Coaxial Protector Reliability Analysis

The purpose of this paper is to estimate the reliability of NexTek coaxial lightning protectors. This analysis is a valuable tool to assist in planning the economics and repair of coaxial protectors. NexTek protectors are exceptionally long lifetime devices, with lifetimes of over 10 million to billions of hours (Equating to a typical annual failure rate of 0.023%/yr to an even less 0.00054%/yr). Without a lightning protection device installed, the risk of equipment damage from lightning ranges from a few percent up to 100% per year. Therefore, adding a high quality NexTek lightning protector will result in negligible additional equipment failure rates when compared to the level of damage that is prevented.

QSS Devices

Typical PTR & PTC Devices

The reliability prediction for a NexTek lightning protector is calculated as the sum of a single connector pair (representing the input and output half connectors) and a protection component (required for the Gas-Discharge-Tube (GDT) based PTC and PTR series). Note that the QSS series are quarter wave stub based protectors and therefore do not use such a component. The PTR analysis assumes GDT maintenance sufficient to eliminate 80% of the GDT component failures. If there is no preventative maintenance, use the PTC reliability for PTR models. Also, this analysis is for the NexTek protector only. Due to the extensive military qualification of NexTek products, we use MIL-STD quality factors. Please add the mating connector halves with the appropriate quality factor for the cable connectors mating to the NexTek protector.

The model for the failure rate of a NexTek coaxial protector is given in equation 1:

$$\lambda\text{Protector} = \lambda\,\text{Connector} + \lambda\,\text{Suppressor}\ \pi_{MT} \qquad (1)$$

Where λProtector is the failure rate of the protector, λ Connector is the failure rate for a single connector pair (for the two halves of the NexTek protector, λ Suppressor is the failure rate of a single suppression component, and π_{MT} is the maintenance and technology factor. The value of π_{MT} for is 1.0 for a PTC or a PTR without maintenance, 0.2 for a PTR with maintenance, or 0.0 for a QSS, since there is no suppression component.

The reliability of NexTek coaxial protectors is summarized in the table 1 below. The failure rate is in failures per 10^6 hours. The mean time between failures (MTBF) is measured in hours. Note that this reliability does not include the significant failure rate reduction of attached equipment or system due to protection, or of the influence of transients on the failure of the protector.

The detailed calculations are provided in the following sections A & B.

Table 1. Predicted Failure Rate and MTBF of NexTek Coaxial Protectors

NexTek Protector Model Types *Failure Rate = 1/10⁶hrs* *MTBF listed in hours*	**PTC – fixed GDT** (or PTR w/o maintenance)		**PTR – replaceable GDT** (with preventive maintenance)		**QSS – quarter wave stub** (all models)	
Environment Reliability Parameters	**Failure Rate**	**MTBF**	**Failure Rate**	**MTBF**	**Failure Rate**	**MTBF**
Low Mating 50ºC and Ground Fixed	0.00844	118,483,794	0.00217999	458,717,280	0.000615	1,626,061,260
Low Mating 30ºC and Ground Mobile	0.0100102	99,897,705	0.00488845	204,563,092	0.003608	277,161,863
High Mating, 50ºC and Ground Mobile	0.0264794	37,739,495	0.01710479	58,453,935	0.01476	67,750,768
Moderate Mating 50ºC and Naval Surface	0.0178874	55,905,419	0.00849749	117,681,873	0.00615	162,601,626
Moderate Mating, 70ºC and Aircraft Inhabited	0.038256	26,140,401	0.01421099	70,368,064	0.0082	121,951,202

A. λ Connector

For a general idea of connector reliability, the generic failure rates can be considered. The mated pair Generic Failure Rate (λ_g) is per MIL-HDBK-217F Notice 2, Appendix A, Section 15.1, RF Coaxial. The failure rate for several environments is given in table 2.

