7PR-16	5 10 50
NAVSEC Depth Sounder	TR-143	RG-12A/U (MOD)	
NVMS	TR-513	FSS-2	

Table 6 - SSN688 class submarine sonar system insulation resistance requirements.

SYSTEM	CABLE TYPE	WHEN CONDUCTED	CONDUCTOR TO CONDUCTOR (megohms)	CONDUCTOR TO GROUND (megohms)	CONDUCTOR TO SHIELD (megohms)	SHIELD TO GROUND (megohms)
WQC-2	DSS-3	1		30		
		2		30		
BQS-15	DSS-3	1		10	10	10
		2		10	10	10
BQN-13	DSS-3	1	10	10	10	10
		2	200	200	200	200
BQQ-5 (TR-155)	DSS-3	1	10		10	
		2	10	10	10	
BQQ-5 (DT-276)	DSS-3	1	35	35		1
		2	35		35	1
BQA-8	FSS-2	1	200	200	200	200
		2	20	20	20	20
BQS-15	FSS-2	1		10	10	10
		2		10	10	10
BQH-1	7SS	1	10	10	10	10
		2				

Note: 1 - test conducted in shop and at dockside
2 - test conducted following deep dive

Table 7 - Sonar system component recommended minimum insulation resistance requirements.

COMPONENT	CONDUCTOR TO CONDUCTOR (megohms)	CONDUCTOR TO SHIELD (megohms)	SHIELD TO WATER (megohms)	CONDUCTOR TO WATER (megohms)	SHIELD TO SHIELD (megohms)
Bulk Cable	500	500	10	500	500
Hydrophone/Transducer	250	250	250	250	250
Hydrophone/Transducer w/Cable	250	250	10	250	250
Hydrophone/Transducer w/Penetrator Plug	100	100	10	100	100
Hydrophone/Transducer Installed in Ship	20	20	2	20	20
Hydrophone/Transducer Followin Deep Dive	10	10	1	10	10
Hydrophone/Transducer in Service	5	5	1/2	5	5
Hydrophone/Transducer at Overhaul	5	5	1/2	5	5

4.19. Addition of RG-12A/U (Modified) Cable Specification Sheet

An RG-12 A/U (Modified) cable specification sheet should be added to the appropriate Navy coaxial cable specification (MIL-C-17 or MIL-C-23020). The cable is used in the AN/BQN-3 depth sounder on the TR-143 transducer. The sonar system manufacturer develops his own specification drawing for this cable. The cable is a standard RG-12A/U coaxial cable with a neoprene jacket extruded over the armor. The armor is also waterblocked. The cable is detailed on General Electric Company, Syracuse, NY, Drawing 7094511.

4.20. Use of MIL-C-17 Coaxial Cables Outboard on Sonar Systems

As seen in Tables 2 and 8, a number of MIL-C-17 coaxial cables are used outboard on sonar systems. Five of the eight cables are jacketed with polyvinyl chloride plastic (PVC). The other three, RG-27/U, RG-28/U, and RG-64A/U are jacketed with neoprene. The General Electric Company modified the RG-12A/U coaxial cable by adding a neoprene jacket (see Section 4.19). It is recommended that any sonar systems which must use the standard MIL-C-17 coaxial cables outboard be fitted with a heavy-duty thickness (see Table 3) neoprene jacket per MIL-C-3432. As seen in Table 8, the jacket thicknesses are thin and do not offer much cable protection. Polyurethane rubber bonding to PVC at cable terminations can be a problem depending on the types of PVC materials used. The PVC jacket material is felt to be more susceptible to jacket damage during installation than the more abrasion resistant rubber materials such as neoprene or polyurethane.

Table 8 - Construction data of MIL-C-17 coaxial cables used outboard in sonar system.

CABLE	CONDUCTOR TYPE AND SIZE	CABLE CORE TYPE AND DIAMETER	OUTER CONDUCTOR DIAMETER (MAXIMUM)	JACKET DIAMETER	JACKET THICKNESS
RG-8A/U	7 STR No. 21 AWG 0.0285	0.275/0.295	0.340	0.395/0.415	0.0275/0.0375
RG-12A/U	7 STR of 0.0159 0.0477	0.278/0.292	0.340	0.398/0.412	0.028/0.036*
RG-27/U	19 STR of 0.0185 0.0955	0.445/0.465	0.500	0.580/0.610	0.040/0.055
RG-28/U	19 STR of 0.0185 0.0955 max	0.445/0.465	0.585	0.715/0.755	0.065/0.085
RG-58A/U	19 STR of 0.0072 0.0375 max	0.112/0.120	0.150	0.191/0.199	0.0205/0.0245
RG-59/U	0.0236 max	0.142/0.150	0.191	0.238/0.246	0.0235/0.0275
RG-64A/U	19 STR of 0.0117 0.0605 max	0.278/0.298	0.368	0.445/0.475	0.0385/0.0535
RG-130/U	Two Conductor 7 STR of 0.0285	0.458/0.487	0.540	0.610/0.640	0.035/0.050

* General Electric Co. jacketed this standard cable with a 0.094/0.116 in. layer of neoprene rubber for use on their AN/BQN-3 transducer.

4.21. Recommended Cable Terminations for Outboard Sonar System Components

A number of hydrophones and transducers are currently designed with cables directly molded to a cable gland which is bolted and O-ring sealed to the component housing. Other designs have cables directly molded to an all rubber (or polythylene) encapsulated hydrophone or transducer. Other low pressure component designs still make use of cable stuffing tubes. Many designs encorporate the use of pressure-proof connectors. The connector can be the glass hermetic seal contact type or the epoxy O-ring-sealed contact type. It is felt that the hydrophone and transducer should be fitted with a connector directly mounted to the component where practicable. If size does not permit mounting the connector to the component then a short length of cable can be directly molded to the component, and an in-line connector can be used at the end of the cable.

The connector provides a needed cable harness disconnect point at the outboard component. The pressure-proof receptacle mounted to the component enclosure ensures sealing the component internals should a water leakage failure occur in the harness. Other reasons for using an electrical connector at the component are as follows:

a. Provides a natural interface between the transducer manufacturer and the shipbuilder.

b. Provides convenient test point for the component.

c. Allows proper packaging of the component for handling, shipping, storage, and installation.

d. Eliminates the need for the transducer manufacturer to provide the electrical cable to a distant, unknown junction point, thus saving a large quantity of cable which is subsequently discarded by the shipbuilding.

e. Provides a proper interface for the maintenance and replacement of components and cables.

f. Facilities and manufacturing and assembly process of components.

g. Allows hermetic or water-tight sealing of the component from the cable harness.

h. Allows the components to be oil filled.

i. Facilitates the outboard hydrostatic pressure testing of the hydrophone or transducer.

In any case, cable stuffing tubes should not be used to seal cables at components in new design submarine applications. They are not suitable at high hydrostatic pressures [above 400 psi (2.758 MPa)] and are most dependent on the design of the cable (cable diameter tolerance, cable fillers, shielding braid, compression set of materials).

4.22. Addition of Harness Cable Specification Sheets

Cable specification sheets should be prepared for the cables listed in Table 9. The preparation of Navy cable specification sheets would make these cables available to other sonar system manufacturers; as a result, they would not be required to develop their own cable specification drawings.

Table 9 - Sonar system outboard harness cables.

CABLE DESCRIPTION	SONAR SYSTEM	SONAR TRANSDUCER	MANUFACTURER'S DRAWING NUMBER
10 Conductor w/overall shield	AN/SQS-35, 38	TR-229	EDO Corporation Dwg 60395
24 Conductor	AN/BQR-19	DT-372	EDO Corporation Dwg A364424
48 Conductor	AN/SQS-35	-	EDO Corporation Dwg 58100
66 Conductor w/strength member	AN/SQS-10, 31 AN/SQA-10	TR-31, 332, 170, 188, 189	Massa Dwg B-21220 Gen. Insr. CD Dwg 91E-CA-0033 Sangamo Co. No. 829026
8 Twisted Pair	AN/SQS-26	TR-227(SC)	General Electric Dwgs 77C705423 & 77D603108
9 Twisted Pair	AN/SQS-23	TR-197(SC)	Massa, Inc. Dwg 30829 Sangamo Co. Dwg 867484
10 Twisted Pair	AN/SQS-23	TR-177(SC)	Sangamo Co. Dwg 820742
8 Shielded Twisted Pair	AN/SQS-53	-	Raytheon Co. Dwg 971248

4.23. Preparation of an Outboard Cable Harness Military Specification

A military specification should be prepared to cover the details of construction and requirements of the common cable harness assemblies used on submarine and surface ship sonar systems (see Table 10). Presently each sonar system manufacturer prepares his own drawings covering these harness assemblies. A military specification could eliminate duplication of effort, provide greater interchangeability and assure proper quality control and quality conformance testing in the manufactured product. The specification should also note the use of special connector designs, where required.

Table 10 - Sonar system cable harness assemblies.

DRAWING TITLE	SYSTEM	MANUFACTURER'S DRAWING NUMBER
Cable Assembly	AN/BQR-19	Raytheon 430679
Cable, Principal, Transducer	AN/SQS-38	EDO 60372
Cable Assembly	AN/SQS-23	Massa C30829
Cable, Trunk, Outline	AN/SQS-26(CX)	G.E. 77D603108
Cable	AN/SQS-26(AX)	G.E. 77C705423
Cable, Element, Outline	AN/SQS-26(CX)	G.E. 77D603109
Stave Cable Assembly	AN/SQS-26	EDO 42892
Cable, Stave	-	Joy HX8104-313
Plug, Female	-	Raytheon 90593
Cable Assembly	-	Raytheon 869359

4.24. Oil-Filled Outboard Cable Design Study

Oil-filled cable are presently used outboard on deep submersible vehicles such as Alvin, DSRV, and DSV 20,000. They should also be considered for use in tactical submarine applications. It is felt that oil-filled connectors, cable glands, and cables can be designed to withstand submarine explosive shock requirements.

One of the major advantages of the oil-filled cables is that cable jacket puncture would be observed immediately following installation - thus allowing cable replacement. Presently, cable jacket puncture problems may only be found following a submarine dive as there is no positive method of checking a cable for damage following installation.

As seen in Fig. 16, the MIL-C-24231 plug connector can be redesigned to provide an oil fill and vent hole and cable jacket attachment and sealing fixture. The adapter is O-ring-sealed to the plug shell - oil on one side of the O-ring and seawater located on the other side. A locking screw is provided in the adapter to prevent rotation. A plastic thrust washer is placed between the adapter and plug coupling ring to aid in removal when unmating the plug with the coupling ring.

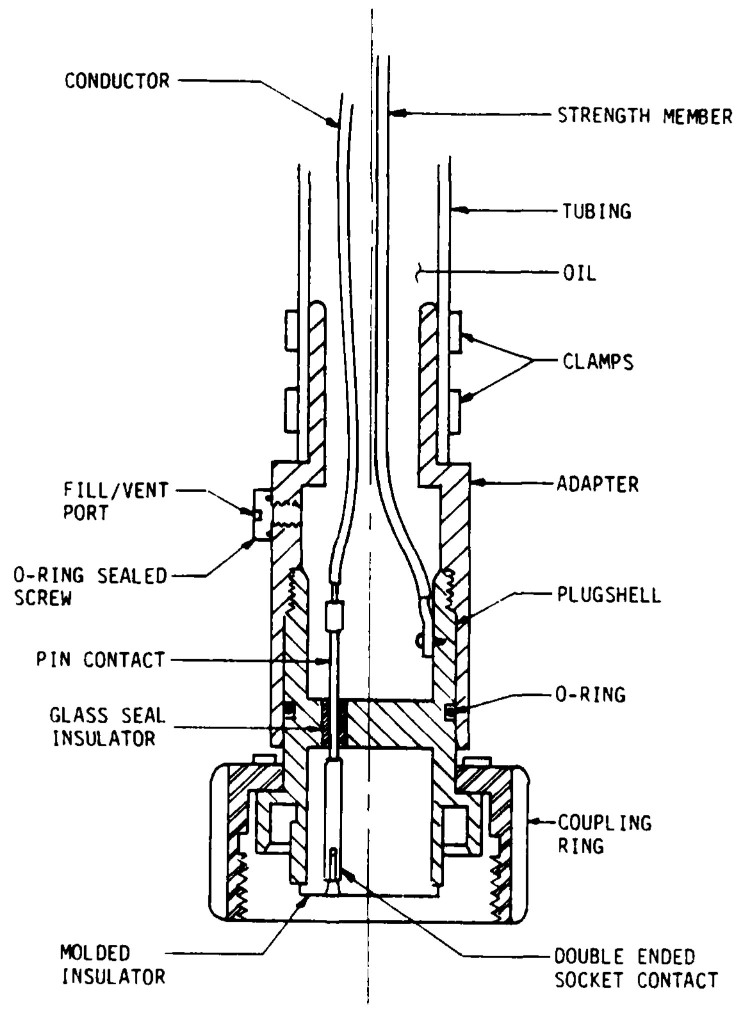

Fig. 16 - Oil-filled MIL-C24231 connector design.

Cost savings may also accrue from this design. Higher connector costs (due to the hermetic sealing of contact and the addition of the adapter) could be offset by lower "cable" costs and less labor required in terminating the cable ends (wiring and molding versus wiring and filling the cable). Also, hydrostatic pressure testing following cable fabrication would not be required with oil-filled cables.

The oil-filled cable harness design will also eliminate the major problem with outboard cable flooding - the long-term bonding of the rubber boot to the plug shell. It is recommended that this type of cable harness design be investigated for use in tactical Navy submarine applications. Oil-filled cables are currently being used by NAVSEA on the Deep Submergence Rescue Vehicles (DSRV) and the DSV-4 vehicle currently being fabricated at the Mare Island Naval Shipyard, Vallejo, CA [19].

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APPENDIX A

Military Specifications

MILITARY SPECIFICATION SHEET
CABLE, ELECTRICAL, 1500 VOLTS, TYPES DSU, TSU, FSU, AND 7SU

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for procuring the cable described herein shall consist of this document and the latest issue of Specification MIL-C-915.

REQUIREMENTS:

Qualification required.

Construction

FIRST - Copper conductor, tin coated, per ASTM B-286, Size per Table I.

SECOND - Insulation of fluoropolymer (TEFZEL). Nominal wall thickness per Table I.

THIRD - The required number of conductors (See Table I) cabled together with a lay length not greater than that specified in Table I. The insulated conductor shall not adhere to one another. Ethylene propylene rubber fillers shall be provided as necessary to provide a firm, round assembly. Filters in outer valleys may be extruded in order to be integral with the belt. (See Fourth).

FOURTH - Belt of ethylene propylene rubber, nominal wall thickness of 0.020 inch over the assembled conductors. Belt and fillers shall be capable of removal from the assembly without damaging the conductor insulation.

FIFTH - Jacket of polychloroprene, black. See Table I for thickness and cable diameter. Cable surface marking required, including manufacturer's identification and year of manufacture.

TABLE I DETAILS

Type and Size	Conductor Size	Number of Conductors	Cond. Dia. Max (inch)	Insulation Thickness, Min. (inch)	Lay Length (inch)	Jacket thickness, minimum (inch)	Overall Diameter Min (inch)	Overall Diameter Max (inch)	Conductor resistance per 1000 max. (ob)
DSU-2	18-19	2	.052	.013	2.0	.080	.380	.400	6.22
DSU-3	16-19	2	.059	.015	2.0	.110	.480	.500	4.82
DSU-4	14-19	2	.073	.017	2.5	.110	.480	.500	3.05
TSU-2	18-19	3	.052	.013	2.0	.075	.380	.400	6.22
TSU-3	16-19	3	.059	.015	2.0	.110	.480	.500	4.82
TSU-4	14-19	3	.073	.017	2.5	.095	.480	.500	3.05
FSU-2	18-19	4	.052	.013	2.0	.110	.480	.500	6.22
FSU-3	16-19	4	.059	.015	2.0	.100	.480	.500	4.82
FSU-4	14-19	4	.073	.017	2.5	.130	.600	.625	3.05
7SU-2	18-19	7	.052	.013	3.0	.150	.600	.625	6.22

EXAMINATION AND TESTS:

Basic electrical:	Requirements:
Voltage withstand - Volts, root mean square (Vrms) minimum	
Conductor to Conductor (5 minutes)	4000
Insulation resistance - Megohms/1000 feet min	
Conductor to Conductor	500
Conductor to Water	500
Conductor resistance - ohms/1000 ft. at 25°C, Maximum (max)	(See Table I)
Group A:	
Visual and dimensional	
Group B:	
Cold Bending - At minus 40° ± 2° C on 4-inch max diameter mandrel	
Physicals (unaged)	
Insulation (conductor)	
Tensile strength - lbf/in^2 min	5000
Elongation - Percent, min	100
Jacket (cable)	
Tensile strength - lbf/in^2 min	1800
Elongation - percent, min	300
Set - Inch, max	3/8
Group C:	
Physicals (aged)	
Insulation (conductor)	
Air pressure heat	
Tensile strength - Percent of unaged, min	80
Elongation - Percent of unaged, min	90
Jacket (cable)	
Hot oil immersion	
Tensile strength - Percent of unaged, min	65
Elongation - Percent of unaged, min	65
Permanence of printing (jacket) - Cycles, min	250

QUALIFICATION INSPECTION

Qualification inspection shall include basic electrical plus all of Groups A, B and C.

MILITARY SPECIFICATION SHEET
CABLE, ELECTRICAL, TYPE 1PR-16, 1TR-16, AND 1Q-16

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for procuring the cable described herein shall consist of this document and the latest issue of Specification MIL-C-915.

REQUIREMENTS

Qualification required.

CONSTRUCTION

FIRST - Copper conductor, tin coated, per ASTM B-286, Size 16-19.*

SECOND - Insulation of fluoropolymer (TEFZEL) Nominal wall thickness 0.010 inch. Colors to be black, white, red, green, as applicable.

THIRD - The required number of conductors (See Table I) cabled together with a lay length not greater than that specified in Table I.

FOURTH - Cable jacket of black polyether polyurethane applied to completely fill the valleys. The cable jacket material shall be B. F. Goodrich Co. ESTANE 58300 or 58863; or Mobay Chemical Co. TEXIN 985A. See Table I for wall thickness and overall cable diameter. Cable jacket shall be capable of removal from the assembly without damaging the conductor insulation.

* Present conductor is Standard Navy size 3 (7). (Seven strands of 0.020 inch diameter wire)

TABLE I DETAILS

Type and Size	Number of Conductors	Conductor Diameter max (inch)	Lay Length (inch)	Jacket Thickness nominal (inch)	Overall Diameter Min (inch)	Overall Diameter Max (inch)	Mandrel Diameter (inch)
1PR-16	2	.059	1 1/8-1 3/8	.105	.380	.400	3
1TR-16	3	.059	2 1/2	.100	.380	.400	3
1Q-16	4	.059	3	.090	.380	.400	4

EXAMINATION AND TESTS: Requirements

Basic electrical:

Conductor resistance - at 20°C, ohms/1000 ft, maximum........4.82
Voltage withstand - volts, rms, minimum
Conductor to conductor................................2000
Conductor to water....................................2000
Impulse dielectric - On 100 percent of insulated conductor. Test in accordance with specification MIL-W-81381A of November 15, 1972, paragraph 4.7.4.1, using a test voltage of 8.0kv (peak) minimum.

Group A:

Visual and dimensional

Group B:

Cold bending, cable - At minus 40°C ± 2°C over a mandrel (See Table I)

Physicals (unaged)
Insulation
Tensile strength - psi, minimum...................5000
Elongation - percent, minimum......................100
Cable Jacket
Tensile strength - psi, minimum...................5000
Elongation - percent, minimum......................500

Group C:

Physicals (aged)
Insulation
Air oven (168 hours at 180°C)
Tensile strength, percent of unaged, minimum..80
Elongation - percent of unaged, minimum.......90

Cable Jacket
Air oven (168 hours at 80°C)
(Specimen shall consist of a length of completed cable approximately 8-1/2 feet long. Ten turns of cable shall be wrapped around a 3-inch diameter mandrel. Upon completion of the conditioning period, specimen shall be allowed to cool to room temperature while still wrapped over the mandrel. Any cracks in the cable jacket which are discernible by visual examination shall be cause for rejection.)

Hot oil immersion

Tensile strength - percent of unaged, minimum......90

Elongation - percent of unaged, minimum............80

QUALIFICATION INSPECTION

Qualification Inspection shall include basic electrical plus all of Groups A, B, and C.

Unit Ordering Length - 500 feet (minimum)

MILITARY SPECIFICATION SHEET
CABLE, ELECTRICAL, TYPE 3PR-16 AND 7PR-16

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for procuring the cable described herein shall consist of this document and the latest issue of Specification MIL-C-915.

REQUIREMENTS

Qualification required.

CONSTRUCTION

FIRST - Copper conductor, tin coated, per ASTM B-286, size 16-19.*

SECOND - Insulation of fluoropolymer (TEFZEL). Nominal wall thickness 0.010 inch. Colors to be black and white. Maximum overall diamter 0.082 inch.

THIRD - Two insulated conductors (one black and one white) twisted together with a lay of 1-1/4 ± 1/8 inch.

FOURTH - Marker braid on each pair, Standard Identification Code, applied by Method 4.

FIFTH - The required number of pairs (See Table I) cabled together with a lay not greater than 24 times the pitch diameter of the layer.

SIXTH - Rubber filler in order to form a firm, round assembly. Filler material shall be capable of removal from the assembly without damaging the insulation of conductor.

SEVENTH - Polyester binder tape applied helically with overlap.

EIGHTH - Cable jacket of black polyether polyurethane. The cable jacket material shall be B.F. Goodrich Co. ESTANE 58300 or 58863; or Mobay Chemical Co. TEXIN 985A. See Table 1 for wall thickness and overall cable diameter. Cable jacket shall be capable of removal from the assembly without damaging the conductor insulation.

* Present cable conductor is Standard Navy Size 3 (7) Seven strands of 0.020 inch diameter wire.

TABLE I DETAILS

Type and Size	Number of Conductors	Conductor diameter, max (inch)	Jacket thickness (inch) (nominal)	Overall diameter Min (inch)	Overall diameter Max (inch)	Mandral Diameter (inch)
3PR-16	6	.059	.100	.530	.550	3
7PR-16	14	.059	.100	.630	.650	4

EXAMINATION AND TESTS:

Basic electrical: Requirements

Conductor resistance - at 20°C, ohms/1000 ft., maximum.......4.82

Voltage withstand - volts, rms, minimum

Conductor to conductor..................................2000

Conductor to water......................................2000

Impulse dielectric - On 100 percent of insulated conductor. Test in accordance with specification MIL-W-81381A of November 15, 1972, paragraph 4.7.4.1, using a test voltage of 8.0kv (peak) minimum.

Group A:

Visual and dimensional

Group B:

Cold bending, cable - At minus 40°C ± 2°C over a mandrel (See Table I)

Physicals (unaged)

Insulation

Tensile strength - psi, minimum...................5000

Elongation - percent, minimum......................100

Cable Jacket

Tensile strength - psi, minimum...................5000

Elongation - percent, minimum......................500

Group C:

Physicals (aged)

Insulation

Air oven (168 hours at 180°C)

Tensile strength, percent of unaged, minimum....80

Elongation - percent of unaged, minimum.........90

Cable Jacket

Air oven (168 hours at 80°C)

(Specimen shall consist of a length of completed cable approximately 8-1/2 feet long. Ten turns of cable shall be wrapped around a 3-inch diameter mandrel. Upon completion of the conditioning period, specimen shall be allowed to cool to room temperature while still wrapped over the mandrel. Any cracks in the cable jacket which are discernible by visual examination shall be cause for rejection.)

Hot oil immersion

Tensile strength - percent of unaged, minimum......90

Elongation - percent of unaged, minimum...........80

QUALIFICATION INSPECTION

Qualification Inspection shall include basic electrical plus all of Groups A, B, and C.

Unit Ordering Length: 500 ft (minimum)

Date of Issue: December 17, 1974

NAVAL SHIP ENGINEERING CENTER
PROCUREMENT SPECIFICATION

(May be used for procurement)

Cable, Electrical, One Twisted Pair AWG-20, for
TRIDENT Submarine Outboard Use (Not for Inboard Use)

Type 1PR-A20E

(This specification will become void upon the publication of a MIL-C-915/xx military specification sheet covering 1PR-A20E)

The complete requirements for procuring the cable described herein shall consist of this document and the latest issue of specification MIL-C-915.

REQUIREMENTS:

Construction

First - Conductor of high strength copper alloy (Phelps-Dodge #PD-135 or equivalent), silver coated, size AWG-20 (7 x .0126).

Second - Insulation of Tefzel fluoropolymer (ETFE), with solid colors (see Fourth). Nominal wall thickness 0.010-inch. Maximum overall diameter 0.060-inch.

Third - Insulation jacket of clear natural polyethylene per L-P-390, Type II, Class L, Grade 3. Nominal wall thickness 0.010-inch. Maximum overall diameter 0.082-inch.

Fourth - Two insulated and jacketed conductors (one white, one red), twisted together with a lay of 1 - 1/4 ± 1/8 inch.

Fifth - Cable jacket of black polyethylene copolymer, applied so as to completely fill the pair valleys. Unless otherwise specified in the contract or order, the cable jacket material shall be Union Carbide Corp. #DFDA-0588, black #9865. Cable jacket shall be capable of being removed without incurring damage to the insulation jacket or the insulation. Nominal wall thickness 0.060-inch. Minimum wall thickness at any cross-section 0.054-inch. Cable overall diameter shall be 0.285 ± .005 inch.

NOTE: All ingredients and components used in this cable shall be of virgin material. That is, one hundred percent new material which has been through only those processes which wereessential to manufacturing and which has been through those processes one time only. Any material which has been previously processed in any other manner is considered non-virgin.

EXAMINATION AND TESTS:	Requirements
Basic electrical:	
Conductor resistance - at 20°C., ohms/1000 ft, max........	11.1
Voltage withstand - volts, rms, minimum	
Conductor to conductor..................................	2000
Conductor to water......................................	2000

Insulation dielectric. Test 100 percent of insulated conductors before application of insulation jacket. Test in accordance with specification MIL-W-81381A, paragraph 4.7.4.1, using a test voltage of 8.0 kv (peak), minimum.

Group A:

Visual and dimensional

Conductor (before application of insulation)	
Silver coating - thickness in microinches, min....... (Test per ASTM B-298)	40
Tensile strength - pounds, minimum..................	55.6
Elongation - percent, minimum.......................	6.0

(Test tensile strength and elongation per FED-STD-228, Method 3212, except as follows. Test not less than 3 specimens per each 1000 feet of conductor. Specimen length shall be not less than 20 inches. Tensile strength shall be in pounds. Specimen zero length shall be as near to 10 inches as practical).

Group B:

Cold bending, cable - At minus 40°, 3-inch dia. mandrel...	No damage
Physicals (unaged)	
Insulation	
Tensile strength - psi, minimum.................	5000
Elongation - percent, minimum..................	150
Insulation jacket	
Tensile strength - psi, minimum.................	1400
Elongation - percent, minimum..................	300
Cable jacket	
Tensile strength - psi, minimum.................	1800
Elongation - percent, minimum..................	500

Group C:

Physicals (aged)

Insulation
Air oven (168 hours at 180°C.)

Tensile strength - percent of unaged, min...	90
Elongation - percent of unaged, minimum.....	90

Insulation jacket
Air oven (96 hours at 100° ± 2°C.)

Elongation - percent of original, min.......	60

Cable jacket
Air oven (96 hours at 100° ± 2°C.)
(Specimen shall consist of a length of completed cable approximately 8 - 1/2 feet long. Ten turns of cable shall be wrapped around a 3-inch diameter mandrel. Upon completion of the conditioning period, specimen shall be allowed to cool to room temperature while still wrapped over the mandrel. Any cracks in the cable jacket which are discernible by visual examination shall be cause for rejection).

Environmental stress crack
(Specimen shall consist of a length of completed cable approximately 12 feet long. Ten turns of cable shall be wrapped around a 3-inch diameter mandrel and suspended for 24 hours in an aqueous solution containing 10% (by volume) of Igepal CO-630 at 50° ± 2°C. The ends of the specimen shall be kept out of the solution. Upon completion of the conditioning period, specimen shall be allowed to cool to room temperature while still wrapped over the mandrel. Any cracks in the cable jacket which are discernible by visual examination shall be cause for rejection.)

