2025 NSRP Panel Project 2019-477-007:
SHIPBOARD FIBER OPTIC CABLES JACKET ENHANCEMENTS

ELECTRICAL TECHNOLOGIES PANEL MEETING

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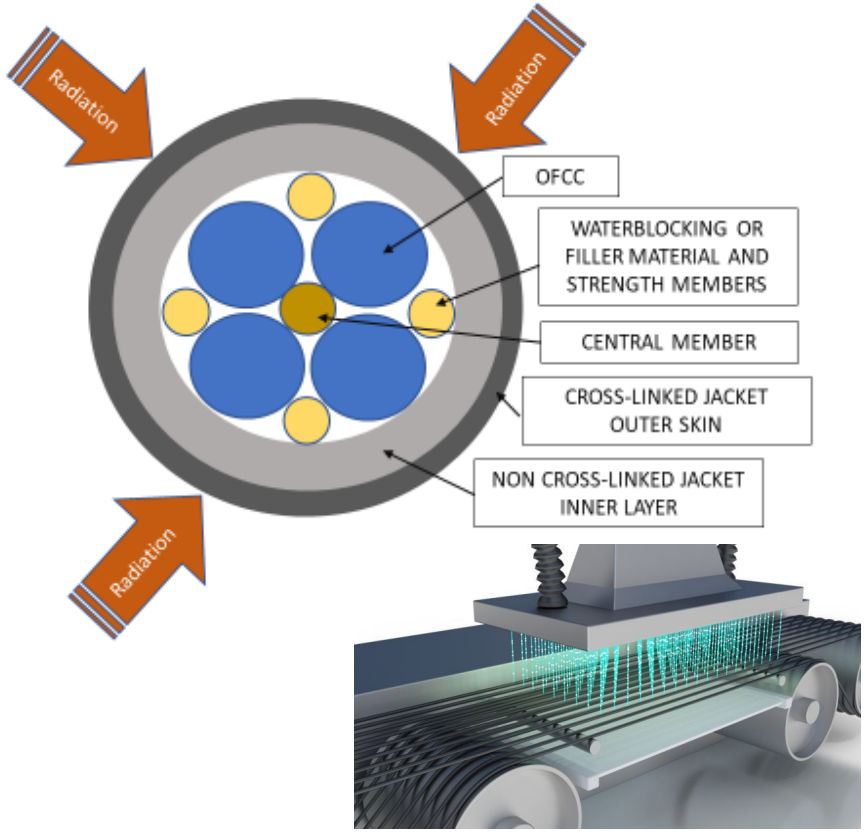
BACKGROUND

- 7,800,000 feet (2,377 Km) of fiber optic cables used annually on new constructions[(1)].
- Optical fibers usage increasing for multiple applications:
  - High density fiber cable designs, up to 432 fibers
  - Distributed sensing systems
  - Remote source lighting included in new MIL-STD-x743 lighting document
  - Power over fiber for Non-Electric Topside
  - Optical power delivery for laser weapons
- M85045 shipboard fiber optic cable jacketing requirements evolved in the early 1990's from MIL-C-24643 electrical power cables' specifications.
  - Power cables' conductors generate heat. Optical fibers do not.
- LSZH Thermoplastic materials available in the 1990's were significantly inferior to Thermoset materials.
  - Shipyards were purchasing Thermoset cables exclusively.
  - M85045 Thermoplastic cable specifications (/13 and /15) were inactivated.
- M85045 shipboard fluid immersion requirements limit jacket selection to Crosslinked / Thermoset materials.
  - Fuel Oil 24 hrs. @ 98-100°C, Lubricating Oil 24 hrs. @ 98-100°C

