NSRP | National Shipbuilding Research Program

Shipboard Fiber Optic Cables Design Enhancements

2019 ELECTRICAL PANEL PROJECT 2019-477

Project Completion Summary

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NSRP Electrical Technologies Panel Meeting

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CHALLENGE

- 10% to 20% of the fiber optic cables are damaged at installation[1].
- At least one of four fibers breaks when installing the 4F cable on a DDG 51[2].
- Some runs require upwards of six (6) tries[3].
- New applications (lighting, power over fiber, and laser weapon systems) require highly reliable cables.

OBJECTIVE →→→ TOC REDUCTION

- Reduce cable damage.
- Reduce the cost of installation.
- Improve systems' reliability.
- Improve commonality of parts.

Ship Class	Est. Cable Qty (ft)	Cost of Damage ($)
CVN 78	4,000,000	$5,240,000
LHA/LPD	2,000,000	$2,620,000
DDG 51	1,000,000	$2,620,000
FFG/LCS	500,000	$1,310,000
SSN	500,000	$1,310,000
	100,000	$262,000

Cable damage estimated at 10% on CVN, LHA, and LPD. 20% on all other classes.

SOLUTION

- Apply technical advances and commercial best practices to make fiber optic cables more reliable and facilitate installation process.
- Identify designs suited for multiple applications: data, lighting, power over fiber, laser delivery…

1. Per Discussions with NSRP Electrical Panel members, July 24-25, 2018, Washington, D.C.
2. Per Discussion with BIW Engineer, October 16, 2018, Bath, ME
3. D.S. Dorfman, F. A. Strom III, "An Optimization Model for Fiber-Optic Cable Installation Aboard Navy Vessels", Navy Postgraduate School Thesis, June 2013

SHIPBOARD FIBER OPTIC CABLES DESIGN ENHANCEMENTS PROJECT

TEAM

- **Lead**: RSL Fiber Systems
- **Support**: Penn State University, Applied Research Lab, Electro-Optics Ctr.
- **Shipyards**: Austal USA, Newport News Shipbuilding, Ingalls Shipbuilding, Bath Iron Works
- **US Navy**: SUPSHIP GC
- **Fiber Optic Cable Manufacturer**: OFS Fitel
- **NSRP Project Manager:** Nick Laney
- **NSRP PTR:** Walt Skalniak

SHIPBOARD FIBER OPTIC CABLES DESIGN ENHANCEMENTS PROJECT

METHODS AND PROCEDURES

1. TASK 1 - Identify Causes of Cables' Failure:
   - Evaluation of the existing M85045 cables, installation, and failure mechanisms (Visits to shipyards, observation of installations, meetings with AITs).
   - Identify the ideal performance parameters to minimize/eliminate cable failures.

2. TASK 2 - Identify Design Enhancements:
   - Investigate new commercial and military cable designs, materials, constructions, and installation hardware.
   - Determine how they may be applied to reduce/eliminate cable breakage.
   - Retain/enhance critical shipboard cable characteristics: low smoke, low toxicity, zero halogen, water blocked.

3. TASK 3 - Minimize Impact of Design Enhancements:
   - Compatibility with legacy hardware, installation and fiber termination methods, require no AITs' re-training.

4. TASK 4 – Determine Costs of Qualification for Changes Recommended:
   - Determine cost of qualification for the changes recommended in cable design / materials and ROI.