Mutual capacitance - pF/ft at 2 kHz, maximum.........	25

NOTE: The cable jacket shall be free of any soft spot, air pocket or void. The cable jacket surface shall be dry and free of any coating, film or treatment which might tend to interfere with the user's bonding to the cable jacket, during encapsulating and/or molding processes normally used in splicing and/or terminating techniques. Cable jacket repairs will be permitted, providing that the materials and techniques used are such that the finished cable complies with all requirements of this specification. The occurrence of such repairs shall be held to a minimum. Materials and techniques used in cable jacket repairs shall have had prior approval of the Naval Ship Engineering Center, Code 6158F.

UNIT ORDERING LENGTH: 1000 feet (nominal)

Prepared by the Naval Ship Engineering Center (Code 6158F), Hyattsville MD in collaboration with the Naval Underwater Systems Center, New London (CT) Laboratory, Code TD-122.

APPENDIX B

MIL-C-915 and MIL-C-915 Specification Sheets
MIL-C-915/7, 8, 22, 47, 48, and 61

MIL-C-915/7D
5 April 1973
SUPERSEDING
MIL-C-915/7C
1 August 1972

MILITARY SPECIFICATION SHEET

CABLE, ELECTRICAL, TYPE DSWS

This specification sheet is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for procuring the cable described herein shall consist of this document and the latest issue of Specification MIL-C-915.

REQUIREMENTS:
Qualification required.

Construction (Watertight)

First - Copper conductor, Navy Standard size 4(7), coated
Second - Synthetic rubber insulation. Nominal wall thickness 0.073 inch. Standard Identification Code, applied by Method 3. An additional covering of clear polyamide may be employed at the manufacturer's option.
Third - Two conductors shall be cabled together with a lay not greater than 5 inches. Fillers of synthetic rubber like compound shall be used to attain a firm, well rounded cross section. Fillers may be laid in the valleys during the cabling operation or may be extruded into the valleys separately. Fillers shall bbe readily separable from the insulation without damage thereto and without destroying the conductor identification.
Fourth - Binder tape over the conductor assembly, at manufacturer's option.
Fifth - Shielding braid of AWG No. 34, tin-coated copper, with an angle of 30 to 40 degrees and minimum coverage of 88 percent.
Sixth - An overall jacket (black), nominal wall thickness 0.060 inch. If needed to meet electrical tests, the jacket may comprise an inner layer of rubber insulation, such as synthetic rubber and an outer layer of polychloroprene. The jacket shall be readily separable from the underlying shield, leaving the shield adequately clean for soldering. Cable surface marking required.

Details

Type and style	Overall diameter	
	Minimum (inch)	Maximum (inch)
DSWS-4	0.770	0.800

EXAMINATION AND TESTS:

	Requirements:
Basic electrical:	
Conductor resistance - Ohms/1000 ft. at 25°C., maximum	2.57
Voltage withstand - Volts, rms, minimum	
Conductor to conductor (5 minutes)	10,000
Conductor to shield (5 minutes)	10,000
Shield to water (5 minutes)	500
Voltage withstand - Volts, d.c., minimum	
Conductor to conductor (15 minutes)	25,000
Conductor to shield (15 minutes)	25,000
Shield to water (15 minutes)	1,500

(D) Denotes changes.

FSC 6145

	Requirements:
Basic electrical (Cont'd):	
Insulation resistance - Megohms/1000 ft., minimum	
Shield to water	100
Conductor to conductor	200
Conductor to shield	200
Group A:	
Visual and dimensional	
Hydrostatic (open end) - 1000 psi, cu. in., 2 hrs, maximum	0
Mutual capacitance - pF/ft. at 1 KHz	40±10
Group B:	
Physicals (unaged)	
Insulation (conductor)	
Tensile strength - psi, minimum	600
Elongation - Percent, minimum	350
Jacket (cable)	
Tensile strength - psi, minimum	1,800
Elongation - Percent, minimum	300
Set - Inch, maximum	3/8
Group C:	
Physical (aged)	
Insulation (conductor)	
Air pressure heat	
Tensile strength - Percent of unaged, minimum	70
Elongation - Percent of unaged, minimum	75
Jacket (cable)	
Air pressure heat	
Tensile strength - Percent of unaged, minimum	50
Elongation - Percent of unaged, minimum	50
Hot oil immersion	
Tensile strength - Percent of unaged, minimum	60
Elongation - Percent of unaged, minimum	60
Permanence of printing (jacket) cycles, minimum	250

D

QUALIFICATION INSPECTION

Qualification inspection shall include basic electrical, all of Group A, B and C plus the following:

Insulation resistance per 1000 feet at room temperature from shield to water, 50 megohms, minimum after 90 days continuous submergence in water; values recorded at 1-week intervals.

Flexing endurance - 1000 cycles of bending a specimen, 4-inch maximum diameter mandrel at minus 40° ± 2°C. Upon successful completion of this test, specimen shall meet the voltage withstand test and the hydrostatic (open end) test.

UNIT ORDERING LENGTHS:
500 feet (Nominal) Coils

Custodians:
Army - MI
Navy - SH
Air Force - 80

Review activities:
Army - EL, MI, AV
Navy - EC
Air Force - 80

User activities:
Army - ME, MU, WC
Navy - CG

Preparing activity:
Navy - SH
(Project 6145-0648-3)

MIL-C-915/8E
16 October 1978
SUPERSEDING
MIL-C-915/8D
1 August 1972

MILITARY SPECIFICATION SHEET

CABLE, ELECTRICAL, 600 VOLTS, TYPES DSS, TSS, FSS AND 7SS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for procuring the cable described herein shall consist of this document and the latest issue of Specification MIL-C-915.

REQUIREMENTS:
Qualification required.

Construction (Watertight)

(E) First - Copper conductor, tin coated. See Table I for size.
(E) Second - Synthetic rubber insulation. See Table I for thickness. Special identification code, applied by Method 3.
(E) Third - The required number of conductors (see Table I) cabled together with a lay length not greater than that specified in Table I. The insulated conductors shall not adhere to one another. Rubber fillers as necessary in order to form a firm, round assembly. Fillers in outer valleys may be extruded in order to be integral with the belt (see Fourth).
Fourth - Belt of synthetic rubber, nominal wall thickness 0.030-inch, over the assembled conductors. Belt and fillers shall be capable of removal from the assembly without damaging the insulation on conductors.
Fifth - Braided shield of AWG No. 34 tin coated copper. Braid angle of 50 degrees, minimum; coverage of 90 percent, minimum.
Sixth - Jacket of either polychloroprene or chlorosulfonated polyethylene, black. See Table I for thickness. If necessary in order to meet the electrical requirements for the completed cable, the jacket may consist of two layers bonded together, with the inner layer consisting of synthetic rubber insulation. Cable surface marking required.

NOTE: Manufacturer's identification tape may be omitted, at the manufacturer's option, from all types and sizes.

TABLE I. Details.

Type and Size	Conductor size, Navy Standard	Number of conductors	Insulation [1/] thickness minimum (inch)	Lay length (inch)	Jacket [1/] thickness minimum (inch)	Overall diameter Min. (inch)	Overall diameter Max. (inch)	Conductor resistance per 1000 ft. max., (ohms)
DSS-2	2(7)	2	0.020	2.0	0.050	0.370	0.390	6.64
DSS-3	3(7)	2	.025	2.0	.080	.480	.500	4.15
DSS-4	4(7)	2	.025	2.5	.065	.480	.500	2.57
TSS-2	2(7)	3	.020	2.0	.050	.385	.400	6.64
TSS-3	3(7)	3	.025	2.5	.070	.480	.500	4.15
TSS-4	4(7)	3	.025	2.5	.055	.480	.500	2.57
FSS-2	2(7)	4	.020	2.5	.080	.480	.500	6.64
FSS-3	3(7)	4	.025	2.5	.060	.480	.500	4.15
FSS-4	4(7)	4	.025	3.0	.085	.600	.625	2.57
7SS-2	2(7)	7	.020	3.0	.085	.600	.625	6.64

(E) 1/ Because of the compact construction necessary in order for these cables to meet the required hydrostatic tests, centering and circularity requirements for insulation and jacket are waived, provided that the finished cable complies with the value specified in table I for minimum thickness of insulation and jacket and for overall cable diameter.

(E) Denotes changes

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EXAMINATION AND TESTS:

	Requirements
E **Basic electrical**:	
Voltage withstand - Volts, root mean square (Vrms) minimum (Min)	
Conductor to conductor (5 minutes)	3000
Conductor to shield (5 minutes)	1000
Shield to water (5 minutes)	500
E Insulation resistance - Megohms/1000 feet (ft) min	
Conductor to conductor	500
Conductor to shield	500
Shield to water	250
Conductor resistance - Ohms/1000 ft. at 25°C., maximum (max)	(See table I)
Group A:	
Visual and dimensional	
E Hydrostatic (open end) - At 500 pounds force per square inch (lbf/in^2), in 2 hours Cubic inches (cu in) max.	0
E Mutual capacitance (type DSS only) - picofarads per foot at 1 kilohertz max	45
(measurement shall be made with black conductor connected to shield at one end of specimen)	
Group B:	
Bending endurance - At minus 40° ± 2°C. on 4-inch max diameter mandrel, cycles, min	1000
Physicals (unaged)	
E Insulation (conductor)	
Tensile strength - lbf/in^2 min.	600
Elongation - Percent, min	300
Jacket (cable)	
E Tensile strength - lbf/in^2 min.	1800
Elongation - percent, min	300
Set - Inch, max	3/8
Group C:	
Physicals (aged)	
Insulation (conductor)	
Air pressure heat	
Tensile strength - Percent of unaged, min.	65
Elongation - Percent of unaged, min.	65
Jacket (cable)	
Hot oil immersion	
Tensile strength - Percent of unaged, min.	65
Elongation - Percent of unaged, min.	65
Permanence of printing (jacket) - Cycles, min	250

QUALIFICATION INSPECTION

Qualification inspection shall include basic electrical plus all of Groups A, B and C plus the following:

E Hydrostatic (open end), after bending endurance - At 500 lbf/in^2 in 2 hours cu. in. max.	0
E Pressure cycling (DDS-3 only) - At 500 lbf/in^2 percent of variation in mutual capacitance, max.	10
Insulation resistance (after 90-day immersion in tap water) - Megohms/1000 ft., min	
Conductor to conductor	500
Conductor to shield.	500
Shield to water.	250

NOTE: This draft, dated 13 April 1981, prepared by the Naval Sea Systems Command, has not been approved and is subject to modification. DO NOT USE FOR ACQUISITION PURPOSES. (Project Number 6145-N298-1)

MIL-C-00915/22F(SH)

USED IN LIEU OF
MIL-C-915/22E
30 May 1980

MILITARY SPECIFICATION SHEET

CABLE, ELECTRICAL, 300 VOLTS, TYPE TSP (INCLUDING VARIATION TSPA)

F This limited coordination military specification sheet has been prepared by the Naval Sea Systems Command based upon currently available technical information but it has not been approved for promulgation as a coordinated revision of MIL-C-915/22E. It is subject to modification. However, pending its promulgation as a coordinated military specification sheet, it may be used in acquisition.

The complete requirements for acquiring the cable described herein shall consist of this document and the latest issue of specification MIL-C-915.

F This cable can be manufactured in two variations: TSP (unarmored) and TSPA (armored).

REQUIREMENTS:

Qualification required.

Construction (watertight)

First - Copper conductor, Navy standard size 3/5(7), tin-coated.
Second - Polyvinyl chloride insulation (80°C). Nominal wall thickness 0.015 inch. Telephone Identification Code, applied by method 3.
Third - Two conductors cabled together to form a pair with a lay not greater than 2-1/2 inches.
Fourth - The specified number of pairs (see details) cabled with a lay not greater than 10 inches in the outer layer. Nonfibrous fillers shall be employed. Cabling sequence shall be consecutive, starting with pair no. 1, from center outward.
Fifth - Binder tape applied helically with overlap.
Sixth - Special thermoplastic jacket (gray). Nominal wall thickness 0.080 inch. Cable surface marking required.

F denotes changes.

FSC 6145

(F) Seventh - When this cable is manufactured with armor, the following additional requirements shall apply:

(a) The type designation shall change to TSPA.
(b) Braided metal armor and paint shall be added.
(c) Cable surface marking shall not be required.
(d) The maximum (max) overall dimension shall be as specified in the Details table plus 0.050 inch.

Details.

Type and size	Number of pairs	Overall diameter max (inches)
TSP-11	11	0.735
TSP-31	31	1.062

EXAMINATION AND TESTS:

	Requirements
Basic electrical:	
Conductor resistance - Ohms/1000 feet (ft) at 25°C, max.	17.06
Voltage withstand - Volts, root mean square (Vrms), minimum (min)	
Conductor to conductor.	2000
Conductor to ground.	1000
Insulation resistance - Megohms/1000 ft, min	100
Group A:	
Visual and dimensional	
Watertightness - See MIL-C-915, table for limits of water leakage.	
Group B:	
Physicals (unaged)	
Insulation (conductor)	
Tensile strength - Pounds force per square inch (lbf/in^2), min.	1800
Elongation - Percent, min	125
Jacket (cable)	
Tensile strength - lbf/in^2, min	2300
Elongation - Percent, min	250

	Requirements
Group C:	
Flammability - Inches, max	2
Physicals (aged)	
Insulation (conductor)	
Air oven	
Elongation - Percent of unaged, min	80
Jacket (cable)	
Air oven (168 hours at 136°C)	
Tensile strength - Percent of unaged, min	80
Elongation - Percent of unaged, min	60
Hot oil immersion	
Tensile strength - Percent of unaged, min.	75
Elongation - Percent of unaged, min	50
(F) Permanence of printing, type TSP only, (jacket) - Cycles, min.	250
Cable filler removability.	
(F) Armor - Conformance to material construction and coverage (type TSPA only).	

QUALIFICATION INSPECTION:

Qualification inspection shall include basic electrical, all of groups A, B, and C, plus the following:

Cable aging and compatibility (95°C $\pm$ 3°C)	No failure
Flame propagation.	No failure
Jacket durometer (type A) hardness, min.	80

UNIT ORDERING LENGTHS:

Size	Feet (nominal)
11	2500
31	1000

Preparing activity:
Navy - SH
(Project 6145-N298-1)

MILITARY SPECIFICATION SHEET

CABLE, ELECTRICAL, TYPE 1SWF

(A) This specification is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for procuring the cable described herein shall consist of this document and the latest issue of Specification MIL-C-915.

REQUIREMENTS:
Qualification required.

Construction (Watertight)

First - Copper conductor, ASTM B-286 size 22-7, uncoated. Maximum diameter 0.033 inch.
(A) Second - Polyethylene insulation, natural, type II, class L, grade 3 of L-P-390. Nominal thickness 0.045 inch.
Third - Braided shield of AWG No. 36 uncoated copper. Braid angle of 30 to 35 degrees; minimum coverage of 85 percent.
Fourth - Shield insulation of one polyester tape, type G of MIL-I-631, plus a jacket of clear polyamide, type III, grade E or type IV of MIL-M-20693. Nominal thickness of 0.003 inch. Standard Identification Code, applied by Method 2.
- Alternate shield insulation of two polyester tapes, type G of MIL-I-631, sealed. Standard Identification Code, applied by Method 2, on inner tape.
Fifth - Two conductors (one black and one white) cabled with a lay not greater than 3 inches. Non-fibrous fillers shall be used.
Sixth - Binder tape applied helically with overlap.
(A) Seventh - Arctic type polychloroprene jacket (black). Cable jacket thickness 0.100 inch maximum. Cable surface marking required.

Details

(A)

Type and size	Number of conductors	Overall diameter	
		Minimum (inch)	Maximum (inch)
1SWF-2	2	0.600	0.625

EXAMINATION AND TESTS:

Requirements:

Basic electrical:
(A) Conductor resistance - At 25°C., ohms/1000 ft., maximum 17.03
Voltage withstand - Volts, rms, minimum
Conductor to shield. 3000
Shield to shield 500

[1] Requirements formerly covered on MIL-C-24145/7.

(A) Denotes changes

FSC 6145

	Requirements:
Group A:	
Visual and dimensional	
Hydrostatic (open end) - Leakage 1000 psi, cu. in., 6 hrs., test each shipping length	Zero
Capacitance - At 1 kHz, pF/ft., maximum	28
Characteristic impedance - At 1 MHz, ohms	61 ± 3
Group B:	
Cold working (minus 54° ± 2°C.)	No damage
Drip - At 75° ± 1°C.,	Zero
Physicals (unaged)	
Insulation (conductor)	
Tensile strength - psi, minimum	1400
Elongation - Percent, minimum	300
Jacket (cable)	
Tensile strength - psi, minimum	1800
Elongation - Percent, minimum	300
Set - Inch, maximum	3/8
Group C:	
Physicals (aged)	
Insulation (conductor)	
Air oven	
Elongation - Percent of unaged, minimum.	60
Permanence of printing (jacket) - Cycles, minimum	250
Cable filler removability	

QUALIFICATION INSPECTION:

Qualification inspection shall include basic electrical, al. of Groups A, B and C plus the following:

Cable aging and compatibility (95° ± 3°C.)	No failure
Cold working (minus 54° ± 2°C.)	No failure

UNIT ORDERING LENGTHS:

All sizes: 1000 feet (nominal)

A Custodians:
Army - MI
Navy - SH
Air Force - 80

A Review activities:
Army - EL, MI, AV
Navy - EC
Air Force - 80

A User activities:
Army - ME, MU, WC
Navy - CG

Preparing activity:
Navy - SH
(Project 6145-0609-52)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1973-714-537/1365

MILITARY SPECIFICATION SHEET

CABLE, ELECTRICAL, TYPE 2SWF

(A) This specification is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for procuring the cable described herein shall consist of this document and the latest issue of Specification MIL-C-915.

REQUIREMENTS:
Qualification required.

Construction (Watertight)

First - Copper conductor, ASTM B-286 size 22-7, tin coated. Maximum diameter 0.033 inch.

(A) Second - Polyethylene insulation, type II, class L, grade 4 of L-P-390. Nominal thickness 0.010 inch. Colored insulation, one black and one white conductor for each pair.

(A) Third - Clear polyamide jacket on each conductor, type III, grade E or type IV of MIL-M-20693. Nominal thickness 0.003 inch.

Fourth - Two conductors (one black and one white) cabled together with a nominal lay of 2.5 inches to form each pair.

Fifth - Binder tape over each pair, at manufacturer's option, applied helically with overlap.

Sixth - Braided shield of AWG No. 34 or 36 tin coated copper. Braid angle 30 to 35 degrees; minimum coverage of 85 percent.

(A) Seventh - Shield insulation of one polyester tape, type G of MIL-I-631, plus a jacket of clear polyamide, type III, grade E or type IV of MIL-M-20693. Nominal thickness of 0.003 inch. Standard Identification Code, applied by Method 2.
- Alternate shield insulation of two polyester tapes, type G of MIL-I-631, sealed. Standard Identification Code, applied by Method 2, on inner tape.

(A) Eighth - The required number of pairs (see details) cabled with a lay not greater than 24 times the pitch diameter of the layer. Cabling sequence shall be consecutive, starting with pair No. 1, from center outward. Non-fibrous fillers shall be employed.

Ninth - Synthetic rubber compound filled binder tape applied helically with overlap. (Surface of tape shall be such that cable jacket will adhere to it).

(A) Tenth - Arctic type polychloroprene jacket (black). (See details for thickness.) Cable surface marking required.

Details

Type and size	Number of pairs	Cable jacket thickness minimum (inch)	Overall diameter Minimum (inch)	Overall diameter Maximum (inch)
2SWF-3	3	0.100	0.600	0.625
2SWF-4	4	.090	.600	.625
2SWF-7	7	.110	.780	.815

1/ Requirements formerly covered on MIL-C-24145/3.

(A) Denotes changes

FSC 6145

EXAMINATION AND TESTS:

	Requirements:
Basic electrical:	
Conductor resistance - Ohms/1000 ft. at 25°C., maximum	17.71
Voltage withstand - Volts, rms, minimum	
Conductor to conductor	2000
Conductor to shield	1000
Shield to shield	500
Group A:	
Visual and dimensional	
Hydrostatic (open end) - Leakage at 1000 psi, cu. in., 6 hrs., (test each shipping length)	Zero
Capacitance	
Mutual capacitance - At 1 mHz, pF/ft., maximum	30
Capacitance unbalance - Percent, maximum	8
Characteristic impedance - At 1 mHz, ohms	75 ± 5
Group B:	
Attenuation - At [illegible] mHz, db/100 ft., maximum	3
Cold working (minus 54° ± 2° C.)	(No damage)
Drip - At 75° ± 1°C.,	Zero
Physicals (unaged)	
Insulation (conductor)	
Tensile strength - psi, minimum	1400
Elongation - Percent, minimum	300
Jacket (cable)	
Tensile strength - psi, minimum.	1800
Elongation - Percent, minimum	300
Set - Inch, maximum	3/8
Group C:	
Physicals (aged)	
Insulation (conductor)	
Air oven	
Elongation - Percent of unaged, minimum	60
Permanence of printing (jacket) - Cycles, minimum	250
Cable filler removability	

QUALIFICATION INSPECTION:

Qualification inspection shall include basic electrical plus all of Groups A, B and C, plus the following:

Cable aging and compatibility (95° ± 3°C.)	No failure
Cold working (minus 54° ± 2°C.)	No failure

UNIT ORDERING LENGTHS: All sizes: 1000 feet (nominal)

Custodians:
Army - MI
Navy - SH
Air Force - 80

Review activities:
Army - EL, MI, AV
Navy - EC
Air Force - 80

User activities:
Army - ME, MU, WC
Navy - CG

Preparing activity:
Navy - SH
(Project 6145-0609-39)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1977-714-537/1381

MILITARY SPECIFICATION SHEET

CABLE, ELECTRICAL, 600 VOLTS, TYPE MWF

This specification sheet is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for procuring the cable described herein shall consist of this document and the latest issue of Specification MIL-C-915.

REQUIREMENTS:
Qualification required.

Construction (Watertight)

First - Copper conductor, AWG No. 18 (7 X 0.0152 inch), tin coated. Maximum diameter 0.050-inch.
Second - Insulation of synthetic rubber or cross-linked polyethylene. Nominal thickness 0.020-inch.
Third - Jacket of clear polyamide, type III grade E, or type IV, of MIL-M-20693, nominal thickness 0.005-inch. Standard identification code, applied by Method 1.
Fourth - The required number of conductors (see details) cabled together with a maximum lay of 20 times the pitch diameter of the layer. Cabling sequence to be consecutive, starting with No. 1, from the center outward. Fillers as necessary in order to form a firm, round assembly. Fillers shall be non-fibrous.
Fifth - Binder tape applied helically with overlap.
Sixth - Arctic type neoprene jacket, black. (See details for thickness.) Cable surface marking required.

Details

Type and size	Number of conductors	Cable jacket thickness nominal (inch)	Overall diameter	
			Minimum (inches)	Maximum (inches)
MWF-7	7	0.060	0.480	0.500
MWF-10	10	.065	.605	.635
MWF-14	14	.065	.605	.635
MWF-19	19	.085	.710	.745
MWF-24	24	.085	.800	.836
MWF-30	30	.110	.905	.945
MWF-37	37	.110	1.005	1.045

EXAMINATION AND TESTS:

Requirements:

Basic electrical:
Voltage withstand - Volts, rms, minimum
Conductor to conductor. 2000
Conductor to water. 1000
Conductor resistance - Ohms/1000 ft. at 25°C., maximum 7.47

[1] Requirements formerly covered on MIL-C-24145/18.

	Requirements:
Group A:	
Visual and dimensional	
Hydrostatic (open end)(on every shipping length) - Leakage at 1000 psi, in 6 hrs. cu. in., maximum	0
Group B:	
Physicals (unaged)	
Insulation (conductor)	
Synthetic rubber	
Tensile strength - psi, minimum	700
Elongation - Percent, minimum	350
Cross-linked polyethylene	
Tensile strength - psi, minimum	1800
Elongation - Percent, minimum	350
Jacket (cable)	
Tensile strength - psi, minimum	1800
Elongation - Percent, minimum	300
Set - Inch, maximum	3/8
Group C:	
Physicals (aged)	
Insulation (conductor)	
Synthetic rubber	
Oxygen pressure	
Tensile strength - Percent of unaged, minimum	75
Elongation - Percent of unaged, minimum	75
Air pressure heat	
Tensile strength - Percent of unaged, minimum	50
Elongation - Percent of unaged, minimum	50
Cross-linked polyethylene	
Air oven	
Tensile strength - Percent of unaged, minimum	80
Elongation - Percent of unaged, minimum	80
Air pressure heat	
Tensile strength - Percent of unaged, minimum	50
Elongation - Percent of unaged, minimum	50
Permanence of printing (conductor) - Cycles, minimum	50
Permanence of printing (jacket) - Cycles, minimum	250
Cold working (minus 54° ± 2°C.)	No damage
Cable filler removability	

QUALIFICATION INSPECTION

Qualification inspection shall include basic electrical plus all of Groups A, B and C plus the following:

Cable aging and compatibility (125° ± 5°C.)	No failure
Cold working (minus 54° ± 2°C.)	

UNIT ORDERING LENGTHS:

Size	Feet (nominal)
7	1000
10	1000
14	500
19	500
24	500
30	500
37	500

MIL-C-915/61B
23 August 1976
SUPERSEDING
MIL-C-915/61A
1 August 1972

MILITARY SPECIFICATION SHEET

CABLE, ELECTRICAL, TYPE S2S

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for procuring the cable described herein shall consist of this document and the latest issue of Specification MIL-C-915.

REQUIREMENTS:

Qualification required.

Construction (watertight)

B First - Copper conductor, tin coated Navy Standard size 2(7). Maximum (max) diameter 0.050-inch.
B Second - Cross-linked thermosetting polyethylene insulation, colored black. Max. wall thickness 0.060-inch.
B Third - Braided shield of AWG No. 34 tin coated copper strands. Sixteen carriers, six ends per carrier, eight picks per inch.
B Fourth - Synthetic rubber insulation. Nominal (nom.) wall thickness 0.055-inch.
B Fifth - Braided shield consisting of 0.0063-inch diameter tin coated, copper-clad steel wires, class 40A of ASTM B452. Twenty-four carriers, eight ends per carrier, nine or ten picks per inch.
B Sixth - Two-layer jacket with the layers bonded together, with a reinforcing braid between layers, and having a total thickness of 0.065-inch, minimum (min). Inner layer of synthetic rubber insulation having 0.033-inch nom wall thickness. Outer layer of artic type polychloroprene. Reinforcing braid of 210-denier nylon, applied with 12 carriers, 2 ends per carrier and 3 picks per inch. Completed cable over all diameter 0.480-inch min, 0.500-inch maximum.
B Seventh - Cable surface marking required.

EXAMINATION AND TESTS:

		Requirements
	Basic electrical:	
B	Conductor resistance - Ohms/1000 ft., at 25° Celsius (C), max	6.5
	Voltage withstand - Volts, root mean square (Vrms), min.	
	Conductor to inner shield.	1500
	Shield to shield	1500
	Insulation resistance - Megohms/1000 ft, min.	
	Conductor to inner shield.	500
B	Shield to shield	100
B	Outer shield to water.	10

B Denotes changes

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Ship Engineering Center, Center Building, SEC 6124, Prince George's Center, Hyattsville, Maryland 20782 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FSC 6145

EXAMINATION AND TEST (con.):

	Requirements
Group A:	
Visual and dimensional	
Hydrostatic (open end) (Test every shipping length) - At a gage pressure of 1000 pounds per square incn (lb/in^2) for 6 hours, leakage.	Zero
Capacitance - At 1 kilohertz (kHz), picofarad per foot (pF/ft.) max.	37 $\pm$ 1
Group B:	
Breaking strength - Pounds, min	150
Physicals (unaged)	
Insulation	
(B) Tensile strength - Pound-force per square inch (lbf/in^2), min	1500
(B) Elongation - percent, min	250
Jacket (outer layer)	
Tensile strength - lbf/in^2, min	1800
Elongation - percent, min	300
Set - inch, max	3/8
Group C:	
(B) Flammability - Inches, max.	2
Physicals (aged)	
Air pressure heat	
Insulation	
Tensile strength - percent of unaged, min.	50
Elongation - percent of unaged, min.	50
Permanence of printing (jacket) - cycles, min.	250

(B) QUALIFICATION INSPECTION:

Qualification inspection shall include basic electrical plus all of Groups A, B and C plus a pressure cycling test in accordance with paragraph 4.8.23, except as follows:

(1) The specimen shall consist of a 10-foot length of completed cable.
(2) Instrumentation shall be connected to one of the protruding cable ends so that capacitance can be measured continuously during the test.
(3) Hydrostatic pressure in the chamber shall be raised from atmospheric pressure to a gage pressure of 1000 lb/in^2 and held for 1 hour. The specimen shall then be given 10 cycles from a gage pressure of 1000 lb/in^2 to atmospheric to a gage pressure of 1000 lb/in^2, with a 10-second dwell time at each extreme. At the end of the tenth cycle, gage pressure shall be held at 1000 lb/in^2 for 1 hour.
(4) Any capacitance measurement during the test which is less than 36 pF/ft. or greater than 40 pF/ft. shall constitute failure.

