Rochester Corporation Singlemode Armored Fiber Optic Cable

1. INTRODUCTION

1.1. Purpose

Testing was performed on The Rochester Corporation (TRC) singlemode, 4 fiber armored cable part number A305911 to determine its conformance to the requirements of this report.

1.2. Scope

This report covers optical and environmental performance of cable manufactured by TRC. Testing was performed by TMT Laboratories in San Diego, CA. between March and May 2006. Additional | temperature testing was performed by Tyco Electronics in Harrisburg, Pa. between April and December | 2007.

1.3. Product Description

The TRC armored cable has a steel inner tube surrounded by stainless steel strength members for ruggedized applications.

1.4. Test Specimens

The cable used in testing was Tyco part number 1588957-4 which is a 4 channel, SM, armored cable, 3.8 mm diameter. The cable was manufactured by The Rochester Corporation in their Culpeper, VA facility using a gel filled steel inner tube which was supplied by K-Tube Corporation. During testing at TMT Laboratories, the 4 fibers were connected in series, such that the optical test results are the total | loss due to all 4 fibers in the cable. In addition, cable was manufactured by the Rochester Corporation, | using a gel filled steel tubing with fiber manufactured by Alcoa Fujikura LTD (AFL) to use in additional Operating Temperature and Storage Temperature testing. The fibers in this specimen were tested individually.

1.5. Test Protocols

Test Description	Specification	Test Condition
Electrical		Excess electrical voltage = 7kV
Tensile load	IEC 60794-1-2	Method E1, 1600 N
Breaking load	IEC 60794-1-2	Method E1, 2900-3400 N
Impact resistance	IEC 60794-1-2	Method E4, 1 Nm/impact, 100 impacts
Crush resistance	IEC 60794-1-2	Method E3, 1200 N/cm
Kink resistance	IEC 60794-1-2	Method E10
Torsion resistance	IEC 60794-1-2	Method E7, 100 N, 1 m, 6 turns
Static bending resistance	IEC 60794-1-2	Method E11, Procedure 1, 3 cycles, 10 mm
Dynamic bending resistance	IEC 60794-1-2	Method E6, 1800 cycles, 50 mm
Chemical resistance	VG95 214	Part 4
Cold winding	MIL-STD-810F	Section 502.4, -51˚C, 20 mm reel, 6 turns
Fire conditions	IEC 60331-25	800˚C, 500 N tension, 60 minutes
Water pressure		500 Bar, 10 minutes

Figure 1 (continued)

* Trademark
| Indicates change

Test Description	Specification	Test Condition
Rodent resistance		2 lengths of cable creating 3, 1.5 cm openings for rat to get food, 12 hours
Operating temperature	IEC 60794-1-2	Method F1, -55 to 85˚C, 9 cycles, 12 hours, 1 km length
Storage temperature	IEC 60794-1-2	Method F1, -60 to 85˚C, 2 cycles, 12 hours, 1 km length
Humidity	MIL-STD-810F	Section 507.4, 95% RH, 60/30/20ºC, 5 cycles at 48 hours
Waterproof	IEC 60529	IPx8, 5 m, 24 hours

Figure 1 (end)
Test Protocols and Conditions

2. SUMMARY OF TESTING

2.1. Electrical

The specimen cable 800 meters long was placed in a tank filled with tap water with the ends of the cable above the surface of the water. For electrical connection purposes, a few inches of the nylon were stripped to expose the tube and armor on those ends. The cable was allowed to soak for 1 hour after which time, 7,100 volts DC was applied to the armor/tube on one of the exposed (dry) cable ends. The water in the tank served as ground. The cable withstood the 7,100 volts DC (no dielectric failures/shorts of the nylon) for 5 minutes.

2.2. Tensile Load

The specimen cable was pulled to 1600 N and optical attenuation was measured. The specimen met the change in attenuation (Δa) objective and the fiber elongation (εf) objective shown in Figure 2.

Parameter	Objective	Value	Pass/Fail
Fiber elongation at 1600 N	$\varepsilon f \leq 0.500\%$	0.305%	Pass
Optical attenuation	$\Delta a \leq 0.1$ dB/100 m (irreversible) $\Delta a \leq 0.2$ dB/100 m (reversible)	No change	Pass

Figure 2

2.3. Breaking Load

The specimen cable was pulled to breaking while continuously monitoring optical power throughput. The specimen cable met the breaking load objective shown in Fig. 3.

Parameter	Objective	Value	Pass/Fail
Breaking load	2900 - 3400 N	3625 N	Pass
Elongation at break	None	1.70%	NA
Optical continuity	Continuous until specimen break	Maintained continuity	Pass

Figure 3

2.4. Impact Resistance

The specimen cable was subjected to 100 impacts with an energy level of 1 Nm/impact at three different locations. The change in attenuation was measured for each of the four channels in the cable at each location. The specimen cable met the change in attenuation objective after each impact as shown in Figure 4. The specimens were inspected for damage at the three impact locations and no visible damage was found.