5. TASK 5 – Final Report and Recommendations:
   - Final Report with Recommendations for Technology Transition.

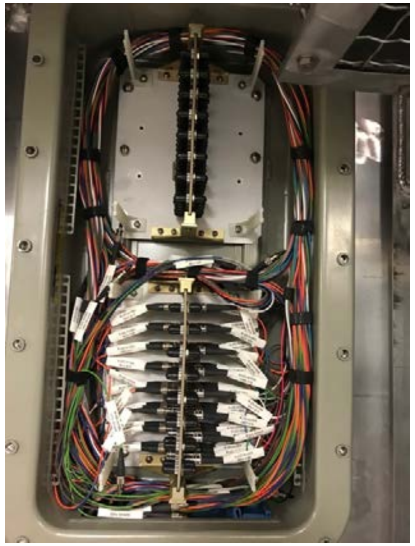
TASKS AND PROGRAM SCHEDULE

	MONTH											
TASK	1	2	3	4	5	6	7	8	9	10	11	12
1.0 <u>Identify Causes of Cables' Failure</u>												
1. Kick-off Meeting	x											
2. Identify AIT PoC and schedule visits to shipyards	x	x										
3. Visit shipyards and meet with AIT	x	x	x	x								
4. **Report 1** - Summarize possible causes of failure.				**X**								
2.0 <u>Identify Design Enhancements</u>												
1. cable manufacturers - identify design enhancements			x	x	x							
2. Evaluate cables used for similar applications			x	x	x							
3. **Report 2** – commercial designs to decrease breakage.					**X**							
4. Determine any additional/enhanced testing.				x	x	x						
5. **Report 3** – Define additional tests required.						**X**						
6. New F.O. technologies and req. cable enhancements.			x	x	x	x						
7. **Report 4** – Cable design options and test methods.							**X**					
3.0 <u>Minimize Impact of Design Enhancements</u>												
1. Review other equipment to insure compatibility.					x	x	x					
2. Review installation methods to insure compatibility.						x	x					
3. **Report 5** – Confirm no neg. impact on equipment & install.								**X**				
4.0 <u>Determine Cost of Qualification and Impact on Breakage</u>												
1. Investigate the cost of qualification.								x	x			
2. Determine cost impact of proposed vs. qualified cables.									x	x		
3. Review design to estimate impact on breakage.									x	x		
4. **Report 6** – Cost of qualification and of changes.											**X**	
5.0 <u>Final Report – Study findings</u>												
1. Recommended enhanced cable design;												**X**
2. Recommended test enhancements;												**X**
3. Estimated impact on cable damage and TOC savings.												**X**

SHIPYARD VISITS

KEY POINTS

- AITs training is critical.
- Much rework is caused by terminating fibers on the ship.
- The rework issue is much greater with SM fibers.
- Use of fiber is anticipated to increase, especially SM.
- Fusion splicing can drastically reduce rework.
- Some cable design improvements can facilitate fusion splicing.
- More flexible cable components may reduce fiber breakage.
- Cable breakage is from negligible to 10% when installed by the shipyards' AITs.
- More breakage can occur as other activities take place around the cables.



Special Thanks to: Greg Stevens, Bath Iron Works; Jason Farmer, Ingalls Shipbuilding; Shawn Wilber, Austal USA; David Ellis, Newport News Shipbuilding for coordinating the visits and the meetings with technical personnel.

Photos Courtesy of Austal USA

CABLE DESIGN ENHANCEMENTS

Three (3) possible areas identified from Task 1:

1. OFCC and buffer designs to facilitate fusion splicing and termination.
2. More flexible and robust OFCC.
3. Outer jacket materials with enhanced abrasion and cut through resistance.

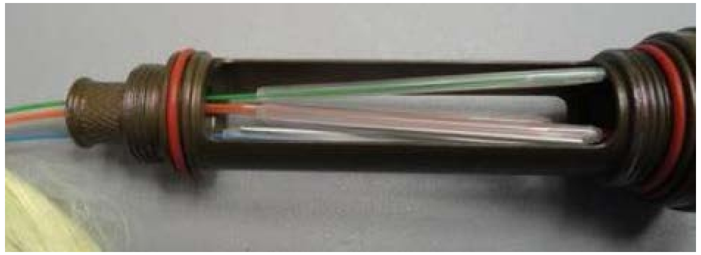


Photo Courtesy of PSU ARL

Investigation Activities:

- Identify and evaluate designs, materials, processes, and requirements to improve cables' performance.
- Compare MIL-PRF-85045 shipboard fiber cables.
- Obtain feedback from AITs on key cable performance parameters.
- Obtain feedback from AITs on fiber buffer types.
- Compare cable jackets abrasion resistance with enhanced test procedure.
- Summarize design enhancements.