UNIT ORDERING LENGTH: 500 feet, nom

Custodians:
Army - MI
Navy - SH
Air Force - 99
Review activities:
Army - EL, AV
Navy - EC
User activities:
Army - ME, MU, WC
Navy - CG

Preparing activity:
Navy - SH
(Project 6145-0674-61)

☆U.S. GOVERNMENT PRINTING OFFICE 1976-703-020/560

MIL-C-915E
AMENDMENT-2
30 May 1980
SUPERSEDING
AMENDMENT-1
5 April 1973

MILITARY SPECIFICATION

CABLE AND CORD ELECTRICAL, FOR SHIPBOARD USE

GENERAL SPECIFICATION FOR

This amendment forms a part of Military Specification MIL-C-915E, dated 1 August 1972, and is approved for use by all Departments and Agencies of the Department of Defense.

PAGE 3

2.1: Add the following Military Specification:

"MIL-I-45208 - Inspection System Requirements."

PAGES 3 and 4

* 2.2: Add the following publication under American Society for Testing and Materials:

"ASTM D 2240 - Indentation Hardness of Rubber and Plastics by Means of a Durometer."

* 2.2: Add the following:

"INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS
"IEEE-STD-383 - IEEE STD for Type Test of Class 1E Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations.

"(Application for copies should be addressed to the Institute of Electrical and Electronic Engineers, Inc., 345 East 47th Street, New York, NY 10017.)"

PAGE 5

* "3.3.3.1, last sentence: Delete.

PAGE 6

3.3.9, first sentence: Delete and substitute: "Tie cords shall be of cotton or synthetic fiber having a maximum diameter of 0.065 inch and a minimum breaking strength of 30 pounds."

FSC 6145

3.4.1: Delete and substitute:

"3.4.1 Conductor stranding. The size and quantity of individual conductor strands and the total circular-mil area of the conductor, unless otherwise specified on the specification sheet, shall be in accordance with tables I, II, or III, as applicable, in accordance with the conductor size designation indicated on the specification sheet. When AWG sizes are specified on the specification sheets for conductors, they shall be in accordance with ASTM B 8."

PAGE 8

Table III, column 2: Delete all values under "Rope" and substitute the following:

Number of strands Minimum
" 49
228
49
304
336
209
49
532
304
133
2107
418
2646
259
3325
259
648
760
427
988
259
1254
6384
259
2052
259
427
427
4033"

PAGE 10

Table IV: Add the following as color, conductor or group No. "50".

Color, conductor or group No.	Background or base color	First tracer color	Second tracer color
"50	Black	Orange	Red"

PAGE 12

* Add the following paragraphs:

* "3.4.9.1.5 T isted pair identification code. This code shall consist of numbers in sequence running from 1 through the number corresponding to the total quantity of twisted pairs in the cable. Both conductors in each pair shall be numbered the same, denoting the sequence number of the pair. Distinction between the two conductors is provided by different colored insulation. Conductors of a cable with a single pair need not be numbered.

* "3.4.9.1.6 Twisted triad identification code. This code shall consist of numbers in sequence running from 1 through the number corresponding to the total quantity of twisted triads in the cable. All three conductors shall be numbered the same, denoting the sequence number of the triad; distinction between the three conductors is provided by different colored insulation. Conductors of a cable with a single triad need not be numbered."

PAGE 13

* Add the following paragraph:

"3.4.9.2.6 Method 6. Identification method 6 shall consist of numerals printed in ink on the conductor insulation. For conductors having a jacket directly over the insulation, the numerals may be printed in ink on the jacket, at the manufacturer's option. White ink shall be used for a red or black background; black ink shall be used for a white background. Numerals shall be upright on the logitudinal axis of the conductor (see figure 6). Numeral width shall be proportional to conductor, outside diameter (o.d.) as follows:

Conductor (o.d.) (inch)	Numeral width (inch)
0.040 - 0.050	0.020
.051 - .070	.025
.071 - .095	.030

Numeral height shall be 2-1/2 to 3 times numeral width. Each numeric legend shall be underlined. Two-digit legends shall have the bottom numeral underlined. Legends shall be alternately inverted and shall be repeated at intervals not greater than 1-1/2 inch.

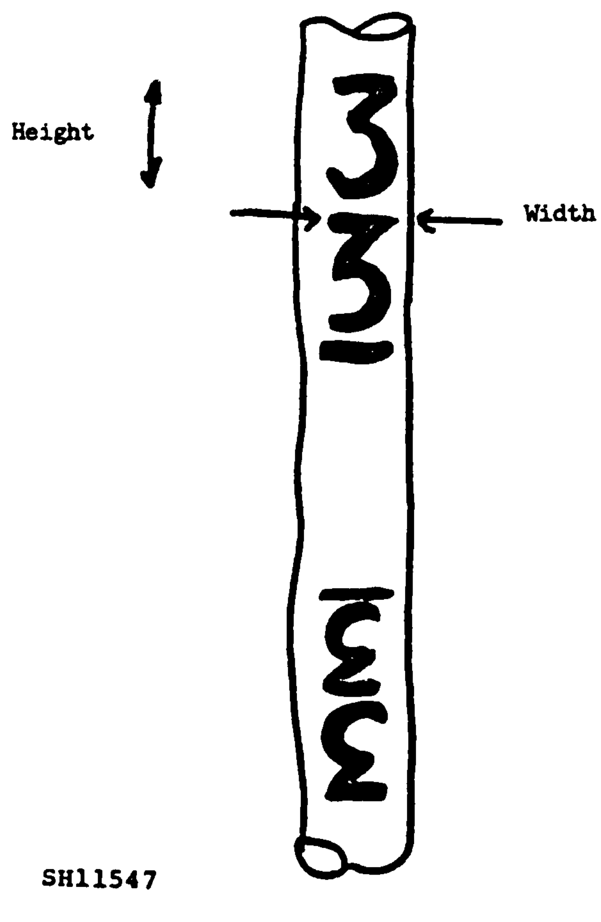


FIGURE 6. Conductor of pair number 33."

PAGE 16

Add the following paragraph as 4.1.1:

"4.1.1 Inspection system. The contractor shall provide and maintain an inspection system acceptable to the Government for supplies and services covered by this specification. The inspection system shall be in accordance with MIL-I-45208."

PAGE 17

* Table VII: Delete and substitute:

* "Table VII - Qualification specimens and groups.

Group No.	Qualification: Flame Propagation 1/	Qualification: Type and Size 2/	Types and Sizes Comprising the Group
1		DLT	DLT
2		DRW	SRW, DRW, TRW
3		DSS-3	All sizes of DSS, TSS, FSS, 5SS and 7SS
4		DSWS	DSWS
5		ECM	ECM, MSP and MSPW
6		JAS	JAS
7		MCOS-6 . . .	All sizes of MCOS
8		MCSF.	MCSF
9	MDU-6 & MDU-23	MDU-23 . . .	All sizes of MDU
10		MHOF-30 . . .	All sizes of MHOF
11		MMOP. . . .	All sizes of DCOP, TCOP and MMOP
12		MNW-10 . . .	All sizes of MNW
13	MSCU-10, MSCU-44 & TSGU-14	MSCU-10 . . .	All those sizes of DSGU, TSGU, FSGU, MSCU, 7SGU, TCJU and TCTU which have conductor sizes 23 and smaller
14		MWF-24 . . .	All sizes of MWF
15	PBTMU-15	PBTMU-15 . .	All sizes of PBTMU and TSP
16	PI-12, TPS-9	PI-12	All sizes of PI, DPS, TPS, FPS and 7PS
17		S2S	S2S
18	TCTX-7	TCTX-7 . . .	All sizes of TCJX, TCKX and TCTX
19		THOF-9 . . .	Sizes 42 and smaller of types DHOF, THOF and FHOF, except type-and-size THOF-14
20		THOF-150 . .	Sizes 60 and larger of types DHOF, THOF and FHOF; type-and-size THOF-14; type CVSF

Table VII - Qualification specimens and groups. - (Continued)

Group No.	Qualification		Types and Sizes Comprising the group
	Flame propagation 1/	Type and size 2/	
21		TNW-150	All sizes of DNW, TNW, FNW, 4NW8 and 8NW6
22	TPNW-20	TPNW-20 . . .	All sizes of TPNW
23		TPU	TPU
24	TSGU-50 & TSGU-150	TSGU-150 . .	All those sizes of SSGU, DSGU, TSGU, FSGU and 6SGU which have conductor sizes 50 and larger
25		TTOP-10 . . .	All sizes of TTOP
26		TTRS-8 . . .	All sizes of TTRS
27	TTSU-10	TTSU-10 . . .	All sizes of TTSU
28	MS & MU	MS	All sizes of MS, MU, 2SJ, 3SJ and 4SJ
29		1S50MU-16 . .	All sizes of 1SAU, 1SMU, 1S50MU, 1S75MU and 1SU.
30		2AU-40 . . .	All sizes of 2AU, 2U, 2SU 3SU and 3U.
31		2SWAU-10 . .	All sizes of 1SMWU, 1SWU, 2SWAU, 2SWU, 2WAU, and 3SWU.
32		2SWF-7 . . .	All sizes of 1SWF, 2SWF and 3SF.
33	5KVTSGU-100	5KVTSGU-100 .	All sizes of 5KVTSGU
34		2UW-42 . . .	2UW
35		TPUM	TPUM

1/ Types and sizes required for flame propagation test for group qualification.

2/ Type and size required for group qualification. Additional type and size requirements for flame propagation test as indicated. Suggested specimen length is 200 feet for all qualifying types and sizes, except 2SWAU-10, for which it is 500 feet. Additional length of cable required where flame propagation test is specified."

PAGE 20

4.6.1: Delete and substitute:

"4.6.1 Sampling procedure for comparison inspection. Once a manufacturer's product has been qualified, the manufacturer shall submit one specimen for comparison inspection from the first lot of each type and size that he produces. Thenceforth, the manufacturer shall submit one specimen of each type and size that he produces within each calendar year. The entire lot of cable or cord which is represented by the specimen submitted for comparison inspection shall be retained by the manufacturer until he receives, from the Government, notice of the results of comparison inspection.

4.6.1.2: Add the following items (a) through (g):

"(a) Manufacturer's name.
"(b) Cable type-and-size designation.
"(c) Applicable specification (that is, the MIL-C-915 specification sheet number).
"(d) The test or qualification reference.
"(e) Footage represented by the specimen.
"(f) The number of the coil or reel from which the specimen was taken.
"(g) Either the manufacturing number or the order number assigned by the customer."

PAGES 25 and 26

4.8.8 through 4.8.8.3.1: Delete and substitute:

"4.8.8 Cable aging and compatibility (125°C). This test is applicable to cables having either thermosetting insulation or silicone rubber-glass tape insulation, and is for the purpose of detecting any significant degradation in the characteristics of the cable or its components, resulting from either component incompatibility or prolonged overheating. The cable aging may be accomplished either by the current overload method or by the hot air oven method.

"4.8.8.1 Specimens. The specimen for the current overload method shall consist of a length of completed cable approximately 40 feet long. The specimens for the hot air oven method shall consist of two lengths of completed cable: One length approximately 30 feet long and one length 2 feet plus 24 times the overall diameter of the specimen.

"4.8.8.2 Apparatus. The test apparatus for both methods shall consist of a heat chamber or oven, a means of measuring and controlling the chamber or oven temperature within plus or minus 3°C of the specified temperature for a continuous period of 400 hours, an internal mercury thermometer and a rack or other means of supporting the specimen or specimens within the chamber or oven. For the current overload method there shall be a source of current capable of supplying the required amount of current for a continous period of 400 hours. For both methods there shall also be a mandrel having a diameter of approximately 12 times the specimen diameter.

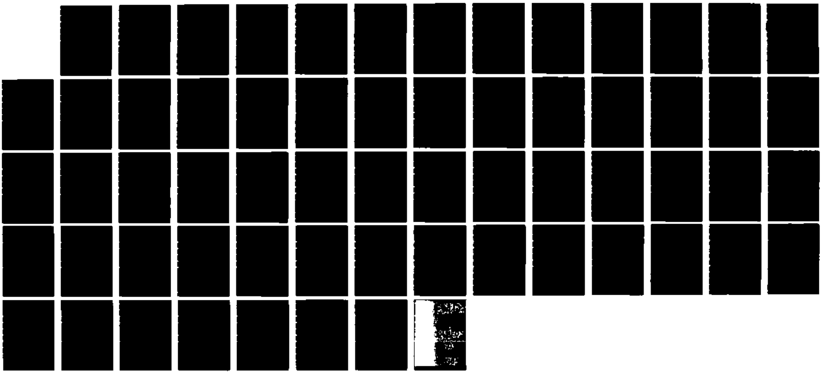
"4.8.8.3 Procedure. The procedure for each method shall consist of two parts: (1) heat aging; (2) bending.

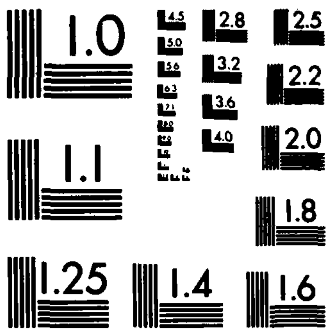
"4.8.8.3.1 Part one - heat aging. (May be accomplished by either of the following methods).

(a) Current overload method. Prior to heat aging, the specimen shall be given the voltage withstand and the insulation resistance tests. The maximum values of insulation resistance measured for each conductor shall be recorded. During aging, conductor temperature shall be determined either by direct measurement or by the measurement of change of copper resistance. For the direct measurement method, a thermocouple shall be inserted through a small knife puncture in the cable, approximately midway between the ends of the specimen. For cables having only one layer of conductors, the thermocouple shall be placed in contact with the strands of any conductor. For cables having more than one layer of conductors, the thermocouple shall be placed in contact with the strands of any conductor in the innermost layer. Thermocouples shall also be attached to the jacket of unarmored cables. In the case of armored cables, the thermocouples shall be attached to the armor. The specimen shall be placed into the chamber so as to have a straight section of approximately 7 feet, and so as to permit free circulation of convection air currents. The chamber temperature shall be maintained at 50°C ± 3°C during the 400-hour period. The amplitudes of loading currents shall be such as to maintain each conductor at a temperature of 125°C ± 5°C continuously for 400 hours. Readings of time, chamber temperature, jacket or armor temperature, and the current in each conductor shall be recorded at 15-minute intervals during the first hour, at 1-hour intervals during the next 5 hours, and twice daily thereafter for the duration of the test. Record shall also be made of any gas or fumes emanating from the specimen, and of any oozing of material from the ends of the specimen. In the case of armored cable, record shall also be made of any exudation of the jacket material through the armor. At the end of the 400-hour test period, the specimen shall be allowed to cool to room temperature. Then it shall be given the voltage withstand and the insulation resistance tests. The maximum insulation resistance values measured for each conductor shall again be recorded. From the portion of the 40-foot specimen which was kept straight during the heat aging, a specimen having an approximate length of 2 feet plus 24 times the overall diameter of the specimen shall be taken. This specimen shall be used for the bending procedure. From the remainder of the 40-foot specimen, an additional specimen shall be taken an given the cable filler removability test.

(b) Hot air oven method. Prior to heat aging, the 30-foot specimen shall be given the voltage withstand and the insulation resistance tests. The maximum value of insulation resistance measured for each conductor shall be recorded. The two specimens shall be suspended horizontally in the oven, with the shorter specimen kept straight. The oven temperature shall be maintained at 125°C ± 3°C during the 400-hour period. Record shall be made of any gases or fumes emanating from the specimens and of any oozing of material from the ends of either specimen. In the case of armored cable, record shall also be made of any exudation of jacket material through the armor. At the end of the 400-hour test period, the specimens shall be allowed to cool to room temperature. The shorter specimen shall be used for the bending procedure. The 30-foot specimen shall again be given the voltage withstand and the insulation resistance tests. The maximum value of insulation

AD-A127 242 RECOMMENDATIONS FOR THE REVISION OF MIL-C-915 OUTBOARD 2/2
CABLE SPECIFICATIONS(U) GENERAL DYNAMICS GROTON CT
ELECTRIC BOAT DIV R F HAWORTH 15 MAR 83 NRL-MR-4935
UNCLASSIFIED N00014-81-C-2262 F/G 13/10 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

resistance measured for each conductor shall again be recorded. One additional specimen shall then be taken from the 30-foot specimen, and given the cable filler removability test."

4.8.8.4, items (b), (c), and (d), line 1: Delete "40-foot".

PAGE 29

4.8.16.2.4, line 3: Delete "certerlines" and substitute "centerlines".

PAGES 34 and 35

4.8.22.3.2, fourth sentence: Delete and substitute: "Each specimen shall be stretched at a uniform rate of 20 inches per minute (unless otherwise specified on the specification sheet), until rupture."

PAGE 37

• Add the following paragraphs 4.8.31 through 4.8.31.3 and 4.8.32 through 4.8.32.2:

• "4.8.31 Flame propagation. The cable shall be tested in accordance with IEEE-STD-383 flame test procedure using the ribbon gas burner, vertical tray configuration.

• "4.8.31.1 Qualification specimens. The cable type and size required for group qualification shall be in accordance with table VII.

• "4.8.31.2 Observation. Cables which propagate the flame and burn the total height of the tray above the flame source fail the test. Cables which self-extinguish when the flame source is removed pass the test. Cables which continue to burn after the flame source is removed shall be allowed to burn in order to determine the extent.

• "4.8.31.3 Report. The report shall include the cable type, size, flame temperature, length of time of afterburn, overall distance of damage to the jacket above the level of the burner, and overall distance of damage to the individual conductors, above the level of the burner, dripping or flaming material falling from the cable onto the floor.

• "4.8.32 Durometer hardness (type A). The durometer hardness of the material shall be tested in accordance with ASTM D 2240, type A.

• "4.8.32.1 Specimen preparation. The specimen shall be a single thickness of material conforming to the requirements of ASTM D 2240. Preparation of the specimen shall effectively represent the curing cycle of the material as used in manufacture of the cable.

• "4.8.32.2 Report. The report shall be in accordance with ASTM D 2240 and shall include details regarding sample preparation and cure cycle."

PAGE 41

4.9.5.1, line 5: After "all other conductors", add "and".

PAGE 44

4.9.8.2, first sentence: Delete and substitute: "The test voltages shall be as specified in the applicable specification sheet. The point of application shall be conductor to conductor unless otherwise specified on the applicable specification sheet."

PAGE 52

* Index, after "drip" add the following listing:

	Paragraph	Page
"Flame propagation	4.8.31	37"

NOTE: The margins of this amendment are marked "*" to indicate where changes (additions, modifications, corrections, deletions) from the previous amendment were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations and relationship to the last prevous amendment.

Custodians:
Army - MI
Navy - SH
Air Force - 85

Review activities:
Army - AV, CR
Navy - EC

User activities:
Army - ME, AR, AL
Navy - CG

Preparing activity:
Navy - SH
(Project 6145-0696)

U.S. GOVERNMENT PRINTING OFFICE: 1980-603-121/2670

MIL-C-915E
1 August 1972
SUPERSEDING
MIL-C-00915D(SHIPS)
20 March 1972
MIL-C-915C
15 March 1968
(See 6.7 and 6.8)

MILITARY SPECIFICATION

CABLE AND CORD ELECTRICAL, FOR SHIPBOARD USE

GENERAL SPECIFICATIONS FOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers electrical cable, and cord for shipboard applications.

1.2 Classification. Cables and cords covered by this specification shall be classified as watertight and non-watertight constructions and further classified for flexing and non-flexing service for power, lighting, control, communications, instrumentation and electronic applications.

1.2.1 Watertight, non-flexing service.

Power and Lighting:

Type	DRW	Two conductors	3000 volts
	DSGU	Two conductors	1000 volts
	FSGU	Four conductors	1000 volts
	MDU	Nineteen conductors	600 volts
	SRW	Single conductor	3000 volts
	SSGU	Single conductor	1000 volts
	TRW	Three conductors	3000 volts
	TSGU	Three conductors	1000 volts
	5KVTSGU	Three conductors	5000 volts
	6SGU	Six conductors	1000 volts
	7SGU	Seven conductors	1000 volts

Control:

Type	MSCU	7 through 91 conductors	1000 volts

Electronic, Communication and Instrumentation:

Type	ECM	56 single conductors plus 8 shielded pairs	600 volts
	MSPW	59 conductors (8 shielded pairs, 3 shielded triads, 34 shielded singles)	
	PBTMU	5, 15 and 30 pairs	
	TCJU	1 pair	
	TCJX	3, 7 and 12 pairs	
	TCKX	1, 3, 7 and 12 pairs	
	TCTU	1 pair	
	TCTX	3, 7 and 12 pairs	
	TSP	11 and 31 pairs	300 volts
	TTSU	1-1/2 through 60 pairs	300 volts
	1SMWU	70 shielded singles	
	1SWU	2, 14, 20 and 30 shielded singles	

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2SWAU	3 through 61 shielded pairs	
2SWU	1 through 61 shielded pairs	
2WAU	40 pairs with overall shield	600 volts
3SWU	3 through 44 shielded triads	

1.2.2 Watertight, flexing service.

Power:

Type DSWS	Two conductors shielded	
MCSF	Four conductors (2-#6 and 2-#1 AWG)	600 volts

Control:

Type MWF	7 through 37 conductors	600 volts

Electronic, Communication and Instrumentation:

Type DLT	Four conductors	300 volts
DSS	Two conductors with overall shield	600 volts
FSS	Four conductors with overall shield	600 volts
S2S	Two conductor (concentric)	
TPU	Six pairs	
TSS	Three conductors with overall shield	600 volts
1SWF	Two shielded singles	
2SWF	3, 4 and 7 shielded pairs	
5SS	Five conductors (4 singles and one shielded single) with overall shield	600 volts
7SS	Seven conductors with overall shield	600 volts

1.2.3 Non-watertight, non-flexing service.

Power and Lighting:

Type DNW	Two conductors	1000 volts
DPS	Two conductors	600 volts
FNW	Four conductors	1000 volts
FPS	Four conductors	600 volts
TNW	Three conductors	1000 volts
TPS	Three conductors	600 volts
2SJ	Two conductors with overall shield	600 volts
3SJ	Three conductors with overall shield	600 volts
4SJ	Four conductors with overall shield	600 volts
7PS	Seven conductors	600 volts

Control:

Type MNW	7 through 44 conductors	1000 volts
MS	37 conductors with overall shield	300 volts
MU	14 conductors	300 volts

Electronic, Communication and Instrumentation:

Type MRI	Twisted pair and twisted triad	
MSP	59 conductors (8 shielded pairs, 3 shielded triads, 34 shielded singles)	
PI	3, 7, and 12 shielded pairs	
TPNW	1-1/2 through 40 pairs	300 volts
1SAU	44 shielded singles	
1SMU	5 shielded singles	
1SU	36 and 60 shielded singles	
1S50MU	16, 20, 40 and 70 shielded singles	
1S75MU	8 shielded singles	
2AU	40 pairs with overall shield	600 volts
2SJ	2 conductor with overall shield	600 volts
2SU	3 through 61 shielded pairs	
2U	10 through 60 pairs with overall shield	300 volts

3SJ	Three conductors with overall shield	600 volts
3SU	3 through 44 shielded triads	
3U	3, 7 and 12 triads	
4SJ	Four conductors with overall shield	600 volts

1.2.4 Non-watertight flexing service.

Power and Lighting:

Type	CVSF	Four conductors (3-#53 and 1-#33)	600 volts
	DHOF	Two conductors sizes 3 through 400	600 volts
	FHOF	Four conductors sizes 3 through 133	600 volts
	JAS	Four conductors (2-#250 and 2-#6)	600 volts
	SHOF	Single conductors sizes 3 through 800	600 volts
	SSF	Single conductor	600 volts
	THOF	Three conductors, sizes 3 through 600	600 volts
	TRF	Single conductor	600 volts
	TRXF	Single conductor	125 volts

Control:

Type	MHOF	7 through 61 conductors	600 volts

Electronic, Communication and Instrumentation

Type	DCOP	Two conductors	300 volts
	MCOS	Multi conductors-shielded	600 volts
	MMOP	Five conductors	300 volts
	TCOP	Three conductors	300 volts
	TTOP	3 through 15 pairs	300 volts
	TTRS	2 through 16 shielded pairs	300 volts
	3SF	7 shielded triads	600 volts

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

SPECIFICATIONS

FEDERAL
QQ-R-175 - Resistance Wire.
TT-P-320 - Pigment, Aluminum: Powder and Paste, For Paint.
PPP-V-205 - Veneer, Paper Overlaid, Container Grade.

MILITARY
MIL-G-160 - Grips, Cable (Naval Shipboard Use).
MIL-C-572 - Cords, Yarns and Monofilaments, Organic Synthetic Fiber.
MIL-Y-1140 - Yarn, Cord, Sleeving, Cloth and Tape-Glass.
MIL-C-12000 - Cable, Cord and Wire, Electric, Packaging of.
MIL-L-17331 - Lubricating Oil, Steam Turbine (Non-Corrosive).
MIL-S-24235/1 - Stuffing Tube, Bulkhead, Pressureproof.
MIL-S-24235/2 - Packing Assemblies for Pressureproof Bulkhead Stuffing Tubes.

See Supplement-1 for applicable specification sheets.

STANDARDS

FEDERAL
FED-STD-595 - Colors.

(Copies of specifications, standards, drawings and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer).

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS
ASTM-B 3 - Soft or Annealed Copper Wire.
ASTM-B 8 - Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.
ASTM-B 33 - Tinned Soft or Annealed Copper Wire for Electrical Purposes.
ASTM-B 172 - Rope-Lay Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors.
ASTM-B 173 - Rope-Lay Stranded Copper Conductors Having Concentric Members, for Electrical Conductors.
ASTM-B 174 - Bunch-Stranded Copper Conductors for Electrical Conductors.
ASTM-B 189 - Lead-Coated and Lead Alloy-Coated Soft Copper Wire for Electrical Purposes.
ASTM-B 193 - Resistivity of Electrical Conductor Materials, Test for.
ASTM-B 228 - Concentric-Lay-Stranded Copper Clad Steel Conductors.
ASTM-B 258 - Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used As Electrical Conductors.
ASTM-B 286 - Copper Conductors For Use In Hookup Wire For Electronic Equipment.
ASTM-B 355 - Nickel-Coated Soft or Annealed Copper Wire.
ASTM-D 297 - Rubber Products, Chemical Analysis of.
ASTM-D 1458 - Fully Cured Silicone Rubber-Coated Glass Fabric and Tapes for Electrical Insulation, Testing.

(Application for copies should be addressed to American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

UNDERWRITERS' LABORATORIES, INC.

(Application for copies of publications should be addressed to Underwriters' Laboratories, Inc., 1285 Walt Whitman Road, Melville, New York 11746 or 207 East Ohio Street, Chicago, Illinois 60611.)

AMERICAN NATIONAL STANDARDS INSTITUTE, INC.
C96.1 - Temperature Measurement Thermocouples

(Application for copies should be addressed to American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018.)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION
Insulated Power Cable Engineers Association (IPCEA)
Publication No. S-66-524 - Cross-linked-thermosetting-polyethylene-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (NEMA Publication No. WC 7-1971).

