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

Electrical Technologies Panel Meeting
Pullman, WA
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- Ingalls Shipbuilding
- Austal USA
- SUPSHIP GC
- ChemPro Technologies

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BACKGROUND

- 7,800,000 feet (2,377 Km) of fiber optic cables used annually on new constructions[(1)].
- Approximately 4 million ft (1,220 Km) of optical fiber on Ford Class Carrier[(2)].
- Optical fibers usage increasing for multiple applications:
  - High density fiber cable designs, up to 432 fibers
  - Distributed Fiber Optic Sensing (DFOS) networks
  - Remote source lighting included in new MIL-STD-x743 lighting document
  - Optical power delivery for laser weapons
- M85045 shipboard 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
(2) Huntington Ingalls Newsroom January 11, 2016

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.

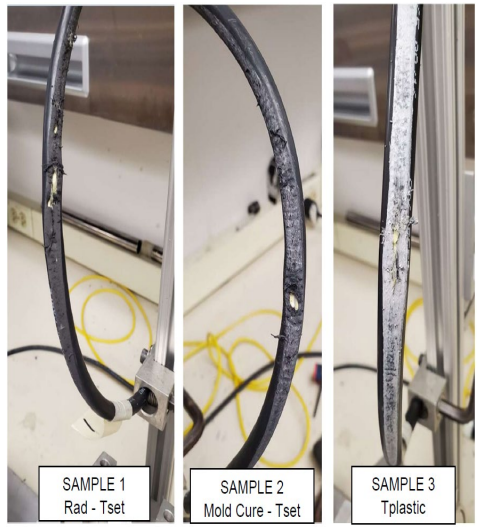
PROJECT FINDINGS

- 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.
- **24 hrs. resistance to hot fluids (98-100°C) ranked lowest priority** by project participants.

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.**

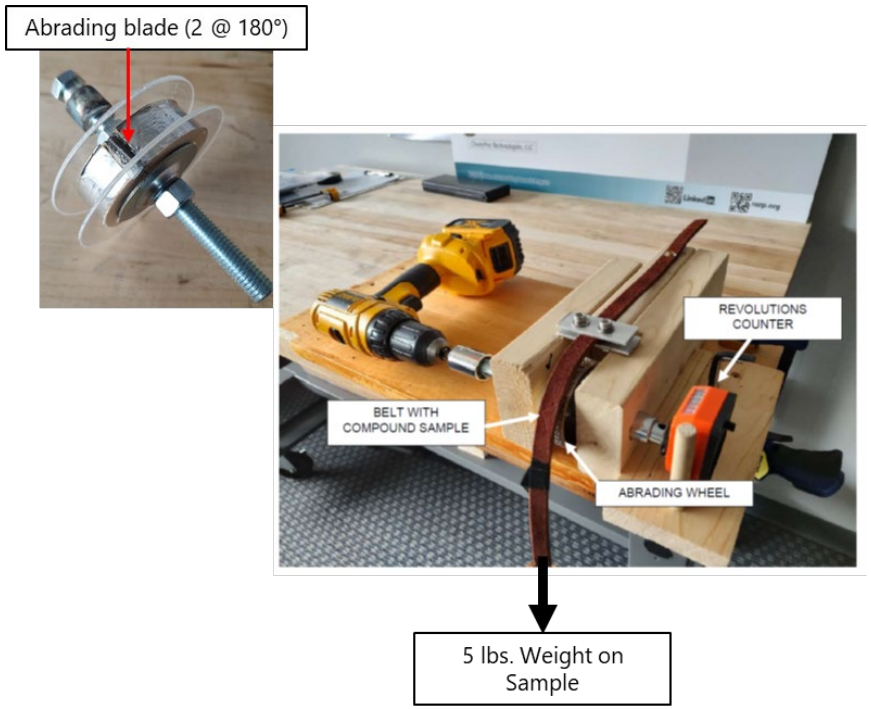
PROJECT 2 HISTORY – 2023 SHIPBOARD FO CABLES JACKETS ENHANCEMENTS PROJECT

(Panel Project 2019-477-003)

OBJECTIVE: Identify new jacketing materials:

a. Enhance performance.

