Fiber Optic Adapter Sleeve Evaluation, Insertion Loss Comparison of Ceramic, Metal and Polymer Alignment Sleeves

1. INTRODUCTION

1.1. Purpose

Testing was performed on CS Electronics 2.5 mm ceramic, metal, and polymer alignment sleeves. The purpose of this test was to determine if there is a significant difference between sleeve types as evidenced by comparison of insertion loss performance before and after environmental and physical test exposures.

1.2. Scope

This report covers the optical, environmenwtal, and mechanical performance of ceramic, metal, and polymer alignment sleeves manufactured by the Fiber Optic Business Unit of CS Electronics. Testing was performed in 1995.

1.3. Conclusion

Ceramic sleeves exhibit lower insertion loss and smaller changes in loss due to the types of environmental and physical stresses that are most apt to cause their performance to deteriorate. Metal sleeves do not perform as well as ceramic, but overall perform better than polymer. Metal sleeves cannot be expected to perform as well as ceramic sleeves, especially in prolonged heat exposure. Ceramic sleeves can be expected to meet Telcordia GR-326, Issue 1 requirements. In exposures prescribed in our generic product specification (flex, durability, and temperature cycling), where a sleeve's performance is most likely to be affected, our ceramic, metal and polymer sleeves will meet current requirements.

1.4. Product Description

CS Electronics 2.5 mm alignment sleeves are used in both Telecom and Datacom applications.

1.5. Test Samples

Samples were constructed using normal manufacturing processes. Sixty of each sleeve was inserted into the Bayonet adapters for evaluation. The following sample quantities were used for the test group.

Test Group	1	2	3
Sleeve Material	Ceramic 502750-1	Metal 502268-1	Polymer 502442-1
Quantity of Samples	60	60	60

Table 1
Sleeve Test Groups

1.6. Design Verification Test Sequence

Test or Examination	Test 1 (n = 90)	Test 2 (n = 30)	Test 3 (n = 30)	Test 4 (n = 30)
Attenuation	1	1	1	1
Extended Heat Age	2			
Flex		2		
Durability			2	
Temperature Cycling				2

Table 2
Test Sequence and Sampling

2. SUMMARY OF TESTING

2.1. Extended Heat Age

Statistical analysis consisted of graphical comparisons (Appendix A) and analysis of variance (ANOVA) (Appendix C). Table 3 summarizes initial and final insertion loss results.

Scatter charts were created for each of the sleeve types for visual confirmation of performance. Some sleeve samples improve while other samples get worse as a result of the heat age exposure. See Appendix A.

In the ANOVA, sleeve type was a fixed factor. Sleeve sample was a random factor (sleeves selected at random from inventory for each type, group and test exposure).

As expected, sleeve types were significantly different from each other in both initial and final results analysis. This can also be seen in the scatter charts. Because of the larger tolerance of the polymer sleeve inner diameter and the tighter tolerance of the single mode ceramic ferrule outer diameter, the initial polymer sleeve insertion loss values were inconsistent. While initial insertion loss for ceramic sleeves appears to compare with initial insertion loss of metal sleeves, ceramic sleeve performance is slightly better. Both ceramic and metal sleeves perform much better than polymer sleeves.

After exposure to extended heat age, differences are much more pronounced. Ceramic is significantly better than either metal or polymer sleeves. Metal sleeve performance is worse after heat age exposure. Polymer sleeve performance improves significantly as a result of heat age, but is still worse than that of either metal or ceramic.

Group ID	Initial		Final	
	Avg.	Std.	Avg.	Std.
Ceramic	0.10	0.18	0.08	0.16
Metal	0.13	0.18	0.23	0.15
Polymer	1.74	0.29	0.32	0.13

Table 3
Extended Heat Age

2.2. Flex/Durability/Temperature Cycling

ANOVA indicates that there is no significant difference in sleeve performance due to exposure to either Flex or Durability testing. In the case of Temperature Cycling, there is slight improvement in performance of Polymer sleeves (likely due to heat exposure). However ceramic and metal sleeves appear not to be affected by these test exposures (see Appendix C).

Scatter charts were created for each test and can be seen in Appendix B. Summary results tables are provided below.

	Initial		Final	
Group ID	Avg.	Std.	Avg.	Std.
Ceramic	0.02	0.02	0.03	0.02
Metal	0.03	0.03	0.03	0.02
Polymer	0.46	0.35	0.40	0.32

Table 4
Flex Testing Results

	Initial		Final	
Group ID	Avg.	Std.	Avg.	Std.
Ceramic	0.01	0.02	0.02	0.02
Metal	0.03	0.02	0.04	0.03
Polymer	0.15	0.21	0.14	0.11

Table 5
Durability Testing Results

	Initial		Final	
Group ID	Avg.	Std.	Avg.	Std.
Ceramic	0.02	0.02	0.02	0.03
Metal	0.02	0.02	0.04	0.03
Polymer	0.30	0.38	0.16	0.17

Table 6
Temperature Cycling Test Results

3. TEST METHODS

All optical measurements were performed with the utilization of a single mode test system by the CS Electronics Fiber Optics Business Unit Test Lab because the sensitivity of a single mode connection amplifies the influence of the sleeves' contribution to ferrule alignment. This measurement facility is compliant with Telcordia GR-326-CORE. Attenuation was measured at 1310 nm wavelength. Following the installation of the samples, sequential testing was performed.