(Application for copies should be addressed to National Electrical Manufacturers Association, 155 East 44th Street, New York, N. Y. 10017.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. REQUIREMENTS

3.1 Detail requirements. Detail requirements or exceptions to the general requirements specified herein shall be as specified by the specification sheet. In the event of any conflict between the general requirements of this specification and the specification sheet, the latter shall govern. Except for those cables having a silicone rubber jacket, the preferred construction of all cables is without armor. Cables for nonflexing service and for which the preferred construction is without armor, may be procured with armor. The special requirements for such alternate construction are shown on the applicable specification sheets.

3.2 Qualification. Cables and cords furnished under this specification which require qualification (see applicable specification sheet) shall be products which are qualified for listing on QPL-915 at the time set for opening of bids (see 4.3 and 6.5).

3.2.1 Requalification. Changes in materials and construction shall require the written approval of the Naval Ship Engineering Center (NAVSEC) Code 6158F. Incorporation of any changes which have not been so approved shall require requalification of the cable or cord or groups of cables or cords in question.

3.3 Materials. All materials used in the construction of those cables or cords requiring qualification shall have the written approval of NAVSEC. In the case of cables or cords not requiring qualification, NAVSEC approval will not be required, and all materials in these cables or cords shall conform to the requirements shown in the applicable specification sheets.

3.3.1 Conductors.

3.3.1.1 Standard copper conductors. Standard copper conductors shall be composed of soft or annealed copper strands conforming to ASTM-B3.

3.3.1.2 High strength conductors. Unless otherwise specified on the specification sheet high strength conductors shall be composed of 30 percent conductivity, high strength, copper-covered steel strands conforming to ASTM-B228.

3.3.1.3 Tin coating. Tin coating shall be commercially pure tin conforming to ASTM-B33.

3.3.1.4 Lead or lead-alloy coating. Lead or lead alloy coating shall conform to ASTM-B189.

3.3.1.5 Nickel coating. Nickel coating shall conform to Class 2 of ASTM-B355.

3.3.1.6 Thermocouple wire. Conductors for thermocouples shall conform to ANSI Standard C96.1.

3.3.2 Insulation. The silicone rubber-coated glass fabric tape insulation shall, before application to a conductor, have a dielectric strength of not less than 475 volts per mil for tapes which are less than 10 mils thick, and 575 volts per mil for tapes which are 10 mils or more in thickness. These dielectric strength values shall be met after the tapes have been conditioned for 24 hours at 23°C and 96 percent relative humidity. The test procedure shall be the short-time dielectric breakdown test of ASTM-D 1458. Extruded silicone rubber insulation shall have a specific gravity of not more than 1.55. Other physical and electrical properties shall be as specified by the specification sheets.

3.3.3 Jackets. The material used for jackets over insulated conductors and groups of insulated conductors, and for the cable or cord jacket, shall have the physical and electrical properties as required by the specification sheet. Unless otherwise specified on the specification sheet all thermoplastic cable or cord jackets shall be gray - color No. 26270 of FED-STD-595.

3.3.3.1 Thermoplastic jackets . Thermoplastic jackets are polyvinyl chloride and are classified as standard thermoplastic or special thermoplastic. The special thermoplastic jacket is used where necessary to provide extra protection. The standard thermoplastic jacket is used for lightweight cables or cords which are classified for either flexing or non-flexing service and the jacket shall be compounded to meet the requirements of the specification sheet. When a specification sheet specifies a special thermoplastic jacket, a standard thermoplastic shall be used if the cable is procured with armor.

3.3.4 Shields. The materials and constructions for shields of insulated conductors, groups of insulated conductors and overall cable or cord shall be as required by the specification sheet. When AWG sizes are specified for wire shields, they shall be in accordance with ASTM-B258.

3.3.5 Fillers. Unless otherwise specified on the applicable specification sheet, fillers for cables or cords which are not required to be watertight may be fibrous. Fillers for cables or cords which are required to be watertight shall be non-fibrous or a combination of non-fibrous and fibrous as required by the specification sheet.

3.3.5.1 Fibrous fillers. Fibrous fillers shall consist of either cotton, jute, synthetic fibers, glass fibers or asbestos. The material selected shall be appropriate for the type of cable or cord in which it is used, and shall have been treated for flame or moisture resistance, or a combination of both, as necessary, to enable the cable or cord to meet the requirements for the particular type of cable or cord.

3.3.5.2 Non-fibrous fillers . Non-fibrous fillers shall consist of elastomeric material which is readily removable from insulation of conductors and insulating tapes over shields without the aid of solvents, cleansers or tools. The acceptability of the material shall be determined by the cable filler removability test and the applicable cable aging and compatibility test.

3.3.6 Tapes. Tapes shall be of the material as specified in the specification sheet or shall be a type approved by NAVSEC for the specific cable or cord construction.

3.3.7 Braids (identification). Colored braids used for conductor identification shall be of rayon in accordance with MIL-C-572.

3.3.8 Braids (glass). Glass braids for use on silicone insulated conductors shall be composed of the appropriate size of either staple or continuous fiber conforming to MIL-Y-1140.

3.3.9 Tie cords. Tie cords shall be of cotton, glass, or synthetic fiber having a maximum diameter of 0.065 inch and a minimum breaking strength of 30 pounds. When necessary tie cords shall be treated with a flexible waterproofing compound.

3.3.10 Separators. Unless otherwise specified in the specification sheet, separators, when required, shall consist of a wind of glass fibers, synthetic fibers, or cotton; they may also be of a tape of cotton, synthetic fiber, paper or polyester. All separators shall be opaque and the choice of separator material shall be appropriate for the type of cable or cord in which is is employed.

3.3.11 Reinforcement. Reinforcing binders or reinforcement for a single or double layer jacket shall be a size 3 nylon seine twine having a minimum breaking strength of 15 pounds. Alternate reinforcement may be used, only when approved by NAVSEC.

3.3.12 Binders. Binders shall be of the material specified in the specification sheet, or shall be of a material approved by NAVSEC for the specific cable or cord construction.

3.3.13 Armor wires. The armor wires shall consist of Alclad 5056 aluminum alloy having a diameter of 0.0126 $\pm$0.0005 inch, a minimum tensile strength of 50,000 pounds per square inch (psi) and a minimum elongation (before application to the cable) of 2 percent in 10-inch length.

3.3.14 Aluminum paint. Aluminum paint shall consist of aluminum pigment (paste form) conforming to TT-P-320, in a suitable vehicle of the synthetic resinuous (Phenol-formaldehyde or glyceride) type designed for good penetration, high bending power, resistance to water and oil, and with flexibility at temperatures up to 100°C.

3.4 Construction.

3.4.1 Conductor stranding. The size and quantity of individual conductor strands and the total circular-mil area of each conductor shall be in accordance with table I, II or III as applicable in accordance with the size designation specified by the specification sheet.

3.4.1.1 Concentric-lay-stranded. The length and direction of lay and the type and number of joints in concentric-lay-stranded conductors shall be in accordance with ASTM-B8 or ASTM-B286, as applicable.

3.4.1.2 Bunch-stranded. The length and direction of lay and the type and number of joints in bunch-stranded conductors shall be in accordance with ASTM-B174.

3.4.1.3 Rope-lay-stranded. The length and direction of lay and the type and number of joints in rope-lay-stranded conductors shall be in accordance with ASTM-B172 or ASTM-B173, as applicable.

Table I - Conductor data, concentric-lay stranded (ASTM B-286).

Conductor Size ASTM-B286 designation	Number of Strands (minimum)	Strand Diameter, Nominal (inch)	Conductor Diameter, Nominal (inch)	Conductor cross-sectional area, nominal (circular mils)	Weight per 1000 feet approximate (pounds)
12-37	37	0.0126	0.088	5874	20.20
12-19	19	.0179	.091	6088	20.20
14-19	19	.0142	.072	3831	12.65
16-19	19	.0113	.057	2426	7.97
18-19	19	.0100	.051	1900	5.02
18-7	7	.0159	.049	1770	5.02

Table I - Conductor data, concentric-lay stranded (ASTM B 286) (Cont'd).

Conductor Size ASTM-B286 designation	Number of Strands (minimum)	Strand Diameter, Nominal (inch)	Conductor Diameter, Nominal (inch)	Conductor cross-sectional area, nominal (circular mils)	Weight per 1000 feet approximate (pounds)
20-19	19	.0080	.041	1216	3.16
20-7	7	.0126	.038	1111	3.16
22-19	19	.0063	.032	754	1.98
22-7	7	.0100	.031	700	1.98
24-19	19	.0050	.026	475	1.24
24-7	7	.0080	.025	448	1.24
26-19	19	.0040	.021	304	.780
26-7	7	.0063	.020	278	.780
28-19	19	.0031	.016	183	.490
28-7	7	.0050	.016	175	.490
30-7	7	.0040	.013	112	.309

Table II - Conductor data, concentric-lay stranded (Navy Standard).

Conductor size Navy Standard	Number of strands (Minimum)	Strand diameter Nominal (inch)	Conductor diameter Nominal (inches)	Conductor cross-sectional area (circular mils) (Nominal)	Conductor cross-sectional area (circular mils) (Minimum)	Max. conductor resist. (d.c.) per 1000 feet at 25°C.[1/] Bare (Ohms)	Max. conductor resist. (d.c.) per 1000 feet at 25°C.[1/] Coated (Ohms)	Weight per 1000 feet Approx. (Pounds)
1(7)	7	0.013	0.038	1,119	1,096	9.89	10.3	3.4
2(7)	7	.016	.048	1,779	1,743	6.25	6.50	5.5
3(7)	7	.020	.060	2,828	2,771	3.92	4.07	8.7
3(19)	19	.013	.063	3,036	2,975	3.64	3.80	9.3
4(7)	7	0.025	0.076	4,497	4,407	2.46	2.52	14
6(7)	7	.031	.092	6,512	6,382	1.69	1.73	20
9(7)	7	.036	.108	9,016	8,836	1.23	1.25	28
14(7)	7	.045	.136	14,340	14,050	0.770	0.784	44
23(7)	7	.057	.171	22,800	22,340	.486	.493	70
30(19)	19	.040	.202	30,860	30,240	.358	.365	95
40(19)	19	.045	.226	38,910	38,130	.284	.288	120
50(19)	19	.051	.254	49,080	48,100	.225	.228	150
60(37)	37	.040	.282	60,090	58,890	.185	.189	190
75(37)	37	.045	.317	75,780	74,260	.146	.149	230
100(61)	61	.040	.363	99,060	97,080	.112	.115	310
125(61)	61	.045	.407	124,900	122,400	.0888	.0904	390
150(61)	61	.051	.457	157,600	154,400	.0704	.0716	490
200(61)	61	.057	.514	198,700	194,700	.0560	.0570	610
250(61)	61	.064	.577	250,500	245,500	.0444	.0453	770
300(91)	91	.057	.628	296,400	290,500	.0375	.0382	910
350(91)	91	.062	.682	349,800	342,800	.0316	.0321	1,100
400(127)	127	.057	.742	413,600	405,400	.0268	.0273	1,300
500(127)	127	.064	.832	521,600	511,100	.0214	.0217	1,600
650(127)	127	.072	.936	657,600	644,500	.0169	.0172	2,000
800(127)	127	.081	1.050	829,300	812,700	.0134	.0136	2,600
1000(127)	127	.091	1.180	1,046,000	1,025,000	.0106	.0108	3,200
1300(127)	127	.102	1.325	1,318,000	1,292,000	.00843	.00851	4,100
1600(127)	127	.114	1.485	1,662,000	1,629,000	.00668	.00676	5,100
2000(127)	127	.128	1.670	2,097,000	2,055,000	.00530	.00536	6,300

1/ Coated refers to tin or lead-tin alloy.

Table III - Conductor data, bunch and rope-lay stranded (Navy Standard)

Conductor size, Navy Standard	Number of strands Minimum	Strand diameter Nominal (Inch)	Conductor Diameter Nominal (Inches)	Conductor cross-sectional area (Circular mils) Nominal (Cir. Mils)	Minimum (Cir. mils)	Max. conductor resist. (d.c.) per 1000 feet at 25°C. 2/ Bare (Ohms)	Coated (Ohms)	Weight per 1000 feet Approx. (Pounds)
Bunch:								
1/2(21)	21	0.005	0.028	525	515	21.1	22.2	1.6
3/5(7)	7	.010	.030	703	689	15.7	16.4	2.2
1(10)	10	.010	.038	1,005	985	11.0	11.5	3.1
1(26)	26	.006	.042	1,034	1,014	10.7	11.2	3.2
1-1/2(16)	16	.010	.049	1,608	1,576	6.88	7.17	4.9
1-1/2(41)	41	.006	.049	1,630	1,597	6.78	7.15	5.0
2-1/2(19)	19	.011	.057	2,426	2,300	4.75	4.90	6.3
2-1/2(26)	26	.010	.061	2,613	2,561	4.23	4.48	8.0
2-1/2(65)	65	.006	.061	2,594	2,542	4.26	4.51	8.0
4(41)	41	.010	.077	4,121	4,038	2.68	2.81	13
6(65)	65	.010	.097	6,533	6,402	1.69	1.78	20
9(90)	90	.010	.120	9,045	8,864	1.22	1.28	28
14(140)	140	.010	.145	14,070	13,790	.786	.823	43
Rope:								
20(49)	7x7	.020	.180	19,800	19,400	.562	.582	61
23(228)	19x12	.010	.190	22,910	22,460	.499	.523	73
26(49)	7x7	.023	.210	26,250	25,730	.428	.440	82
30(304)	19x16	.010	.220	30,550	29,940	.374	.392	97
33(336)	7x48	.010	.235	33,370	33,090	.344	.360	106
42(209)	19x11	.014	.260	42,110	41,280	.272	.284	130
42(49)	7x7	.029	.260	41,740	40,910	.268	.275	130
53(532)	19x28	.010	.304	53,470	52,400	.213	.218	169
60(304)	19x16	.014	.310	61,260	60,040	.187	.196	190
66(133)	19x7	.022	.330	66,370	65,040	.171	.175	210
84(2107)	2107	1/	.410	83,690	82,020	.138	-----	270
83(418)	19x22	.014	.380	84,230	82,560	.136	.142	270
105(2646)	2646	1/	.460	105,500	103,400	.108	-----	340
105(259)	37x7	1/	.410	105,500	103,400	.108	.113	330
133(3325)	3325	1/	.520	133,100	130,400	.0876	-----	430
133(259)	37x7	1/	.460	133,100	130,400	.0856	.0892	420
133(684)	19x36	.014	.480	137,800	135,100	.0830	.0867	440
150(760)	19x40	.014	.510	153,100	150,100	.0747	.0780	490
168(427)	61x7	1/	.520	167,800	164,400	.0681	.0710	530
200(988)	19x52	.014	.580	199,100	195,100	.0575	.0600	630
220(259)	37x7	.029	.610	220,700	216,300	.0494	.0507	718
250(1254)	19x66	.014	.680	252,700	247,700	.0453	.0472	800
250(6384)	19x7x48	.006	.713	250,000	245,000	.0461	------	821
300(259)	37x7	.034	.714	300,000	294,000	.0378	------	926
400(2052)	19x108	.014	.850	413,500	405,300	.0277	.0289	1,300
500(259)	37x7	.044	.922	500,000	490,000	.0234	-----	1,585
600(427)	61x7	.038	1.013	600,000	588,000	.0196	-----	1,910
650(427)	61x7	.039	1.053	650,000	637,000	.0154	-----	2,070
800(4033)	37x109	.014	1.150	812,700	796,500	.0141	.0148	2,600

1/ These are conductors for flexible cables, for which the minimum number of strands and minimum area are specified. The individual strand diameter is determined from the required area and the actual number of strands used.

2/ Coated refers to tin or lead-tin alloy.

3.4.2 Separators. Separators employed directly over conductors shall be applied so as to give 100-percent coverage to the conductors.

3.4.3 Insulation.

3.4.3.1 Extruded insulation. Extruded insulations shall be applied concentrically and to the dimensions required by the specification sheet.

3.4.3.2 Taped insulation. Tapes used as insulation shall be applied in such a manner that they lie smoothly and free from wrinkles. The tape width shall be proper for the diameter over which it is applied so as to minimize splits, creases and edge tears when the completed cable is subjected to bending. Registrations shall be held to a minimum, consistent with the best commercial practice.

3.4.3.2.1 Silicone rubber-glass tapes. Silicone rubber-glass tapes shall be held from unwinding from conductors when the conductors are exposed and subjected to normal handling during splicing and terminating. The tapes may be held from unwinding by the use of self-bonding tapes, by the use of a silicone rubber adhesive or by using self-bonding or heat sealable polyester tapes over the insulating tapes. All voids within the insulating wall shall be filled with a compound so as to exclude air and moisture and prevent the passage of water through the insulation. Any adhesive or sealing compound shall have no deleterious effect on the other cable parts during tests or during the normal service life of the cable.

3.4.4 Glass braids. Glass braids for use on extruded silicone rubber insulation shall have a thickness of approximately 6 mils. The braid angle shall be such that the completed cable will conform to all inspection and test requirements.

3.4.5 Braid covering (over glass braid). When a specification sheet requires a covering over the glass braid, the covering shall consist of a layer or layers of a black material that will provide high resistance to moisture, abrasion and hydraulic fluids and also provide a smooth surface for printed identification marking.

3.4.6 Fillers. Fillers shall be used to provide firmness and roundness of completed cables or cords and to provide watertightness when required. The type of filler material shall be as specified in 3.3.5.

3.4.7 Binder. A binder shall be employed over the assembled core of all cables or cords to provide a firm core and to serve as a barrier, when necessary, between the core and cable or cord jacket.

3.4.8 Shields. The material and construction of the shields shall be as specified in the specification sheet.

3.4.8.1 Braided wire shield. Braided wire shields shall have the angle of application and the percent coverage as required in the specification sheet. The percent coverage and the angle of application shall be determined by the following formula:

$$\text{Percent coverage (k)} = 100(2F-F^2)$$

Where $F = NPd/\sin a$

$\tan a = 2\pi DP/C$

a = acute angle of braid with axis of cable or cord
d = diameter (inch) of individual braid wires
D = diameter (inch) of cable under braid
N = number of wires per carrier
C = number of carriers
P = picks per inch of cable or cord length

3.4.8.2 Served wire shield. When served wire shield is required, it shall be composed of a serve or wrap of fine copper wires evenly spaced and providing the coverage as specified in the specification sheet. The percent coverage shall be determined by the following formula:

$$\text{Percent coverage} = \frac{Nd}{W} \times 100$$

Where N = Number of parallel wires
d = Diameter of individual wires in inches
$W = \pi D \cos a$
D = Diameter under shield in inches
a = Angle between serving wires and axis of cable or wire
$\tan a = \pi \frac{D}{C}$
C = Pitch of serving in inches

3.4.9 Identification codes and methods. Individual conductors and groups of conductors shall be separately identified. The applicable identification code and the method by which the code is applied shall be as specified in the specification sheet.

3.4.9.1 Identification codes.

3.4.9.1.1 Standard identification code. Standard identification code shall be in accordance with table IV.

Table IV - Standard Identification code.

Color, conductor or group No.	Background or base color	First tracer color	Second tracer color
1	Black	---	---
2	White	---	---
3	Red	---	---
4	Green	---	---
5	Orange	---	---
6	Blue	---	---
7	White	Black	---
8	Red	Black	---
9	Green	Black	---
10	Orange	Black	---
11	Blue	Black	---
12	Black	White	---
13	Red	White	---
14	Green	White	---
15	Blue	White	---
16	Black	Red	---
17	White	Red	---
18	Orange	Red	---
19	Blue	Red	---
20	Red	Green	---
21	Orange	Green	---
22	Black	White	Red
23	White	Black	Red
24	Red	Black	White
25	Green	Black	White
26	Orange	Black	White
27	Blue	Black	White
28	Black	Red	Green
29	White	Red	Green
30	Red	Black	Green
31	Green	Black	Orange
32	Orange	Black	Green
33	Blue	White	Orange
34	Black	White	Orange
35	White	Red	Orange
36	Orange	White	Blue
37	White	Red	Blue
38	Brown	---	---
39	Brown	Black	---
40	Brown	White	---
41	Brown	Red	---
42	Brown	Green	---
43	Brown	Orange	---
44	Brown	Blue	---
45	White	Black	Blue
46	Red	White	Blue
47	Green	Orange	Red
48	Orange	Red	Blue
49	Blue	Red	Orange

Table IV - Standard Identification Code (Cont'd).

Color, conductor or group No.	Background or base color	First tracer color	Second tracer color
51	White	Black	Orange
52	Red	Orange	Black
53	Green	Red	Blue
54	Orange	Black	Blue
55	Blue	Black	Orange
56	Black	Orange	Green
57	White	Orange	Green
58	Red	Orange	Green
59	Green	Black	Blue
60	Orange	Green	Blue
61	Blue	Green	Orange
62	Black	Red	Blue
63	White	Orange	Blue
64	Red	Black	Blue
65	Green	Orange	Blue
66	Orange	White	Red
67	Blue	White	Red
68	Black	Green	Blue
69	White	Green	Blue
70	Red	Green	Blue
71	Green	White	Red
72	Orange	Red	Black
73	Blue	Red	Black
74	Black	Orange	Blue
75	Red	Orange	Blue
76	Green	Red	Black
77	Orange	White	Green
78	Blue	White	Green
79	Red	White	Orange
80	Green	White	Orange
81	Blue	Black	Green
82	Orange	White	---
83	Green	Red	---
84	Black	Green	---
85	White	Green	---
86	Blue	Green	---
87	Black	Orange	---
88	White	Orange	---
89	Red	Orange	---
90	Green	Orange	---
91	Blue	Orange	---
92	Black	Blue	---
93	White	Blue	---
94	Red	Blue	---
95	Green	Blue	---
96	Orange	Blue	---
97	Yellow	---	---
98	Yellow	Black	---
99	Yellow	White	---
100	Yellow	Red	---
101	Yellow	Green	---
102	Yellow	Orange	---
103	Yellow	Blue	---
104	Black	Yellow	---
105	White	Yellow	---
106	Red	Yellow	---
107	Green	Yellow	---
108	Orange	Yellow	---
109	Blue	Yellow	---
110	Black	Yellow	Red

Table IV - Standard Identification Code (Cont'd).

Color, conductor or group No.	Background or base color	First tracer color	Second tracer color
111	White	Yellow	Red
112	Green	Yellow	Red
113	Orange	Yellow	Red
114	Blue	Yellow	Red
115	Black	Yellow	White
116	Red	Yellow	White
117	Green	Yellow	White
118	Orange	Yellow	White
119	Blue	Yellow	White
120	Black	Yellow	Green
121	White	Yellow	Green
122	Red	Yellow	Green
123	Orange	Yellow	Green
124	Blue	Yellow	Green
125	Black	Yellow	Blue
126	White	Yellow	Blue
127	Red	Yellow	Blue

3.4.9.1.2 Telephone identification code. Conductor identification code for telephone cables shall be as follows:

Color or Conductor No.	Color	Color or Conductor No.	Color
1	Black	7	Brown
2	White	8	Gray
3	Red	9	Yellow
4	Green	10	Purple
5	Orange	11	Tan
6	Blue	12	Pink

The mating of conductors for forming pairs shall be as follows:

No. 1 mated with Nos. 2 thru 12 for first 11 pairs
No. 2 mated with Nos. 3 thru 12 for next 10 pairs
No. 3 mated with Nos. 4 thru 12 for next 9 pairs
No. 4 mated with Nos. 5 thru 12 for next 8 pairs
No. 5 mated with Nos. 6 thru 12 for next 7 pairs
No. 6 mated with Nos. 7 thru 12 for next 6 pairs
No. 7 mated with Nos. 8 thru 12 for next 5 pairs
No. 8 mated with Nos. 9 thru 12 for next 4 pairs
No. 9 mated with Nos. 10 thru 12 for next 3 pairs
No. 10 mated with Nos. 11 thru 12 for next 2 pairs
No. 11 mated with No. 12

3.4.9.1.3 Special identification code. Special identification code shall be in accordance with the following:

Color or Conductor No.	Color	Color or Conductor No.	Color
1	Black	7	Brown
2	White	8	Gray
3	Red	9	Yellow
4	Green	10	Purple
5	Orange	11	Tan
6	Blue	12	Pink

3.4.9.1.4 Letter identification code. Letter identification code shall consist of the letters A, B, C, and D printed in block type and with black, white, red, and green ink, respectively.

3.4.9.2 Identification methods.

3.4.9.2.1 Method 1. Identification method 1 shall be surface printing of both number and color designations. The legend shall be printed in contrasting color: preferably white ink on black or dark background or black ink on white or light background. The legend shall be repeated at intervals not exceeding 3-inches and alternate legends shall be inverted. For example: 10-ORANGE-BLACK 10-ORANGE-BLACK The character type shall be block or italic and shall have a height in accordance with the diameter over which it is applied as follows:

Diameter range (inch)	Height of character Approx. (inch)
0.045 to 0.070	0.025
.070 to .095	1/32
.095 to .115	3/64
.115 to .200	1/16
.190 to .250	5/64
.235 to .375	3/32
.330 and larger	1/8

3.4.9.2.2 Method 2. Identification method 2 shall be the use of opaque white polyester tapes which have been printed with both the number and color designation prior to application. The legend shall be printed with black ink and shall be repeated at intervals not exceeding 3 inches. The character type shall be block and shall be approximately 3/32 inch high.

3.4.9.2.3 Method 3. Identification method 3 shall be the use of solid base colors or solid base colors with tracers as required. The base color may be either the color of the insulation or the color of a coating applied to the insulation. The tracers shall be approximately 1/32-inch wide ink stripes of the required color applied helically with 1-1/2 $\pm$1/4 inch lay.

3.4.9.2.4 Method 4. Identification method 4 shall be the use of colored braids. Tracers shall consist of the required colors applied by three adjacent carriers. Where two tracers are required, they shall be applied with reverse lay.

3.4.9.2.5 Method 5. Identification method 5 shall be the use of the printed letter on the outermost insulating tape or the printed letter on a polyester binder tape over the insulating tapes. The letters shall be approximately 3/16 inch high and shall have been printed at intervals not exceeding 3 inches prior to the application of the tape to the conductor.

Note: If the insulating tapes are white, no printing is required on the B (white) conductor.

3.4.10 Manufacturer's identification tape. Unless otherwise indicated on the specification sheet, all cables and cords shall contain a continuous, thin, moisture-resistant marker tape, not less than 1/10 inch wide. The marker tape shall be placed directly under the cable or cord binder tape or jacket unless otherwise approved by NAVSEC. The tape shall be printed to show the following information at intervals not greater than 1 foot: Name and location of manufacturer; year of manufacture; specification number (MIL-C-915); and progressive serial number. The serial number is not necessarily a footage marker. A serial number shall not be repeated by a manufacturer in any one year for any one type and size of cable or cord.

3.4.10.1 Marker threads. The use of marker threads in lieu of the manufacturer's identification tape, in small cables or cords, shall have written approval of NAVSEC. If approved, marker threads shall be in accordance with those assigned by Underwriter's Laboratory (U.L.) Incorporated, to indicate the manufacturer of the cable or cord. When U.L. marker threads are used, yearly marker threads shall also be used to indicate the year of manufacture, as follows:

Year	Color Codes
1971	Red-Yellow
1972	Red-Slate
1973	Red-Green
1974	Red-Brown
1975	Red-Black
1976	Red-Pink

Year	Color Codes
1977	Blue-Yellow
1978	Blue-Slate
1979	Blue-Green
1980	Blue-Brown
1981	Blue-Black

3.4.11 Cable or surface marking. When overall cable or cord jacket surface marking is required by the specification sheet, ink marking shall be used. The legend shall be printed in contrasting color: preferably white ink on a dark background or black ink on a light background. The legend shall consist of the manufacturer's name, the cable or cord type and size[1/] designation, the type of jacket material and the year of manufacture. The legend shall be repeated at intervals not exceeding 1 foot and the year of manufacture need not be in line with the balance of the legend.

For example: "Manufacturer's name - MWF-24-NEOP - 1973"

The character type may be either block or italic and shall have a minimum height in accordance with the diameter over which it is applied as follows:

Diameter range (inch)	Height of character Approx. (inch)
0.125 to 0.200	3/64
.200 to .285	1/16
.285 to .350	5/64
.350 to .500	3/32
.500 and larger	1/8

Jacket material names shall be abbreviated as follows:

Polychloroprene: NEOP
Standard thermoplastic: STD PVC
Special Thermoplastic: SPL PVC
Chlorosulfonated polyethylene: CSPE

3.4.12 Watertightness. When watertight cable construction is specified in the specification sheet, all voids within the cable or cord construction shall be filled to prevent the passage of water longitudinally through the cable or cord.