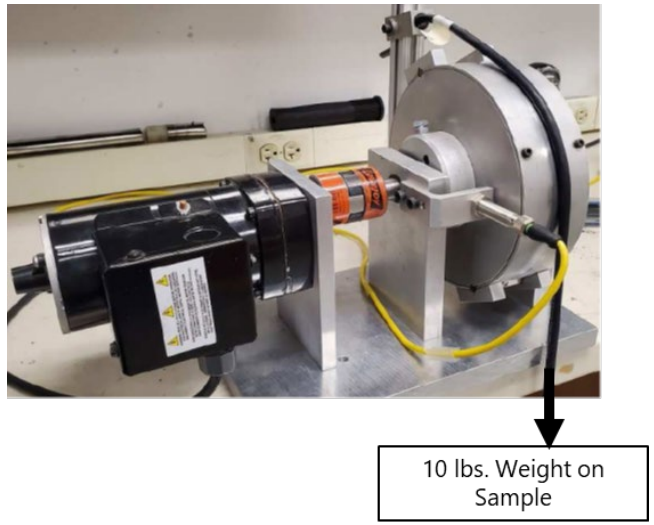
b. Lower TOC of fiber optic systems.



SCRAPE ABRASION TEST ON COMPOUND STRIPS

METHODOLOGY

1. Identify top 3 LSZH thermoplastic compounds.
2. 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.



SCRAPE ABRASION TEST ON CABLE SAMPLES

PROJECT 2 HISTORY – 2023 SHIPBOARD FO CABLES JACKETS ENHANCEMENTS PROJECT

(Panel Project 2019-477-003)

MODIFIED SCRAPE ABRASION TEST RESULTS

Irrad X-Link (Fail @ 50 Cycles)

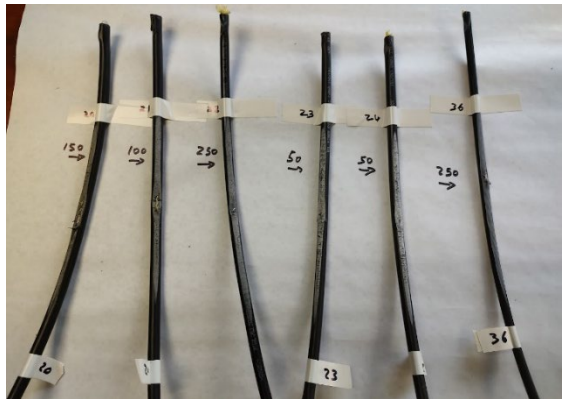
1. M85045 cables x-linked w/**Electron Beam Irradiation: failed @ <50 cycles**.
2. M85045 cables x-linked w/**Mold Cure method:** most **failed after 50 cycles**. M85045/17 (8F) after 100 cycles.
3. **Thermoplastic LSZH generally outperformed the M85045 cables.**
4. **ABS marine shipboard** had only minimal core exposed after **250 cycles**.
5. **All three (3) new compounds passed 250 scrape abrasion cycles with ½ to ¾ wear**.

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

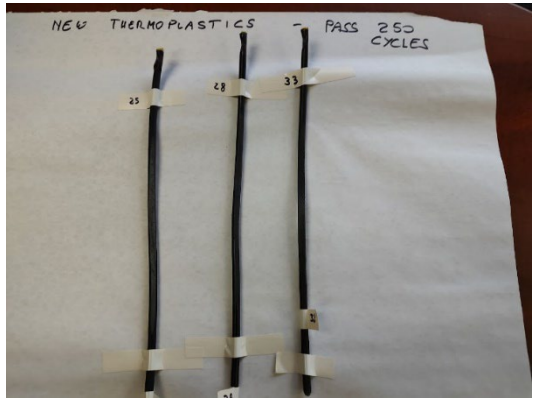
CONCLUSIONS:

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.



Thermoplastic (Fail @ 50 to 250 Cycles)



New Thermoplastic (Pass)

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) fluid immersion temperatures to those for cables used on marine oil and gas platforms.** 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) > 5X Enhancement in Scrape Abrasion Resistance
2) Same as Prysmian/Draka S611T Marine Fiber Optic Cables

TASKS

TASK 1: Down select LSZH compound identified under PP 2019-477-003.

- Select compound 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 built with the compound selected.

TASK 3: Manufacture lengths of fiber optic cables to M85045/18-01 design.