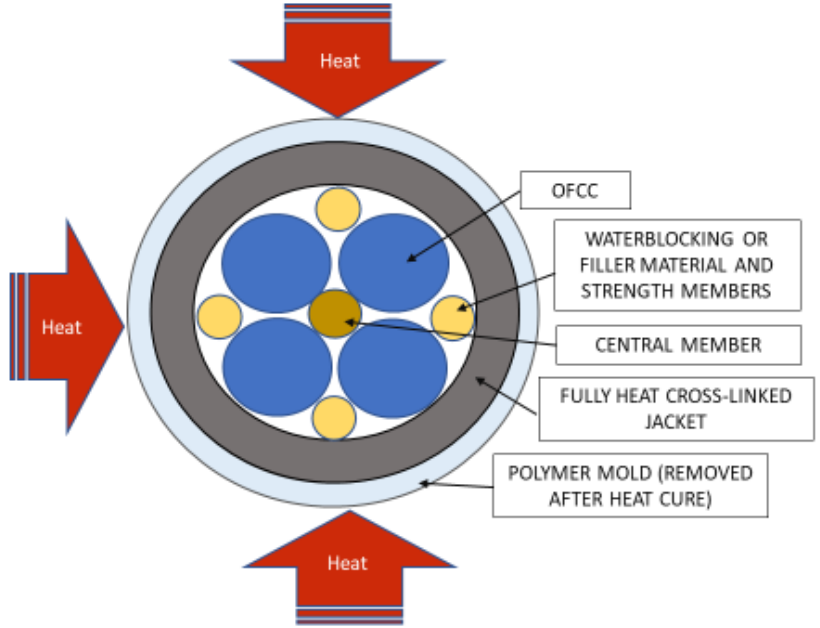
(1) 2019 estimated usage

BACKGROUND - CABLE JACKET CROSS LINKING METHODS



Irradiation x-linking

- Jacketed cable exposed to electron beam.
- May not fully penetrate jacket thickness.
- Affects fiber attenuation.
- Requires recovery period of up to 30 days.
- Irradiation effects limit the fiber selection.



Heat Activated x-linking (Mold Curing)

- Polymer "mold" is applied in co-extrusion process with outer jacket.
- Entire cable is placed in oven for jacket curing.
- Polymer mold is removed after cure process.
- Cure temperature may exceed inner components' max. operating temperature.
- Heat process limits the materials that can be used for the inner components.

MIL-PRF-85045 SHIPBOARD FLUID IMMERSION REQUIREMENTS

- Temperatures used for the fluid immersion tests derived from MIL-C-24643 shipboard power cable requirements.

Fluid	Temperature	% T&E Retention
Fuel Oil	98°C – 100°C	≥ 50%
Turbine Fuel	48°C – 50°C	≥ 50%
Lubricating Oil	98°C – 100°C	≥ 50%

- In power cables the **flow of current** causes the electrical conductors to heat the jacket above ambient temperature.
- In **overcurrent conditions, the outer jacket can exceed 100°C**. If immersed in fluids, the conductors will continue to keep the jacket at the high temperatures and contribute to heating the leaked fluid.
- **Optical fibers do not generate heat**. In the case of a leaked fluid, the fluid will reach ambient temperature in a short time, not exposing the jacket of fiber cables to the same temperatures as power cables.

PROJECT 1 HISTORY - 2019 SHIPBOARD FIBER OPTIC CABLES DESIGN ENHANCEMENTS

(Panel Project 2019-477-001)

OBJECTIVE: Identify ways to reduce cable damage / rework by improving the cable design.

PROJECT FINDINGS

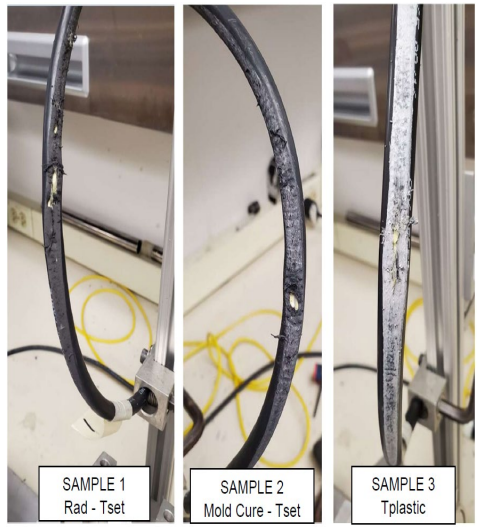
- Baseline cable designs are suited for shipboard environment.
- Most of rework is caused by **on-ship fiber terminations**.
- M85045 cables' buffers were more difficult to strip than similar commercial buffers.
- **Jacket abrasion** described as a cause of damage at installation.
  - MIL-STD-1678-3 Scrape Abrasion test (750 cycles, 1 lb. weight) may not represent conditions encountered at installation.
- **Resistance to hot fluids (98-100°C) ranked lowest priority** by project participants.