3.4.13 Jacket reinforcement. When a reinforced polychloroprene jacket is required by the specification sheet, the jacket shall be applied in two layers with a size 3 nylon cord applied as a braid or two reverse serves between the layers. The minimum thickness of the outer layer of jacket shall be 50 percent of the total. The reinforcement shall be applied with approximately four picks or crossovers per inch.

3.4.14 Braided armor. The armor shall be applied in the form of a braid. The weave of the braid shall be of either the "one over-one under" or the "two over-two under" type. The weave shall be such that the wires of a carrier are laid closely together, flat and parallel. The braid shall be applied with maximum tension possible so as to prevent loosening and creeping but not to cause broken ends. The braid shall remain snug to the cable jacket and not spring away when cut. Splices in the braid strands shall be infrequent staggered, and inconspicuous so as not to increase the nominal diameter of the cable or result in rough spots. The selection of the number of wires per carrier and the number of carriers per braider shall be such as to produce a basket weave to give a minimum of 88 percent coverage and a braid angle within the limits shown in table V. The number of wires per carrier shall be not more than shown in table VI.

Table V - Armor braid angle.

Diameter over jacket (Inches)	Braid angle	
	Minimum (Degrees)	Maximum (Degrees)
0.100 thru 0.600	30	60
.601 thru 1.000	35	60
1.001 thru 1.500	40	70
1.501 thru 2.000	45	70
2.001 thru 3.000	50	80

[1/] When applicable.

Table VI - Wires per carrier.

Diameter under braid (Inches)	Maximum number of ends per carrier	
	One over-one under	Two over-two under
0.100 thru 0.400	8	5
.401 thru .800	12	10
.801 thru 3.000	16	10

3.4.14.1 Coverage. The 88 percent minimum coverage shall be as determined by the following formula:

$$\text{Percent coverage (K)} = 100(2F-F^2)$$

Where, $F = NPd/\sin a$
$\tan a = 2 // DP/C$
a = acute angle of braid with axis of cable
d = diameter (inch) of individual braid wires
D = diameter (inch) of cable under braid
N = number of wires in carrier
C = number of carriers
P = picks per inch of cable length

3.4.15 Armor paint. Aluminum paint shall be applied to the armor as soon as practicable after completion of manufacturing operations so as to prevent accumulation of dirt, moisture, and foreign matter on the braid or in the interstices. The paint shall be properly dried and shall not be tacky. The painting shall be done preferably by the immersion method so as to fill all interstices to the outer cable surface. The paint finish shall provide a relatively smooth overall coating that will facilitate making watertight glands with stuffing tubes and packing. The coating shall be flexible and adhere firmly so that it will not crack, peel, or flake off.

3.4.16 Dimensional tolerances. Where minimum or maximum dimensions, or both, are specified, no minus or plus tolerances, respectively, will be permitted. Where a dimension is specified as nominal, the average dimension shall be not less than the specified nominal. Where no minimum overall cable or cord diameter is specified, the minimum permissible diameter shall be not less than 92-1/2 percent of the specified maximum overall cable or cord diameter. Where a specification sheet gives the maximum overall diameter for unarmored cables and the cable is procured with armor, the maximum overall diameter shall be increased by 0.050 inch.

3.4.16.1 Conductor insulation wall thickness. For conductor insulation wall thickness specified as nominal, the average thickness shall be not less than the specified nominal. The minimum thickness, measured at any cross section, shall be not less than 90 percent of the specified nominal.

3.4.16.2 Cable or cord jacket thickness. The average thickness of a cable or cord jacket measured at any cross section shall be not less than the specified nominal. In case of multiconductor cables or cords the jacket thickness shall be determined from the measurements made at the high point of each conductor taken on a line through the center of the cable or cord and through the center of each conductor in the outer layer. The minimum thickness at any cross section shall be not less than 80 percent of the specified nominal.

3.4.17 Centering and circularity.

3.4.17.1 Insulation. The insulation on the individual conductors shall be uniform in diameter throughout the conductor length. At any cross section, the maximum wall thickness shall not exceed the minimum by more than 25 percent for specified thickness greater than 0.025 inch, nor by more than 40 percent for specified thicknesses of 0.025 inch and less.

3.4.17.2 Cable or cord jacket. The cable or cord jacket shall be applied concentrically to the cable or cord core in a manner to maintain circularity in the completed cable or cord. The maximum wall thickness of the jacket at any cross section shall not exceed the minimum by more than 66 percent.

3.4.18 Surface condition (cable or cord jacket). The surface of the cable or cord jacket of all unarmored cables or cords shall be dry and free from any coating, film or treatment which would tend to interfere with the bonding to it of encapsulating or molding materials normally used in splicing and terminating.

3.5 Electrical properties. All electrical properties of the completed cable or cord shall be as required by the specification sheet.

3.6 Physical properties. All physical properties of the completed cable or cord and cable or cord components shall be as required by the specification sheet.

3.7 Repair of insulation or cable or cord jacket. Repair of cable or cord jacket will not be permitted on unarmored cables which are required to pass a hydrostatic test. Repair of cable or cord jacket will be permitted on cables or cords which are not required to pass a hydrostatic test, provided the materials and techniques used are such that the finished cable or cord complies with all the requirements of this specification. The materials and techniques used in the repair of either insulation or cable or cord jacket shall be subject to approval of NAVSEC. The frequency of repairs shall be held to a minimum.

3.8 End seals. All cables and cords covered by this specification shall have both ends of each shipping length sealed to prevent the entrance of moisture. Materials used for end seals and method of application shall have the written approval of NAVSEC.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performing (or having performed) all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities (approved by NAVSEC) for performing (or having performed) the inspection requirements specified herein. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of inspection. The examination and testing of all cable, and cord covered by this specification shall be classified as follows:

(a) Qualification inspection
(b) Specification conformance inspection
  (1) Basic electrical
  (2) Group A examination and test
  (3) Group B tests
  (4) Group C tests
(c) Comparison inspection
(d) Conductor inspection

4.3 Qualification tests.[2/] Qualification tests shall be conducted at a laboratory satisfactory to the Naval Ship Engineering Center. Qualification tests shall consist of the examination and tests specified on the applicable specification sheet.

4.3.1 Qualification specimens. The manufacturers seeking qualified products listing shall manufacture and be responsible for testing at least one specimen of cable or cord of each type, size or group for which qualification is sought. The cable or cord type and size required for group qualification shall be in accordance with table VII. When a manufacturer desires qualification of an individual type or size, the selection of test specimens shall be subject to review by NAVSEC. A sufficient length of any test specimen must be manufactured at one time. Suggested manufacturing lengths for test specimens are given in table VII. The groups are based on similar characteristics and requirements. The Naval Ship Engineering Center may extend approval of any one type and size of cable or cord to cover any or all types in the same group; however, NAVSEC may require performance of any or all qualification inspections on additional types in the same group prior to such extension of approval.

2/ Application for Qualification tests shall be made in accordance with "Provisions Governing Qualification SD-6" (see 6.5 through 6.5.2).

Table VII - Qualification specimens and groups.

Group No.	Qualifying Type and Size[1/]	Types and Sizes Comprising the Group
1	DLT	DLT
2	DRW	SRW, DRW, TRW
3	DSS-3	All sizes of DSS, TSS, FSS, 5SS and 7SS
4	DSWS	DSWS
5	ECM	ECM, MSP and MSPW.
6	JAS	JAS
7	MCOS-6	All sizes of MCOS
8	MCSF	MCSF
9	MDU-23	All sizes of MDU
10	MHOF-30	All sizes of MHOF
11	MMOP	All sizes of DCOP, TCOP and MMOP
12	MNW-10	All sizes of MNW
13	MSCU-10	All those sizes of DSGU, TSGU, FSGU, MSCU, 7SGU, TCJU AND TCTU which have conductor sizes 23 and smaller.
14	MWF-24	All sizes of MWF
15	PBTMU-15	All sizes of PBTMU and TSP
16	PI-12	All sizes of PI, DPS, TPS, FPS and 7PS
17	S2S	S2S
18	TCTX-7	All sizes of TCJX, TCKX AND TCTX.
19	THOF-9	Sizes 42 and smaller of types DHOF, THOF AND FHOF, excepting type-and-size THOF-14.
20	THOF-150	Sizes 60 and larger of types DHOF, THOF and FHOF; type-and-size THOF-14; type CVSF.
21	TNW-150	All sizes of DNW, TNW and FNW.
22	TPNW-20	All sizes of TPNW.
23	TPU	TPU
24	TSGU-150	All those sizes of SSGU, DSGU, TSGU, FSGU and 6SGU which have conductor sizes 50 and larger.
25	TTOP-10	All sizes of TTOP
26	TTRS-8	All sizes of TTRS
27	TTSU-10	All sizes of TTSU
28	1SU-36	All sizes of 1SU
29	1S50MU-16	All sizes of 1SAU, 1SMU, 1S50MU and 1S75MU.
30	2AU-40	All sizes of MS, MU, 2AU, 2SJ, 2U, 3SJ and 4SJ.
31	2SWAU-10	All sizes of 1SHWU, 1SWU, 2SWAU, 2SWU, 2SU, 2WAU, 3SU, 3SWU and 3U.
32	2SWF-7	All sizes of 1SWF, 2SWF and 3SF.
33	5KVTSGU-100	All sizes of 5KVTSGU.

1/ Suggested specimen length is 200 feet for all qualifying types and sizes, except 2SWAU-10, for which it is 500 feet.

4.4 Definition of terms. For the purpose of this section, the following definitions apply:

4.4.1 Inspection lot. An inspection lot shall consist of the total number of units of product of any one type, size, and construction manufactured under the same conditions and offered for delivery at one time.

4.4.2 Unit of product. A unit of product is the unit ordering length as specified on the specification sheet, except that when the unit ordering length is 500 feet, two such lengths shall constitute a unit of product. Random and remnant lengths or special order lengths may be added together to equal a unit ordering length.

Note: Length tolerances as given for standard lengths shall apply. (See 6.2.2).

4.4.3 Sample. A sample is one unit of product selected from an inspection lot.

4.4.4 Specimen. A specimen is an individual length of cable or cord or an individual length of a part of cable or cord which has been taken from a sample.

4.4.5 Defective unit. A defective unit is a unit of product from which a specimen that failed to meet one or more requirements was taken.

4.4.6 Rejected lot. A rejected lot is a lot which contains more than the acceptable number of defective units.

4.5 Specification conformance inspection. Specification conformance inspection shall be performed on all completed cable or cord in accordance with the procedures given or referenced herein. This inspection shall consist of basic electrical tests plus groups A, B and C examination and tests in accordance with the specification sheets.

4.5.1 Basic electrical tests. Basic electrical tests shall consist of voltage withstand, insulation resistance and conductor resistance. These tests shall be performed on each length of completed cable or cord. The conductor resistance test shall be performed on all conductors which have a nominal circular mil area of less than 1600; for conductors which have a nominal circular mil area of 1600 or greater, the conductor resistance test shall be performed on conductors selected as follows:

No. of insulated conductors in cable or cord	No. of insulated conductors selected for test
1 thru 4	All
5 thru 20	4
21 thru 30	5
31 thru 42	6
43 thru 56	7
57 thru 72	8
73 thru 91	9
92 thru 110	10
111 thru 132	11
133 thru 156	12

4.5.2 Sampling procedure. The required number of samples for groups A, B and C examination and tests shall be selected at random from the inspection lot. All nonconforming starting and finishing ends of completed cable or cord shall be removed by the manufacturer prior to selecting samples.

4.5.2.1 Sampling for group A examination and tests. Samples for group A examination and tests shall be selected from each lot in accordance with the first two columns of table VIII.

Table VIII - Sampling for group A examination and tests.

Units of product in lot	Number of samples	Acceptance number defective units	Rejection number defective units
10 or under	2	0	1
11 thru 30	3	0	1
31 thru 90	7	0	1
91 thru 210	15	1	2
211 and over	25	2	3

4.5.2.2 Sampling for group B tests. Samples for group B tests shall be selected from each lot in accordance with table IX.

Table IX - Sampling for group B tests.

Units of products in lot	Number of samples
8 and under	1
9 thru 30	2
31 thru 90	3
91 thru 210	4
211 and over	5

Note 1: The number of conductors from which specimens of insulation shall be taken shall be chosen as follows:

Number of insulated conductors in sample	Number of insulated conductors to be chosen for specimens
1 thru 4	All
5 thru 20	4
21 thru 30	5
31 thru 42	6
43 thru 56	7
57 thru 72	8
73 thru 91	9
92 thru 110	10
111 thru 132	11
133 thru 156	12

Note 2: At least one specimen of insulation shall be tested from each conductor chosen. The minimum number of specimens of insulation and jacket shall be five. The test result shall be the median value obtained.

4.5.2.3 Sampling for group C tests. Samples for group C tests shall be selected in accordance with table X.

Table X - Sampling for group C tests.

Two months' production (units of product)	Number of samples
8 or under	1
9 thru 30	2
31 thru 90	3
91 thru 210	4
211 and over	5

4.5.2.4 Tightened sampling and accept-reject criteria. If the number of defective units in a lot exceeds the acceptance number for group A examination and tests (see table VIII), or if there are any failures in group B tests, the manufacturer shall have the option of reworking the lot and performing examination and tests on the tightened sampling basis in accordance with table XI. If there are any failures on tests performed on the tightened sampling basis, if there are any failures in group C tests, or if the manufacturer chooses not to rework and retest, the lot shall be rejected.

Table XI - Tightened sampling.

Units of product in lot	Number of samples
10 or under	3
11 thru 30	5
31 thru 90	9
91 thru 210	15

4.5.2.5 Action in case of rejection. Rejected cable, or cord may be referred to the Government for determination of acceptability of the point or points of non-compliance, for the particular contract or order. All non-conforming cable, or cord which contains a MIL-C-915 marker tape and which is determined to be unacceptable to the Government shall be recorded with NAVSEC. Such record shall be furnished to NAVSEC by the manufacturer within ten days of receiving notification of non-acceptance. The record shall include the cable or cord type and size, the basis for rejection, footage of each length and serial numbers of the marker tape from each end of each length.

4.5.3 Group A examination and tests. Group A examination and tests as required by the specification sheet shall be performed on samples selected in accordance with 4.5.2.1.

4.5.4 Group B tests. Group B tests as required by the specification sheet shall be performed on specimens taken from samples selected in accordance with 4.5.2.2.

4.5.5 Group C tests. Group C tests as required by the specification sheet shall be performed on specimens taken from samples selected in accordance with 4.5.2.3. The number of conductors chosen from each sample and the number of specimens of insulation and jacket shall be the same as for group B tests (see 4.5.4).

4.5.6 Certified test reports. For all cables and cords requiring qualification the manufacturer shall furnish certified test reports to NAVSEC and to all original purchasers of these cables and cords. A copy of the test report shall be forwarded to NAVSEC upon shipment of the cable or cord from the factory. The test report shall contain the following information:

(a) Manufacturer's QPL number and date or serial number and date of NAVSEC letter of approval.
(b) A statement to the effect that the product was constructed from materials listed on the manufacturer's approved details of construction sheet.
(c) A statement that the product meets all of the requirements of this specification.
(d) Results of all specification conformance tests showing actual values obtained.
(e) Year and month cable or cord was manufactured.
(f) Serial numbers of the marker tape taken from each end of each length of cable or cord.
(g) Customer's name and contract or order number.

4.6 Comparison inspection. Comparison inspection is testing performed at the Government's expense and at a NAVSEC designated laboratory. The purpose of comparison inspection is to evaluate and compare constructions and test results to specification and qualification requirements.

4.6.1 Sampling procedure for comparison inspection. Once a manufacturer's product has been qualified, the manufacturer shall submit one specimen for comparison inspection from the first lot of each type and size that he produces. Thenceforth, the manufacturer shall submit one specimen from every fourth lot of each type and size that he produces unless there is a period of one year or longer between any two successive lots of the same type and size in which case, a specimen from the next lot of the same type and size shall be submitted. The entire lot of cable or cord represented by the specimen submitted for comparison inspection shall be retained by the manufacturer until notice of inspection results are received from the Government.

4.6.1.1 Length of specimens. The length of specimens required for comparison inspection shall be as follows:

Length	Cable Types
15 feet for	2AU, 3U, 2SU, 1SU, 3SU, 2U, MU, MS, 2SJ, 3SJ, 4SJ and 1SAU. All sizes.
15 feet for	SRW, DRW, TRW, PBTMU, ECM, TSP, MDU, TTOP, MMOP, DCOP, TCOP, DLT. All sizes.
20 feet for	DSWS, MCSF, MHOF, DHOF, THOF, FHOF, CVSF, JAS, TPU, 3SWU, 2SWU, 1SWU, 2WAU, 3SF, 1SMWU, 2SWAU, DNW, TNW, FNW, MNW, TPNW, 1SMU. All sizes.
25 feet for	All silicone rubber insulated cables having conductor size 30 and smaller; 1S50MU, 1S75MU, MCOS, MSP, MSPW.
35 feet for	1SWF, 2SWF, MWF, S2S. All sizes.
38 feet for	All silicone rubber insulated cables having conductor size 40 and larger.
50 feet for	DSS, TSS, FSS, 5SS, 7SS, TTRS. All sizes.

4.6.1.2 Marking of specimens. All test specimens shall be marked with the following information:

4.6.1.3 Packaging of specimens for shipment. To facilitate handling, specimens may be shipped in boxes or wrapped coils.

4.6.1.4 Notice of shipment. When specimens are shipped to a laboratory for comparison inspection, notice of such shipment shall be sent separately to the laboratory with a copy to NAVSEC. The notice shall contain the same information as required for marking of the specimen.

4.6.2 Action in case of failure. If any specimen fails one or more of the specified comparison inspection tests, the lot represented by that specimen shall be held in abeyance. The manufacturer shall have the option of resubmitting the lot, but only after the lot has been re-evaluated, the cause of failure determined, and corrective action has been taken. If the manufacturer resubmits the lot, the specimen representing the lot shall be subjected to the test or tests under which failure occurred plus any other tests which NAVSEC may deem necessary to assure compliance with this specification. If the manufacturer chooses not to resubmit the lot, or if the lot is resubmitted and a failure is found, the lot shall be rejected. Once comparison inspection reveals a failure in a particular type and size of cable or cord, all lots of the particular type and size subsequently produced shall be submitted until two successive lots pass comparison inspection. The manufacturer shall then resume the normal rate of submission of samples for comparison inspection.

4.6.3 Action in case of rejection. Any cable or cord which requires qualification and which contains a MIL-C-915 marker tape and which has been rejected on the basis of comparison inspection and has been determined to be unacceptable to the Government shall be recorded with NAVSEC. Such record shall be furnished to NAVSEC by the manufacturer within ten days of receiving notification of non-acceptance. The record shall include the cable, or cord type and size, the basis for rejection, footage of each length and serial numbers of the marker tape from each end of each length.

4.6.4 Test reports. One copy of laboratory reports covering comparison inspection shall be forwarded to the cable or cord manufacturer and one copy shall be forwarded to NAVSEC.

4.7 Conductor strand inspection. Before individual strands are assembled into a conductor they shall be tested for coating when applicable, tensile strength and elongation. Test procedures shall be in accordance with the applicable ASTM standard referenced in 3.3.1. Lot sizes and number of specimens per lot shall be as follows:

Diameter of individual strand (inch)	Lot size	Number of test specimens
0.003 to .013	2500 pounds or less	2
	Each additional 2500 pounds or fraction thereof	1
.014 to .040	5000 pounds or less	2
	Each additional 5000 pounds or fraction thereof	1
.041 to .129	10,000 pounds or less	2
	Each additional 10,000 pounds or fraction thereof	1

Records of tests shall be kept, and copies of the applicable records shall become a part of the test reports for finished cable or cord.

4.8 Test methods (physical).

4.8.1 Abrasion resistance.

4.8.1.1 Specimens. Specimens shall be approximately 24-inch lengths of completed conductor (insulation plus coverings, if any). For cables or cords containing four conductors or less, one specimen shall be taken from each conductor. For cables or cords containing more than four conductors, the number of specimens shall be the square root (to the nearest whole number) of the total number of conductors, but in no case less than four.

4.8.1.2 Apparatus. The abrading machine shall consist of an 8-inch diameter metal drum with two abrading tools mounted 180 degrees apart on the circumference. Each abrading tool shall be a 5/16-inch square high-speed steel tool bit (Cleveland Twist Drill Co. #855 or equal). The tool bits shall be ground off so as to produce 90-degree sharp edges free of visible nicks, with not more than 0.004 inch per surface being removed. The grinding wheel used shall be medium grade (Macklin Co. #48A-H8-V6, or equal). The tools shall be secured in notches in the rim of the drum so that one diagonal through the cross-section of the bit is coincident with the diameter of the drum, and the other diagonal is tangent to the surface of the drum. The distance from the center of the drum to the longitudinal axis of the tool bit shall be 4 inches.

4.8.1.3 Procedure. Prior to testing, specimens shall be wiped with a clean, dry cloth to remove any lubricant or dirt. The test specimen shall be laid over the drum so as to extend approximately half way around the drum. One end of the specimen shall be secured to the base of the drum support, and a 1-pound weight fastened to the other end. The direction of rotation of the drum shall be away from the fixed end of the specimen, toward the weighted end. Rate of rotation shall be approximately 17 revolutions per minute. A voltage from 12 to 120 volts shall be applied between the abrading tools and the conductor of the specimen.

4.8.1.4 Observation. Electrical contact between the abrading tools and the conductor, before the required number of scrapes have been performed, shall constitute failure of the specimen.

4.8.2 Accelerated service.

4.8.2.1 Specimens. A specimen shall consist of a length of completed cable 15 feet long.

4.8.2.2 Apparatus. The test voltage (see 4.8.2.3) shall be 60 Hz, and shall be supplied by either one three-phase transformer or three single-phase transformers. Transformer minimum voltage rating shall be equal to the test voltage; minimum current rating shall be 3 amperes when testing cable rated at 1 kv, and 1/2 ampere when testing cable rated at 5 kv. The loading current shall be supplied by three single-phase loading transformers having the secondary winding isolated from ground. Instruments for measuring voltage and current to an accuracy of plus or minus 2 percent shall be provided.

4.8.2.3 Procedure. The specimen shall be formed into a large loop within the test chamber, in a horizontal position so as to permit free circulation of convection air currents. There shall be means of preventing drafts of air from directly striking the specimen. Each phase of the test voltage shall be connected to the conductors of the specimen through a fuse. The fuses shall be normal-blow 1-ampere for cables rated for 1 kv, and normal-blow 1/4-ampere for cables rated for 5 kv. (In lieu of fuses, overload relays having equivalent tripping characteristics may be used). The specimen shall be heated by the circulation of the loading current specified on the specification sheet. Air temperature within the test chamber shall be maintained at 30° +2°C. during the test. The test voltages and their points of application shall be as follows:

(a) Cables rated for 5 kv:
  (1) 4160 volts from conductor to conductor
  (2) 2400 volts from conductor to armor (when specimen is armored)
(b) Cables rated for 1 kv:
  (1) 450 volts from conductor to conductor
  (2) 260 volts from conductor to armor (when specimen is armored)

(Four-conductor cables shall have the green conductor either isolated or grounded to the armor when the specimen is armored, and shall be treated as three-conductor cables. For six-conductor cables, the physically opposite conductors shall be connected in parallel to form three pairs, and shall be treated as three-conductor cables. For all sizes of cable, the voltage and the loading currents shall be maintained continuously for a period of 7 hours, unless dielectric failure occurs before the expiration of this period. Measurement of the maximum and average temperatures of the cable jacket shall be accomplished by means of four thermocouples placed on the top of the specimen, at 2-inch intervals near the mid-point of the specimen.)

4.8.2.4 Observation. Blowing of any fuse or tripping of any overload relay, before the expiration of the 7-hour period, shall constitute a failure of the specimen. Also, a jacket temperature exceeding 135°C., exudation of the jacket through the armor (when specimen is armored), or the sagging away of the cable jacket from the foundation of the specimen, within the 7-hour test period, shall constitute failure of the specimen. (Exudation is defined as actual flow or expansion of the jacket to such an extent that the armor cuts through the jacket material. Bulging of the jacket through the armor, without actual flow or cutting, is not considered exudation.)

4.8.3 Armor.

4.8.3.1 Physical. Specimens of the armoring wire shall be subjected to tests of tensile strength, and elongation, springiness, and toughness before application to the cable.

4.8.3.1.1 Springiness. A length of armoring wire shall be coiled snugly around a 1/4-inch mandrel for several turns with a tension of not less than 100 grams nor more than 125 grams, and then released. The outside diameter of the coil, as measured in several places at or near its middle, shall not exceed 3/8-inch.

4.8.3.1.2 Toughness. The toughness of the wire shall be determined by bending a specimen back and forth, in a specially designed fixture, over a 0.030-inch radius support. Each 90-degree movement in either direction shall be taken as one bend. The bends shall be made under a uniform tension of 100 grams, and at a uniform rate not to exceed 50 bends per minute. The wire shall withstand a minimum of ten 90-degree bends before breaking.

4.8.4 Bending endurance.

4.8.4.1 Specimen. A specimen shall consist of a 30-inch length of completed cable or cord.

4.8.4.2 Procedure. All conductors of the specimen shall be connected so as to form a single series circuit for the purpose of detecting conductor breakage during the test. The specimen shall be suspended vertically between two sets of rollers with the top end secured to a power driven reciprocating arm. Except at the arm clamp and between each set of rollers, the specimen shall be not closer than 1/4 inch to any machinery part. The specimen shall be kept under a tension of 40 ± 2 psi of the specimen's cross-sectional area by attaching a weight to the lower end. The cross-sectional area of the specimen shall be determined by the maximum diameter for the cable or cord type and size as given by the specification sheet. The tension force (clamping device plus weight) shall be directly downward. The clamping devices used to secure the weight to the specimen and the specimen to the arm shall be such as to apply uniform radial pressure to the specimen to prevent slippage of the specimen or any of its parts during the test. The distance from the axis of rotation of the arm and the nearest surface of the arm clamp shall be 9 $\pm 1/4$ inches. The top set of cylindrical metal rollers over which the specimen will be bent shall have smooth sides, shall have the diameter as required by the specification sheet and shall be mounted so as to be free-rotating at all times. The axis through the centers of these rollers shall be horizontal and the horizontal distance between roller faces shall be equal to the maximum overall diameter of the specimen to be tested plus 1/8 inch. The rollers shall be equidistant from the vertical centerline through the axis of rotation of the reciprocating arm. The vertical positioning of the top pair of rollers shall be such that the distance between a horizontal centerline through the axis of rotation of the arm and the top of the rollers is equal to one-half the maximum diameter of the specimen. The vertical positioning of the lower or guide rollers shall be approximately midway between the top rollers and the bottom clamp. The bottom rollers shall be not less than 3/8 inch in diameter and shall have the same horizontal spacing as the top rollers. The entire assembly (equipment plus specimen) shall be conditioned in a chamber to the temperature specified on the specification sheet ± 2°C. While at this temperature, the specimen shall be bent, at approximately its mid-point, over the rollers at the rate of 12 to 14 cycles per minute. One cycle shall consist of the reciprocating arm swinging through an arc of 180 degrees and returning (360 degrees total swing). After completion of the number of cycles and at the temperature specified by the specification sheet, the specimen shall be removed from the test apparatus and subjected to the voltage withstand test specified by the specification sheet.

4.8.4.3 Observation. After completion of the voltage withstand test, the specimen shall be visually examined, inside and out. Any electrical breakdown, breaking of conductor strands or cracking of insulation or jacket material shall constitute failure. If failure occurs within 2 inches of the grip on either end of the specimen, the results shall be disregarded and the test repeated.

4.8.5 Breaking strength.

4.8.5.1 Specimen. A specimen shall consist of a length of completed cable or cord approximately 6 feet long.

4.8.5.2 Apparatus. The testing machine shall be power-driven, and shall be equipped with a dial, scale, or automatic recorder that will record within plus or minus 1 percent of the force required to break the specimen.

