2019 - 2025 NSRP Panel Projects:
SHIPBOARD FIBER OPTIC CABLES DESIGN ENHANCEMENTS

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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.
- 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

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

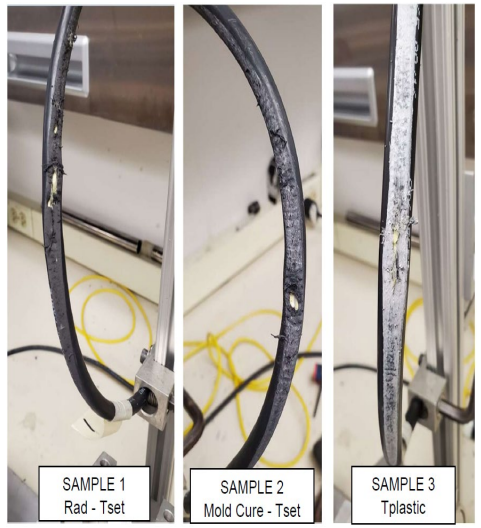
- Baseline cable designs are suited for shipboard environment.
- Most of rework is caused by **on-ship fiber terminations**.
- M85045 cables' buffers were more difficult to strip than similar commercial buffers.
- **Jacket abrasion** described as a cause of damage at installation.
  - MIL-STD-1678-3 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)

PRELIMINARY REQUIREMENTS

MIL-PRF-85045G CABLE SAFETY REQUIREMENTS (NON-NEGOTIABLE!!!)

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)

OTHER SELECTION CRITERIA

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

PROJECT 2 HISTORY – 2023 SHIPBOARD FO CABLES JACKETS ENHANCEMENTS PROJECT

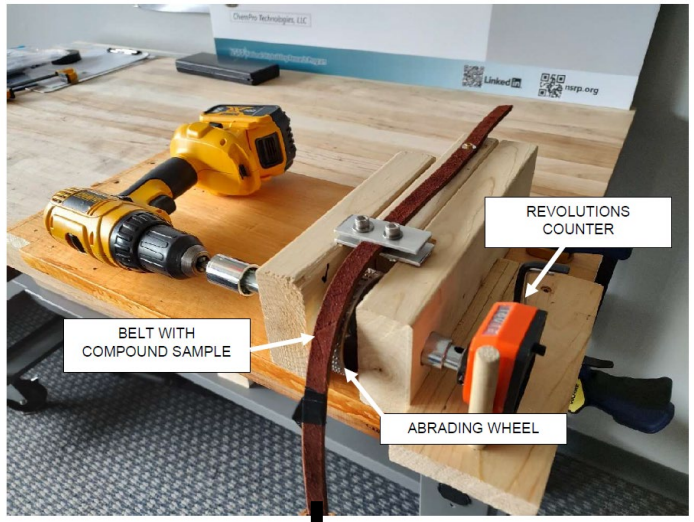
(Panel Project 2019-477-003)

TEST SET-UP

SCRAPE ABRASION TEST ON STRIPS

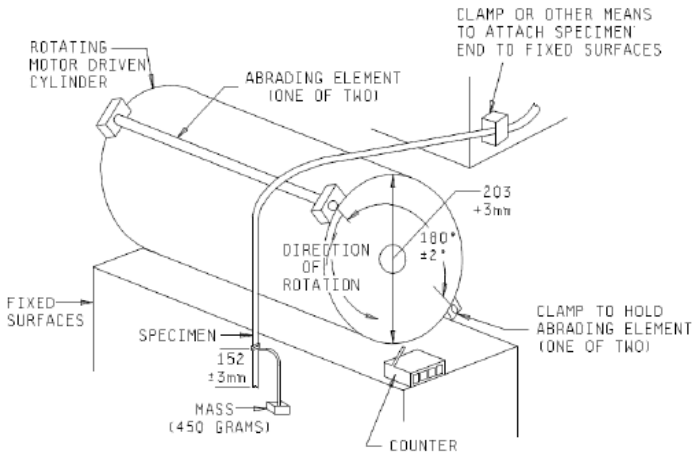
Abrading blade (2 @ 180°)