Fluid	Temperature	% T&E Retention
Fuel Oil	98°C – 100°C	≥ 50%
Turbine Fuel	48°C – 50°C	≥ 50%
Lubricating Oil	98°C – 100°C	≥ 50%

PROJECT FINDINGS – CABLE JACKETS

- Thermoplastic jacket outperformed thermoset jackets in modified scrape abrasion resistance test (10 lbs. weight vs. 1 lb. weight).

Type	Jacket Type	Cable Outer Dia. (mm)	Avg. Wall Thick. (mm)	Results (Scrapes to Failure per mm thickness)
M85045/18	Tset (Radiation)	8.0	1.165	**40%**
M85045/18	Tset (Mold Cure)	8.2	1.39	**94%**
RSL 118052	Tplastic	10.2	1.77	**100%**



RECOMMENDED IMPROVEMENTS

- More strippable buffer.
- Fusion splice pre-terminated connectors vs. field terminations.
- **More durable outer jacket materials for improved resistance to abrasion/cut-through.**

PROJECT 2 HISTORY – 2023 SHIPBOARD FO CABLES JACKETS ENHANCEMENTS PROJECT
(Panel Project 2019-477-003)

OBJECTIVE

1. Identify new jacketing materials:
    a. Enhance performance.
    b. Decrease manufacturing cost.
    c. Increase the potential sources of supply.
    d. Increase cable design options.
    e. Lower TOC of fiber optic systems.
2. Recommend enhancements that:
    a. Improve the resilience of all shipboard fiber optic cables.
    b. Can be used to create new M85045 sheets.

METHODOLOGY

1. Down-select Low Smoke, Zero Halogen thermoplastic compounds by testing slabs on modified abrasion test set-up.
2. Apply top 3 compounds over dummy cable core.
3. Obtain samples of M85045 shipboard cables from shipyard partners.
4. Perform modified MIL-STD-1678-3 scrape abrasion test on:
    i. New Thermoplastics over dummy core.
    ii. M85045 shipboard cables.
    iii. Samples of commercial marine cables.

PROJECT 2 HISTORY – 2023 SHIPBOARD FO CABLES JACKETS ENHANCEMENTS PROJECT

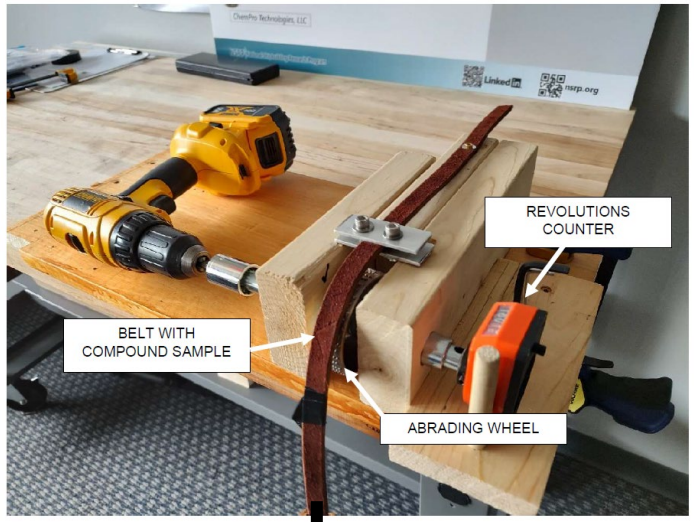
(Panel Project 2019-477-003)

