DEPARTMENT OF THE NAVY
NAVAL SURFACE WARFARE CENTER
CARDEROCK DIVISION

NAVAL SHIP SYSTEMS
ENGINEERING STATION
PHILADELPHIA, PA 19112-5083

IN REPLY REFER TO

9504
Ser 9542/06

MAR 14 1997

From: Commander, Naval Surface Warfare Center, Carderock Division, Philadelphia Station, Philadelphia, PA 19112-5083
To: Commander, SPACE & Naval Warfare Systems Command (Code PD 151, Attn: CDR Rackliffe)

Subj: FIBER OPTIC EPOXYLESS ST CONNECTOR EVALUATION

Ref: (a) Phonecon SPAWAR Code 151 (CDR Rackliffe) /NSWCCD-SSES Code 9542 (E. Bluebond) of 15 Nov 96
(b) Mtg. SPAWAR Code 151 (CDR Rackliffe)/ SPAWAR Code 15Q2A (N. Isfahani)/ NSWCCD-SSES Code 9542 (E. Bluebond of 27 Feb 97

Encl: (1) ST Connector Cable Terminator Study Using Connectors Requiring None Or Different Type Epoxies (Test Plan) dated 27 Nov 96
(2) Preliminary Test Estimate, ST Connector Cable Termination Study Using Connectors Requiring Non Or Different Type Epoxies dated 27 Nov 96

1. This letter addresses the request made by the Space and Naval Warfare Systems Command (SPAWAR) during reference (a) to investigate a particular type of fiber optic ST connector. This type ST connector is terminated onto the end of a fiber optic cable without embedding the end of the optical fiber in epoxy. For brevity, this type ST connector will be referred to as an epoxyless connector.

2. During reference (b), time saving advantages and long term reliability concerns with the epoxyless connector were discussed. The Naval Surface Warfare Center, Carderock Division, Ship Systems Engineering Station (NSWCCD-SSES) recommended that the planned time trial study be expanded to include both short term performance and long term reliability testing. The time trial study, covered under a separate statement of work, will be performed first to determine time savings as the first part of this investigation. This letter covers the short term performance and long term reliability testing. Short term testing would assess initial performance. Simulated long term or reliability testing would assess areas of concern discussed during reference (b).

3. By references (a) and (b), SPAWAR requested that NSWCCD-SSES prepare separate cost estimates and a statement of work to perform both the short term performance and long term reliability testing. Enclosures (1) and (2), respectively, are the prepared cost estimates for the short term performance and long term reliability testing. Enclosure (3) is a combined statement of work. The cost estimate for NSWCCD-SSES to perform this testing is $90,000.00.

4. The fiber optic test and qualification point of contact at NSWCCD-SSES is Eric Bluebond. He can be contacted at (215) 897-8510.

J. P. Coppola

By direction,
J. P. Coppola

Copy to:
SPAWAR CODE PD15Q2A (Nikki Isfahani)
NAVSEA 03J21 (H. Lewis)
NAVSEA 03j21 (K. Long)
NSWCCD B35 (G. Brown)
NSWCCD-SSES 95,954,9542(2)