3.1. Phase 1: Extended Heat Age

A. Attenuation (TIA/EIA 455-171, Method D3)

Thirty samples of each sleeve type were randomly selected. Initial insertion loss was recorded using the method prescribed by TIA/EIA 455-171, Method D3. Single mode measurements were taken with reference quality leads. A ceramic (zirconia) sleeve adapter was used as a reference to detect deterioration of lead quality. Sleeves within a given type were selected at random until all sleeves of that type were measured. Sleeve types were selected at random until all sleeve types were tested. Sleeves were inserted into a 2.5 mm bayonet style adapter to facilitate testing. Ten replicate measurements were recorded for each sleeve sample.

Once initial insertion loss was documented, stainless steel pins representing maximum ferrule outer diameter were inserted into the samples to simulate the condition of having ferrules mated in them. Sleeves were not removed from the adapters.

B. Heat Age (TIA/EIA 455-4B)

An acceleration stress relaxation prediction model developed by J. Whitley in 1976 was used to determine the appropriate time and temperature relationship that closely represented the limits specified in Telcordia’s extended life test of 85°C for 5000 hours. Using the curves in Whitley’s report, all samples were exposed to 150°C for 250 hours. Insertion loss measurements were repeated after the samples reached thermal equilibrium at room ambient conditions.

3.2. Phase 2: Flex, Durability and Temperature Cycling

A. Thirty (30) samples of each sleeve type were randomly selected for Flex, Durability and Temperature Cycling tests.

B. Attenuation (TIA/EIA 455-171, Method D3)

Initial and final insertion loss was recorded using the method prescribed by TIA/EIA 455-171, Method D 3. Single mode measurements were taken with master quality leads. A ceramic (zirconia) sleeve adapter was used as a reference to detect deterioration of lead quality. Sleeves within a given type were selected at random until all sleeves of that type were measured. Sleeve types were selected at random until all sleeve types were tested. Sleeves were inserted into a 2.5 mm bayonet style adapter to facilitate testing. After initial insertion loss was measured, samples were divided evenly for each of the three tests (Flex, Durability, Temperature Cycling). Three replicate measurements were recorded for each sleeve sample tested.

C. Flex (TIA/EIA 455-1A)

Ten samples of each sleeve type were inserted into a 2.5 mm bayonet adapter fixtured to a flex machine. A “dummy” cable assembly was mated to the adapter and a 1.1 pound load applied. Each sample was flex-tested for a total of 500 cycles at a rate less than 30 cycles per minute. Flex arc was ± 90 degrees. Upon completion of testing, final insertion loss was measured as described in Attenuation, paragraph 3.2.B.

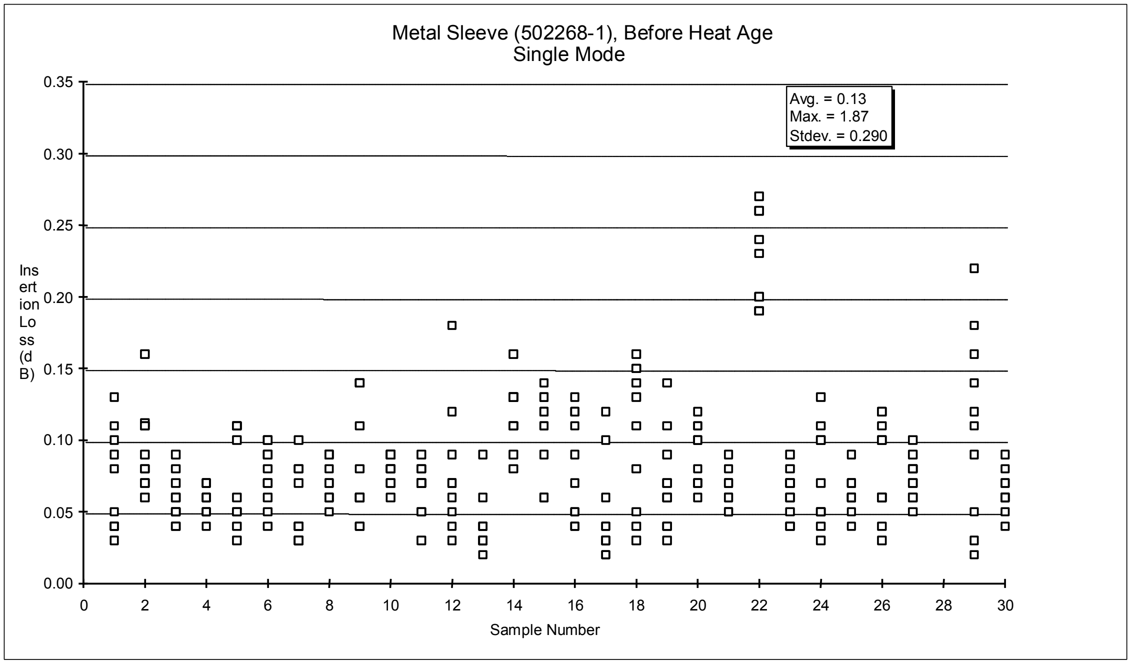
D. Durability (TIA/EIA 455-21A)

