NSRP Panel Project: (2019-477-003)

SHIPBOARD FIBER OPTIC CABLES JACKETS PERFORMANCE ENHANCEMENTS

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RSL Fiber Systems, LLC

FINAL REPORT

April 3, 2024

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2023 – SHIPBOARD FIBER OPTIC CABLES JACKETS PERFORMANCE ENHANCEMENTS

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. Can be used to revise the existing MIL-PRF-85045 shipboard cable sheets **or**
    b. Used to create new sheets.

TEAM MEMBERS

- Prime/Lead: RSL Fiber Systems, LLC
- Team Members: Huntington Ingalls – Ingalls Shipbuilding, U.S. Navy – SUPSHIP Gulf Coast, ChemPro Technologies LLC
- ATI Project Manager: Nick Laney
- Program Technical Representative: Walt Skalniak (Ashby Co.)

ESTIMATED ROI

1. Savings from Thermoset to Thermoplastic: **$ 5.8M /year**
2. Thermoplastic w/50% reduction in damage: **$ 8.3M / year**

PROGRAM FUNDS

$ 150,000

DURATION

12 Months

PROJECT HISTORY - 2019 SHIPBOARD FIBER OPTIC CABLES DESIGN ENHANCEMENTS PROJECT (Panel Project 2019-477)

ADVANCED LIGHTING TECHNOLOGIES

CONCLUSIONS

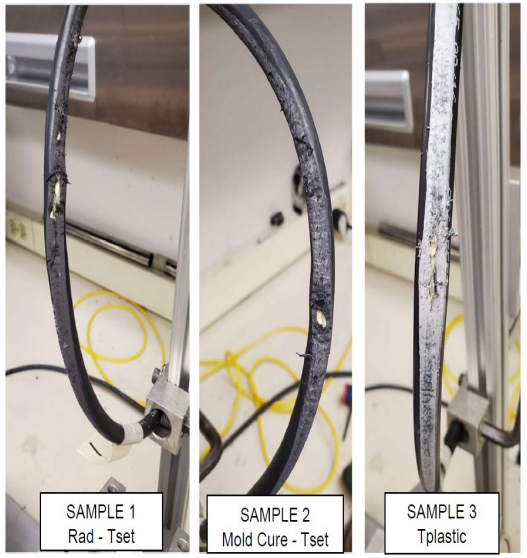
- Baseline cable designs are suited for shipboard environment.
- Most of rework is caused by on-ship fiber terminations.
- **Jacket abrasion** described as a cause of damage at installation.
- Resistance to hot fluids (98-100°C) ranked lowest priority by project participants.

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

- Use of Thermoset jacket driven primarily by fluids' immersion temperature requirements taken from M24643 power cables specifications.
- Thermoplastic jacket outperformed thermoset jackets in modified scrape abrasion resistance test (10 lbs. weight vs. 1 lb. weight).
- Thermoset jackets may have been preferred for perceived vs. actual abrasion resistance.
- Thermoplastic jackets have potential to:
  - Improve abrasion resistance.
  - Decrease cable cost.
  - Decrease fiber damage.
  - Lower TOC of fiber optic shipboard systems.

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.**

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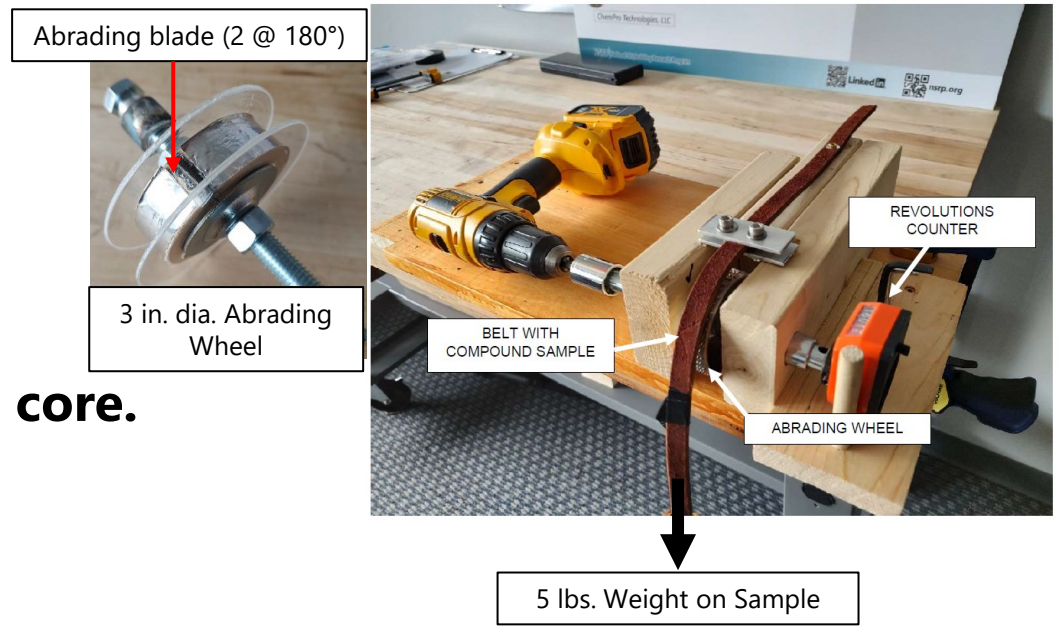
NON – NEGOTIABLE REQUIREMENTS