Parameter	Channel	Objective	Location 1 Value	Location 2 Value	Location 3 Value	Pass/Fail
Optical Attenuation	1	Δa ≤ 0.2 dB (irreversible)	0.00 dB	0.01 dB	0.00 dB	Pass
Optical Attenuation	2	Δa ≤ 0.2 dB (irreversible)	0.00 dB	0.01 dB	0.00 dB	Pass
Optical Attenuation	3	Δa ≤ 0.2 dB (irreversible)	0.00 dB	0.01 dB	0.00 dB	Pass
Optical Attenuation	4	Δa ≤ 0.2 dB (irreversible)	0.00 dB	0.00 dB	0.00 dB	Pass

Figure 4

2.5. Crush Resistance

The specimen cable was subjected to a load of 1200 N/cm at three locations no less than 500 mm apart with the specimens held in the same angular orientation. The specimen cable met the change in attenuation objective for all three tests shown in Figure 5.

Parameter	Location	Objective	Value	Pass/Fail
Optical attenuation	1	Δa ≤ 0.1 dB (irreversible) Δa ≤ 0.2 dB (reversible)	0.057 dB 0.030 dB	Pass
Optical attenuation	2	Δa ≤ 0.1 dB (irreversible) Δa ≤ 0.2 dB (reversible)	0.000 dB 0.039 dB	Pass
Optical attenuation	3	Δa ≤ 0.1 dB (irreversible) Δa ≤ 0.2 dB (reversible)	0.009 dB 0.082 dB	Pass

Figure 5

2.6. Kink Resistance

The specimen cable was sandwiched between two sheets of acrylic and the ends pulled until the cable reached a specified bend radius. The optical throughput was noted at each bend radius. The cable was then returned to the straight condition, checked for straightness, and the optical throughput recorded. If the specimen showed no signs of kinking, it was bent again to a smaller bend radius. The minimum diameter reached before evidence of kinking due to permanent deformation of the specimen was noted. A measurable diameter loop that could be clearly listed as the point where the kinking occurred could not be determined. The cable showed a dramatic drop in optical throughput at a bend diameter of 13 mm, and it fully recovered when the cable was straightened. A similar competitor's cable showed a dramatic drop in optical throughput at a bend diameter of 19 mm, and it fully recovered, as well. Visible damage to the cable was not apparent until the cable was bent back upon itself with a very small bend radius. Even when the cable was bent in half and kinked, it could be straightened out and the kink location would not be apparent.

2.7. Torsion Resistance

The specimen cable was pulled to a tension of 100 N. One end of the cable was then twisted 180 degrees clockwise, returned to the starting position, twisted 180 degrees counter-clockwise, and returned to the starting position. This sequence was repeated five more times for a total of six cycles. The specimen met the change in attenuation objective shown in Figure 6.

Parameter	Objective	Value	Pass/Fail
Optical attenuation	Δa ≤ 0.1 dB (irreversible) Δa ≤ 0.2 dB (reversible)	0.000 dB	Pass

Figure 6

2.8. Static Bending

The specimen cable was wrapped and then unwrapped one turn around a 10 mm radius mandrel in a close helix at a uniform rate for a total of three cycles. Optical throughput was measured continuously during the winding and unwinding. While the total reversible change in attenuation for four fibers in series exceeded the objective, the calculated change in attenuation per fiber met the objective (assuming that each fiber contributed one fourth of the total loss) shown in Figure 7.

Parameter	Objective	Value	Pass/Fail
Optical attenuation	Δa ≤ 0.1 dB (irreversible) Δa ≤ 0.2 dB (reversible)	0.003 dB 0.061 dB	Pass

Figure 7

2.9. Dynamic Bending Resistance

The specimen cable was suspended vertically between two rollers or filleted blocks having a radius of 50 mm. The upper end of the specimen was attached to a pivoted lever, and the lower end was attached to a 225 pound weight. The specimen cable was bent at angles from +90 degrees to -90 degrees from the initial orientation for 1800 machine cycles with a period of approximately two seconds. Optical throughput was continuously monitored during the test. The specimen met the change in attenuation objective shown in Figure 8.