4.8.5.3 Procedure. One end of the specimen shall be wrapped two full turns around the upper mandrel and secured in place to provide sufficient snubbing action to prevent slipping. The other end of the specimen shall be secured in a similar manner to the lower mandrel. The distance between the jaws with the specimen in place shall be not less than 6 inches. The jaws shall be separated at a uniform rate of approximately 1 inch per minute until the specimen breaks.

4.8.5.4 Observation. The breaking strength of the specimen shall be not less than that required by the specification sheet.

4.8.6 Cable aging (260°C.).

4.8.6.1 Specimen. A specimen shall consist of a 4-foot length of completed cable.

4.8.6.2 Procedure. The specimen shall be coiled or bent into a "U" shape and secured. The inside radius of the coil or "U", measured to the nearest 1/4-inch, shall be six times the diameter of the specimen. The specimen shall be suspended vertically, with the ends extending downward, in an air oven which has forced circulation of fresh air. The oven temperature shall be raised gradually, in a 2 to 3-hour period, from room temperature to 260°C. and held at 260° ±10°C. for a period of 24 hours and then returned to room temperature. When the oven has reached room temperature, the specimen shall be removed and examined visually. After visual examination of the cable specimen is made, tensile strength and elongation measurements shall be made on specimens of the jacket removed from the aged cable specimen.

4.8.6.3 Observation. The falling away of any material in excess of 1 gram from the ends of the cable specimen, during the time the specimen is in the oven shall be cause for rejection. Any flow or expansion of the jacket through the armor to such an extent that the armor cuts into the jacket material shall be cause for rejection. (Expansion of the jacket without actual cutting of the armor into the jacket shall not be considered cause for rejection). Shrinkback of the jacket in excess of 1/8-inch from either end of the specimen shall be cause for rejection. Jacket specimens cut from the aged cable specimen shall exhibit a tensile strength of not less than 600 psi and an elongation of not less than 150 percent.

4.8.7 Cable aging and compatibility (95°C.). This test is applicable to cables having thermoplastic insulation and is for the purpose of detecting any significant degradation in the characteristics of the cable or its parts, resulting from either part incompatibility or prolonged overheating.

4.8.7.1 Specimens. Two specimens of completed cable are required. Specimen number 1 shall be approximately 30 feet long. Specimen number 2 shall have an approximate length of 2 feet plus 24 times the overall diameter of the cable. Both specimens shall be taken from one sample length of cable.

4.8.7.2 Apparatus. The test apparatus shall consist of a heat chamber, a means of measuring and controlling the chamber temperature, a recording thermometer for chamber temperature, and racks or other means of supporting the specimens within the chamber. The temperature control shall be capable of maintaining the chamber temperature at 95° ±3°C. for a continuous period of 400 hours. Additional apparatus shall consist of a mandrel having a diameter of approximately 12 times the specimen diameter.

4.8.7.3 Procedure. The procedure shall consist of two parts: (1) heat aging; (2) bending.

4.8.7.3.1 Part one - heat aging. Prior to aging, Specimen number 1 shall be given the voltage withstand and the insulation resistance tests. The maximum insulation resistance values measured for each conductor shall be recorded. The two specimens shall be placed into the chamber in a horizontal position. Specimen number 2 shall be kept straight during the aging. The two specimens shall be conditioned at 95° ±3°C. continuously for

400 hours. At the end of this period they shall be allowed to cool to room temperature. Specimen number 1 shall again be given the voltage test and the insulation resistance test. The maximum insulation resistance values obtained for each conductor shall again be recorded. Then two additional specimens shall be cut from Specimen number 1. One of these shall be given the watertightness test; the other shall be given the cable filler removability test.

4.8.7.3.2 Part two - bending. With one end of Specimen number 2 secured to the mandrel, or directly adjacent thereto, force shall be applied to the free end so as to bend the specimen over the mandrel through an arc of approximately 180 degrees, at a rate of approximately 20 degrees per second. The specimen shall be secured so as to maintain it in this bent position, after which it shall be dissected and given a visual examination of all components.

4.8.7.4 Observations. Any of the following results shall be cause for rejection.

(a) Failure of the specimen to meet the requirements of the cable filler removability test.
(b) Failure of Specimen number 1, after heat aging, to meet the value of voltage withstand required by the applicable specification sheet.
(c) Insulation resistance values for Specimen number 1, after heat aging, which are below the minimum values specified on the applicable specification sheet
(d) Any dripping of the filler material away from the ends of the specimens during the heat aging.
(e) Any change in either the filler material or any part with which it is in contact, such as hardening, discoloration or other visible deterioration, of a nature or to an extent as to impair the performance of the cable in service.

4.8.8 Cable aging and compatibility (125°C.). This test is applicable to cables having either thermosetting insulation or silicone rubber-glass tape insulation, and is for the purpose of detecting any significant degradation in the characteristics of the cable or its component resulting from either component incompatibility or prolonged overheating.

4.8.8.1 Specimens. A specimen shall consist of a length of completed cable approximately 40 feet long.

4.8.8.2 Apparatus. The test apparatus shall consist of a heat chamber, a means of measuring and controlling the chamber temperature, a recording thermometer for chamber temperature, an internal mercury thermometer, and a rack or other means of supporting the specimen within the chamber. The temperature control shall be capable of maintaining the chamber temperature at 50° ±3°C. for a continuous period of 400 hours. There shall also be a source of current capable of supplying the required amount of current for a continuous period of 400 hours. There shall also be a mandrel having a diameter of approximately 12 times the specimen diameter.

4.8.8.3 Procedure. The procedure shall consist of two parts: (1) heat aging; (2) bending.

4.8.8.3.1 Part one - heat aging. Prior to heat aging, the specimen shall be given the voltage withstand and the insulation resistance tests. The maximum values of insulation resistance measured for each conductor shall be recorded. During aging, conductor temperature shall be determined either by direct measurement or by the measurement of change of copper resistance. For the direct measurement method, a thermocouple shall be inserted through a small knife puncture in the cable, approximately midway between the ends of the specimen. For cables having only one layer of conductors, the thermocouple shall be placed in contact with the strands of any conductor. For cables having more than one layer of conductors, the thermocouple shall be placed in contact with the strands of any conductor in the innermost layer. Thermocouples shall also be attached to the jacket of unarmored cables. In the case of armored cables, the thermocouples shall be attached to the armor. The specimen shall be placed into the chamber so as to have a straight section of approximately 7 feet, and so as to permit free circulation of convection air currents. The amplitudes of loading currents shall be such as to maintain each conductor at a temperature of 125° ±5°C. continuously for 400 hours. Readings of time, chamber temperature, jacket or armor temperature, and the current in each conductor shall be recorded at 15-minute intervals during the first hour, at 1-hour intervals during the next 5 hours, and twice daily thereafter for the duration of the test. Record shall also be made of any gas or fumes emanating from the specimen, and of any oozing of material from the ends of the specimen. In the case of armored cable, record shall also be made of any exudation of jacket material through the armor. At the end of the 400-hour test period, the specimen shall be allowed to cool to room temperature. Then it shall be given the voltage withstand and the insulation resistance tests. The maximum insulation resistance values measured for each conductor shall again be recorded. From the portion of the 40-foot specimen which was kept straight during the heat aging, specimen having an approximate length of 2 feet plus 24 times the overall diameter of the specimen shall be taken. This specimen shall be used for the bending procedure. From the remainder of the 40-foot specimen, two additional specimens shall be taken. One of these shall be given the watertightness test; the other shall be given the cable filler removability test.

4.8.8.3.2 Part two - bending. With one end of the specimen secured to the mandrel, or directly adjacent thereto, force shall be applied to the free end so as to bend the specimen over the mandrel through an arc of approximately 180 degrees, at a rate of approximately 20 degrees per second. The specimen shall be secured so as to maintain it in this bent position, after which it shall be dissected and given a visual examination of all parts.

4.8.8.4 Observations. Any of the following results shall be cause for rejection.

(a) Failure of the specimen to meet the requirements of the cable filler removability test.
(b) Failure of the 40-foot specimen, after heat aging, to meet the value of voltage withstand required by the applicable specification sheet.
(c) Insulation resistance values for the 40-foot specimen, after heat aging, which are below the minimum values specified on the applicable specification sheet.
(d) Any dripping of the filler material away from the ends of the 40-foot specimen, during the heat aging.
(e) Any change in either the filler material or any part with which it is in contact, such as hardening, discoloration or other visible deterioration, of such a nature or to an extent as to impair performance of the cable in service.

4.8.9 Cable filler removability. This test is applicable to the non-fibrous filler material used to fill the voids between insulated conductors or groups of insulated conductors. It is not applicable to filler material used to fill the voids between the strands of conductors or the strands of shields.

\# 4.8.9.1 Specimens. A specimen shall consist of a length of completed cable or cord approximately 2 feet long.

\# 4.8.9.2 Procedure. All overall cable or cord parts, such as armor, jacket, binders, shield, etcetera shall be removed from one end of the specimen so as to expose the cable or cord core and the filler material, for a distance of about 1 foot. Using fingers only (no hand tool), the filler shall be separated from the conductors or groups of conductors for approximately their fully exposed length. In the case of a group of conductors such as a pair or triad which has a common covering such as a shield or a binder tape, this covering shall be removed so as to expose the conductors and the filler material, for a distance of about 6 inches. The filler material shall be separated from the conductors as was done in the preceding step. For cables or cords having more than one such group, the test shall be performed on not less than one group.

\# 4.8.9.3 Observation. The filler material shall be flexible and shall be removable from any part with which it is in contact, through the use of fingers only. It shall not adhere to the fingers, to the insulation of conductors, or to tapes or other coverings over shields. The presence of occasional particles or slivers of filler residue will be acceptable, providing that these can be removed by light brushing with the fingers or with a dry cloth. Filler material which leaves residue that is removable only by vigorous wiping or through the use of solvents will not be acceptable.

4.8.10 Cold bending, cable.

4.8.10.1 Specimen. A specimen shall consist of a 5-foot length of completed cable.

\# 4.8.10.2 Procedure. The specimen shall be straightened and, if necessary, kept straight by securing to a straight wooden bar. The straight specimen shall be placed in a cold chamber and conditioned for a minimum of 6 hours. The conditioning temperature shall be minus 20° $\pm$2°C., unless otherwise specified by the specification sheet. The specimen shall then be removed from the conditioning chamber and, without delay, bent 180 degrees around a wooden mandrel of the specified diameter (see specification sheet) at a rate of from 10 to 20 degrees per second. The specimen shall be secured so as to maintain this bent position.

4.8.10.3 Observation. While the specimen is in the bent position, it shall be dissected and a visual examination made of all its parts. When defects or disarrangements are discovered in any part, examination shall be made of specimens in the "as received" condition to determine whether the defect existed prior to the cold bend test. Any defects, such as torn tapes or broken or cracked parts of a nature or to an extent as to impair the performance of the cable, in service, shall be cause for rejection.

4.8.11 Cold bending, cord.

4.8.11.1 Specimens. Two specimens of completed cord, each approximately 20 inches long, are required.

4.8.11.2 Apparatus. The apparatus shall consist of a refrigerator chamber, temperature controls, mandrels and magnifying glass. The chamber shall be large enough to permit vertical suspension of the specimen. The chamber shall be equipped with a device to hold a mandrel, with specimen attached, in such a manner that the specimen can be wrapped around the mandrel without touching either the mandrel or the specimen with the hands. The temperature controls shall be capable of maintaining a chamber temperature of minus 40° $\pm$2°C. for a period of 20 hours. The mandrels for testing the complete cord shall have a diameter not greater than three times the specified minimum diameter of the specimen. The mandrels for testing the insulated conductors shall have a diameter not greater than the nominal diameter over the insulated conductor. The magnifying glass shall provide at least 3-diameter magnification.

4.8.11.3 Procedure. The specimen selected for testing the complete cord shall be attached at one end to the proper size mandrel. The specimen selected for testing the insulated conductors shall have the conductors removed therefrom and each insulated conductor shall be attached at one end to the proper size mandrel. All specimens shall be suspended vertically within the chamber with their lower ends weighted sufficiently to keep the specimens taut and to permit wrapping them without handling. The temperature within the chamber shall be reduced to minus 40° $\pm$2°C and held at this temperature for a period of 20 hours. At the end of 20 hours and while the specimens are still in the chamber at minus 40° $\pm$2°C., they shall be wrapped for five close turns around their respective mandrels and then secured to the mandrels in the wrapped position. The specimens and mandrels shall then be removed from the chamber and the specimens examined through a magnifying glass of at least 3-diameter magnification.

4.8.11.4 Observation. Evidence of cracks, flaws or other damage caused by the cold bend procedure shall constitute failure.

4.8.12 Cold working (minus 20°C.).

4.8.12.1 Specimen. A specimen shall consist of a 20-foot length of completed cable.

4.8.12.2 Procedure. The specimen shall be conditioned in a chamber at minus 20° $\pm$2°C. for a period of not less than 6 hours. After the conditioning period the specimen shall be removed from the chamber and immediately shaped around two rollers, each 12 to 13 times the diameter of the cable. The specimen shall be shaped and pulled over the pulleys in such a manner that an "S" bend of 180 degrees is imposed progressively on the entire length of the specimen. The pull shall be done once in each direction at the rate of 35 $\pm$5 feet per minute.

4.8.12.3 Observation. After the cold working, the specimen shall be dissected and visual examination shall be made of all parts. When any defects or disarrangements are discovered, examination shall be made of a specimen in the "as received" condition to determine whether the defect or disarrangement existed prior to the cold working. Any defects such as torn tapes or broken or cracked parts of a nature or to an extent as to impair the performance of the cable in service shall be cause for rejection.

4.8.13 Cold working (minus 54°C.).

4.8.13.1 Specimen. A specimen shall consist of a 20-foot length of completed cable or cord.

4.8.13.2 Procedure. A specimen shall be conditioned in a chamber at minus 54° $\pm$2°C. for a period of not less than 6 hours. After the conditioning period and while still in the chamber at minus 54° $\pm$2°C., the specimen shall be shaped and pulled around two 12-inch diameter grooved sheaves in such a manner that an "S" bend of 180 degrees in each direction is imposed progressively on the entire length for a total of four times in each direction. The specimen shall be pulled over the sheaves at the rate of 50 $\pm$5 feet per minute.

4.8.13.3 Special procedure (for qualification). When the cold working (minus 54°C.) test is being performed for qualification purposes additional steps shall be taken as follows:

(a) Immediately prior to subjecting the specimen to minus 54° ± 2°C. for 6 hours, precondition the specimen by soaking in salt water (approximately 3 percent salt by weight) at a temperature of 22° ±5°C. for a period of not less than 21 days.
(b) The number of cycles for pulling the specimen over the sheaves shall be ten.
(c) After the ten cold-working cycles and after the specimen has returned to room temperature, the center 5-foot section shall be removed and subjected to the hydrostatic (open end) test.

4.8.13.4 Observation. After the cold working, the specimen shall be removed from the chamber and dissected. Visual examination shall be made of all parts. When any defects or disarrangements are discovered, examination shall be made of a specimen in the "as received" condition to determine whether the defect or disarrangement existed prior to the cold working. Any defects such as torn tapes or broken or cracked parts of a nature or to an extent as to impair the performance of the cable or cord in service shall be cause for rejection. In addition, when the test has been performed for qualification, water leakage in excess of that permitted by the specification sheet or slippage of the core in excess of 1/4-inch shall also be cause for rejection.

4.8.14 Crack resistance.

4.8.14.1 Specimens. Specimens shall consist of lengths of completed conductors (insulation plus coverings, if any), which have been taken from completed cable. For cables containing four conductors or less, one specimen shall be taken from each conductor. For cables containing five or more conductors, the number of specimens taken (one per conductor selected), shall be the square root (to the nearest whole number) of the total number of conductors in the cable; in no case shall the number of specimens be less than four. The length of specimens shall be in accordance with 4.8.14.2.

4.8.14.2 Procedure. The test shall be performed at room temperature (23° ±3°C.). The specimen shall be hand-wound around a mandrel for three complete turns, unwound, wound around the mandrel for three complete turns in the opposite direction, unwound and straightened. The specimen shall then be immersed for 1/2 hour in an aqueous solution of gentian violet which is at room temperature. Mandrel diameters and specimen lengths shall be in accordance with the following or as specified in the individual specification sheet:

Conductor size (Navy Standard)	Mandrel diameter (inches, nom.)	Specimen length, minimum (inches)
23	1-1/2	24
14	1	18
9	1/2	12
4	1/2	12
3	1/3	8
2	1/3	8
Smaller than 2	1/4	6

4.8.14.3 Observation. Any visible damage to the braid, or any cracking or peeling of the braid or insulation covering, such as to permit the penetration of fluid to the dielectric, shall be cause for rejection. The number of pinholes in the braid covering shall not exceed an average of one per linear foot of conductor. When necessary to more accurately determine this limit, a 10-foot long specimen shall be subjected to immersion after bending.

4.8.15 Drip.

4.8.15.1 Specimen. A specimen shall consist of an 18-inch length of completed cable.

4.8.15.2 Procedure. The specimen shall be suspended vertically in an oven for a period of not less than 18 hours. Oven temperature shall be maintained within plus or minus 1°C. of the temperature specified on the specification sheet.

4.8.15.3 Observation. The falling away of any material from the lower end of the specimen, during the time the specimen is in the oven, shall be cause for rejection.

4.8.16 Flammability.

4.8.16.1 Specimens. Specimens shall consist of completed cable or cord approximately 18 inches in length.

4.8.16.2 Apparatus. The apparatus shall consist of an enclosure, supports, heater coil, spark plugs, flame travel gage, and associated accessories.

4.8.16.2.1 Enclosure. An enclosure of sufficient size to contain the specimen, supports, heater coil, spark plugs, flame travel gage, and their associated accessories shall be arranged to eliminate air drafts and permit clear view of the interior through shatterproof glass windows. Vent holes, distributed around the sides adjacent to the base, shall be provided to admit fresh air when an exhaust fan connected to the top of the enclosure is operated at a minimum suction just sufficient to carry off smoke and gases.

4.8.16.2.2 Supports. Supports shall be suitable for holding the specimens in a vertical position with an unsupported span not less than 14 inches long. At the lower end of the specimen, means shall be provided for containing the gases expelled from the specimen so that they do not diffuse throughout the test enclosure, but instead are deflected upward toward the spark plugs. (A simple cup-shaped device, placed just under the specimen, should be suitable for this purpose).

4.8.16.2.3 Heater coil. Heater coils shall consist of seven turns of 0.102-inch diameter resistance wire conforming to composition E of QQ-R-175, space wound to 0.25-inch between centers. The inside diameter of the coil shall exceed the overall diameter of the specimen by not less than 0.5 inch nor more than 0.6 inch. The lower end of the heater coil shall be located 1.5 inches above the top of the lower specimen support.

4.8.16.2.4 Spark plugs. Two spark plugs, with extended electrodes spaced 1/8-inch from the surface of the specimen and the plugs located on diametrically opposite sides of the specimen, shall be placed with their longitudinal certerlines in a horizontal plane 1/2-inch above the top of the heater coil, to ignite the gases emitted from the heated specimen. An electric circuit adequate to maintain continuous sparking at the electrodes during the specified time shall be provided. The spark plugs shall be mounted in such a manner that they may be moved away from the specimen after ignition takes place so as not to impede the travel of the flame and to prevent their electrodes from becoming fouled by soot.

4.8.16.2.5 Flame travel gage. A flame travel gage shall be positioned near the specimen to judge the distance of flame travel without appreciably impeding the progress of the flame.

4.8.16.3 Procedure. With the enclosure closed and ventilated, the specimen centered in the heater coil, and the spark plugs and flame gage properly located, a stop watch shall be started simultaneously with the energizing of the heater coil and spark plugs. A constant current as specified in table XII shall be supplied from a transformer source to the heater coil. Ignition shall be considered as occurring when the flame transfers from the escaping gases to the surface of the specimen and continues there, disregarding the flashes which may occur in the gassing space prior to the sustained flame. The time required to ignite the specimen shall be recorded. For all armored cable, the heating current shall be turned off 30 seconds after ignition occurs. When armored cable does not ignite in 250 seconds or more, the specimen is considered satisfactory, and the test shall be discontinued. For all unarmored cables or cords where ignition time is less than 60 seconds, the heating current shall be turned off 60 seconds after being turned on; where the ignition time is greater than 60 seconds, the heating current shall be turned off when ignition occurs. Immediately after ignition occurs, the electrical supply to the spark plugs shall be cut off, and the plugs shifted away from the flame. The maximum distance to which the flame travels along the surface of the specimen, measured from the top of the heater coil, before extinction shall be noted and recorded.

Table XII - Current in heating coil.

Nominal diameter of cable or cord (inches)	Current amperes a.c. (rms)	Nominal diameter of cables or cord (inches)	Current amperes a.c. (rms)
0.050 thru 0.099	45	0.80 thru 0.89	53
.100 thru .19	46	.90 thru .99	54
.20 thru .29	47	1.00 thru 1.09	55
.30 thru .39	48	1.10 thru 1.39	56
.40 thru .49	49	1.40 thru 1.79	57
.50 thru .59	50	1.80 thru 2.29	58
.60 thru .69	51	2.30 to 3.00	59
.70 thru .79	52		

4.8.16.4 Observation. The number of seconds that the specimen continues to burn until the cessation of all flaming, after the current in the heater coil has been cut off, shall be recorded as the time required for self-extinction. If a specimen tested fails to comply with any of the limitations specified in table XIII or burns for a distance greater than that permitted by the specification sheet, upon the first trial, two additional specimens shall be tested, and the results of all three trials averaged together. Specimens not passing the flammability limits shall constitute a failure.

Table XIII - Flammability limits

Cable or cord construction or type	Ignition time, minimum (seconds)	Burning time, maximum (seconds)
With armor	60	60
Without armor (except MRI)	30	120
MRI	25	60

4.8.17 Gas flame.

4.8.17.1 Specimen. A specimen shall consist of a length of completed cable approximately 4 feet long, with the ends prepared for electrical connection.

4.8.17.2 Apparatus. The test chamber shall be equipped with means for exhausting gases resulting from burning, without causing horizontal air currents which prevent a steady, even gas flame. The power supply shall be of the three-phase, four-wire type, capable of supplying 3 amperes minimum. (Instruments for measuring current, capacitance and power factor are required at the Government laboratory only). The source of flame shall be a 24-inch ribbon type gas burner designed to produce a flame which is uniform in height throughout the length of the burner. Means of metering both air and gas inputs to the burner shall be provided.

4.8.17.3 Procedure. The specimen shall be suspended horizontally over the burner and parallel to it, so that the underside of the specimen is 1-3/4 to 2 inches above the top surface of the burner. The specimen shall be supported adequately so that during the time it is exposed to flame, no part of it may sag closer than 3/4 inch from the top of the burner. The chamber shall permit free circulation of convection air currents. The standard flame shall be that produced by combustion of 27.5 cubic feet per hour of natural gas having a heat content of 1030 $\pm$2 percent British thermal units (Btu) per cubic foot, or another gas having the equivalent heat output and temperature. The conditions for measurement of gas and air flow rates shall be atmospheric pressure (14.7 psi) and 23°C. If measured at other pressures or temperatures, the values shall be corrected to the above specified conditions. The transformer shall be connected to the conductors of the specimen through a fuse in each phase leg. The fuses shall be normal-blow 1-ampere for cables rated for 1 kv and normal-blow 1/4-ampere for cables rated for 5 kv. (In lieu of fuses, overload relays having equivalent tripping characteristics may be used.) The gas flame shall be applied continuously for the duration of the time period specified by the specification sheet, unless failure of the specimen occurs first. The test voltages and their points of application shall be as follows:

(a) Cables rated for 5 kv:
(1) 4160 volts for conductor to conductor

(2) 2400 volts from conductor to armor (when specimen is armored)

(b) Cables rated for 1 kv and having conductor sizes 14 and larger:
   (1) 450 volts from conductor to conductor
   (2) 260 volts from conductor to armor (when specimen is armored)

(c) Cables rated for 1 kv and having conductor sizes smaller than 14:
   (1) 120 volts from conductor to conductor
   (2) 70 volts from conductor to armor (when specimen is armored)

(For four-conductor and six-conductor cables, the physically opposite conductors shall be connected in parallel and the cables treated as two-conductor and three-conductor cables, respectively. Cables having seven or more conductors shall have adjacent conductors connected to different phases. In a 10-conductor cable, for example, conductors 2, 4, 6 and 9 should be connected to phase A; conductors 3, 5 and 8 should be connected to phase B; conductors 1, 7 and 10 should be connected to phase C. When the specimen is armored, the armor should be connected to the system neutral).

4.8.17.4 Observation. Blowing of any fuse or tripping of any overload relay, before the expiration of the period of time specified on the specification sheet, shall constitute failure of the specimen.

4.8.18 Heat distortion.

4.8.18.1 Specimens. Specimens for conductor sizes 200 MCM and smaller shall consist of 1-inch lengths of insulated conductor. Specimens for conductor sizes larger than 200 MCM shall consist of sections of insulation which have been prepared by removing the insulation from approximately 8-inch lengths of conductor, buffing strips of the insulation to a thickness of 0.050 $\pm$0.010 inch and then cutting the buffed insulation into sections which are 1-inch long and 9/16 $\pm$1/16-inches wide.

4.8.18.2 Apparatus. The apparatus shall consist of a small oven with controls capable of maintaining a constant temperature of 121° $\pm$1°C. for a period of 3 hours, a Randall and Stickney gauge, or equivalent gauge having a 3/8-inch foot which weighs approximately 85 grams, and weights for loading the gauge foot. The weights shall be in addition to the weight of the gauge foot and shall be as follows:

Specimen or conductor size	Load for gauge (Grams)
3	400
4 thru 14	500
23 thru 75	750
100 thru 200	1000
Specimens from sizes larger than 200	2000

4.8.18.3 Procedure. The procedure for determining the percentage of distortion shall be as follows:

(a) Determine T_1, the thickness of the section of insulation to be tested. Where the specimen consists of a buffed strip of insulation, use a Randall Stickney, or equivalent, gauge which has a 3/8-inch foot with no load weight of 85 grams. Where the specimen consists of a 1-inch length of insulated conductor, use a micrometer caliper which has flat surfaces for both the anvil and spindle, and measure the diameter over and under the insulation and designate these values D and C respectively. Determine the thickness of the insulation, T_1, by the formula $T_1 = \frac{D-C}{2}$

(b) Preheat the oven to 121° $\pm$1°C. and maintain it at this temperature for the remainder of the test.

(c) Place the gauge, which has been weighted in accordance with 4.8.18.2, into the preheated oven.

(d) At the end of 1 hour, place the specimen into the oven with the weighted gauge.

(e) At the end of the second hour, place the specimen under the weighted foot of the gauge.

(f) At the end of the third hour, read the dial of the gauge. Designate the value as T_2 when the specimen consists of a buffed strip of insulation. Designate the value as F when the specimen consists of a 1-inch length of insulated conductor and calculate T_2 by the formula $T_2 = \frac{F-C}{2}$.

(g) Calculate the percent of distortion by the formula,

$$\text{Percent distortion} = \frac{T_1 - T_2}{2} \times 100.$$

4.8.18.4 Observation. Distortion which exceeds 30 percent for specimens which consist of buffed strips of insulation or 20 percent for specimens which consist of a 1-inch length of insulated conductor shall constitute failure of the specimen.

4.8.19 Hydrostatic (open end).

4.8.19.1 Specimen. A specimen shall consist of a 5-foot length of completed cable or cord.

4.8.19.2 Procedure. One end of the specimen shall be fitted into the appropriate size of stuffing tube in accordance with MIL-S-24235/1. Water pressure shall be applied to the stuffing tube end of the specimen. The pressure and duration of application shall be as specified on the specification sheet covering the cable.

4.8.19.3 Observation. Unless otherwise specified by the specification sheet, no water leakage through the specimen will be permitted, and there shall be not more than 1/4 inch slippage of the cable or cord core or components.

4.8.20 Permanence of printing (conductor). The test shall be performed on a horizontal abrasion machine, using a tape approximately 1/2-inch wide, comprised of No. 50-2/20 unbleached cotton braid. The tape shall be drawn back and forth across a portion of the specimen which bears the printed identification code legend. Motion of the tape shall be perpendicular to the axis of the specimen. The area of mutual contact between tape and specimen shall be such that the tape extends around the periphery of the specimen so that an arc of contact is not less than 135 degrees. A constant tension of 1/2 pound shall be maintained on one end of the tape. Total excursion of the tape across the specimen shall be 10 inches. A complete excursion of the tape across the specimen in one direction, followed by a complete excursion in the reverse direction to the starting point, shall constitute a cycle. The cyclic rate should be 28 $\pm$ 3 cycles per minute. No tape shall be used to perform more than 500 cycles per side.