MIL-PRF-85045G CABLE SAFETY 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)

NSRP PROJECT ACTIVITIES



- **Collected slabs of 12 LSZH jacketing compounds.**
- **Devised scrape abrasion test set-up to evaluate slabs.**
  - 250 cycles with 5 lbs. weight.
- **Identified four (4) materials for application over cable core.**
  - Other performance parameters included in selection process.
- **Added UL-94 Drip Test to requirements.**
- **Identified fiber cable manufacturer with LSZH, marine, and MIL QPL experience to apply materials over cable core (Optical Cable Corporation).**
  - Held meetings with compounds' manufacturers and cable manufacturer to review optimal processing conditions.
- **Built four (4) cable samples over dummy core.**
- **Tested M85045, other marine cables, and new samples to modified MIL-STD-1678-3 Cable Scrape Abrasion Test.**
  - 10 lbs. weight vs. 1 lb. weight. 250 scrape abrasion cycles vs. 500 scrape abrasion cycles.

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JACKET COMPOUNDS SELECTED FOR CABLING

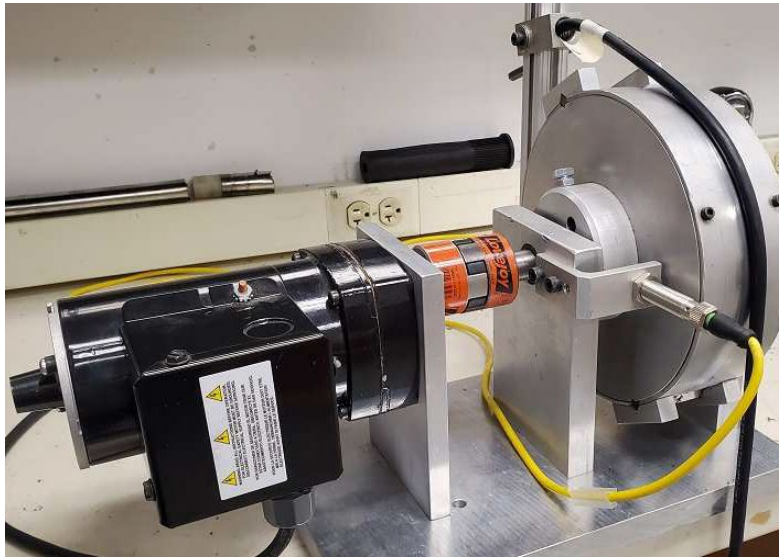
							Oil (IRM 902) 4 hrs @ 70°C		Diesel 24 hrs @ 25°C	
Compound	UL 94	Tensile (psi)	Elong. (%)	Low Temp Brittle Point (°C)	O2 Index (%)	Acid gas (%)	Tensile Ret (%)	Elong Ret (%)	Tensile Ret (%)	Elong Ret (%)
Test A		1800	230	-44	39	0.2	70	96	77*	98*
Test B	V-0	1827	190	-41	49		100**	100**	97	99
Test C		5282	555		32		98	118	90	94
Test D	V-0	1827	130	-27	41		75	126	75	113