MIL-PRF-85045/18 CABLES COMPARISON

- Draka feels more rugged.
- Draka is stiffer → significantly larger central member + thicker outer jacket wall.
- Draka OFCCs are less flexible with slightly larger diameter of OFCC and fiber buffer.
- Draka OFCC jacket is easy to remove. General Cable OFCC jacket is considerably tighter and more difficult to remove.
- Draka buffers are marginally easier to strip than General.
- Neither Draka or General Cable allows the secondary buffer to be stripped separately from the primary (acrylate) coating.

	X-linking	Cable Dia. (mm)	Jacket Wall Thickness (mm)	OFCC Dia. (mm)	Fiber Buffer Dia. (µm)	Central Mem. Dia. (mm)	Construction
Prysmian / General Cable	Radiation	8.0	1.14 - 1.19	1.85 - 2.00	840 - 850	0.38	Braided Aramid Yarns, swellable tape over OFCCs, swellable tape longitudinally pulled around central member.
Prysmian / Draka	Mold Cure	8.2	1.28 - 1.50	1.96 - 2.07	860 - 880	0.92	Mylar tape under jacket, served Aramid Yarns, swellable tape over OFCCs, four (4) filler yarns in OFCC voids.
M85045/18 Requirements	Not Specified	7.75 – 8.5	≥ 1.0	1.8 – 2.2	900 ± 50	Not Specified	

FIBER BUFFER COMPARISON

- Samples sent to shipyard AITs, PSU EOC, and NSWC DD.
- Rank based on preferred for Epoxy & Polish and for Fusion Splicing
- Recipients unaware of origin of samples to keep effort “blind comparison”
- Set of criteria:
  - ✓ Ease of buffer removal (how much buffer can be removed with one “strip” action)
  - ✓ Ease of removal of the secondary buffer, leaving the acrylate coating on the fiber
  - ✓ Which buffer would work best for epoxy & polish terminations
  - ✓ Which buffer would work best for fusion splicing

Origin	Rank
Corning (from FIS)	1
AFL LSZH	2
OFS Flex 300 OFNP	3
Draka M85045/18	4
General Cable M85045/18	5

RANKING OF CABLE PERFORMANCE CHARACTERISTICS

MIL-PRF-85045 SHIPBOARD FIBER OPTIC CABLE CHARACTERISTIC	Rank (by Importance)
Tensile Load	1
Twist Bend	2
Cycle Flex	3
Low Temperature Flexibility	4
Impact	5
Scrape Resistance	6
Cable to Cable Abrasion	7
Fluid Immersion - Fuel Oil 98-100°C	8
Fluid Immersion - Turbine Fuel 48-50°C	9
Fluid Immersion - Lube Oil 98-100°C	10

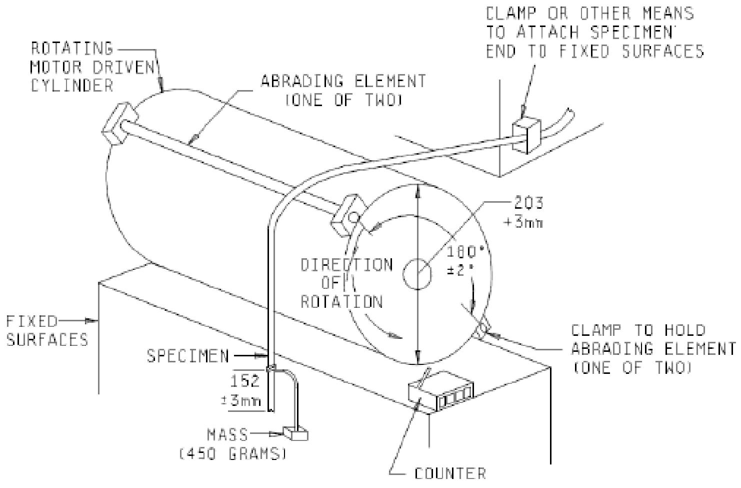
- Tensile load ranked highest by all respondents.
- Fluids' immersion performance ranked lowest by all.