Parameter	Objective	Value	Pass/Fail
Optical attenuation	Δa ≤ 0.1 dB (irreversible) Δa ≤ 0.2 dB (reversible)	0.000 dB 0.029 dB	Pass

Figure 8

2.10. Chemical Resistance

The specimen cable was subjected to baths of five different chemicals:

- Turbine fuel, wide cut type (MIL-DTL-5624T)
- Gasoline, automotive
- 15w40 engine oil
- Hydraulic fluid, petroleum superclean (MIL-PRF-5606H)
- De-icing de-frosting fluid: aircraft surfaces in flight (TL 6850-0011)

The cable remained in the chemical baths for a period of one week at ambient temperature. Following the soak in the chemical baths, the test sections of the cable were examined under an optical microscope. The cable specimens showed no signs of damage due to the chemical exposure. There were no signs of jacket cracks or softening of the jacket.

2.11. Cold Winding

The specimen cable was cooled at a rate not exceeding 3˚C per second to a temperature of -51˚C and held until the temperature was stabilized. The cable was then wrapped six turns around a 20 mm diameter reel at a speed of one winding every five seconds. The cable was then allowed to warm to room temperature, at which point it was unwound from the reel and visually inspected for damage. The specimens cable showed no evidence of damage to the cable jacket.

2.12. Fire Conditions

The specimen cable was supported horizontally and a tension of 500 N applied to the specimen. A burner of specified proportions was positioned at a horizontal distance of 45 mm and at a vertical distance of 70 mm below the specimen. The test was conducted inside a fume hood with an ambient temperature in the range of 5 to 40˚C. The flame temperature was measured by two Type K thermocouples positioned 250 mm apart at a distance of 45 mm from the burner (coincident with the cable). These thermocouples read 800 +0/-50˚C. Flame was to be applied to the specimen for 60 minutes. Optical continuity was to be measured for an additional 15 minutes following the flame test. The specimen cable and a similar competitor's cable did not survive the planned duration of the flame test before breaking. The specimen cable remained intact for an elapsed time of 2 minutes 20 seconds. Initial measurements of the flame at the thermocouple points called out in the specification showed the temperature to be within the acceptable range. Measurements of flame temperature at the break locations after the tests confirmed that the flame temperature at those locations was also within the acceptable range.

2.13. Water Pressure

The specimen cable was placed into the test chamber with the ends sealed by high-pressure glands. The tube was pressurized to 500 bar (7,350 psi) and held for ten minutes. Optical attenuation was measured constantly during the test. The specimen met the change in attenuation objective shown in Figure 9.

Parameter	Objective	Value	Pass/Fail
Optical attenuation	$\Delta a \leq 0.1$ dB (irreversible) $\Delta a \leq 0.2$ dB (reversible)	0.000 dB 0.000 dB	Pass

Figure 9

2.14. Rodent Resistance

A box was built to house one ordinary rat. A divider in the center of the box had a 45 mm square opening with two instances of cable crossing the opening to create three, 15 mm wide gaps. The rat was placed on one side of the divider, and containers that held food and water were placed on the other side. A surveillance camera attached to a time-lapse recording system monitored the actions of the rat. Sufficient tension was held on the cable to prevent the rat from bending the cable in order to squeeze around it. The rat remained in the box for a period of eight hours after the rat bit the cable for the first time. The rat was deprived of both food and water for a period of 24 hours. Although the rat was observed biting the cable specimen, there was no observable damage to the cable jacket and no change in optical throughput.

2.15. Operating and Storage Temperature

One km of the cable on a 16.5 inch diameter reel was placed in a chamber with the optical pigtails extending out of the chamber. The cable was then exposed to Storage Temperature cycling following the temperature profile shown below in Figure 10. Optical power readings were recorded every 20 minutes throughput the exposure. Final optical measurements were recorded 60 minutes after returning to ambient.

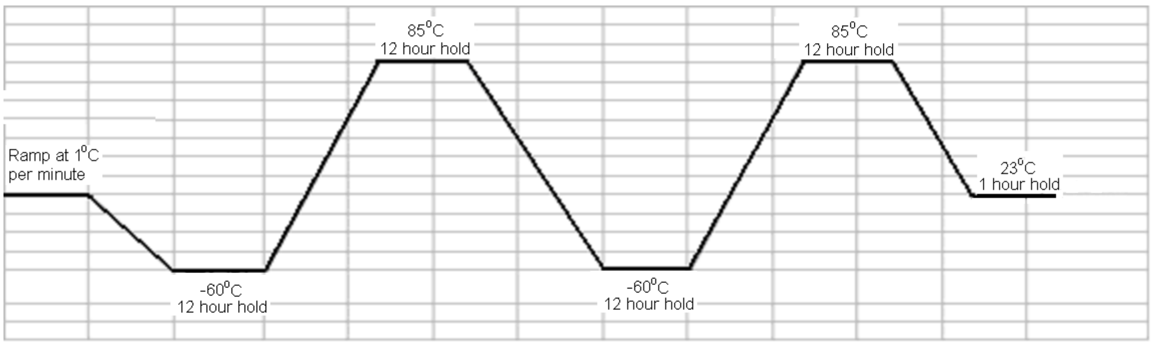

Figure 10

Following the Storage Temperature Cycling, the cable reel was collapsed and the cable was allowed to lie loosely in the chamber for 24 hours before starting the Operating Temperature testing.