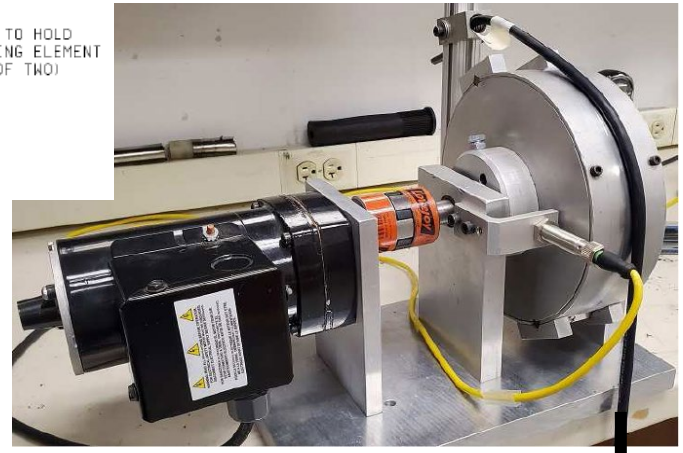
3 in. dia. Abrading Wheel



5 lbs. Weight on Sample

SCRAPE ABRASION TEST ON CABLES





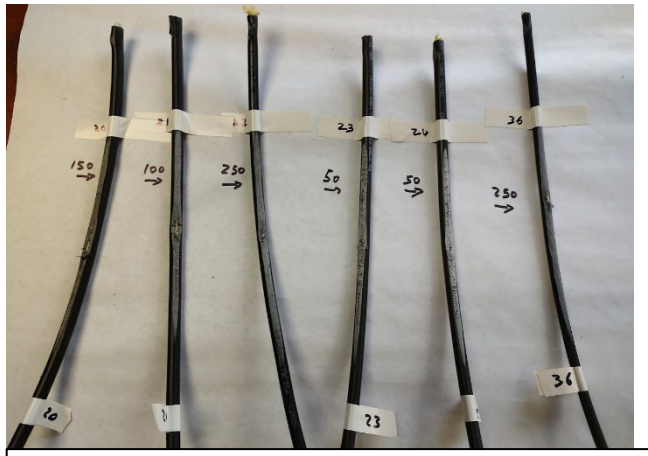
10 lbs. Weight on Sample

PROJECT 2 HISTORY – 2023 SHIPBOARD FO CABLES JACKETS ENHANCEMENTS PROJECT

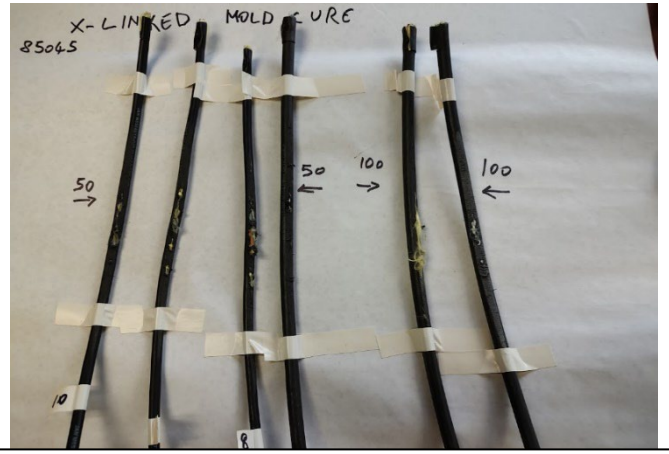
(Panel Project 2019-477-003)

MODIFIED SCRAPE ABRASION TEST RESULTS

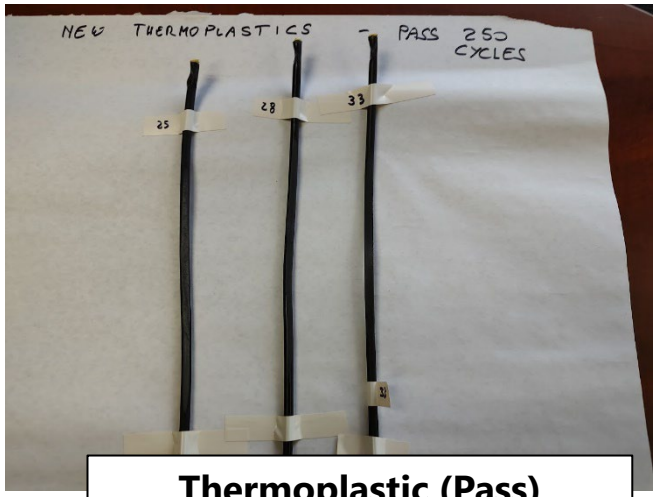
Thermoset Irrad X-Link (Fail @ 50 Cycles)



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 at 50 scrape abrasion cycles**. Photos indicate failure occurred well before the full 50 cycles.

2. M85045 cables with the thermoset jacket using the **Mold Cure method performed better than irradiated cables** based on photos of exposed inner cable components after 50 cycles. Thicker jacket of the 8 fiber cables (M85045/17) provided marginally more protection to 100 cycles.

3. Cable samples with **thermoplastic LSZH generally outperformed the M85045 cables** based on the amount of cable core exposed. The ABS marine shipboard had only minimal core exposed and performance (based on scrapes per mm of jacket thickness) surpassed all other cables currently in use.

4. The **three (3) compounds that passed after 250 scrape abrasion cycles** (samples 25 – 30) were worn to about **½ to ¾ of the full jacket wall thickness**.

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

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.

2025 PANEL PROJECT 3 - OBJECTIVES

Evaluate the new LSZH thermoplastic materials for use as jacketing for shipboard fiber optic cables.

- Use the materials identified by the Shipboard Cable Jackets Performance Enhancements project (2019-477-003) as baseline.
  - Down-select one (1) or two (2) materials to apply over 4F or 8F cable design to M85045/18 or /17.