OUTER JACKET PERFORMANCE

- Use of Thermoset jacket driven primarily by fluids' immersion temperature requirements.
- Thermoplastic materials are very similar to Thermosets in many areas of interest.
- Thermoplastic materials eliminate one (1) or two (2) manufacturing processes.

							Oil (4 hrs @ 70°C)		Diesel (24 hrs @ 25°C)	
Process	Tensile (psi)	Elongation (%)	Tear (lb-in)	Durometer	Low Temp Brittle Point (°C)	O2 Index (%)	Tensile Ret (%)	Elong Ret (%)	Tensile Ret (%)	Elong Ret (%)
Tplastic	2000	225	40	95	-53	37	73	97	56	62
Radiation	1750	180	42	90	-31	38	69	60	63	60
Mold Cure	1800	200	45	96	-26	38	98	94	58	80

OUTER JACKET PERFORMANCE



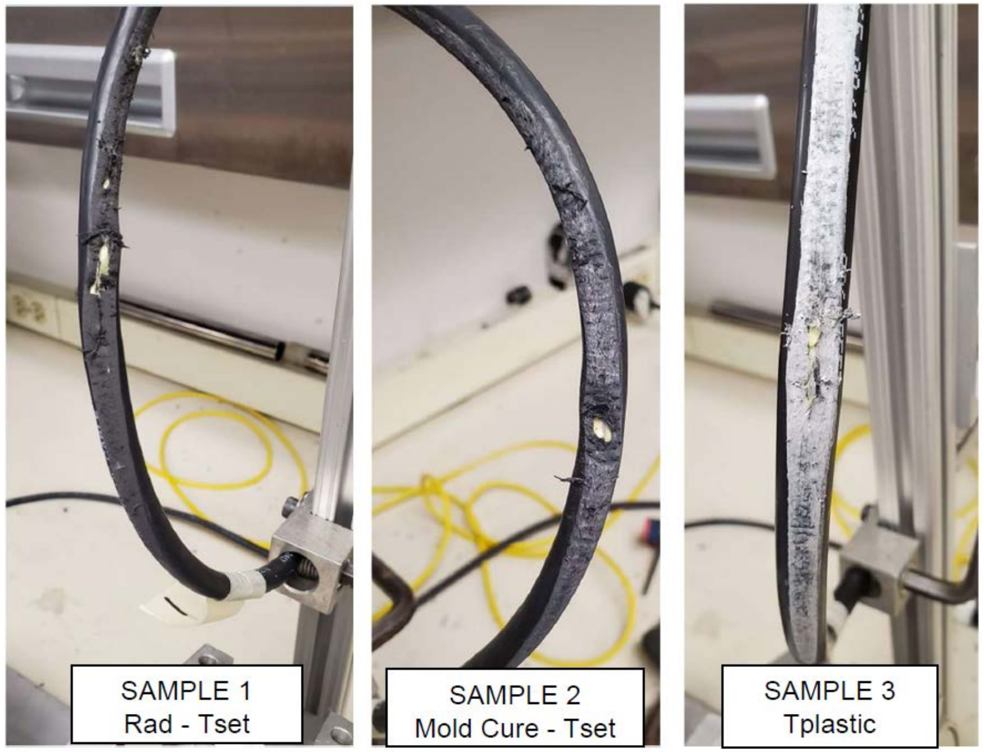
JACKET SCRAPE ABRASION

- Jacket abrasion described as a cause of damage at installation.
- MIL-PRF-85045 specifies use of 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
- Three (3) Cables Tested:
  1. M85045/18 with Thermoset Jacket by Irradiation
  2. M85045/18 with Thermoset Jacket by Mold Cure
  3. RSL 118052 with Thermoplastic Jacket

OUTER JACKET PERFORMANCE

JACKET SCRAPE ABRASION

- Comparison based on Scrapes per mm of wall thickness.
- Thermoplastic outperformed both Thermosets (> 100 scrapes to failure).
- Results provided as % of top performing jacket.
- Irradiation X-linking does not cure entire jacket thickness.
- "White Scrapes" may give false impression that Thermoplastic is more susceptible to damage.