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.

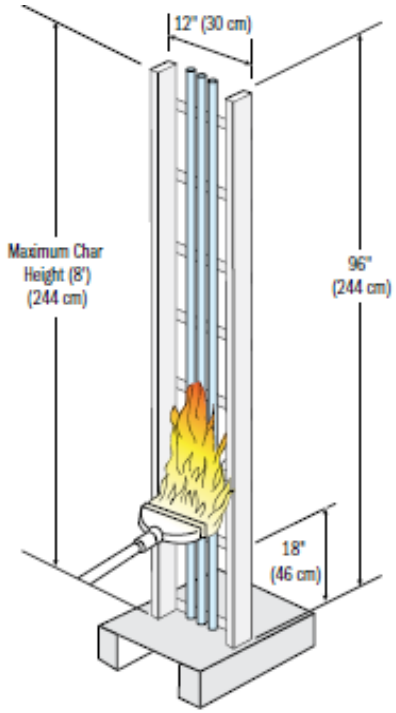
TASK 1 – SELECT COMPOUND(S) FOR TASK 3

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

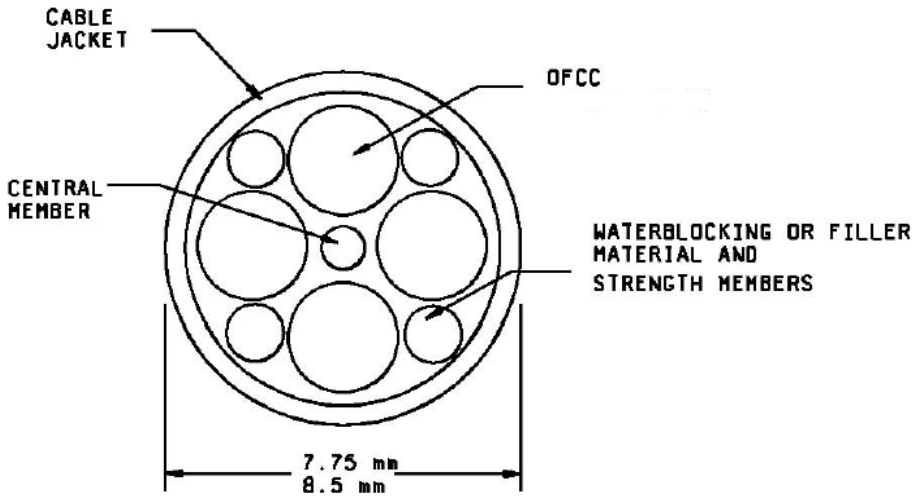
Compound	UL 94	Tensile (psi)	Elong. (%)	Low Temp Brittle Point (°C)	O2 Index (%)	Acid gas (%)	Oil (IRM 902) 4 hrs @ 70°C		Diesel 24 hrs @ 25°C	
							Tensile Ret (%)	Elong Ret (%)	Tensile Ret (%)	Elong Ret (%)
Gendon OH-2-BK 2289	V-0	1800	230	-44	39	0.2	70	96	77*	98*
Celanese Hytrel HTR 8813 BK320	V-0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

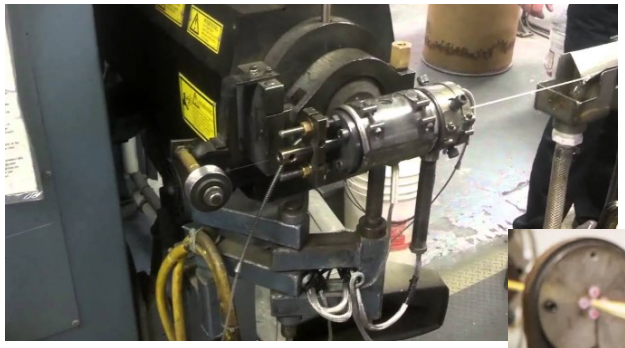
(*) Tested at 35°C vs. 25°C.