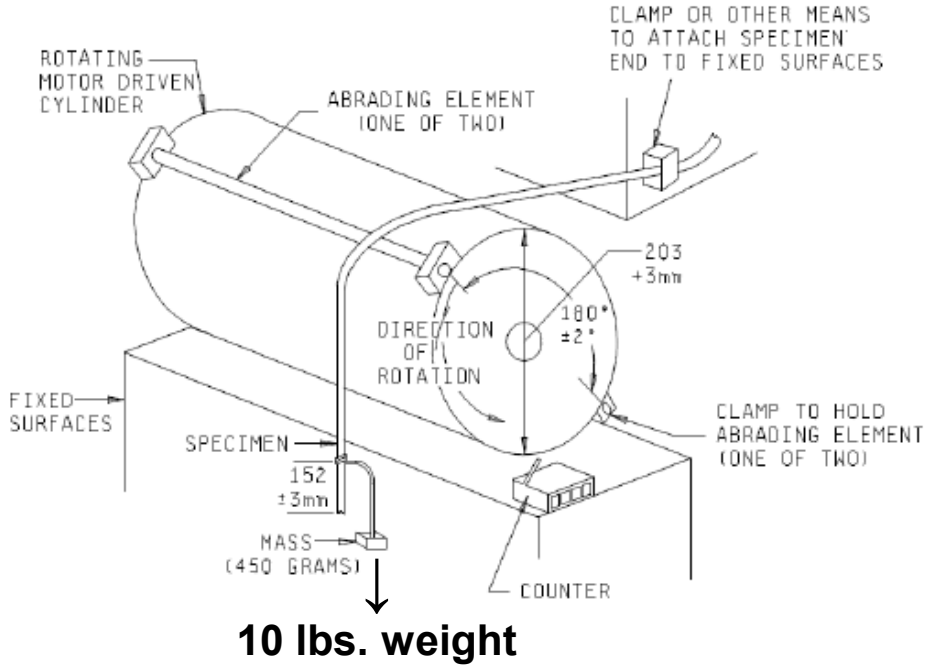
(*) Tested at 35°C vs. 25°C.

(**) Tested 1 week at 100°C.

MODIFIED SCRAPE ABRASION TEST

- MIL-PRF-85045/MIL-STD-1678-3 specifies 454 grams (1 lb.) weight, 500 cycles.
- Actual conditions at installation are likely:
  - **Higher force / Less cycles.**
- Test performed at Intertek to failure point of jacket:
  - 4.45 Kg (10 lbs.)
  - Up to 250 cycles.
  - Inspect every 50 cycles.
  - Failure = exposed cable inner components.





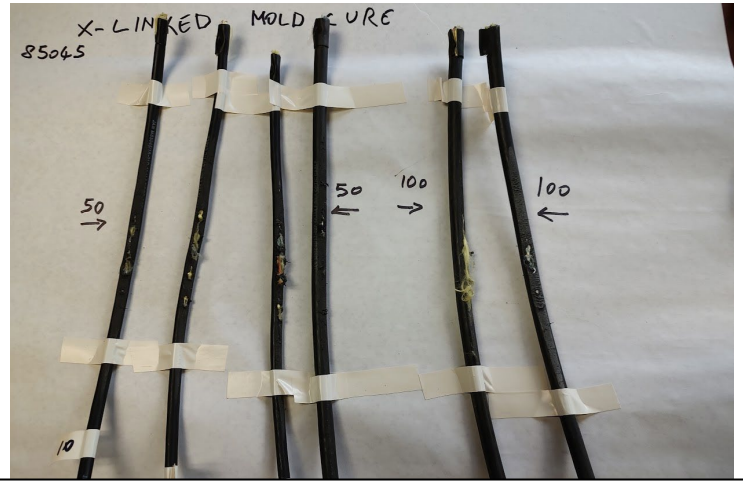
MODIFIED SCRAPE ABRASION TEST RESULTS

SAMPLE NO.	DESCRIPTION	JACKET COLOR	Wall Thick. (mm)	O.D. (mm)	JACKET TYPE	FAILURE AFTER # SCRAPES	Scrapes per mm of jacket thickness
1	/17-01P	Blue	1.45	11.05	TSet (Irrad)	50	34.5
3	/17-02P	Black	1.52	11.20	Tset (Mold Cure)	100	65.8
7	/18-02P	Black	1.20	7.94	TSet (Irrad)	50	41.7
8	/18-01P	Black	1.14	7.96	Tset (Mold Cure)	50	43.9
20	Tplastic Marine 1	Black	1.81	10.30	Tplastic	150	82.9
22	ABS Marine Shipboard	Black	1.93	9.31	Tplastic	250	129.5
23	Tplastic Marine 2	Black	1.80	10.65	Tplastic	50	27.8
27	**Test A**	**Black**	**1.17**	**7.93**	**Tplastic**	**Pass**	
30	**Test B**	**Black**	**1.14**	**7.94**	**Tplastic**	**Pass**	
33	**Test C**	**Black**	**1.09**	**7.77**	**Tplastic**	**Pass**	
36	Test D	Black	1.12	8.15	Tplastic	150	133.9