TEST SET-UP

SCRAPE ABRASION TEST ON STRIPS

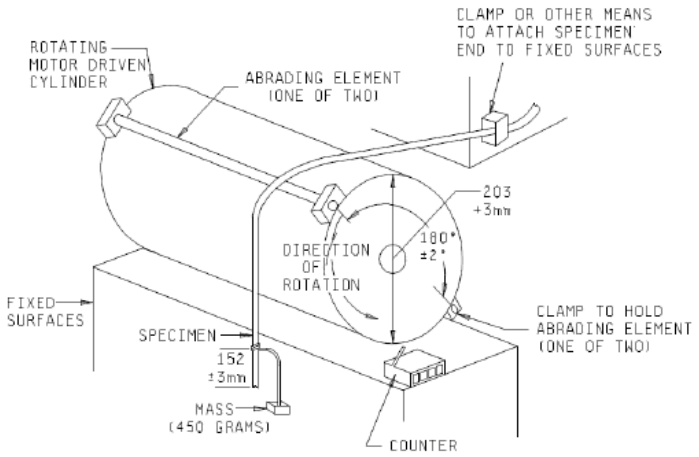
Abrading blade (2 @ 180°)

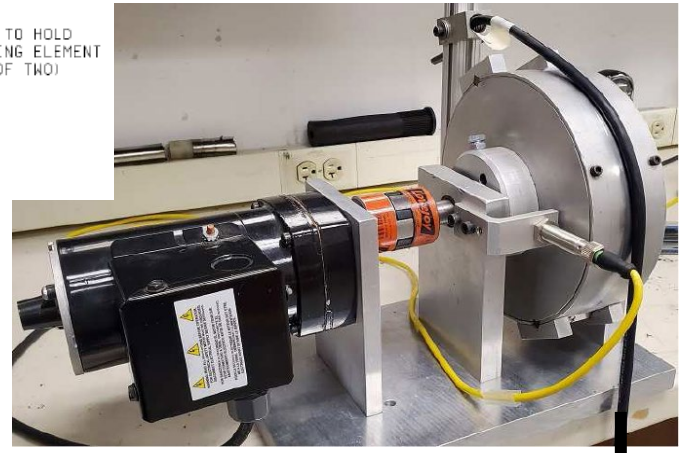
3 in. dia. Abrading Wheel



5 lbs. Weight on Sample

SCRAPE ABRASION TEST ON CABLES





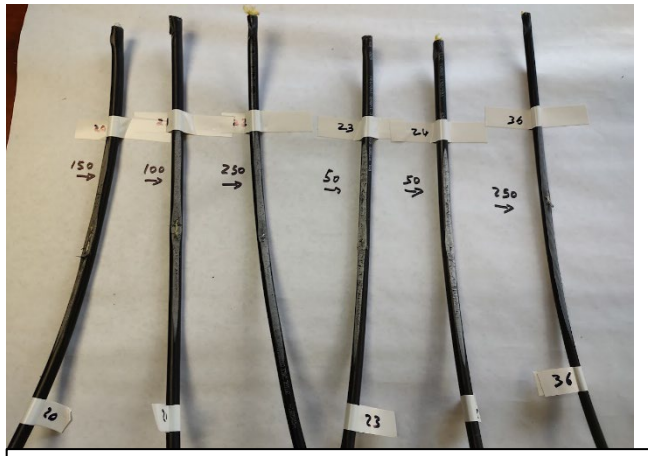
10 lbs. Weight on Sample

PROJECT 2 HISTORY – 2023 SHIPBOARD FO CABLES JACKETS ENHANCEMENTS PROJECT

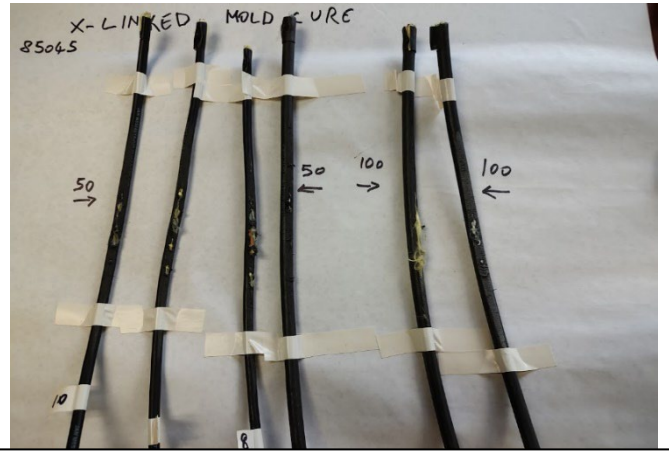
(Panel Project 2019-477-003)

