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Methodologies for Reliability Prediction of Electronic Component in Military Vehicles

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Abstract:

Reliability prediction is conducted in all phases of the product life cycle. The purpose of these predictions is to identify the potential weaknesses in design, to evaluate the design feasibility, to compare alternative designs, to provide the model for reliability analysis, to track reliability improvement, etc. Reliability of electronic component is predicted by using statistical prediction methods (standards-based), statistical analysis of operation & maintenance data or by performing reliability testing. The article describes statistical prediction methods such as MIL-HDBK-217, RIAC 217Plus, FIDES Guide 2009, which are widely used for predicting the reliability of electronic components. In addition, we have calculated and compared the failure rate of electronic components in military vehicles conducted with the use of these different methods.

Keywords:

reliability, failure rate, electronic components, LED

1. Introduction

The modern military vehicles are equipped with electronic systems which have a direct impact on the main functional characteristics and parameters of the whole vehicle. The digitization of military technologies is one of the key requirements of individual armaments, newly purchased military vehicles or weapon systems. Due to the increasing number of electronic systems used in military vehicles, it can be said that this is the process of digitizing military technology. The modern military vehicles achieve the parameters of the major military characteristics (tactical-technical parameters) through a high proportion of electronic components with digital control. The structure, materials, packaging technology and using conditions of electronic components are factors that influence the reliability of the electronic system. Thus, the reliability of electronic components characterizes the resulting values of reliability of the entire electronic system in military vehicles. Consequently, the

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electronic component failure can lead to catastrophic effects in the combat operations. Therefore, it is necessary to study and develop methods for predicting the reliability of electronic components used in military vehicles.

At present the reliability of electronic components can be predicted through the following methods: the statistical method (standard handbook), similarity analysis method based on operation & maintenance data (reliability database) and reliability test method base on the physics-of-failure approach [1]. Each approach has its unique advantages and disadvantages. The reliability test method based on physics-of-failure approach provides complete information about the various degradation mechanisms and causes of failure, thereby providing insight into the reliability of electronic components. The reliability databases provide reliability parameters for specific types of electronic components (e.g. integrated circuits, discrete semiconductors, resistors, capacitors). This data is obtained by long-term monitoring of systems and its components in actual operation with a variety of sources, operating conditions and quality levels. The statistical methods contain computational procedures for individual groups of components, which allow the selection of a range of coefficients to take into account the actual situation and to calculate the reliability parameter, which is usually the failure rate (λ). The reliability models used in this method include the effects of environmental stresses and quality levels (e.g. unknown; lower; commercial; military). The most common operating environments are: Ground, Benign (GB); Ground, Fixed (GF); Ground, Mobile (GM); Naval, Unsheltered (NU); Airborne, Inhabited, Cargo (AIC); Space, Flight (SF); Cannon, Launch (CL), etc [2].

There are many different statistical methods for specific applications. This paper describes a number of statistical methods for electronic components (e.g. MIL-HDBK-217F, RIAC-217Plus, FIDES Guide 2009) and comparison of these methods is also performed with LEDs in military vehicles.

2. Method of Reliability Prediction

2.1. MIL-HDBK-217F Predictive Method

Although the Military Handbook MIL-HDBK-217F was primarily developed to predict the reliability of electronic systems in the military, over time it started to be used in civilian industry as well. The goal of the Military Handbook MIL-HDBK-217F is to provide a consistent approach to estimate the inherent reliability of components and systems [3]. It then establishes a common basis for comparing and predicting the reliability of relevant designs. MIL-HDBK-217F is also used as a tool to increase the reliability of electronics designed. It was created in 1961 by the Department of Defense USA, and since then it has been modified many times, most recently in 1995 (MIL-HDBK-217F N2).

In this handbook, the determination of failure rates for various electronic components is based on statistical analysis of actual failure data. The common electronic components in the standard include: microcircuits, semiconductors, tubes, lasers, resistors, capacitors, coils, rotors, relays, switches, connectors, lamps, electronic filter. The MIL-HDBK-217F includes two reliability prediction methods, the parts stress analysis and the parts count [4]. The former one requires a large amount of detailed information and is applied in the later design phase while the latter one requires little information about the design, which is usually the type of electronic components, part of the quantity, quality level and operating environment. Therefore, it is often used in the early stages of design and development.

The part stress analysis method defines the failure rate based on the multiplication of base failure rate with the stress factors of operating conditions and environment. An example of mathematical model for determining the failure rate using part stress method is given [5]:

$$\lambda_p = \lambda_b \pi_T \pi_A \pi_R \pi_S \pi_C \pi_Q \pi_E \,, \tag{1}$$

where λ_b is the basic failure rate usually represented by a model that relates the effects of electrical and temperature stress, π_T is the temperature factor; π_A is the application factor; π_R is the power rating factor; π_S is the voltage stress factor; π_C is the construction factor; π_E is the environment factor; π_Q is the quality factor.