Table 2. Generic Failure Rate (/10⁶hours) Coaxial Connectors

Environment	**G_F**	**G_M**	**N_S**	**A_{IC}**
T_A (ºC)	40	45	40	55
Failure Rate λ_g	0.00053	0.0046	0.0027	0.002

For more detailed predictions, the model provided in Connector Prediction per MIL-HDBK-217F/Notice 2 Section 15.1 is used. For a mated pair of connectors the failure rate is modeled by equation 2:

$$\lambda_p = \lambda_b \pi_T \pi_K \pi_Q \pi_E \qquad (2)$$

Where λ_p =is the predicted failure rate in failures per 10^6 hours, λ_b is the base failure rate, π_T is the temperature factor, π_K is the mating rate factor, π_Q is the quality factor, and π_E is the environment factor. The reliability predictions with typical factors are shown table 3:

Table 3 Predicted Failure Rate of Coaxial Connectors

Single Connector	λ_b	π_T	π_K	π_Q	π_E	λ_p
Low Mating and Medium Temperature and Ground Fixed	0.00041	1.5	1	1	1	0.000615
	Base FR	50ºC	<0.05	MIL	G_F	
Low Mating and Temperature and Ground Mobile	0.00041	1.1	1	1	8	0.003608
	Base FR	30ºC	<0.05	MIL	G_M	
High Mating, Medium Temp. and Ground Mobile	0.00041	1.5	3	1	8	0.01476
	Base FR	50ºC	<50	MIL	G_M	
Moderate Mating and Temp and Naval Surface	0.00041	1.5	2	1	5	0.00615
	Base FR	50ºC	<5	MIL	N_S	
Moderate Mating, High Temp and Aircraft Inhabited	0.00041	2.0	2	1	5	0.0082
	Base FR	70ºC	<5	MIL	A_{IC}	

Note that π_K relates to average times between mating cycles. To illustrate the average mating or cycling time, the cycles per thousand hours has been converted to time between mating in table 4.

Table 4 π_K and Maximum Average Time between Mating

Connection Cycle Rate (for Maintenance or Deployment)	π_K	Cycles / 1000 hr	Avg. maximum time between mating
Permanently Installed / Rarely Cycled	1	0<cycles<0.05	Over 28+ months
Infrequent	1.5	0.05<cycles<0.5	2.8 months
Moderate	2	0.5<cycles<5	9 days
Frequent	3	5<cycles<50	20 hours

B. λ Suppressor

For a general idea of the reliability of the shunting component, the generic failure rates for varistors are considered. The Generic Failure Rate (λ_g) per MIL-HDBK-217F Notice 2, Appendix A, Section 6.1, Suppressor/Varistor is given below. Note that the junction temperatures relate to power dissipation and cooling functions, whereas the protection component temperature is more closely related to the ambient temperature. The generic failure rates for several environments are shown in table 5.

Table 5 Generic Failure Rate (/10^6hours) of Suppression Components

Environment	G_F	G_M	N_S	A_{IC}
T_J (°C)	60	65	60	75
Failure Rate λ_g	0.023	0.040	0.035	0.075

For more detailed predictions the Connector Prediction model provided in MIL-HDBK-217F/Notice 2 Section 6.1 is used. The failure rate for a varistor is modeled by equation 3:

$$\lambda_p = \lambda_b \pi_T \pi_S \pi_C \pi_Q \pi_E \qquad (3)$$

Where λ_p=is the predicted failure rate, λ_b is the base failure rate in failures per 10^6 hours, π_T is the temperature factor π_S is the voltage stress factor, π_C is the contact construction factor, π_Q is the quality factor, and π_E is the environmental factor.

Table 6 shows the failure rate prediction of a single suppression component with typical factors.

Table 6. Predicted Failure Rate of a Suppression Component

Single Connector	λ_b	π_T	π_S	π_C	π_Q	π_E	λ_p
Low Mating and Medium Temperature and Ground Fixed	0.0013	2.2	.19	1	2.4	6	0.00782496
	Base FR	50°C	<50%	Metal	JAN	G_F	
Low Mating and Temperature and Ground Mobile	0.0013	1.2	.19	1	2.4	9	0.00640224
	Base FR	30°C	<50%	Metal	JAN	G_M	
High Mating, Medium Temp. and Ground Mobile	0.0013	2.2	.19	1	2.4	9	0.01173744
	Base FR	50°C	<50%	Metal	JAN	G_M	
Moderate Mating and Temp and Naval Surface	0.0013	2.2	.19	1	2.4	9	0.01173744
	Base FR	50°C	<50%	Metal	JAN	N_S	
Moderate Mating, High Temp and Aircraft Inhabited	0.0013	3.9	.19	1	2.4	13	0.03005496
	Base FR	70°C	<50%	Metal	JAN	A_{IC}	