Rev A: 9 March 1997

PRELIMINARY TEST ESTIMATE
EPOXYLESS ST CONNECTOR EVALUATION: SHORT TERM PERFORMANCE TEST

Description	O/D/ M/E/ S&V	Duration per Group (days)	Quantity /Number of Mandays	Unit Cost /Manday Cost @ $500	Outside Cost $	Cost per Test $
Material Procurements						
Material ***		14				
MM ST connectors (commercial)			12	$25.00 ea		$300.00
MM ST-To-ST adapters (commercial)			6	25.00 ea		150.00
MM Single fiber cable			60 m	0.20/m		12.00
Polishing paper						200.00
Labor	P	0.25	0.25	500		125.00
Test Cable Fabrication						
Prepare test cables	A	0.5	0.5	250.00		250.00
Testing						
Group 1-3 MM mated pair						
Visual & mechanical	D	0.5	0.5	250.00		250.00
Size	D	1	1	500.00		500.00
Identification marking	D	0.125	0.125	65.00		65.00
Workmanship	D	0.125	0.125	65.00		65.00
Optical						
Insertion loss	O	2	2	1000.00		1000.00
Return loss (reflectance)	O	1	1	500.00		500.00
Group 2-3 MM mated pair						
Pretest-pistoning & reflectance	O/M	2	2	1000.00		1000.00
Tensile loading	M	1	1	500.00		500.00
Mating durability	M	2	2	1000.00		1000.00
Post test-pistoning & reflectance	O/M	2	2	1000.00		1000.00
Group 3-3 MM mated pair						
Pretest-pistoning & reflectance	O/M	2	2	1000.00		1000.00
Temperature/humidity cycling	E	15	5	2500.00		2500.00
Reflectance measurements during test *	O	10	10	5000.00		5000.00
Temperature cycling	E	10	4	2000.00		2000.00
Reflectance measurements during test *	O	5	5	2500.00		2500.00
Temperature life	E	10	2	1000.00		1000.00
Post test-pistoning & reflectance	O/M	2	2	1000.00		1000.00
Group 4 - 3 MM mated pairs + 2 unassembled ST						
Fungus-2 unassembled ST	C/O	30	0.25	250.00	4750.00	5000.00
Salt spray-1 mated pair	E	7	0.5	250.00	1550.00	1800.00
Flammability-2 mated pair	E	1	1	500.00		500.00
Test report	R	5	3	1500.00	100.00	1600.00
Miscellaneous						
Facility usage						1000.00
Test equipment automation **						0.00
Interferometer repair						2000.00
Consumables						200.00
Calibration (8 % of in-house)				2000.00		2000.00
DESC cert requirements/documentation				250.00		2500.00
Totals						$38,517.00

* Two reflectance measurements per cycle.
** Not used for this testing.
*** Assumes that ST connectors to be tested are supplied by OEM at no cost(18 required)

Enclosure (1)

DOC:CST3COST.DOC

Rev A: 9 March 1997

PRELIMINARY TEST ESTIMATE
EPOXYLESS ST CONNECTOR EVALUATION: LONG TERM RELIABILITY TEST

Description	O/D/ M/E/ S&V	Duration per Group (days)	Quantity /Number of Mandays	Unit Cost /Manday Cost @ $500	Outside Cost $	Cost per Test $
Material Procurements						
Material *#		14				
MM ST connectors (commercial)			126	$25.00 ea		$3150.00
MM ST-To-ST adapters (commercial)			60	25.00 ea		1500.00
MM Single fiber cable (62.5/126 um)			300 m	0.20/m		6.00
MM Single fiber cable (50/125 um)			30 m	0.20/m		0.60
Polishing paper						200.00
Labor	P	0.25	0.25	500.00		125.00
Test Cable Fabrication						
Prepare 62.5/125 um test cables *##	A	2	2	1000.00		1000.00
Check 50/125 um test cables *###	A	2	2	1000.00		1000.00
Testing						
DUT fabrication & optical performance						
Insertion loss	O	2	2	1000.00		1000.00
Return loss (reflectance)	O	1	1	500.00		500.00
Pretest-pistoning measurement	O/M	2	2	1000.00		1000.00
High temperature at constant high humidity test						
Accelerated test (9 months) 15 mated pair						
Optical transmittance each week	O	0	0	0.00		0.00
Reflectance each month	O	9	1	4500.00		4500.00
Post-test pistoning measurement	D	1	1	500.00		500.00
Abbreviated test (3 months) 15 mated pair						
Optical transmittance each week	O	0	0	0.00		0.00
Reflectance each month	O	3	1	1500.00		1500.00
Post test-pistoning measurement	D	1	1	500.00		500.00
Statistical Analysis						
Learn to use statistical software package *		10	10	0.00	5000.00	5000.00
Perform statistical analysis *	E	5	5	0.00	2500.00	2500.00
Test report	R	3	3	1500.00	100	1600.00
Miscellaneous						
Chamber operation & usage **					20000.00	20000.00
Test equipment automation ***		10	10	0.00	5000.00	5000.00
Consumables						200.00
Calibration (8 % of in-house)				1600.00		1600.00
DESC cert requirements/documentation				200.00		200.00
Totals						$52,581.60