MODIFIED SCRAPE ABRASION TEST RESULTS

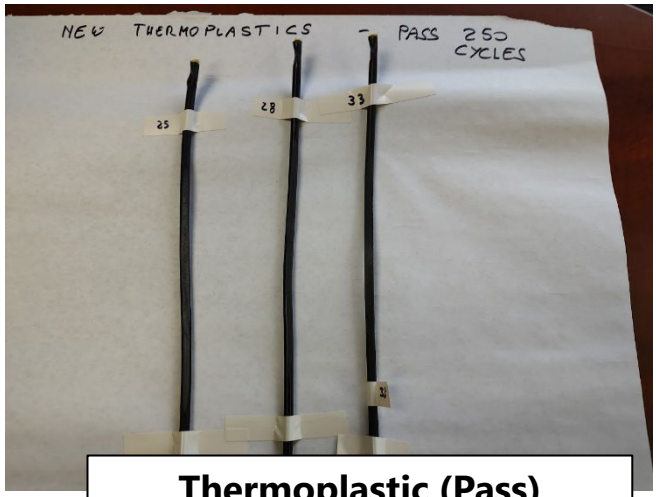
Thermoset Irrad X-Link (Fail @ 50 Cycles)



Thermoplastic (Fail @ 50 to 250 Cycles)



Thermoset Mold Cure X-Link (Fail @ 50 to 100 Cycles)



Thermoplastic (Pass)

PROJECT 2 HISTORY – 2023 SHIPBOARD FO CABLES JACKETS ENHANCEMENTS PROJECT
(Panel Project 2019-477-003)

OBSERVATIONS

1. All M85045 cables with the thermoset (crosslinked) jacket using **Electron Beam Irradiation failed before 50 scrape abrasion cycles**.

2. M85045 cables with thermoset **Mold Cure method performed better than irradiated cables** but most **failed after 50 cycles**. M85045/17 (8F) provided marginally more protection to 100 cycles.

3. **Thermoplastic LSZH generally outperformed the M85045 cables.**

4. **The ABS marine shipboard** had only minimal core exposed after **250 cycles**.

5. **Three (3) compounds passed 250 scrape abrasion cycles with ½ to ¾ wear**.

CONCLUSIONS:

a. New LSZH thermoplastics may improve the resiliency of shipboard cables used on Navy ships.

b. Additional testing required to confirm the compounds' suitability to shipboard use.

PROJECT 3 - 2025 SHIPBOARD FO CABLES JACKET PERFORMANCE ENHANCEMENTS
(Panel Project 2019-477-007)

OBJECTIVE

1. Identify jacketing material(s) that will **enhance the resilience of all fiber optic cables** used on naval vessels for multiple applications.
2. **Recommend** the creation of an **ENHANCED PERFORMANCE(1)** version of MIL-PRF-85045 documents with the following:
    a. **MIL-STD-1678-3 Cable Scrape Abrasion Test with 10.0 lbs. weight vs. 1.0 lb.** and 250 cycles to ensure the highest level of abrasion resistance.
    b. **Reduced(2) immersion temperature in Fuel Oil and Lubricating Oil from 100°C to 70°C.** This will preserve the resistance to fluids that may compromise the cable integrity, better reflect actual conditions that may be encountered on a naval vessel and allow the use of new LSZH thermoplastic materials.

(1) ENHANCED PERFORMANCE:
a. > 5X Enhancement in Scrape Abrasion Resistance
b. 30% Decrease in Fluid Immersion Temperature

TASKS

TASK 1: Down select one (1) or two (2) LSZH compounds identified under PP 2019-477-003.

- Select compound(s) providing high level of confidence based on previous use in similar applications.
- Avoid use of developmental compounds to reduce risk.