4.8.20.1 Observation. Failure of the printed identification code legend to remain legible after completion of the number of cycles specified on the specification sheet shall constitute failure of the specimen.

4.8.21 Permanence of printing (jacket).

4.8.21.1 Specimen. A specimen shall consist of a length of completed cable approximately 6 inches long.

4.8.21.2 Apparatus. The apparatus shall consist of a motor-driven reciprocating mechanism capable of holding and moving a 0.025 $\pm$0.001 inch steel mandrel (usually a needle) in a horizontal motion back and forth for a distance of 3/8 inch on the surface of the specimen. In addition, there shall be a jig to hold the specimen at right angles to the mandrel and in a horizontal position and a counter to record the number of strokes.

4.8.21.3 Procedure. The specimen shall be mounted horizontally, at right angles to the mandrel with the printed legend on the top side. The mandrel shall be adjusted or weighted so as to exert a 1-pound force on the specimen throughout the test. The mandrel shall be rubbed along the printed legend for a distance of 3/8 inch and returned to original position to complete one cycle. The frequency of the cycles shall be 60 per minute. The specimen shall be subjected to a minimum of 250 cycles.

4.8.21.4 Observation. Failure of the printed legend to remain legible after completion of 250 rubbing cycles shall constitute failure of the specimen.

4.8.22 Physical tests on insulation and jacket. Tests shall be made on specimens of insulation and jacket to determine the physical properties of the materials before and after accelerated aging. Testing shall be performed on the aged and unaged specimens at the same time insofar as possible.

4.8.22.1 Specimens. Test specimens shall be approximately 6 inches long and shall be obtained from samples of completed cable. In the case of small conductors with thin walls, the specimen shall be the entire section of insulation. In the case of cable jackets or large conductors with thick walls, the specimen shall be either (a) a segment or section cut with a sharp knife held tangent to the conductor or cable core, or (b) a shaped specimen cut with a standard die. When the whole section is used the specimen shall not be cut longitudinally. The specimen shall be as free as possible from surface incisions and imperfections. In the event of surface irregularities, such as corrugations from stranding, the specimen shall be buffed to obtain smooth surfaces and uniform thicknesses. The cross-sectional area of the specimens shall be as large as possible but shall not exceed 0.030 square inch.

4.8.22.1.1 Calculation of area. The area of specimens shall be calculated before aging. Calculation of the area of the test specimens shall be made as follows:

(a) Where the total cross section of the insulation is used, the area shall be taken as the difference between the area of the circle whose diameter is the minimum average outside diameter of the insulation and the area of the conductor. The area of a stranded conductor shall be figured from its maximum diameter. The following formula may be used to advantage:

$$A = 0.7854\ (D + d)\ (D-d)$$

Where: A = Area of cross section in square inches.
D = Outside diameter of insulation in inches.
d = Diameter over conductor in inches.

(b) Where a slice cut from the insulation by a knife held tangentially to the wire is used, and the slice so cut has the cross section of a segment of a circle, the area shall be calculated as that of the segment of a circle whose diameter is that of the insulation. The height of the segment is the wall of insulation on the side from which the slice is taken. The values may be obtained from a table giving the areas of segments of a unit circle for the ratio of the height of the segment to the diameter of the circle.

(c) Where the cross section of the slice is not a segment of a circle, the area shall be calculated from the direct measurement of the volume or from the specific gravity and the weight of a known length of the specimen having a uniform cross section.

(d) Where a portion of sector or circle has to be taken as where the conductor is large and the insulation thin, the area shall be calculated as the thickness times the width. This applies either to a straight test piece or one stamped out with a die, and assumes that corrugations have been removed by buffing.

(e) Where a portion of a sector of a circle has to be taken, as where the conductor is large and the insulation thick, the area shall be calculated as the proportional part of the area of the total cross section.

4.8.22.1.2 Temperature. Specimens for both the aged and unaged physical tests shall be at a temperature of 25° ±3°C. and shall have been at this temperature for at least 30 minutes prior to testing.

4.8.22.1.3 Bench marks. All specimens shall be marked near the middle to provide a basis for determining elongation and set. The marks shall be 1 inch apart for polyproplyene and thermoplastic polyethylene insulations, and 2 inches apart for all other materials. Aged specimens shall be marked after aging.

4.8.22.2 Accelerated aging. Conditioning periods and temperatures for specimens to be aged shall be as shown in table XIV.

Table XIV - Accelerated aging of specimens.

Materials	Conditioning	Temperature (degrees C.)	Period (hours)
Insulations			
Polyethylene (thermoplastic)	Air oven	100	96
Polypropylene	Air oven	121	96
80°C. Polyvinyl chloride	Air oven	100	96
80°C. Semi-rigid Polyvinyl chloride	Air oven	113	168
105°C. Polyvinyl chloride	Air oven	136	96
Cross-linked polyethylene	Air oven	121	168
	Air pressure heat	127	40
Ethylene propylene rubber	Air oven	121	168
	Air pressure heat	127	40

Table XIV - Accelerated aging of specimens (Cont'd).

Materials	Conditioning	Temperature (degrees C.)	Period (hours)
Insulations (Cont'd)			
Synthetic rubber	Air pressure heat	127	20
	Oxygen pressure	80	168
Butyl rubber	Air oven	100	168
	Air pressure heat	127	40
Jackets			
Special thermoplastic	Hot oil immersion	121	18
	Air pressure heat	126	20
Standard thermoplastic	Hot oil immersion	121	18
Polychloroprene	Hot oil immersion	121	18
	Air pressure heat	126	20
	Oxygen pressure	80	168
Chlorosulfonated polyethylene	Hot oil immersion	121	18
	Air pressure heat	126	20
	Oxygen pressure	80	168
Silicone rubber	Air oven	260	24

4.8.22.2.1 Air oven. Air oven aging shall be accomplished by heating the specimens at the required temperature and for the required period (see table XIV) in an oven which has forced circulation of fresh air. The oven temperature shall be maintained within plus or minus 2°C. of the specified temperature.

4.8.22.2.2 Air pressure heat. Air pressure heat aging shall be accomplished by suspending the specimens in a pressure chamber for the required period and at the required temperature (see table XIV). The required temperature shall be reached during the first 15 minutes of the period and maintained within plus or minus 2°C. for the duration of the period. The pressure within the chamber shall be maintained at 80 + ? psi throughout the period. At the completion of the period, the chamber pressure shall be reduced to atmospheric pressure at a uniform rate over a 5-minute period.

4.8.22.2.3 Oxygen pressure. Oxygen pressure aging shall be accomplished by suspending the specimens in an atmosphere of oxygen at 300 $\pm$10 psi for the required period and at the required temperature (see table XIV). The pressure chamber temperature shall be controlled to within plus or minus 1°C. and shall be automatically recorded during the entire period. At the completion of the period, the chamber pressure shall be reduced to atmospheric pressure at a uniform rate over a 5-minute period.

4.8.22.2.4 Hot oil immersion. Specimens shall be immersed in lubricating oil conforming to Symbol No. 2190 TEP of MIL-L-17331, at a temperature and period specified (see table XIV) of 121° $\pm$1°C. for 18 hours. The specimens shall then be removed, blotted lightly to remove excess oil, then suspended in air at room temperature for not less than 3-1/2 nor more than 4-1/2 hours before testing for tensile strength and elongation.

4.8.22.3 Tensile strength and elongation.

4.8.22.3.1 Apparatus. The testing machine shall be power-driven and preferably be the pendulum type. A spring balanced type of apparatus may be used if provided with a device which will indicate the actual maximum load at which rupture takes place and provision is made to prevent recoil of the spring. The testing machine shall be accurate within 1 percent of the breaking load.

4.8.22.3.2 Procedure. The specimen shall be placed in the jaws of the machine and adjusted so that the tension will be distributed uniformly over the cross section. For specimens with bench marks 1 inch apart, the maximum distance between jaws shall be 2 inches. For specimens with bench marks 2 inches apart, the maximum distance between jaws shall be 4 inches. Each specimen shall be stretched at a uniform rate of 20 inches per minute until rupture. The elongation shall be measured at the instant of rupture. Rupture of the specimen at any point other than between the bench marks shall invalidate the test. The tensile strength shall be determined from the area of the unstretched and unaged specimen.

4.8.22.3.3 Observation. Failure of the material to meet the tensile and elongation requirements of the specification sheet shall be cause for rejection.

4.8.22.4 Set. The set test shall be performed on unaged specimens which have bench marks 2 inches apart. The specimen shall be placed in the jaws of the machine and adjusted so that the tension will be distributed uniformly over the cross section. The maximum distance between jaws shall be 4 inches. The specimen shall be stretched at a uniform rate of 20 inches per minute until the bench marks are 6 inches apart. The specimen shall be held in the stretched position for 5 seconds and then released. The distance between bench marks shall be determined 1 minute after release and this distance, less 2 inches, shall be considered the set.

4.8.22.4.1 Observation. Failure of the material to meet the set requirements of the specification sheet shall be cause for rejection.

4.8.23 Pressure cycling.

4.8.23.1 Specimen. A specimen shall consist of a 50 to 70-foot length of completed cable or cord.

4.8.23.2 Procedure. The specimen shall be installed in a pressure chamber with both ends brought out approximately 1 foot through bulkhead stuffing tubes conforming to MIL-S-24235/1 and MIL-S-24235/2. The protruding ends of the specimen shall be prepared for capacitance and insulation resistance testing. The specimen within the chamber shall be subjected to five pressure cycles at the pressure specified on the specification sheet. The pressure within the chamber shall be reduced to zero between cycles. For the first and fifth cycles the maximum pressure shall be held for 30 minutes. The maximum pressure for the second, third and fourth cycles shall be held only long enough for the electrical tests to be made. Capacitance and insulation resistance measurements shall be made before and after the pressure cycling and just before pressure is released at the end of each cycle.

4.8.23.3 Observation. The insulation resistance and capacitance values obtained throughout the test shall meet those required by the specification sheet.

4.8.24 Specific gravity. The specific gravity of extruded silicone rubber insulation shall be determined in accordance with method D of ASTM-D297.

4.8.25 Stress endurance.

4.8.25.1 Specimen. The specimen shall consist of a 7-foot length of completed cable.

4.8.25.2 Procedure. The specimen shall be drawn back and forth under alternate loads of 490 and 180 pounds tension through 90 degrees around a 3-inch diameter pulley with a total travel of 18 inches in one direction, for a total of 500 cycles. After the required number of cycles, the tension of the specimen shall be released, and the specimen shall be subjected to the voltage withstand test applicable to the type of cable being tested.

4.8.25.3 Observation. After the stress endurance and voltage withstand tests, the specimen shall be visually examined. Any dielectric failure, breaking of conductors, or cracking of the insulation or jacket shall constitute a failure.

4.8.26 Tension.

4.8.26.1 Specimen. The specimen shall consist of a 6-foot length of completed cable.

4.8.26.2 Procedure. The specimen shall be secured at each end with a woven cable grip similar to type HD of MIL-G-160. A tension load as required by the applicable specification sheet shall be applied to the specimen through the cable grips for 1 hour, and then released. After release of the tension, the specimen shall be given the voltage withstand test applicable to the type of cable being tested.

4.8.26.3 Observation. The specimen shall withstand the tension and voltage withstand tests.

4.8.27 Thermoplastic flow.

4.8.27.1 Specimen. The specimen shall consist of a length of completed cable sufficient to make two complete turns around the appropriate size mandrel, stripping of ends, and securing to mandrel.

4.8.27.2 Procedure. Ends of specimen shall first be prepared for electrical connections as required herein. The specimen shall then be wrapped for two close turns around a mandrel having a diameter of 10 to 12 times the diameter of the specimen. The specimen shall be secured to the mandrel and placed in an oven. Electrical connections shall be made so that all conductors will be tested from conductor to shield at 70 volts and also between conductors at 120 volts, when two or more conductors have a common shield. The specimen shall be kept in the oven for 6 hours at a temperature of 120° ±2°C. during which time the voltage shall be applied to all conductors.

4.8.27.3 Observation. Electrical failure between conductors or between conductors and shield shall constitute failure of the specimen.

4.8.28 Twisting endurance.

4.8.28.1 Specimen. The specimen shall consist of one length of completed cable or cord. The length shall be 24 inches for cables or cords having a diameter of 5/8-inch or less, and 18 inches plus 10 times the cable diameter in length for cables having a diameter larger than 5/8 inch.

4.8.28.2 Procedures. The specimen shall be conditioned to the temperature specified by the specification sheet and maintained at that temperature during the test. The twisting apparatus may be an assembly powered by a single drive and equipped with means for counting the number of cycles impressed upon the specimen. The specimen shall be clamped in cable grips and subjected to 180 degrees of twist in each direction (360 degrees total twist) at the rate of 12 to 14 complete cycles per minute. The distance between grips shall be 6 inches plus 10 times the maximum diameter of the specimen. The upper grip shall be oscillated by the twisting apparatus. The lower grip shall be free to move vertically, but restrained from oscillation, and shall have a weight attached which stresses the specimen in tension 40 ±2 psi of its cross-sectional area. The cross-sectional area of the specimen shall be determined by the maximum diameter for the cable or cord type and size as given by the specification sheet. After completion of the number of cycles and at the temperature specified by the specification sheet the specimen shall be removed from the test apparatus and subjected to the voltage withstand test specified by the specification sheet.

4.8.28.3 Observation. After the twisting and voltage withstand tests, the specimen shall be visually examined. Any voltage withstanding failure, breaking of the conductors, or cracking of the insulation or jacket shall constitute a failure. If failure occurs within 2 inches of the grip and either end of the specimen, the results shall be disregarded and the test repeated.

4.8.29 Visual and dimensional examination. Each selected sample of completed cable or cord shall be examined visually to determine conformance with the requirements of this specification and the applicable specification sheet.

4.8.29.1 Materials examination. Each component material included in the construction of the cable or cord shall be examined to determine that it is an approved material, as shown on the applicable details of Construction sheet (when applicable) issued to the manufacturer by NAVSEC.

4.8.29.2 Dimensional examination. Measurements shall be made to determine conformance with all dimensional requirements of this specification and the specification sheet.

4.8.29.3 Identification. Examination shall be made for proper marker tapes and threads and for proper conductor and group identification codes and methods and surface markings.

4.8.29.4 Repairs. Repairs of any nature to the cable or cord shall be examined for workmanship. Repairs to insulation and jacket shall meet the criteria of 3.7.

4.8.29.5 End seals. End seals shall be examined for proper application and adequacy.

4.8.30 Watertightness.

4.8.30.1 Specimen. A specimen shall consist of a 5-foot length of completed cable.

4.8.30.2 Procedure. One end of the specimen shall be placed in a terminal fitting which will allow water pressure to be applied directly to the exposed cross-sectional area of the end of the cable. Exposure of the sides of the cable to the water shall be kept to a minimum, and the fitting shall not exert radial compression against the cable. Unless otherwise approved by the qualifying activity, the sealer used for the packing gland in the terminal fitting shall be a metal alloy having a maximum melting point of 89°C. The specimen shall be subjected to a water pressure of 25 psi for a period of 6 hours.

4.8.30.3 Observation. Water leakage through the specimen in excess of that permitted by the specification sheet or table XV, whichever is applicable, shall be cause for rejection.

Table XV - Limits for water leakage.

Total circular-mil area of conductors in cable	Maximum water leakage in cubic inches (cu. in.) during 6-hour test at 25 psi			
	Full contract price (cu. in.)	95 percent of contract price (cu. in.)	90 percent of contract price (cu. in.)	80 percent contract price (cu. in.)
0 to 9,000	1	2	3	4
9,050 to 15,000	2	3	4	5
15,050 to 25,000	3	4	5	6
25,050 to 50,000	4	5	6	8
50,050 to 100,000	5	6	7	9
100,050 to 200,000	6	7	8	10
200,050 to 500,000	7	8	9	11
500,050 to 800,000	8	9	10	12
800,050 to 2,100,000	9	10	11	13

Note 1. - Circular-mil area to be based on nominal circular-mil area required by the specification.

Note 2. - Cable with water leakage in excess of the values shown in the 80 percent column will not be acceptable to the Government.

4.9 Tests methods (electrical).

4.9.1 Attenuation. Attenuation per unit length is defined as the logarithmic decrement in transmitted power. The attenuation, expressed in db per 100 feet, shall be measured at a sufficiently low-power level that the resulting temperature rise will be negligible. An acceptable method for measuring attenuation is as follows:

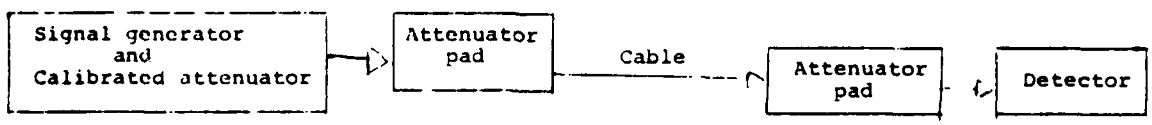


Figure 1 - Attenuation measurement.

In the block diagram (figure 1) a length of cable with an attenuation of at least 3 db shall be inserted between the connectors. The signal generator and calibrated attenuator shall be adjusted to produce a reasonable indication at the detector when the detector is tuned. The detector reading is noted, and the calibrated attenuator output level is recorded. The cable under test is then withdrawn and the circuit completed with the connectors (or a very short length of cable). With the detector tuned, the calibrated attenuator shall be re-adjusted to reproduce the original reading at the detector, and the attenuator output level is again recorded. Attenuation is then computed as follows:

$$A = \frac{100}{L} \text{ (difference in calibrated attenuator readings in db)}$$

Where:

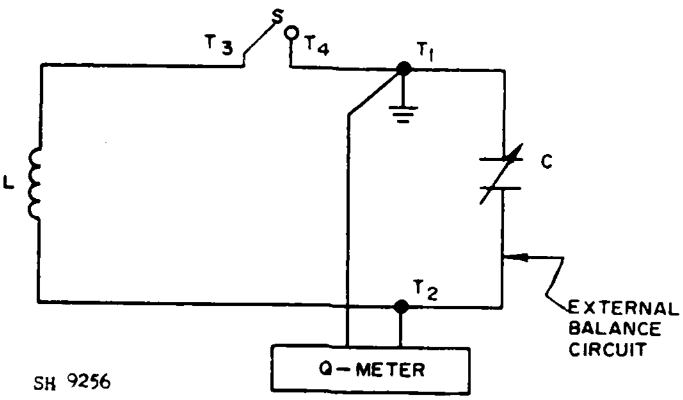
A = Attenuation in db per 100 feet.
L = Length of cable under test in feet.

For measurements at frequencies of 400 MHz. or less, the characteristic impedance of the attenuator pads and connectors shall preferably be the same as that of the cable under test.

4.9.2 Capacitance.

4.9.2.1 Specimen. Specimen shall consist of a 10-foot 2-inch length of completed cable with all shields removed for a distance of 1 inch from each end and the insulation removed from a distance of 1/2 inch from each end of all conductors. Th- length of the specimen shall be the shielded length.

4.9.2.2 Test equipment. A Q-meter and oscillator equipped with the external balance circuit, as shown on figure 2 is recommended. Other equipment may be used where it can be demonstrated that such an alternate will yield equally accurate results.



L: Coil, of inductance suitable for the magnitude of the reactances to be measured.
C: Variable calibrated precision condenser.
T_1 and T_2: Terminals of Q-meter-T_1 grounded.
T_3 and T_4: Terminals in the inductive branch of the balance circuit. (T_4 can be identical with terminal T_1.)
S: Means of connecting T_3 to T_4.

Figure 2 - Test equipment for capacitance test.

The leads from L and C to the Q-meter terminals shall be as short as practicable. The test specimen or leads from the specimen shall be terminated at or as near as possible to the terminals of L.

4.9.2.3 Procedure (shielded singles). The shield at each end of the conductor under test shall be grounded. Measurements shall be made for each shielded conductor using the frequency required by the specification sheet. Proceed as follows for each conductor of the specimen:

(a) Connect terminal T_3 to T_4.

(b) Balance the circuit to resonance (maximum reading on the Q-meter) by adjusting C. Designate this reading of C as C_0.

(c) Connect the conductor to terminal T_2 and the shield to terminal T_1. Balance the circuit by adjusting C to a new value. Designate this value as C_1.

4.9.2.3.1 Calculation. The capacitance (C) per foot, for each conductor, shall be determined by the formula:

$$C = \frac{(C_0 - C_1)}{(\text{Length of specimen in feet})}$$

4.9.2.4 Procedure (shielded pairs). All shields at each end of the specimen shall be grounded. The capacitance shall be measured for each pair at the frequency specified on the specification sheet. For each pair, one conductor shall be designated as No. 1, the other conductor as No. 2 and the shield as No. 3. Proceed as follows for each pair:

(a) Connect terminal T_3 to T_4.

(b) Balance the circuit to resonance (maximum reading on the Q-meter) by adjusting C. Designate this reading of C as C_O.

(c) Connect No. 1 and No. 3 to terminal T_1, and connect No. 2 to terminal T_2. Balance the circuit by adjusting C to a new value C_1. Designate the capacitance $(C_O - C_1)$ measured between terminals T_1 and T_2 as C_a.

(d) Disconnect No. 1 from terminal T_1 and No. 2 from terminal T_2. Connect No. 2 with No. 3 to terminal T_1 and connect No. 1 to terminal T_2. Balance the circuit by adjusting C to a new value C_2. Designate the capacitance $(C_O - C_2)$ as C_b.

(e) Disconnect No. 2 from terminal T_1 and connect it to terminal T_2. Balance the circuit by adjusting C to a new value C_3. Designate the capacitance $(C_O - C_3)$ as C_c.

4.9.2.4.1 Calculation. Calculation shall be made as follows:

(a) The mutual capacitance (C_m) per foot for each pair shall be determined by the formula:

$$C_m = \frac{2(C_a + C_b) - C_c}{4 \times (\text{Length of specimen in feet})}$$

(b) The capacitance unbalance or coefficient of asymmetry (C_u) of a shielded pair, expressed in percent, shall be determined by the formula:

$$C_u = \frac{400(C_a - C_b)}{2(C_a + C_b) - C_c}$$

4.9.2.5 Procedure (shielded triads). The shield at each end of the triad under test shall be grounded. Measurements shall be made for each triad using the frequency required by the specification sheet. For each triad designate one conductor as No. 1, the second conductor as No. 2; the third conductor as No. 3 and the shield as No. 4. Proceed as follows for each triad:

(a) Connect terminal T_3 to T_4.

(b) Balance the circuit to resonance (maximum reading on the Q-meter) by adjusting C. Designate this reading of C as C_O.

(c) Connect No. 2, No. 3 and No. 4 to terminal T_1. Connect No. 1 to terminal T_2. Balance the circuit by adjusting C to a new value C_1. Designate the capacitance $(C_O - C_1)$ measured between terminals T_1 and T_2 as C_a.

(d) Disconnect No. 2 from terminal T_1 and disconnect No. 1 from terminal T_2. Connect No. 2 to terminal T_2. Connect No. 1 with No. 3 and No. 4 to terminal T_1. Balance the circuit by adjusting C to a new value C_2. Designate this capacitance $(C_O - C_2)$ as C_b.

(e) Disconnect No. 3 from terminal T_1 and disconnect No. 2 from terminal T_2. Connect No. 3 to terminal T_2. Connect No. 1 with No. 2 and No. 4 to terminal T_1. Balance the circuit by adjusting C to a new value C_3. Designate this capacitance $(C_O - C_3)$ as C_c.

(f) Disconnect No. 1 and No. 2 from terminal T_1 and connect them with No. 3 to terminal T_2. Balance the circuit by adjusting C to a new value C_4. Designate this capacitance $(C_O - C_4)$ as C_d.

4.9.2.5.1 Calculation. Calculation shall be made as follows:

(a) The mutual capacitance (C_m) per foot for each shielded triad shall be determined by the formula:

$$C_m = \frac{3\ (C_a + C_b + C_c)\ -\ C_d}{12\ X\ (\text{length of specimen in feet})}$$

(b) The capacitance unbalance or coefficient of asymmetry (K) of a shielded triad, expressed in percent, shall be determined by the formula:

$$K_1 = \frac{200\ (C_a - C_b)}{(C_a + C_b)}$$

$$K_2 = \frac{200\ (C_a - C_c)}{(C_a + C_c)}$$

$$K_3 = \frac{200\ (C_b - C_c)}{(C_b + C_c)}$$

Where: K_1 = The percent of capacitance unbalance of conductor No. 1 in relation to conductor No. 2.
K_2 = The percent of capacitance unbalance of conductor No. 2 in relation to conductor No. 3.
K_3 = The percent of capacitance unbalance of conductor No. 3 in relation to conductor No. 1.

Note: In the formula, the relative positions of C_a, C_b and C_c may be transposed as necessary to avoid negative values.

4.9.2.6 Procedure (unshielded pairs). For unshielded pairs, the procedure shall be the same as given for shielded pair cables except the overall shield, if any, and all conductors of the specimen, except the pair under test shall be designated and treated as No. 3 when making measurements.

4.9.2.6.1 Calculations. The mutual capacitance (C_m) for each pair shall be determined by the formula as given for shielded pairs.

4.9.2.7 Procedure (unshielded triads). For unshielded triads the procedure shall be the same as for triads, except that the overall shield if any, and all conductors of the specimen outside of the triad under test, shall be designated and treated as No. 4 when making measurements.

4.9.2.7.1 Calculations. The mutual capacitance (C_m) and the capacitance unbalance (K) shall be determined by the formulas specified for shielded triads.

4.9.3 Characteristic impedance. The characteristic impedance for shielded singles or paired conductors shall be determined from the measured values of capacitance and the inductance.

4.9.3.1 Specimen. The specimen shall consist of a 10-foot 2-inch length of completed cable with all shields removed for a distance of 1 inch from each end and the insulation removed for a distance of 1/2 inch from each end of all conductors. The length of the specimen shall be the shielded length.

4.9.3.2 Procedure. Measurements for the capacitance shall be made first in accordance with the procedure given for the cable construction being tested. Measurements for determining the inductance shall be made as follows and on the same specimen used for determining the capacitance. (See 4.9.2).

4.9.3.2.1 Measurements for shielded pairs shall be made as follows:

(a) Connect terminal T_3 to T_4.

(b) Balance the circuit to resonance (maximum reading on the Q-meter) by adjusting C. Designate this reading of C as C_O.

(c) Disconnect terminal T_3 from T_4. Connect the two conductors of the pair under test together at the far end of the specimen. Connect conductor No. 1 to terminal T_3. Connect conductor No. 2 and the shield of the pair to terminal T_4. Balance the circuit by adjusting C to a new value C_1. Designate the change $(C_O - C_1)$ as dC.

4.9.3.2.2 Measurements for shielded singles shall be made as follows:

(a) Connect terminal T_3 to T_4.

(b) Balance the circuit to resonance (maximum reading on the Q-meter) by adjusting C. Designate this reading of C as C_O.

(c) Disconnect terminal T_3 from T_4. Connect the shield to the conductor under test at the far end of the specimen. Connect the conductor to terminal T_3 and connect the shield to terminal T_4. Balance the circuit by adjusting C to a new value C_1. Designate the change $(C_O - C_1)$ as dC.

4.9.3.2.3 Calculations. The inductance of the shielded pair or shielded single (L_p) may be determined by the formula:

$$L_p = \frac{dC}{W^2 C_O (C_O - dC)}$$

Where W = 2π times the frequency. If dC is 1 percent or less of C_O, the formula may be reduced to:

$$L_p = \frac{dC}{W^2 C_O{}^2}$$

The characteristic impedance of the shielded pair or shielded single (Z_O) may be determined by the formula:

$$Z_O = \sqrt{\frac{L_p}{Cp}}$$

4.9.4 Conductor resistance. Electrical resistance shall be determined on conductors of completed cable. The test procedure shall be in accordance with ASTM B193. The measured resistance shall be not greater than the value permitted by the specification sheet.

4.9.5 Insulation resistance. The insulation resistance shall be determined for conductor insulation and for cable or cord jackets, when required by the specification sheet.