* Performed by NSWC DD (Dahlgren, VA)
** Includes one day per week environmental chamber maintanance, chamber rent and projected repair cost over 9 month period.
*** Automate optical transmittance measurements to obtain 3 measurements per day.
*# Assumes that ST connectors to be tested are supplied by OEM at no cost (64 required)
*## Fabricate thirty 62.5/125 um test cables, 10 meters long, to insert the ST connectors to be tested.
*### Fabricate thirty 50/125 um test cables, 1 meter long, to simulate 70/70 optical launch conditions.

Enclosure (2)

DOC:CST4COST.DOC

9 March 1997

EPOXYLESS ST CONNECTOR EVALUATION
PERFORMANCE AND RELIABILITY TESTING
STATEMENT OF WORK

1. Introduction.

This evaluation covers both short term performance and a long term reliability of the epoxyless ST connector. This fiber optic connector design has exposed, bare optical fiber inside the ST connector ferrule as well as at the ferrule end face. Industry test data shows that exposed, bare optical fiber is attacked by humidity which results in stress corrosion cracking of the optical fiber. Industry field data does not show trouble-free usage with epoxyless ST connectors. The Navy is aware of three industrial applications in which epoxyless ST connectors were cut off and replaced within months of being installed after latent defects were experienced. In one of these applications, over 10,000 epoxyless ST connectors were removed. It is not certain if the "latent defects" experienced were design or installation related. Design engineers for the epoxyless ST connector will state candidly that the intended use is for short term installations and emergency replacements.

This evaluation will study the performance over time and the reliability over time. Performance over time will be determined by the change in optical transmittant levels and the axial movement of the optical fiber with respect to the end face of the ST connector ferrule (fiber pistoning). Also, material and mechanical performance will be evaluated. One reason to evaluate each will be cited. Most ST connectors are made with zinc die cast barrels (ferrule support) and bayonet caps (housing). The Navy has found that these zinc die cast components "disintegrate" in high temperature/high humidity conditions. A tensile loading test is a measure of the cable capture mechanism mechanical performance. ST connector designs that crimp directly on the cable, versus a kevlar capture mechanism, is unsatisfactory since there is no allowance for pull strength on the cable.

Reliability over time will look at the degradation of the bare optical fiber. This degradation will be determined indirectly by measuring the return loss (reflectance) over time. Also, change in optical transmittance and fiber pistoning will provide a more gross indication of optical fiber degradation.

A separate study will compare fabrication times to terminate a ST connector onto a fiber optic cable. Connectors with four different types of epoxy systems will be used for this study: connectors injected with a two-part, heat cured epoxy (heat cured type), connectors injected with an anaerobic epoxy (anaerobic type), connectors pre-injected with a re-heatable type epoxy (re-heatable type) and connectors in which no epoxy is used to secure the optic fiber in the ferrule (epoxyless type). This study will be performed under a separate statement of work.

Enclosure (3)

2. Purpose.

a. Short term testing assesses initial performance of basic optical, mechanical and material characteristics.
b. Simulated long term or reliability testing assesses long term exposure by accelerated testing in a high temperature/high humidity environment.

3. Limitation of Scope.

The scope of this evaluation is to assess short term performance and long term reliability of a particular OEM epoxyless ST connector for commercial, industrial grade applications. Onboard ships, this would equate to ones for non-critical, non-tactical applications. Short term performance tests are restricted to the same tests as those performed by the Navy for other type commercial ST connectors (i.e., epoxy systems such as heat-cured epoxy, anaerobic epoxy, re-heatable epoxy) with the addition of fiber pistoning and return loss. Long term reliability testing is limited to accelerated type testing performed in a high temperature/high humidity environment.
Return loss (reflectance) tests are performed in accordance with EIA/TIA-455-107. Reflectance measurement need only be performed in one direction and can be performed with a single mode return loss meter. Correlation data between single mode and multimode reflectance measurements is not required. The objective is to measure the mechanical change in the fiber position. The optical effect of this mechanical change is used as a diagnostic tool.