TASK 2: Identify tests in the M85045 documents to evaluate the performance of the cable(s) built with the compound(s) selected.

TASK 3: Manufacture length(s) of fiber optic cable(s) to M85045 designs.

TASK 4: Perform the tests at a Nationally Recognized Testing Laboratory (NRTL) and at the cable manufacturer's certified testing laboratory.

- Provide samples to shipyards for hands-on feedback.

TASK 5: Report with test results and with recommendations for an enhanced version of the M85045 shipboard cable specifications.

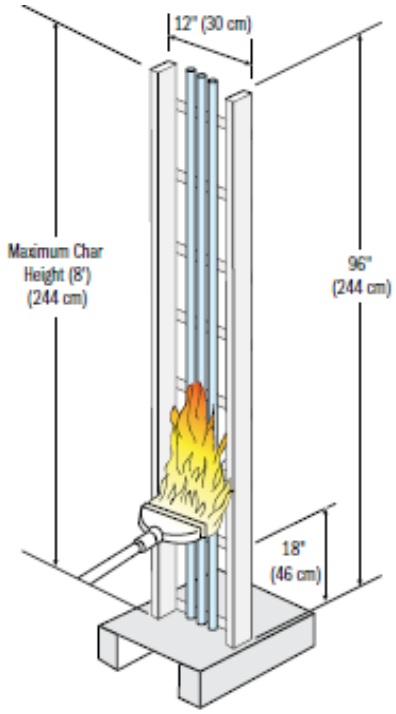
TASK 1 – SELECT COMPOUND(S) FOR TASK 3

BASELINE REQUIREMENTS

TEST DESCRIPTION	Test Std	Requirements (M85045)
Flame Test - Flame Travel (inches)	IEEE 383	96 (Max)
Flame Test - Smoke (Total/MRR)		95/0.25
Smoke Index - Jacket	NES 711	25 (Max)
Acid Gas Equivalent - Complete cable (%)	M85045 4.8.1	2.0 (Max)
Toxicity Index	NES 713	5.0 (Max)
Halogen Content (%)	M85045 4.8.2	0.2 (Max)

DESCRIPTION	Min. Req.
Fuel Oil 4 hrs. @ 70 °C	≥ 50% T&E Retention
Tensile Strength(*)	≥ 1500 PSI
Elongation(*)	≥ 150%
Low Temp. Brittle Point	< -40 °C

(*) Exceed M85045 requirements



Vertical Tray Flame Test (UL-1685 / IEEE 383)

TASK 1 – COMPOUNDS SELECTION

TOP 3 COMPOUNDS

Compound	UL 94	Tensile (psi)	Elong. (%)	Low Temp Brittle Point (°C)	O2 Index (%)	Acid gas (%)	Oil (IRM 902) 4 hrs @ 70°C		Diesel 24 hrs @ 25°C	
							Tensile Ret (%)	Elong Ret (%)	Tensile Ret (%)	Elong Ret (%)
Gendon OH-2-BK 2289	V-0	1800	230	-44	39	0.2	70	96	77*	98*
Celanese Hytrel HTR 8813 BK320	V-0	1827	190	-41	49		100**	100**	97	99
ECC 21085		5282	555		32		98	118	90	94

(*) Tested at 35°C vs. 25°C.

(**) Tested 1 week at 100°C.

COMPOUND	PROCESSING COMMENTS	SELECTION
Celanese Hytrel 8813	Runs well, no issues encountered. Ran with same temperature profile as the regular Hytrel used in fiber optic. Requires drying.	Compounded at facility in China.
Gendon OH-2-BK 2289	Has best processability of all 3 compounds, and cable surface is nice and smooth. A good benefit of this compound is that it doesn't require drying.	**SELECTED FOR PROJECT** **(Compounded in Canada)**
ECC 21085	Had some difficulties getting a smooth surface. Ran very slow due to high crosshead pressure. Requires drying.	Still at development phase. Difficult to run.