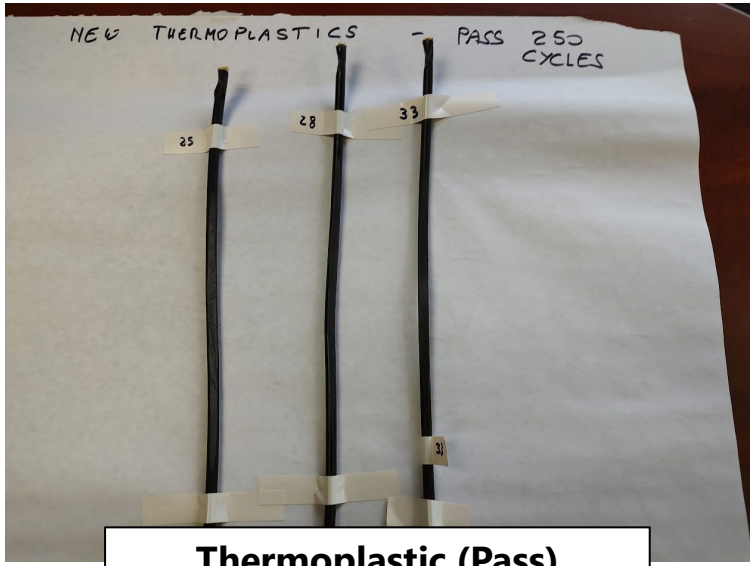
MODIFIED SCRAPE ABRASION TEST RESULTS

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)

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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.

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RECOMMENDATIONS

Improve resilience of shipboard fiber optic cables with **ENHANCED PERFORMANCE** version of MIL-PRF-85045 documents as follows:

1. **Modify the MIL-STD-1678-3 Cable Scrape Abrasion Test weight from 1.0 lb. to 10 lbs.** to ensure the highest level of abrasion resistance.

2. **Reduce the 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.

3. In addition to the IEEE 383 flame test, **add UL 94 Standard for Safety of Flammability of Plastic Materials for Parts in Devices and Appliances (Drip Test) with a minimum rating of V-0**: burning stops within 10 seconds on a vertical specimen; drips of particles allowed as long as they are not inflamed.

QUESTIONS?

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BACK UP SLIDES

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JACKET COMPOUND SCRAPE ABRASION TEST

OBJECTIVE

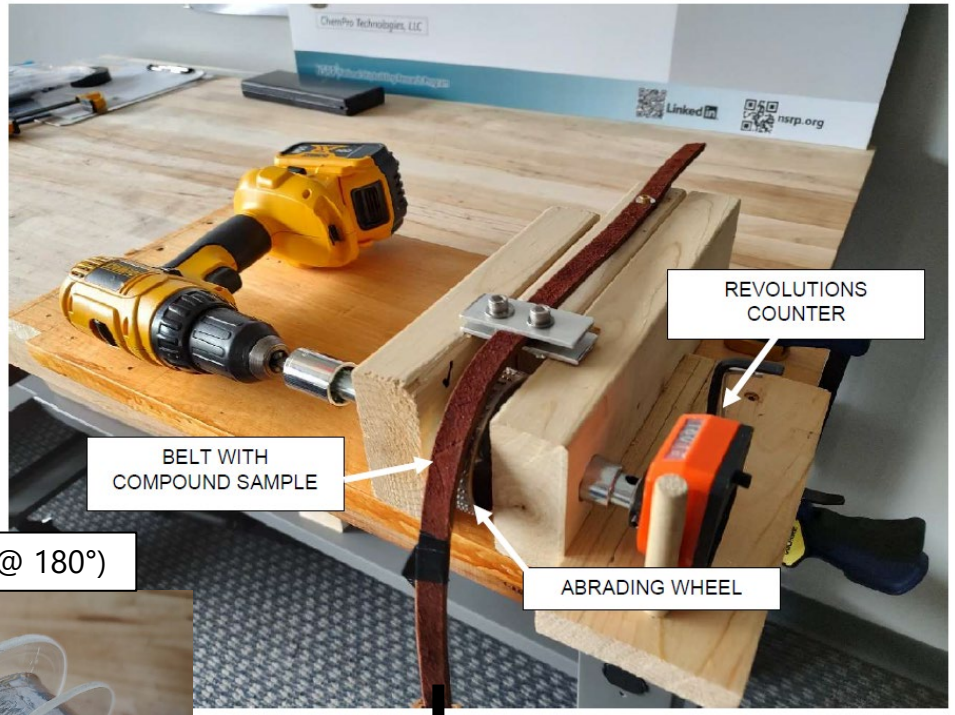
Develop a repeatable test method to evaluate 3 in. x 3 in. slabs of LSZH compound for resistance to scrape abrasion.