4.9.5.1 Procedure. The test shall be performed on each length of completed cable or cord immediately following the voltage withstand test. The leakage current shall be measured after 1-minute electrification with a direct current potential of not less than 200 nor more than 500 volts. Multi-conductor cables or cords with unshielded conductors shall be tested between each conductor and all other conductors to overall shield, armor or water. Cables or cords having shielded groups, such as pairs and triads, shall be tested between each conductor and all other conductors in the group and to the group shield. Cables or cords with individually shielded conductors shall be tested between conductor and shield. For cables or cords having combinations of shielded and unshielded, groups or singles, the applicable procedure shall be used. Where cable or cord jackets have insulation resistance requirements, the test shall be made between the overall cable or cord shield and the water bath. The conductor or shield whose insulation is under test shall be connected to the negative terminal of the test equipment and readings shall be taken after 1-minute electrification.

4.9.5.2 Observation. The insulation resistance values at 15.5°C. shall be not less than required by the specification sheet. If the measurement is made at a temperature other than 15.5°C., the manufacturer shall correct the measured value to 15.5°C. If the insulation resistance is equal to or greater than that required, when the measurement is made at a temperature greater than 15.5°C., no correction factor need be employed. The manufacturer shall demonstrate that the correction factor used is accurate for his insulating compound.

4.9.6 Mutual inductance.

4.9.6.1 Specimen. The specimen shall consist of a 10-foot length of completed cable with the insulation removed for a distance of 1/2 inch from each end of all conductors. The braided copper shield shall be removed or pushed back to expose 1-1/2 inches of the twisted pair at both ends. The conductors of one end of each shielded pair shall be shorted.

4.9.6.2 Procedure. An approximate 1000-Hz current shall be circulated in the red and green conductors, then in the red and blue conductors, then in the green and blue conductors for MCOS-5, and in the yellow and green conductor for MCOS-6. The induced voltage appearing across the open end of each shielded pair shall be measured to an accuracy of 1 microvolt while the current is flowing.

4.9.6.3 Calculations. The mutual inductance in henries shall be determined as follows:

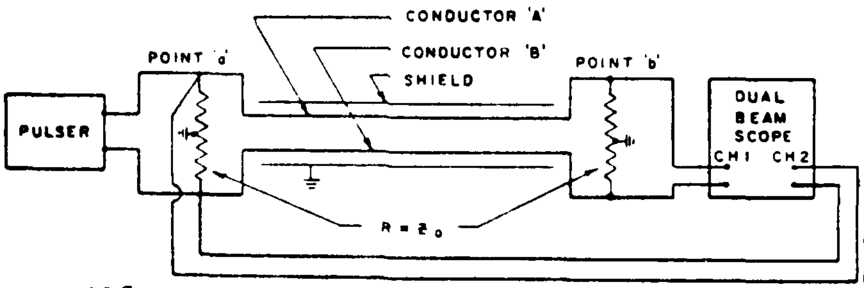
$$\text{Mutual inductance} = \frac{\text{Induced voltage (microvolts)}}{2\pi \times \text{frequency (Hz)} \times \text{current (amps)}}$$

Mutual

4.9.7 Pulse response time. The following procedure shall be used for the determination of the pulse response time:

(a) The test shall be performed on the reel length of a balanced cable circuit. The balanced condition can be achieved by several means:
(1) Employing balanced test equipment.
(2) Transformer - These must be good quality pulse transformers.
(3) Electronic balancing circuits or devices.

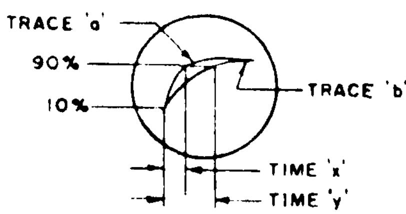
A dual beam oscilloscope of the fast rise type with a good band pass capability combined with a good quality square wave pulser connected as shown in schematic in figure 3 (simplified representative schematic).



SH 1423

Figure 3 - Pulse response circuit diagram.

(b) It is important that the generator output pulse width be of sufficient duration to permit trace "b" of figure 4 to reach its full amplitude before "cutoff" is reached. For this test a pulse duration of 2.0 micro-seconds will be used.
(1) Rise time determination. The dual beam oscilloscope should show a trace with the following characteristics:

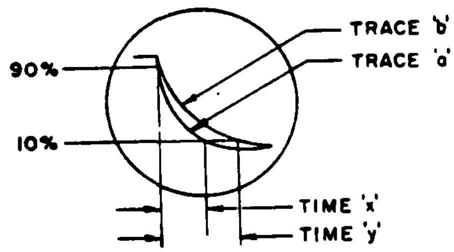


SH 1424

Figure 4 - Rise time.

Time "x" is the measurement of the arithmetic mean of the times of all parts (pulser, scope, test leads to point "a", and so forth) connected to the input end of the cable. Time interval "y" is the mean of time "x" combined with the cable's rise time. It is important that the length, composition, and characteristics of the connecting leads to the oscilloscope from points "a" and "b" be identical, and as short as possible. Now, with both traces on the same time base, and coincident at the 10 percent amplitude value, determine the time duration of trace "b" from the 10 percent to 90 percent amplitude. Call this time "y". Next, insert these values ("x" and "y") into the formula $t_r = \sqrt{y^2 - x^2}$ where t_r is the cable's rise time and "x" and "y" are the times previously determined.

(2) Decay time (see figure 5) may be determined as follows:



SH 8425

Figure 5 - Decay time.

Traces "a" and "b" are coincident at the 90 percent amplitude value. With the traces on the same time base, time interval "x" is the decay time mean as in the rise time determination, and time interval "y" is the mean of all decay times including that of the cable. As before, insert these values of "x" and "y" into the formula:

$$t_d = \sqrt{y^2 - x^2}$$

Where: t_d = the decay time of the cable: "x" and "y" are as previously described.

(c) If transformers or other balancing devices are used to provide the balanced condition, time "x" will have to be determined by reading the time of trace "b" in both cases with the cable out of the circuit, and the transformers or devices connected directly together, then time "y" will be determined as before with the cable inserted in the circuit. The difference between the traces "a" and "b" when the transformers or devices are connected directly together is the difference in the mean value of the rise and decay time caused by these items. One channel of the dual beam scope is connected at point (a) in this test to provided a reference for any possible change to the input pulse caused by the insertion of the cable.

(d) Insert the values found for the rise and decay times into the formulas:

$$t_r/500 = \frac{500\ t_r}{l}$$

$$t_d/500 = \frac{500\ t_d}{l}$$

to determine the rise or decay time for a 500 ft. length of cable.

Where: t_r = rise time determined for sample.

t_d = decay time determined for sample.

l = sample length in feet.

4.9.8 Voltage withstand. Voltage withstand tests shall be made on all lengths of completed cable or cord.

4.9.8.1 Apparatus. The voltage withstand tests shall be made with alternating potential from a source of ample capacity, but in no case less than 5 kilovolt-ampere, having a frequency not greater than 100 Hz and a wave shape approximately a sine wave under all test conditions. The testing voltage may be measured by any method satisfactory to NAVSEC, which gives a root-mean-square value. The preferable method is by means of a voltmeter connected to voltmeter coil in the high-tension winding of the testing transformer, or to a separate instrument transformer.

4.9.8.2 Procedure. The test voltages and application (conductor to ground, conductor to conductor, shield to shield, and so forth) shall be as required by the specification sheet. The time of application for all voltage withstand tests shall be 1 minute. The initially applied voltage shall be not greater than 600 volts. The rate of increase shall be approximately uniform and not over 100 percent in 10 seconds nor less than 100 percent in 60 seconds. All unarmored cables requiring electrical tests for the jacket shall be immersed in a grounded water bath for at least 1 hour, and tested while still immersed, using the water as the ground.

4.9.8.3 Observation. All cable shall withstand without failure the voltages specified on the specification sheet.

5. PREPARATION FOR DELIVERY

(The preparation for delivery requirements specified herein apply only for direct Government procurements. For the extent of applicability of the preparation for delivery requirements of referenced documents listed in section 2, see 6.6.)

5.1 All cables covered by this specification shall be shipped on reels, unless otherwise specified on the specification sheet.

5.1.1 Reels. Reels shall be of a design, strongly constructed, with flanges of sufficient diameter to protect the cable from injury during handling and storage. Where the gross weight of cable and reel exceed 1000 pounds, the reels shall have metal hubs. The diameter of the drum shall be not less than 14 times the overall diameter of the cable.

5.1.1.1 Placement of cable on the reel. The cable on each reel shall have both ends readily available for testing without re-reeling. The inner end shall extend through a hole in the flange near the drum, and the outer end shall be available at the top of the reel. Both ends of the cable shall be secured to the reel flange with 1/4-inch rope, applied with two half-hitches, one 6 inches and the other 4 inches (approximately) back of the end seal, then twisting the rope ends together, knotting them, pulling the cable up tight and stapling the rope to the flange with at least two 1-1/2 inch staples driven into the flange. The inner end which extends through the flange hole shall be protected by a metal end cover.

5.1.1.2 Lagging. Lagging shall be used on reels having flange diameters of 42 inches and larger and on all reels which contain 1000 pounds or more of cable. Reels smaller than 42 inches in diameter which contain less than 1000 pounds of cable may be covered in accordance with 5.1.1.3. Lagging boards shall have a thickness equal to the thickness of the reel flange but not greater than 2-inch commercial lumber. Lagging for all reels shall extend to within 1/4-inch of the outside of the flanges. All lagging boards shall be installed so that they are touching adjacent boards. All lagging which rests entirely on the rim of the flange shall be nailed with cement-coated nails. Lagging which is notched and recessed may be secured by the use of strapping only. In addition to nailed lagging or for notched and recessed lagging on reels of cable weighing 1000 pounds or more and having a flange diameter less than 78 inches , two 0.162 $\pm$0.003-inch (8-gage) high-tensile round steel wires or two 3/4 by 0.035-inch steel straps shall be used. For all reels having a flange diameter of 78 inches or more two 1-1/4 by 0.035-inch steel straps shall be used. In addition to nailed lagging or for notched and recessed lagging on reels of cable weighing less than 1000 pounds, two 0.0915 $\pm$0.003-inch (13-gage) high-tensile round steel wires or two 5/8 by 0.020-inch steel straps shall be used. All straps shall be stapled at approximately 15-inch intervals. A minimum clearance of 2 inches shall be provided between inner face of lagging and outer layer of cable.

5.1.1.3 Alternate to lagging. As an alternate to lagging for reels having a flange diameter smaller than 42 inches and containing less than 1000 pounds of cable, a covering may be used which consists of the following:

(a) A cushioning inner layer of asphalt-impregnated, corrugated, fiberboard, or the equivalent, wrapped to give 100-percent coverage.
(b) An outer covering consisting of two layers of weather-resistant veneer paper conforming to PPP-V-205 or two layers of three-ply weather-resistant toxic-

treated plywood wrapped to give 100-percent coverage.

This covering shall be secured in place between the reel flanges by at least two 3/8 by 0.020-inch steel straps.

5.1.1.4 Yearly marking. In addition to any other required marking, reels shall be marked with a keyed series of colors to indicate the year of manufacture. The cycle of colors shall be repeated every fifth year. The reel marking shall consist of a stripe approximately 2 inches wide, colored to designate the particular year of manufacture as follows:

Year of manufacture		Identifying color
1971	1976	Red
1972	1977	Green
1973	1978	Orange
1974	1979	Blue
1975	1980	White

5.1.1.4.1 Location of yearly marking. The colored stripe on reels shall be applied circumferentially over the lagging or the alternate to lagging and midway between the flanges. The stripe shall consist of one coat of commercial quality outside paint of the appropriate color. In addition to the stripe, both flanges of the reel shall be stenciled with 4-inch high figures to show the year of manufacture.

5.1.1.5 Standard reel markings. Each reel shall be plainly marked on both flanges with the following information:

(a) Reel number.
(b) Type and size of cable.
(c) Footage.
(d) Contract or order number.
(e) Contractor's name.
(f) Manufacturer's name (if other than contractor).
(g) Gross weight.

5.1.2 Coils. Coils shall contain one continuous length of cable or cord (standard length, see table XVI).

5.1.2.1 Yearly marking. In addition to any other required marking, coils shall be marked with a keyed series of colors to indicate the year of manufacture. This marking shall consist of a stripe approximately 2-inches wide and colored for the particular year of manufacture. The cycle of colors shall be the same as those used for yearly marking of reels (see 5.1.1.4).

5.1.2.2 Identification. Two shipping tags shall be securely attached to each coil, both inside and outside the wrapping, and marked with the following information:

(a) Type and size of cable or cord.
(b) Footage.
(c) Contract or order number
(d) Contractor's name.
(e) Manufacturer's name (if other than contractor).
(f) Gross weight.

5.2 Packaging and packing. Cable and cord as specified (see 6.2) shall be packaged and packed level A, B, or C in accordance with MIL-C-12000, as specified (see 6.2). Marking shall be in accordance with MIL-C-12000 and with the requirements of any special marking specified herein or as specified (see 6.2).

6. NOTES

6.1 Intended use. Cables and cords specified herein are intended for use in various application involving naval ships and shore stations.

6.2 Ordering data. Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Type and size of cable or cord required with reference to applicable specification sheet.

(c) Quantity required
(d) Level of packaging and packing required (see 5.2).
(e) Special marking required (see 5.2).

6.2.1 Quantity. The quantity of each type and size on a contract or order should be specified as an integral multiple of the unit ordering length shown by the specification sheet.

6.2.2 Lengths. The range of standard, random, remnant and scrap lengths for each nominal length is shown in table XVI. In order to compensate for handling and probable loss on issue, remnant lengths are subject to the price reductions given in table XVI. Scrap lengths are not acceptable. It is not intended that items being procured in exact lengths for a specific job or ship shall necessarily be shipped in lengths which are integral multiples of the unit ordering length or that price reductions shall apply in the event that exact footages or fractional lengths are required and so indicated in procurement of cable or cord for other than stock purposes.

Table XVI - Cable or cord lengths.

Type of package	Nominal length (feet)	Standard lengths: No price reduction (feet)	Random lengths: No price reduction (feet)	Remnant lengths: Price reduction 5 percent (feet)	Remnant lengths: Price reduction 10 percent (feet)	Scrap lengths: Not acceptable (feet)
Coil	500	550 to 450	449 to 150	149 to 100	99 to 50	49 to 0
Coil	600	660 to 540	539 to 180	179 to 120	119 to 60	59 to 0
Reel	500	550 to 450	449 to 150	149 to 100	99 to 50	49 to 0
Reel	800	880 to 720	719 to 240	239 to 160	159 to 80	79 to 0
Reel	1000	1100 to 900	899 to 300	299 to 200	199 to 100	99 to 0
Reel	1500	1650 to 1350	1349 to 450	449 to 300	299 to 150	149 to 0
Reel	2000	2200 to 1800	1799 to 600	599 to 400	399 to 200	199 to 0
Reel	2500	2750 to 2250	2249 to 750	749 to 500	499 to 250	249 to 0
Reel	3000	3300 to 2700	2699 to 900	899 to 600	599 to 300	299 to 0

6.3 Special clause. Except when small quantities are to be purchased, invitations for bid and contracts or orders should specify the following:

"In order to compensate for handling and probable loss on issue, remnant lengths shall be subject to the price reductions shown in table XVI. In order that the number of lengths be kept to a minimum consistent with good manufacturing practices, for each type and size of cable or cord on the contract or order, not less than 70 percent of the total footage to be shipped shall be in standard lengths, and not more than 30 percent may be in any combination of random and remnant lengths. When the total quantity of any one item is six nominal lengths or less, a footage approximately two nominal lengths (in lieu of 30 percent) may be in any combination of random and remnant lengths. When the total quantity of any one item is two nominal lengths or less, the total footage may be in any combination of random lengths."

6.4 Time delay. Comparison inspection will normally require 40 calendar days from the date the sample is sent to the Government-designated laboratory to the date the inspection results are received by the manufacturer. This time delay should be taken into consideration by a supplier when estimating delivery time.

6.5 With respect to products requiring qualification, awards will be made only for products which are at the time set for opening of bids, qualified for inclusion in applicable Qualified Products List QPL-915 whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Naval Ship Engineering Center, Prince George's Center, Center Building, Hyattsville, Maryland 20782, and information pertaining to qualification of products may be obtained from that activity. Application for Qualification tests shall be made in accordance with 6.5.1 and "Provisions Governing Qualification SD-6" (see 6.5.2).

6.5.1 Application for qualification. The application shall provide the following information:

(a) Company name and business address. Also address of manufacturing facility if different from business address.
(b) The type and size designations of the cables or cords for which qualification approval is being sought.
(c) A details of construction sheet covering each type of cable or cord for which qualification approval is being sought. This details of construction shall show all materials by manufacturer's name and part number which the cable or cord manufacturer proposes to use in the construction of his product.
(d) If the company proposes to have the qualification testing performed at a laboratory other than his own, the name and address of the laboratory.

6.5.2 Copies of "Provisions Governing Qualification SD-6" may be obtained upon application to Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

6.6 Sub-contracted material and parts. The preparation for delivery requirements of referenced documents listed in Section 2 do not apply when material is procured by the supplier for incorporation into the cable or cord and loses separate identity when the cable or cord is shipped.

6.7 Supersession data. This specification supersedes Specifications MIL-C-00915D(SHIPS), MIL-C-915C of 15 March 1960, MIL-C-2194E(SHIPS) of 31 January 1968, MIL-C-23206(SHIPS) of 23 February 1962 and MIL-C-24145A(SHIPS) of 16 October 1967.

6.7.1 New types and obsoleted types. All detail specifications covered by the specifications in 6.7 are listed in table XVII both by type designation and by detail specification number. Table XVII also lists (a) new type designations for cables for which a design change has been made, and a remark on the nature of the design change: (b) the replacement types, for cable types which have been obsoleted.

Table XVII - Supersession data

Previous type and detail specification number		Present type and applicable MIL-C-915 Specification sheet number	Remarks
CVSF	MIL-C-915/1	CVSF ----- /1	No change
DBSP	/2	2SJ ----- /60	DBSP obsolete
DCOP	/3	DCOP----- /3	No change
DHFR	/4	DRW ----- /73	DHFR obsolete
DHOF	/6	DHOF----- /6	No change
DLT	MIL-C-915/5	DLT ----- /5	No change
DPS	MIL-C-23206/3	DPS ----- /40	No change
DSGA	MIL-C-2194/2	DSGU ---- /29	Armor eliminated
DSS	MIL-C-915/8	DSS ----- /8	No change
DSWS	/7	DSWS ---- /7	No change
ECM	MIL-C-24145/14	ECM ----- /54	No change
FBSP	MIL-C-915/2	4SJ ----- /60	FBSP obsolete
FHOF	/6	FHOF ---- /6	No change
FPS	MIL-C 23206/3	FPS ----- /40	No change
FSGA	MIL-C-2194/4	FSGU ---- /31	Armor eliminated
FSS	MIL-C-915/8	FSS ----- /8	No change
JAS	/9	JAS ----- /9	No change
MA	MIL-C-24145/3	MU ------ /43	Armor eliminated
MCOS	MIL-C-915/11	MCOS ---- /11	No change
MCSF	/10	MCSF ---- /10	No change

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Table XVII - Supersession data (cont'd).

Previous type and detail specification number		Present type and applicable MIL-C-915 specification sheet number	Remarks
MDU	MIL-C-915/12	MDU ----- /12	No change
MDY	/13	MDU ----- /12	MDY obsolete
MHOF	/14	MHOF ---- /14	No change
MMOP	/15	MMOP ---- /15	No change
MRI	/16	MRI ----- /16	No change
MS	MIL-C-24145/10	MS ------ /50	No change
MSCA	MIL-C-2194/5	MSCU ---- /32	Armor eliminated
MWF	MIL-C-24145/18	MWF ----- /58	No change
PBTM	MIL-C-915/17	PBTMU --- /17	Armor eliminated
PI	MIL-C-23206/2	PI ------/39	Improved design
SHFR	MIL-C-915/4	SRW ----- /73	SHFR obsolete
SHOF	/6	SHOF ---- /6	No change
SSF	/18	SSF ----- /18	No change
SSGA	MIL-C-2194/1	SSCU ---- /28	Armor eliminated
SS5P	MIL-C-2194/7	None	SS5P obsolete
S2S	MIL-C-24145/21	S2S ----- /61	No change
TBSP	MIL-C-915/2	3SJ ----- /60	TBSP obsolete
TCJA	MIL-C-2194/10	TCJU ---- /35	Armor eliminated
TCJX	MIL-C-23206/1	TCJX ---- /38	No change
TCKX	/1	TCKX ---- /38	No change
TCOP	MIL-C-915/3	TCOP ---- /3	No change
TCTA	MIL-C-2194/10	TCTU ---- /35	Armor eliminated
TCTX	MIL-C-23206/1	TCTX ---- /38	No change
THFR	MIL-C-915/4	TRW ----- /73	THFR obsolete
THOF	/6	THOF ---- /6	No change
TPS	MIL-C-23206/3	TPS ----- /40	No change
TPU	MIL-C-915/19	TPU ----- /19	No change
TRF	/20	TRF ----- /20	No change
TRXF	/21	TRXF ---- /21	No change
TSGA	MIL-C-2194/3	TSGU ---- /30	Armor eliminated
TSP	MIL-C-915/22	TSP ----- /22	No change
TSS	MIL-C-915/8	TSS -----/8	No change
TTHFWA	/23	TTSU --- /37	TTHFWA obsolete
TTOP	/24	TTOP ----/24	No change
TTRS	/25	TTRS ----/25	No change
TTRSA	/26	TTRS ----/25	TTRSA obsolete
TTSA	MIL-C-2194/12	TTSU ----/37	Armor eliminated
1SA	MIL-C-24145/17	1SAU ----/57	Armor eliminated
1SMWA	/27	1SMWU ---/65	Armor eliminated
1S50MA	/2	1S50MU --/42	Armor eliminated
1S75MA	/15	1S75MU --/55	Armor eliminated
1SMU	MIL-C-24145/16	1SMU ----/56	No change
1SU	/19	1SU -----/59	No change
1SWA	/4	1SWU ----/44	Armor eliminated
1SWF	/7	1SWF ----/47	No change

Table XVII - Supersession data (Cont'd).

Previous type and detail specification number		Present type and applicable MIL-C-915 specification sheet number	Remarks
1SMU	MIL-C-24145/16	1SMU ----/56	No change
1SU	/15	1SU -----/59	No change
1SWA	/4	1SWU ----/44	Armor eliminated
1SWF	/7	1SWF ----/47	No change
2A	/1	2AU -----/41	Armor eliminated
2SA	MIL-C-24145/5	2SU -----/45	Armor eliminated
2SJ	/20	2SJ -----/60	No change
2SWA	/6	2SWAU ---/46	Armor eliminated
2SWF	/8	2SWF ----/48	No change
2SWU	/9	2SWU ----/49	No change
2U	MIL-C-24145/23	2U ------/63	No change
2WA	/24	2WAU ----/64	Armor eliminated
3SA	/11	3SU -----/51	Armor eliminated
3SF	/22	3SF -----/62	No change
3SJ	/20	3SJ -----/60	No change
3SWA	MIL-C-24145/12	3SWU ----/52	Armor eliminated
3U	/13	3U ------/53	No change
4SJ	/20	4SJ -----/60	No change
5KVTSGA	MIL-C-2194/11	5KVTSGU--/36	Armor eliminated
6SGA	MIL-C-2194/6	6SGU ----/33	Armor eliminated
7PS	MIL-C-23206/3	7PS -----/40	No change
7SGA	MIL-C-2194/9	7SGU ----/34	Armor eliminated
7SS	MIL-C-915/8	7SS -----/8	No change
		DNW -----/68	New type
		FNW -----/70	New type
		MNW -----/71	New type
		MSP -----/67	New type
		MSPW ----/66	New type
		TNW -----/69	New type
		TPNW ----/72	New type
		5SS -----/74	New type

6.8 THE MARGINS OF THIS SPECIFICATION ARE MARKED "#" TO INDICATE WHERE CHANGES (ADDITIONS, MODIFICATIONS, CORRECTIONS, DELETIONS) FROM THE PREVIOUS ISSUE WERE MADE. THIS WAS DONE AS A CONVENIENCE ONLY AND THE GOVERNMENT ASSUMES NO LIABILITY WHATSOEVER FOR ANY INACCURACIES IN THESE NOTATIONS. BIDDERS AND CONTRACTORS ARE CAUTIONED TO EVALUATE THE REQUIREMENTS OF THIS DOCUMENT BASED ON THE ENTIRE CONTENT IRRESPECTIVE OF THE MARGINAL NOTATIONS AND RELATIONSHIP TO THE LAST PREVIOUS ISSUE.

Custodians:
Army - MI
Navy - SH
Air Force - 80

Review activities:
Army - EL, MI, AV
Navy - EC
Air Force - 80

User activities:
Army - ME, MU, WC
Navy - CG

Preparing activity:
Navy - SH
(Project 6145-0609)

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APPENDIX C

Letter Forwarded To Personnel For Comment

GENERAL DYNAMICS
Electric Boat Division
Eastern Point Road, Groton, Connecticut 06340 • 203 446-5960

August 19, 1981

The Electric Boat Division of GENERAL DYNAMICS Corporation, has been tasked by the Naval Research Laboratory, NRL, Orlando, Florida, to review and recommend revising where necessary the pressure-proof outboard cable specifications used on submarine and surface ship sonar systems. This work is being accomplished under the sponsorship of the Submarine Transducer Reliability Improvement Program (STRIP) which is managed by Dr. R. Timme, NRL/Florida, for the Naval Sea Systems Center Sonar Branch (SEA 63X5), Washington, D.C.

Table 1 is a listing of MIL-C-915 outboard cables that have or are being used on submarine and surface ship sonar systems.

Your positive or negative comments regarding the adequacy of these cables in meeting the electrical, mechanical, environmental, fabrication, installation, and maintenance requirements of existing and near future Navy Sonar Systems would be greatly appreciated. Table 2 is a listing of most cable design and test areas for which comments can be made.

Comments are being solicited from sonar system manufacturers, cable manufacturers, Navy Transducer Repair Facilities, Navy laboratories, Naval Ship System Center engineers, and Private and Naval Shipyards.

Your written or telecon comments would be appreciated prior to September 30, 1981.

Very truly yours,

GENERAL DYNAMICS
Electric Boat Division

R.F. Haworth
(203) 446-2825

TABLE 1

MIL-C-915 Outboard Cables Used on Sonar Systems

Cable Type	Military Specification
DSS-2	MIL-C-915/8
DSS-3	
DSS-4	
FSS-2	
FSS-4	
7SS-2	
2SWF-3	MIL-C-915/48
2SWF-4	
2SWF-7	
1SWF-2	MIL-C-915/47
S2S	MIL-C-915/61
DSWS-4	MIL-C-915/7
TSP-11	MIL-C-915/22
TSP-31	

PLEASE COMMENT ON THE FOLLOWING CABLE DESIGN AND TEST CONSIDERATIONS AS TO THE ADEQUACY OF THE CABLES IN TABLE 1 AND RECOMMEND CHANGES TO THE SPECIFICATION TO IMPROVE THEIR ADEQUACY.

TABLE 2

Cable Design and Test Considerations

Cable Design	Remarks
Number of conductor strands	
Conductor size	
Conductor lay length	
Strand sealant	
Interstices sealant	
Insulation thickness, conductor	
Jacket thickness	
Requirement for shield	
Shield insulation thickness	
Binder thickness	
Fillers	
Cable bend radius	
Materials of Construction	
Conductor	
Insulation, conductor	
Fillers	
Binders	
Shield	
Cable jacket	
Shield insulation	
Strand sealant	
Other	

TABLE 2

(Cont'd)

Testing	Remarks
Insulation resistance	
Voltage withstand	
Attenuation	
Mutual capacitance	
Capacitance unbalance	
Characteristic impedance	
External watertightness	
Internal watertightness	
Visual	
Dimensional	
Cold working	
Drip	
Cable filler removability	
Permanence of printing (jacket)	
Permanence of printing (conductor)	
Bending endurance	
Pressure cycling-hydrostatic	
Breaking strength	
Cable jacket bondability	
Maximum boot molding temperature	
Conductor installation	
Tensile strength, elongation	
Cable jacket	
Tensile strength, elongation, set	
Abrasion resistance	
Jacket water permeability	
Other	

APPENDIX D

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