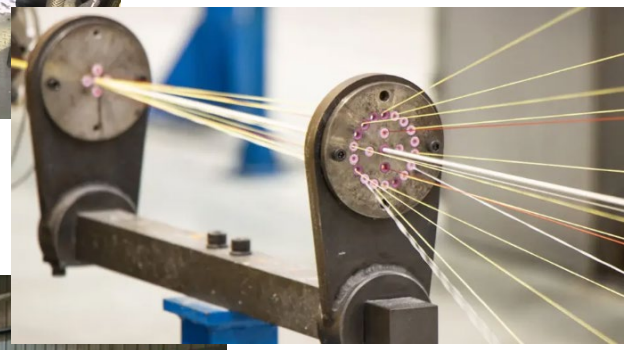
(**) Tested 1 week at 100°C.

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.

TASKS 3 BUILD CABLE







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.

TASK 4 – TEST CABLE

Group	Qualification inspection	Req. Par.	Test Par.	PASS/FAIL
I	Visual and mechanical inspection	3.4, 3.9, 3.10	4.7.2	PASS
	Attenuation rate	3.5.1	4.7.4.1	PASS
III	Temperature cycling	3.7.1	5/	PASS
	Temperature humidity cycling	3.7.3	4.7.6.3	PASS
	Storage temperature	3.7.4	4.7.6.4	PASS
	Low temperature flexibility (cold bend)	3.6.3	4.7.5.3	PASS
	Cyclic flexing (500 @ 25°C)	3.6.4	4.7.5.4	PASS
	Cyclic flexing (100 @ -28°C)			PASS
	Cable twist-bend (500 @ 25°C)	3.6.6	4.7.5.6	PASS
	Cable twist-bend (100 @ -28°C)			PASS
	Impact (50 @ 25°C & 20 @ -28°C)	3.6.8	4.7.5.8	PASS
	Temperature life (life aging)(@110°C vs. 175°C)	5/	5/	PASS
	Tensile loading and elongation	3.6.1	4.7.5.1	PASS
	Operating tensile loading	3.6.1.1	4.7.5.1.1	PASS
	Fungus resistance	3.8.4	4.8.4	PASS
	Cable element removability	3.6.18	4.7.5.18	PASS
IV	Thermal shock	3.7.2	4.7.6.2	PASS
	Weathering (720 hours under QUV testing)	SEE TDS	SEE TDS	PASS
	Fluid immersion (fuel oil @ 37°C)	3.7.9	4.7.6.9	PASS
	Fluid immersion (Turbine fuel @ 50°C)			**FAIL***
	Fluid immersion (lubricating oil @ 70°C)			PASS
	Fluid immersion (IRM902 @ 70°C, Deisel @ 35°C, IPA @ 23°C)	SEE TDS	SEE TDS	PASS
	Paint susceptibility	3.7.15	4.7.6.15	PASS
	Jacket self-adhesion or blocking	3.7.11	4.7.6.11	PASS

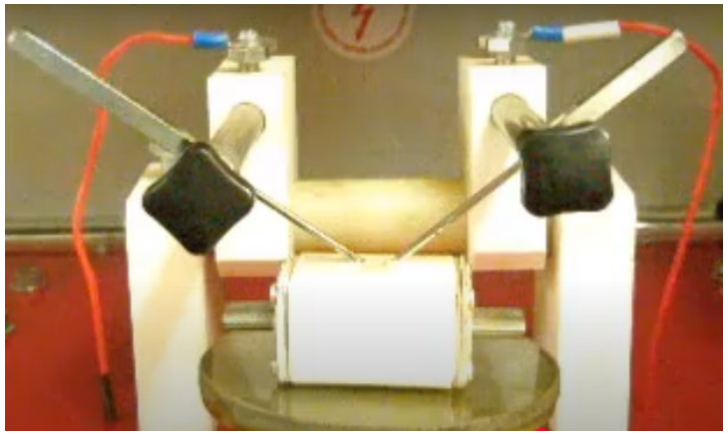
Group	Qualification inspection	Req. Par.	Test Par.	PASS/FAIL
V	Dripping	3.6.13	4.7.5.13	PASS
	Cable jacket tear strength (45 LBF/IN) (TYPICAL)	SEE TDS	SEE TDS	PASS
	Cable jacket material tensile strength and elongation (1800 PSI)(230%)(TYPICAL)	SEE TDS	SEE TDS	PASS
	Cable abrasion resistance	3.6.16	4.7.5.16	PASS
	Flame extinguishing and smoke generation	3.7.12.2	4.7.6.12.2	PASS
	Water absorption	3.7.14	4.7.6.14	PASS
VI	Acid gas generation	3.8.1	4.8.1	PASS
	Halogen content	3.8.2	4.8.2	PASS
	Toxicity index	3.8.3	4.8.3	PASS
	Smoke index	3.8.5	4.8.6	PASS

*Likely to pass 37°C

ADDITIONAL TEST – From NSRP RA 2025-04

OBJECTIVE – Prevent fiber cables used internal to electrical equipment from causing arcing between energized sections.