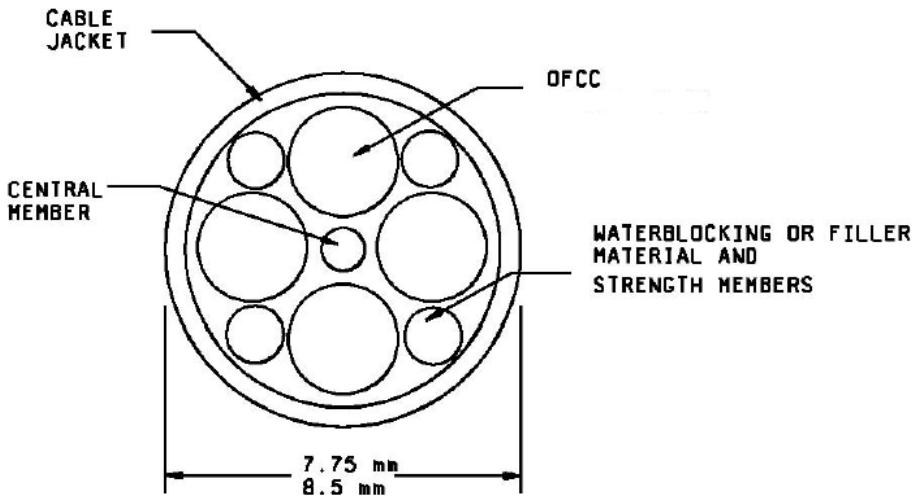
TASK 2 – IDENTIFY TESTS FOR TASK 4

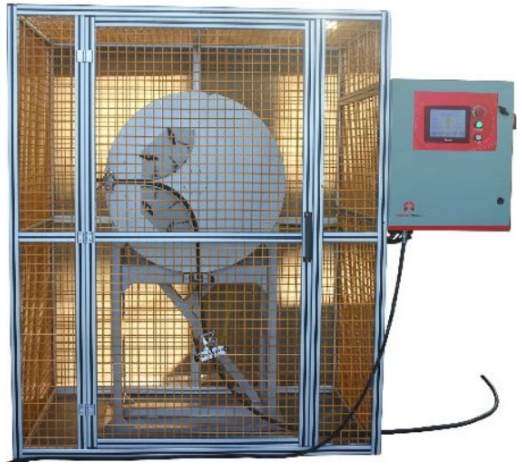
Identify tests in the M85045 document to evaluate the cable jacket material.

Group	Qualification inspection	Req. Par.	Test Location / Data Origin
I	Visual and mechanical inspection	3.4, 3.9, 3.10	Optical Cable Corp.
	Attenuation rate	3.5.1	Optical Cable Corp.
III	Temperature cycling	3.7.1	Optical Cable Corp.
	Temperature humidity cycling	3.7.3	Optical Cable Corp.
	Cyclic flexing (500 @ 25°C)	3.6.4	Optical Cable Corp.
	Cyclic flexing (100 @ -28°C)		Optical Cable Corp.
	Cable twist-bend (500 @ 25°C)	3.6.6	Optical Cable Corp.
	Cable twist-bend (100 @ -28°C)		Optical Cable Corp.
	Impact (50 @ 25°C & 20 @ -28°C)	3.6.8	Optical Cable Corp.
	Fungus resistance	3.8.4	Experior Labs
	Cable element removability	3.6.18	Experior Labs
IV	Thermal shock	3.7.2	Optical Cable Corp.
	Weathering		Data from Gendon
	Fluid immersion (fuel oil @ 70°C)	3.7.9	Experior Labs
	Fluid immersion (Turbine fuel @ 50°C)		Experior Labs
	Fluid immersion (lube oil @ 70°C)		Experior Labs
	Fluid immersion (3 per each fluid)		Data from Gendon
	Paint susceptibility	3.7.15	Experior Labs
	Jacket self-adh. or blocking	3.7.11	Experior Labs