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

OUTER JACKET PERFORMANCE

RECOMMENDATIONS – JACKET ENHANCEMENT

- Revise MIL-PRF-85045 fluid immersion temperature requirements

FLUID	Present Requirements		Recommended Revision	
	Temperature	% T&E Retention	Temperature	% T&E Retention
Fuel Oil	98°C – 100°C	≥ 50%	48°C – 50°C	≥ 50%
Turbine Fuel	48°C – 50°C	≥ 50%	30°C – 35°C	≥ 50%
Lubricating Oil	98°C – 100°C	≥ 50%	48°C – 50°C	≥ 50%

- Allow the use of Thermoplastic option to Thermoset:

PROS:

  - Improved abrasion and cut-through.
  - Lower production costs.
  - More sources of supply.

CONS:

  - Lower resistance to hot fuel and lube oil.

QUALIFICATION COSTS AND ROI

NEXT STEPS

- Four (4) possible re-design and qualification approaches:

QUALIFICATION EFFORT	Est. Cost ($)	Cost Comparison
Full Cable Redesign and Qualification	476,421	100%
Jacket + OFCC Buffer Redesign	347,049	73%
Outer Jacket Redesign	272,247	57%
OFCC Buffer Redesign	250,910	53%

- Costs include:
  a) Required cable length(s);
  b) Engineering and program management;
  c) Tests at Nationally Recognized Testing Laboratories (NRTL);
  d) Related travel.

RETURN ON INVESTMENT

New Thermoplastic Jacket

Note: Ship Class specific data was removed for Distribution A version of report.

		5% & 10% Damage (Tset Jkt)			2.5% & 5% Damage (Tplastic Jkt)			
Ship Class	FO Cable/yr (000 ft)	Cable ($ 000)	Labor ($ 000)	Total ($ 000)	Cable ($ 000)	Labor ($ 000)	Total ($ 000)	Cost Saving ($ 000/yr)
CVN 78								
LHA/LPD								
DDG 51								
FFG/LCS								
SSN								
TOTAL	7,800	$42,200	$56,500	$98,700	$34,510	$52,571	$87,081	**$11,619**

- Estimates Include:
  - a) 15% reduction in cable cost due to Thermoplastic Jacket;
  - b) 50% Reduction in Cable Damage.
- Estimated ROI:
  - a) Savings from Thermoset to Thermoplastic: $ 6.3M /year
  - b) Thermoplastic w/50% reduction in damage: $ 11.6M / year

NEXT STEPS

1. Test larger lot of M85045/18 cables for modified Scrape Abrasion to verify results.

2. Recommend revisions to MIL-PRF-85045:
   a) Reduce temperature of fluid immersion test.
   b) Increase weight of scrape abrasion test to 4.54 Kg (10 lbs) and reduce from 500 to 50 cycles.

3. Evaluate materials/processes to improve buffer strippability.

4. Evaluate and identify more resilient jacketing compounds.

CONCLUSIONS

- Baseline cable designs are suited for shipboard environment.
- Improvements can be made with no impact on physical design:
  - Facilitate terminations with improved buffer strippability.
  - Increase jacket resistance to abrasion/cut-through with more durable compounds.
- Thermoset jackets may have been preferred for perceived vs. actual abrasion resistance.
- Thermoplastic jackets have potential to:
  - Improve abrasion resistance.
  - Decrease material cost.
  - Decrease fiber damage.
  - Lower TOC of fiber optic shipboard systems.

QUESTIONS?