- Test fiber optic cable jacketing materials for Arc-Tracking resistance.
- Test to ASTM D 495 – Dry Arc Resistance of Solid Electrical Insulation.
- Added Gendon OH-2289 to materials under test – PASSED.
- Can be used in 450 VAC and 4,160 VAC switchboards.



FEEDBACK FROM TEAM MEMBERS

- The integrity of the cable jacket, evaluated both visually and by touch, represents a significant improvement in durability and robustness… the modified jacket will drastically reduce the risk of damage during cable routing, hopefully improving the efficiency of those responsible for the fiber installation.
- The cable is stiffer, more robust than the cables currently used. Jacket strippability is good. The OFCC stripped well down to the fiber…it was noted that the OD of the cable outer jacket results in a tight fit.
- Overall, the feedback on the newly developed cable jacket material is positive and is anticipated to increase durability.

TESTS NOT PERFORMED

Group	Qualification inspection	Req. Par.	Test Par.
II	Crosstalk	3.5.3	4.7.4.3
	Electromagnetic effects	3.7.16	4.7.6.16
III	Crush	3.6.5	4.7.5.5
IV	Shock	3.7.13	4.7.6.13
	Dynamic bend	3.6.2	4.7.5.2
	Hosing: hydrostatic	3.6.12.2	4.7.5.12.2
	Radial compression (for application B only)	3.6.7	4.7.5.7
	Corner bend	3.6.9	4.7.5.9
	OFCC kink	5/	5/
V	Cable shrinkage	3.6.17	4.7.5.17
	Durability of identification	3.6.19	4.7.5.19

ESTIMATED COST TO COMPLETE TESTS: $ 30K - $40K

- Use cable lengths built for Panel Project

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]	Cost Savings	Estimated Annual $ for Tplastic
M85045/18-01 (4F MM)	70%	$3.32	$2.85	***$2,566,200***	$15,561,000
M85045/18-02 (4F SM)	20%	$3.51	$2.85	***$1,029,600***	$4,446,000
M85045/17-01 (8F MM)	6%	$5.81	$5.11	***$327,600***	$2,391,480
M85045/17-02 (8F SM)	2%	$7.82	$5.11	***$422,760***	$797,160
OTHER (18F & 36F, SM & MM)	2%				
Estimated Total Cable Cost		$27,541,800	$23,195,640	***$4,346,160***	

NOTES:

(1) ROM Estimates from Shipbuilders and Ship Repair. Does not include BOF (~10% of total FO cable usage)

(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.

RECOMMENDATIONS

1. Enhanced abrasion resistance. Scrape abrasion test with 4.54 Kg (10 lbs.) vs. 0.454 Kg (1 lb.), 200 scrape abrasion cycles.
2. Fiber Buffer Strippability. Add requirements for the force to strip the buffer. Reference: Telecommunications Industry Association TIA-455-178-C: Measurement Methods and Test Procedures – Coating Strippability.
3. Revised fluid immersion requirements. Use requirements invoked by ABS and DNV for fiber optic cables used on marine vessels and marine oil exploration platforms.

FLUID	Enhanced Shipboard Cables	
	Temperature / Time	% T&E Retention
Fuel Oil	37°C / 4 hrs.	≥ 50%
Turbine Fuel	25°C / 4 hrs.	≥ 50%
Lubricating Oil	70°C / 4 hrs.	≥ 50%

TECHNOLOGY TRANSFER / IMPLEMENTATION

- Use 4F cable for 2026 RA to install Distributed Temperature Sensing (DTS) system on Vessel(*)
- Add sheets to MIL-PRF-85045 for Enhanced Performance shipboard cables.
- Complete qualification of 4F cable to the enhanced requirements and begin usage for ships' construction and upgrades.
- Present Findings at Technical Conferences: ASNE, SNAME, IWCS

(*) Under evaluation by SUPSHIP GC and Austal USA

QUESTIONS?