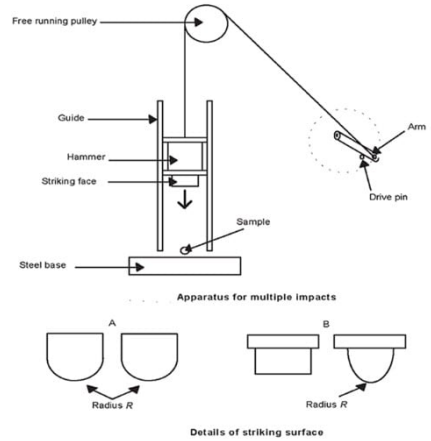
Group	Qualification inspection	Req. Par.	Test Location / Data Origin
V	Dripping	3.6.13	Experior Labs
	Cable jacket tear strength	3.6.14	Data from Gendon
	Cable jacket material T&E	3.6.15	Data from Gendon
	Cable abrasion resistance	3.6.16	Data from NSRP 2019-477-003
	Flame Extin. & Smoke Gen,	3.7.12.2	Element (formerly NTS)
	Water absorption	3.7.14	Data from Gendon
VI	Acid gas generation	3.8.1	Element (formerly NTS)
	Halogen content	3.8.2	Element (formerly NTS)
	Toxicity index	3.8.3	Element (formerly NTS)
	Smoke index	3.8.5	Element (formerly NTS)

TASKS 3 & 4 BUILD AND TEST CABLE





Cyclic Flexing Tester



Impact Tester

Build 1,500 meters of 4 Fibers 62.5/125 cable to M85045/18-01P design.

- One (1) at 1 Km
  - Cut in two (2) at 500 meters each
- One (1) at 500 meters
- Test the three (3) lengths in a predetermined sequence.

ROI ESTIMATES

Est. Annual FO Cable Usage (2019 Data): 7,800,000 feet (2,377 Km)

CABLE TYPE	% OF TOTAL[1]	Sell Price ($/ft) [2]	Est. Tplastic Price[3]	Difference
M85045/18-01 (4F MM)	70%	$3.32	$2.85	$0.48
M85045/18-02 (4F SM)	22%	$3.51	$2.85	$0.66
M85045/17-01 (8F MM)	6%	$5.81	$5.11	$0.69
M85045/17-02 (8F SM)	2%	$7.82	$5.11	$2.70
OTHER	>1%			
Average Cable price[4]		$3.55	$2.99	$0.56
Estimated Total Cable Cost		$27,687,384	$23,284,537	$4,402,847

NOTES:

(1) From Newport News Shipbuilding cable usage by type.

(2) From Defense Logistics Agency 2024 IDIQ Contracts Data.

(3) Optical Cable Corporation ABS LSZH Marine Cables with **25% cost adder** for M85045 periodic requalification.

(4) Weighted average based on quantity usage.

PROJECT SCHEDULE

TASK	Description	1 Apr-25	2 May-25	3 Jun-25	4 Jul-25	5 Aug-25	6 Sep-25	7 Oct-25	8 Nov-25	9 Dec-25	10 Jan-26	11 Feb-26	12 Mar-26
	Kick-Off	X											
T1	Down select one (1) or two (2) LSZH compounds from PP 2019-477-003.	X											
T2	Identify tests in the M85045 to evaluate cable(s) built with the jacketing material(s) selected.	X	X										
T3	Manufacture length(s) of fiber optic cable(s) to M85045 designs with the compound(s) identified for evaluation.			X	X	X	X						
T4	Test at NRTL & at cable manufacturer's certified testing lab. Provide samples to shipyards for feedback.						X	X	X	X	X	X	
T5	Report with test results & recommendations for Enhanced M85045 shipboard requirements.												X

DELIVERABLES

- Tasks 1 and 2 Report: LSZH jacketing materials selected and recommended tests.
- Final Report: Test Results, Recommended new MIL-PRF-85045 SS, and Estimate for Full Qualification.

TECHNOLOGY TRANSFER / IMPLEMENTATION

- Add sheets to MIL-PRF-85045 for Enhanced Performance shipboard cables.
- Identify cable manufacturers interested in qualifying cables to the enhanced requirements.
- Qualify cables to the enhanced requirements and begin usage for ships' construction and upgrades.
- Present Findings at Technical Conferences: ASNE, SNAME, IWCS

QUESTIONS?

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