Challenges

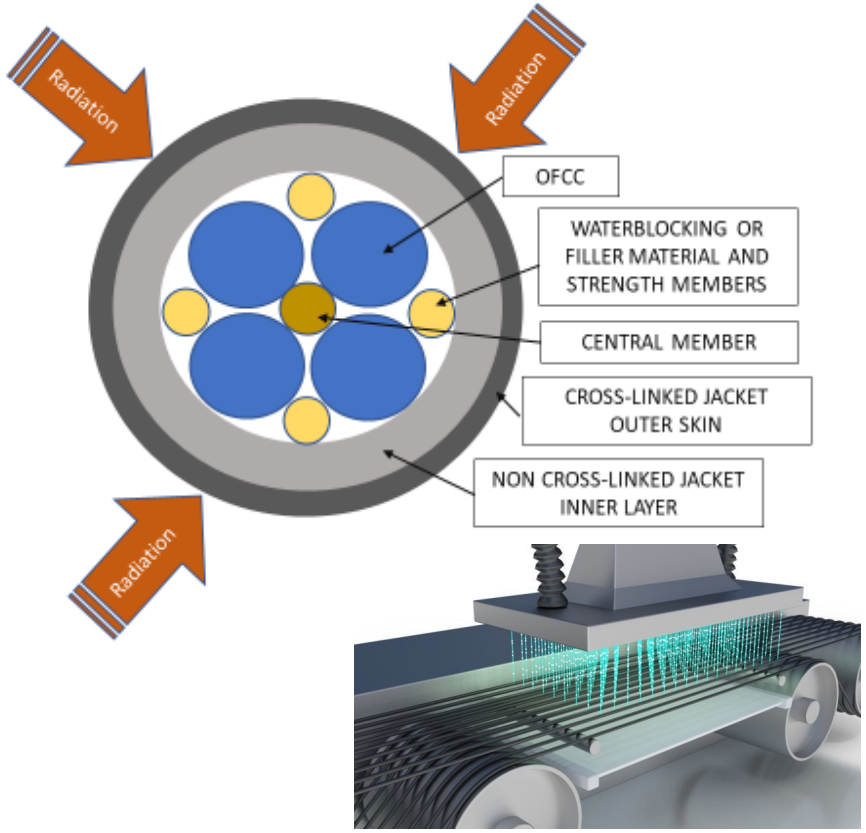
- Samples too small to use MIL-STD-1678-3 scrape abrasion wheel.
- No other standard test identified to measure scrape abrasion of jacket materials in slab form.

Solution

- Build a miniature scrape abrasion tester based on the MIL-STD-1678-3 design.
- Run test on multiple slabs to identify the material(s) to apply over cable core.

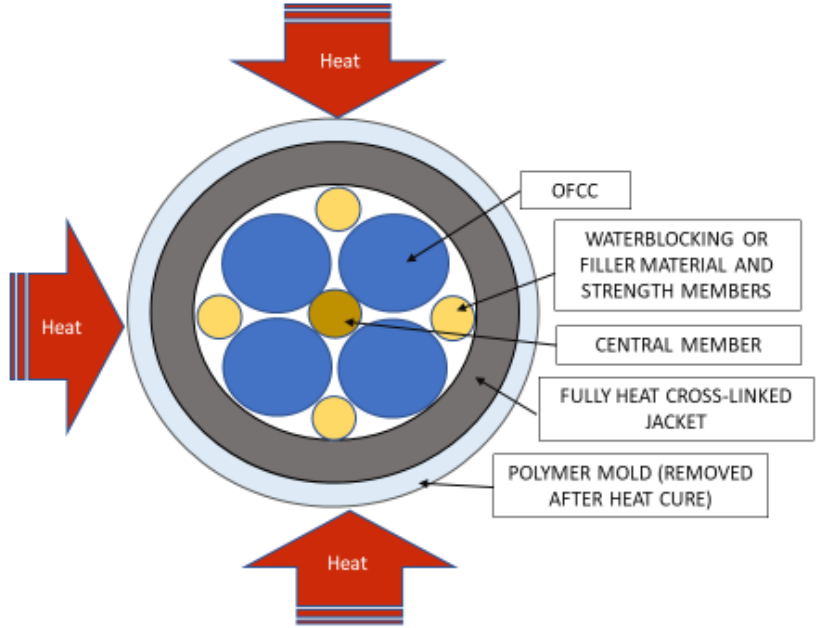


CABLE JACKET CROSS LINKING METHODS



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.

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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.