The cable was then exposed to Operating Temperature cycling following the temperature profile shown in Figure 11. The specimens was exposed to Optical power readings were recorded every 20 minutes throughput the exposure. After the initial two cycles, the test was continued for a total of 9 cycles. Final optical measurements were recorded 60 minutes after returning to ambient.

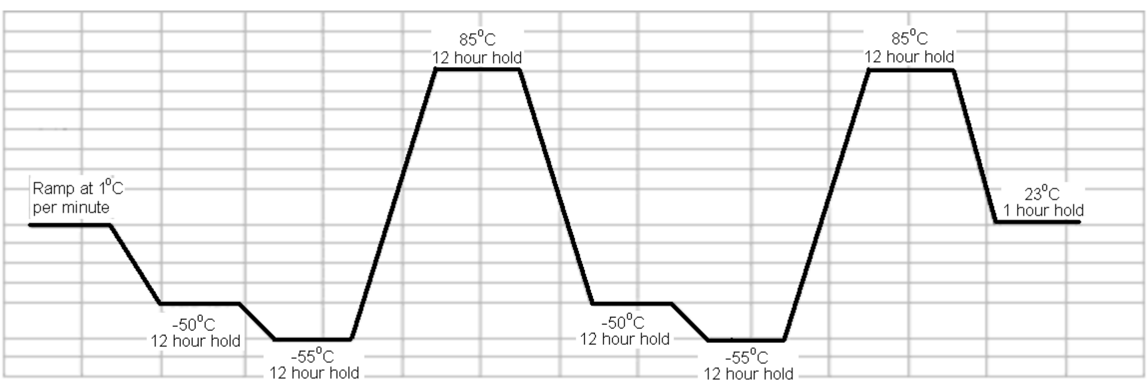

Figure 11

The initial specimen cable manufactured using the gel filled inner steel tube from K-Tube Corporation did not meet the reversible attenuation goal for Operating Temperature. The Rochester Corporation found it necessary to switch to a different gel filled steel tubing with fiber manufactured by Alcoa Fujikura LTD (AFL) to obtain the proper Effective Fiber Length (EFL) in the tubing. This was believed to be a major contributor to the increased attenuation change during the Operating Temperature testing.

The specimen built using the gel filled steel tubing with fiber from AFL met the change in attenuation objectives as shown in Figure 12.

Parameter	Channel	Objective	Value	Pass/Fail
Optical Attenuation, Storage Temperature	1	Δa ≤ 0.2 dB (irreversible)	0.040 dB	Pass
Optical Attenuation, Storage Temperature	2	Δa ≤ 0.2 dB (irreversible)	0.050 dB	Pass
Optical Attenuation, Storage Temperature	3	Δa ≤ 0.2 dB (irreversible)	0.040 dB	Pass
Optical Attenuation, Storage Temperature	4	Δa ≤ 0.2 dB (irreversible)	0.050 dB	Pass
Optical Attenuation, Operating Temperature	1	Δa ≤ 0.2 dB (irreversible) Δa ≤ 0.5 dB (reversible)	0.030 dB 0.320 dB	Pass
Optical Attenuation, Operating Temperature	2	Δa ≤ 0.2 dB (irreversible) Δa ≤ 0.5 dB (reversible)	0.030 dB 0.320 dB	Pass
Optical Attenuation, Operating Temperature	3	Δa ≤ 0.2 dB (irreversible) Δa ≤ 0.5 dB (reversible)	0.020 dB 0.410 dB	Pass
Optical Attenuation, Operating Temperature	4	Δa ≤ 0.2 dB (irreversible) Δa ≤ 0.5 dB (reversible)	0.010 dB 0.300 dB	Pass

Figure 12

2.16. Humidity

The specimen cable was placed in a test chamber with the optical pigtails extending outside of the chamber and allowed to rest for 24 hours. The humidity was maintained at 95% RH, and the temperature cycled from 60 to 30 to 20˚ C over a period of 48 hours. This sequence was repeated for a total of five cycles. The specimen met the change in attenuation objective shown in Figure 13.

Parameter	Objective	Value	Pass/Fail
Optical attenuation	Δa ≤ 0.2 dB (irreversible) Δa ≤ 0.5 dB (reversible)	0.000 dB 0.064 dB	Pass

Figure 13

2.17. Waterproof

The specimen cable was submerged in water equivalent to a depth of five meters for a period of 24 hours. There was no change in optical throughput over the duration of the test.