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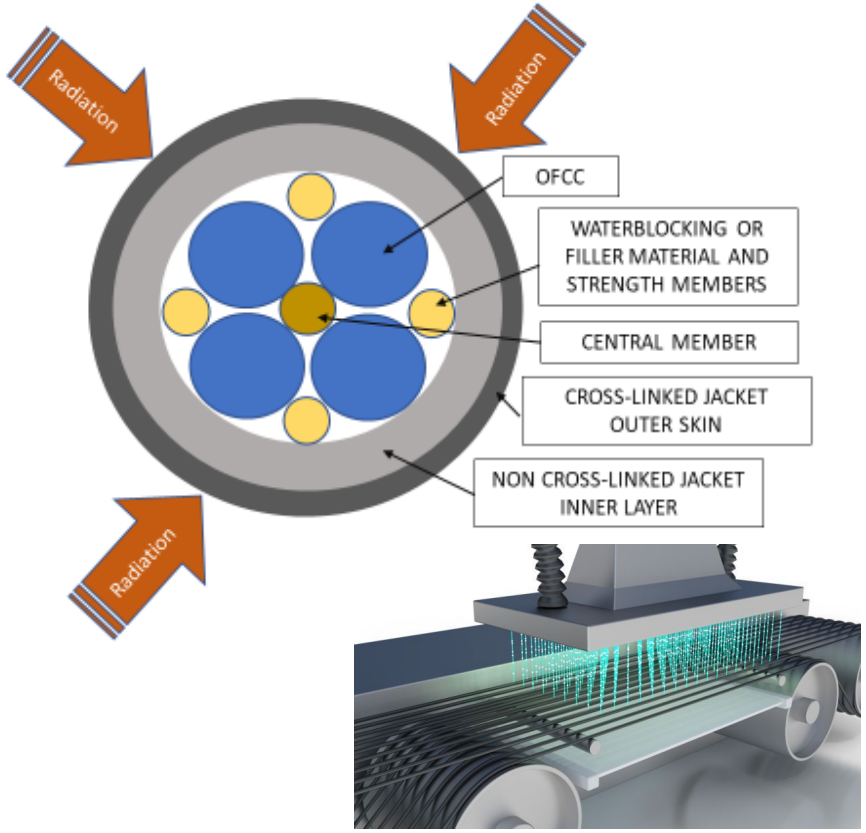
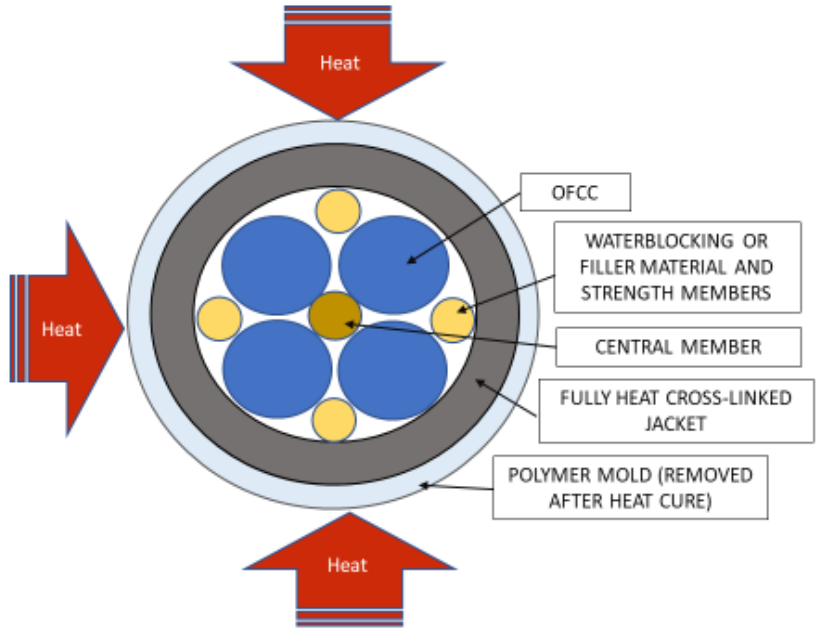
BACK UP SLIDES

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.