4. Test Plan.

a. Phase 1: Perform short term performance testing.

(1) Test agenda. The test agenda is listed in Table I. The test sequence is divided into four groups. Group 1 is for dimensional and optical performance. Groups 2, 3 and 4 are for mechanical, environmental and material performance, respectively. These tests represent the minimum requirements acceptable and almost exclusively obtained from industry test procedures.

(2) Test procedure and requirements. Test procedures and requirements are listed under the test agenda in Table I. Only two of the tests are not being performed using industry (TIA) test procedures. This is due to lack of a suitable commercial test procedure at the present time. Optical performance is dictated by the requirements in MIL-STD-2052, Fiber Optic Systems Design.

b. Phase 2: Perform long term reliability testing.

(1) Test agenda. The test agenda is listed in Table II. The test sequence is divided into two groups. One group is for the accelerated samples which will be tested for 9

months. The other group is for the abbreviated samples which will begin the test with the accelerated samples and be removed after 3 months. The two groups will provide two different data sets. A statistical analysis package, now being used by industry for similar type tests, will be used to analyze differences in the two data sets.

(2) Test procedure and requirements. Test procedures and requirements are listed under the test agenda in Table II. The accelerated high temperature/high humidity test procedure and test conditions are the same ones being used in industry for this type reliability evaluation. Again, optical performance is dictated by the requirements in MIL-STD-2052, Fiber Optic Systems Design.

5. Time and Funding Constraints.

a. This study will be performed under the following time and funding constraints:

(1) Test personnel availability. Qualified Products List (QPL) testing has priority over commercial studies. It is anticipated that there will be sufficient personnel available to perform testing for all funded programs in a timely manner.

(2) Test equipment availability. Test equipment needed for this study is not an issue for this study. Consumables (epoxy, polishing paper, etc.) required for this study can be purchased in a timely manner.

b. Connector availability. The cost estimate assumes that the epoxyless ST connectors used in this study will be provided by the manufacturer. The total quantity of connectors required are as follows:

Epoxyless ST connectors for the short term performance testing: 18

Epoxyless ST connectors for the long term reliability study: 64

Other ST connectors, cable plant components and consumables required for this evaluation will be included in a separate cost estimate.

DOC: STNOGLU2.POA

TABLE I: TEST AGENDA
COMMERCIAL OFF-THE-SHELF (COTS) EPOXYLESS ST CONNECTOR
PERFORMANCE STUDY (SHORT TERM), MULTIMODE CONFIGURATION ONLY

TEST PERFORMED	O/D/ M/E/ S&V	DURATION PER GROUP (DAYS)	OPTICAL DATA	TEST STATUS		
				START DATE	END DATE	ACTUAL MANDAYS
Material procurement	P	14				
Test cable fabrication	A	0.5				
Group 1-3 MM mated pair						
Visual & mechanical	D	0.5				
Size	D	1				
Identification marking	D	0.125				
Workmanship	D	0.125				
Optical						
Insertion loss	O	2	OIL			
Return loss (reflectance)	O	1	ORL			
Group 2-3 MM mated pair						
Pretest-pistoning & reflect	O/M	2	ORL			
Tensile loading	M	1	OOT			
Mating durability	M	2	OOT			
Post test-piston & reflect	O/M	2	ORL			
Group 3-3 MM mated pair						
Pretest-pistoning & reflect	O/M	2	ORL			
Temperature/humidity cycling	E	15	OOT			
Reflectance during test	O	--	ORL			
Temperature cycling	E	10	OOT			
Reflectance during test	O	--	ORL			
Temperature life	E	10	OOT			
Post test-piston & reflect	O/M	2	ORL			
Group 4						
Fungus-2 unassembled ST	C/O	30				
Salt spray-1 mated pair	E	7				
Flammability-2 mated pair	E	1	OOT			
Test Report		5				
Totals	---		---			

Note: Use same three mated pair for Groups 1, 2 and 3 testing.
Performance Tests:

1. Group 1
   - a. Visual/dimensional
     - (1) Size (TIA/EIA 604-2 (FOCIS-2))
     - (2) Workmanship (EIA-455-13; no pits, burrs, etc., mates properly, ^c)
     - (3) Identification markings (EIA-455-13, Mfr id/logo legible)
   - b. Optical
     - (1) Insertion loss (TIA/EIA-455-34, Method A, <1.0 dB initial)
     - (2) Return loss (from detector end, EIA-455-107, ≤ 30dB per mated pair) Do from detector end and do not disturb launch conditions.
2. Group 2 Mechanical
   - a. Tensile loading (20 lb for 1 minute, no damage, *a, ^c)
   - b. Mating durability (EIA-455-21, 500 times, *d, ^c)
3. Group 3 Environmental
   - a. Temperature humidity cycling (TIA/EIA-455-5, -10/65 ^{o}C for 10 cycles, *d, ^c)
   - b. Temperature cycling (EIA/TIA-455-3, -46/85 ^{o}C for 5 cycles, *d, ^c)
   - c. Temperature life (TIA/EIA-455-4, 110 ^{o}C for 240 hr, *a, ^c)
4. Materials
   - a. Fungus resistance (TIA/EIA-455-56) For info purposes only
   - b. Flammability (MIL-STD-1344, Method 1012) For info purposes only
   - c. Salt spray (TIA/EIA-455-16, 5%salt sol'n/96 hr, ^c)
5. Fiber pistoning (fiber movement at ferrule end face - protrusion or undercut)
   - a. Axial movement of optical fiber with respect to ferrule ≤ 0.2 microns.

*d = Change in optical transmittance ≤ 0.5 dB both during and after the test.
*a = Change in optical transmittance ≤ 0.5 dB after the test.
^c = No visual evidence of cracking, degradation, deterioration, distortion, separation, corrosion, etc.

DOC: CSTNOGLU.DOC

Table II: TEST AGENDA
COMMERCIAL OFF-THE-SHELF (COTS) EPOXYLESS ST CONNECTOR
RELIABILITY STUDY (LONG TERM)
(MULTIMODE CONFIGURATION ONLY)

TEST PERFORMED	O/D/ M/E/ S&V	DURATION PER GROUP (DAYS)	OPTICAL DATA	TEST STATUS		
				START DATE	END DATE	ACTUAL MANDAYS
Test Cable Fabrication						
Prepare 62.5/125 um cables	A	2				
Prepare 50/125 um cables	A	2				
Testing						
DUT fab & optical perform						
Insertion loss	O	2	OIL			
Return loss (reflectance)	O	1	ORL			
Pretest-pistoning	O/M	2				
High temp/high humidity test						
Accelerated test (9 months)						
Optical transmittance	O	0	OOT			
Reflectance each month	O	9	ORL			
Post-test pistoning	D	1				
Abbreviated test (3 months)						
Optical transmittance	O	0	OOT			
Reflectance each month	O	3	ORL			
Post test-pistoning	D	1				
Statistical Analysis						
Stat software package prem*		10				
Perform stat analysis *	E	5				
Test report	R	3				
Totals	---		---			

Note: Use same three mated pair for Groups 1, 2 and 3 testing.
Performance Tests:

1. Optical
   a. Insertion loss (TIA/EIA-455-34, Method A, <1.0 dB initial)
   b. Return loss (from detector end, EIA-455-107, ≤ 30dB per mated pair)
   Do from detector end and do not disturb launch conditions.
2. Temperature humidity soak (85 °C at 95 percent relative humidity *d, ^c)
   a. Automate optical transmittance to obtain 3 measurements per day.
   b. Obtain return loss (reflectance) measurement each week.
3. Fiber pistoning (fiber movement at ferrule end face - protrusion or undercut)
   a. Axial movement of optical fiber with respect to ferrule ≤ 0.2 microns.

*d = Change in optical transmittance ≤ 0.5 dB both during and after the test.
^c = No visual evidence of cracking, degradation, deterioration, distortion, separation, corrosion, etc.
* Performed by NSWC DD (Dahlgren, VA)

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