Ten samples of each sleeve type were randomly selected. The connector on the detector side of the mated samples was subjected to 500 cycles of durability. Samples were manually cycled at a rate not in excess of 300 cycles per hour. Optical transmittance was measured before and after every 50 cycles throughout the test. Samples were unmated, cleaned, inspected, and re-mated before each measurement. Final insertion loss was measured as described in Attenuation, paragraph 3.2.B.

E. Temperature Cycling (TIA/EIA 455-3A)

Ten samples of each sleeve type were randomly selected and subjected to 5 cycles of temperature extremes, each cycle consisting of 8 hours, for a total of 40 hours exposure to temperature cycling. One cycle consisted of a 1 hour ramp down to and a 1 hour dwell at -40°C, then a 1 hour ramp up to and a 1 hour dwell at 25°C, then a 2 hour dwell at 85°C. The maximum transition time between temperatures was 40°C per hour. Optical transmittance was recorded before and after exposure with the samples in place in test chamber and 5 minutes before the end of each dwell during exposure. Final optical transmittance was recorded at least two hours after temperature cycling exposure, after the samples were unmated, inspected, cleaned and re-mated. Final insertion loss was measured as described in Attenuation, paragraph 3.2.B.

APPENDIX A
Scatter Charts
(Extended Heat Age)


Metal Sleeve (502268-1), Before Heat Age
Single Mode
Avg. = 0.13
Max. = 1.87
Stdev. = 0.290
Insertion Loss (dB)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Sample Number

APPENDIX B
Scatter Charts
(Flex, Durability, Temperature Cycle)

APPENDIX C
ANOVA Results Summary

ANOVA: LossHA versus TypeHA, BeforeAfter, SampleHA (Heat Age)

Factor	Type	Levels	Values					
TypeHA	fixed	3	1	2	3			
SampleHA(TypeHA)	random	30	1	2	3	4	5	6
			7	8	9	10	11	12
			13	14	15	16	17	18
			19	20	21	22	23	24
			25	26	27	28	29	30
BeforeAf	fixed	2	1	2				

Analysis of Variance for LossHA

Source	DF	SS	MS	F	P
TypeHA	2	344.486	172.243	10.51	0.000
SampleHA(TypeHA)	87	1425.580	16.386	17.38	0.000
BeforeAf	1	82.806	82.806	87.83	0.000
Error	1709	1611.179	0.943		
Total	1799	3464.051			

ANOVA: Loss1 versus Type1, Time1, Sample1 (Flex)

Factor	Type	Levels	Values					
Type1	fixed	3	1	2	3			
Sample1(Type1)	random	10	1	2	3	4	5	6
			7	8	9	10		
Time1	fixed	2	1	2				

Analysis of Variance for Loss1

Source	DF	SS	MS	F	P
Type1	2	6.35305	3.17653	16.76	0.000
Sample1(Type1)	27	5.11792	0.18955	12.17	0.000
Time1	1	0.00735	0.00735	0.47	0.493
Error	149	2.32157	0.01558		
Total	179	13.79990			

ANOVA: Loss2 versus Type2, Time2, Sample2 (Durability)

Factor	Type	Levels	Values					
Type2	fixed	3	1	2	3			
Sample2(Type2)	random	10	1	2	3	4	5	6
			7	8	9	10		
Time2	fixed	2	1	2				

Analysis of Variance for Loss2

Source	DF	SS	MS	F	P
Type2	2	0.581221	0.290611	13.00	0.000
Sample2(Type2)	27	0.603602	0.022356	2.77	0.000
Time2	1	0.001561	0.001561	0.19	0.661
Error	149	1.202823	0.008073		
Total	179	2.389206			

ANOVA: Loss3 versus Type3, Time3, Sample3 (Temp Cycling)

Factor	Type	Levels	Values					
Type3	fixed	3	1	2	3			
Sample3(Type3)	random	10	1	2	3	4	5	6
			7	8	9	10		
Time3	fixed	2	1	2				

Analysis of Variance for Loss3

Source	DF	SS	MS	F	P
Type3	2	1.67465	0.83732	7.10	0.003
Sample3(Type3)	27	3.18402	0.11793	7.92	0.000
Time3	1	0.06844	0.06844	4.60	0.034
Error	149	2.21737	0.01488		
Total	179	7.14449			