- Perform select tests in the M85045 document to evaluate the most resilient cable jacket material.
  - Preliminary List – subject to review bt project team

Group	Qualification inspection	Notes for NSRP Panel Project
III	Temperature cycling	One sample on reel.
	Fungus resistance	
	Cable element removability	
IV	Thermal shock	
	Weathering	
	Fluid immersion	Temperatures: fuel oil (68 to 70 °C vs. 98 - 100 °C), turbine fuel (48 to 50 °C), and lubricating oil (68 to 70 °C vs. 98 - 100 °C).
	Paint susceptibility	
	Jacket self-adhesion or blocking	

Group	Qualification inspection
V	Dripping
	Cable jacket tear strength
	Cable jacket material tensile strength and elongation
	Flame extinguishing and smoke generation
	Water absorption
VI	Acid gas generation
	Halogen content
	Toxicity index
	Smoke index

EXPECTED PROJECTS' OUTCOME

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

QUESTIONS?

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BACK UP SLIDES

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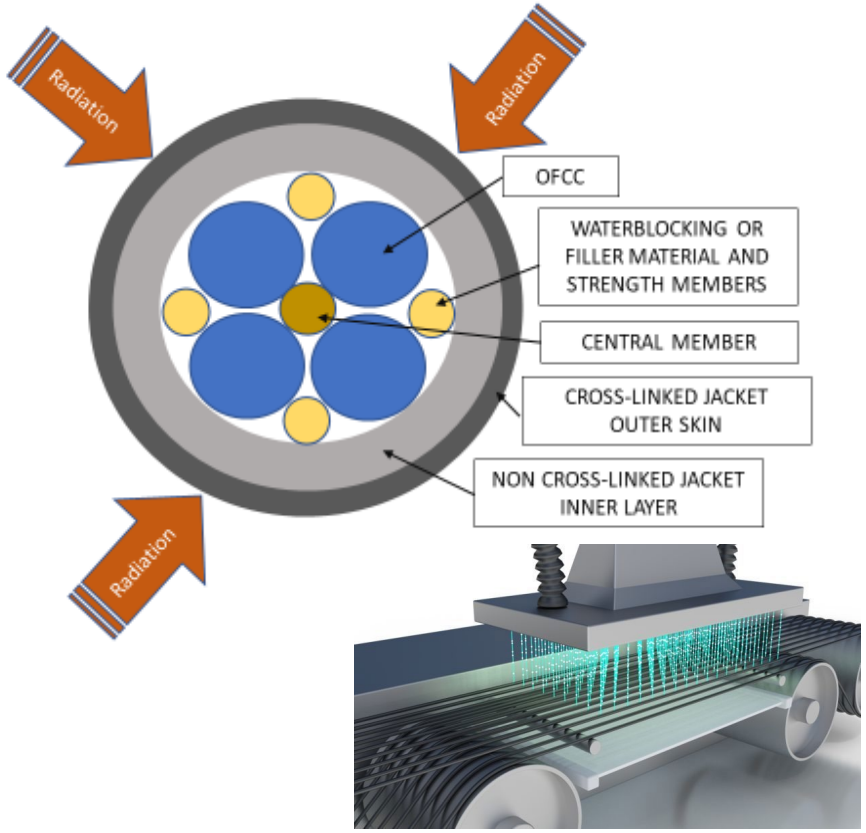
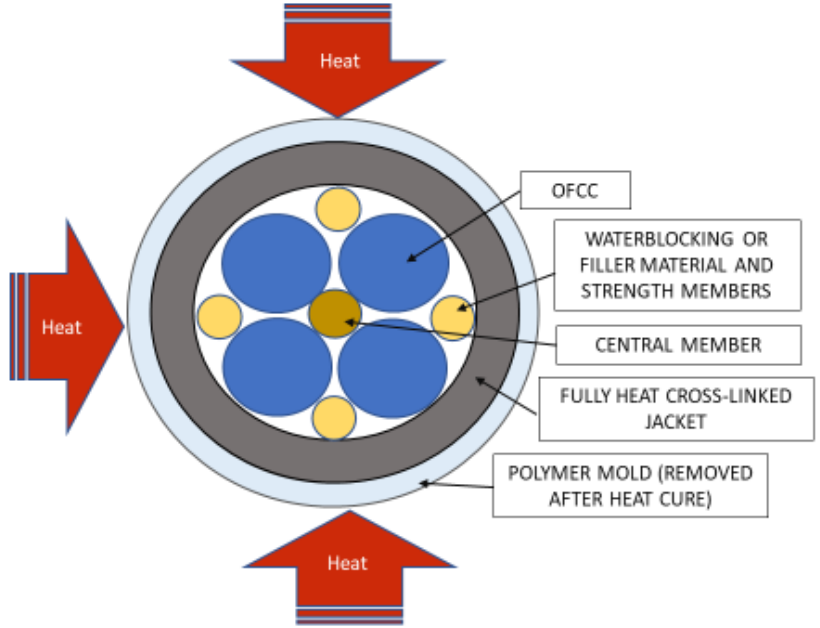
CABLE JACKET CROSS LINKING METHODS



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.

2023 – SHIPBOARD FIBER OPTIC CABLES JACKETS PERFORMANCE ENHANCEMENTS

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.