The specific values of the basic failure rate and all the coefficients required are determined according to the tables in the handbook.

The mathematical model for determining the failure rate of the light emitting diode (LED) from methodology MIL-HDBK 217 is as follows [5]:

$$\lambda_p = \lambda_b \pi_T \pi_Q \pi_E \,, \tag{2}$$

where λ_b is the basic failure rate ($\lambda_b = 0.00023$), π_T is the temperature factor, π_E is the environment factor, π_Q is the quality factor.

$$\pi_T = \exp\left[-2790\left(\frac{1}{T_j + 273} - \frac{1}{298}\right)\right], \tag{3}$$

where T_j is the junction temperature,

$$T_j = T_C + \theta_{JC} P \,, \tag{4}$$

where T_C is the case temperature, θ_{TC} is the junction-to-case thermal resistance (°C/W), P is the power dissipation.

For parts count method, it is necessary to know the general type of electronic components, quality level and operating conditions. Therefore, this method usually results in a more conservative prediction of the reliability of electronic devices. The mathematical model for determining the failure rate of electronic equipment using parts count method is given [5]:

$$\lambda_{Eq} = \sum_{i=1}^{n} N_i \left(\lambda_g \pi_Q\right)_i \,, \tag{5}$$

where λ_{Eq} is the total failure rate of electronic equipment, λ_g is the generic failure rate of i^{th} part, π_Q is the quality factor of i^{th} part, N_i is the quantity of i^{th} part, n is the number of different parts.

The values of the generic failure rate (λ_g) for each environment and the quality factor (π_Q) for the individual components are contained in the handbook.

2.2. RIAC-Handbook-217Plus Predictive Method

The RIAC-Handbook-217Plus is the reliability prediction method developed by the Reliability Information Analysis Center (RIAC) to replace MIL-HDBK-217F and PRISM [6]. The reliability prediction models in this handbook are based on the physics-failure principle that is confirmed by statistical analysis of reliability data from various sources. RIAC 217Plus significantly updates prediction models. However, it is still compatible with the types of electronic components and reliability-related processes established in MIL-HDBK-217F. This method can be used to predict the reliability of thirteen groups of different electronic components. In particular, the predictive model of six groups is more modern than PRISM.

RIAC 217Plus is performed in two phases; firstly, the component reliability prediction is calculated at the components level, and then it is modified at the system level. The component reliability model form is as follows [7]:

$$\lambda_p = \lambda_0\pi_0 + \lambda_e\pi_e + \lambda_c\pi_c + \lambda_i + \lambda_{sj}\pi_{sj}\,, \tag{6}$$

where λ_0 is the failure rate due to operational stresses, λ_e is the failure rate due to environmental stresses, λ_c is the failure rate due to temperature cycle, λ_i is the failure rate due to induced stresses, λ_{sj} is the failure rate due to solder joints, π_0, π_c, π_e, π_{sj} are multiplier factors.

The values of the failure rates and coefficients are determined based on the input information on the environment, operation, manufacturing, development, type of stress, etc. Reliability models for different groups of components are different but based on the general model.

For example, the mathematical model for determining the failure rate of LED that RIAC 217Plus has developed as follows [7]:

$$\lambda_p = \pi_G\left(\lambda_{OB}\pi_{DCO}\pi_{TO} + \lambda_{EB}\pi_{DCN}\pi_{TE} + \lambda_{TCB}\pi_{CR}\pi_{DT}\right) + \lambda_{IND} \tag{7}$$

where π_G is the reliability growth multiplier factor, λ_{OB} is the basic failure rate – operation, π_{DCO} is the multiplier factor for cycling – operation, π_{TO} is the multiplier factor for temperature – operation, λ_{EB} is the basic failure rate – environmental, π_{DCN} is the multiplier factor, duty – non-operation, π_{TE} is the multiplier factor for temperature – environment, λ_{TCB} is the basic failure rate – temperature cycle, π_{CR} is the multiplier factor-cycling rate, π_{DT} is the multiplier factor-delta temperature.

The mathematical model of failure rates at the system level takes into account the elements of the design process, manufacturing process, environment, infant mortality, system management process, etc. The RIAC 217Plus system model is [7]:

$$\lambda = \lambda_{IA}\left(\pi_p + \pi_D + \pi_M + \pi_S + \pi_I + \pi_N + \pi_W\right) + \lambda_{SW} \tag{8}$$

where λ_{IA} is the initial assessment of failure rate, π_P is the part factor, π_D is the design factor, π_M is the manufacturing factor, π_S is the system management factor, π_I is the induced factor, π_N is the no-defect factor, π_W is the wear-out factor, λ_{SW} is the failure rate of software.

2.3. FIDES Guide 2009 Predictive Method

The FIDES Guide 2009 was created by companies in the FIDES Group, under the supervision of the Ministry of Defence in France. This methodology was developed using actual data from civil aeronautics, military systems and data from manufacturers. The goal of the FIDES Guide 2009 is to make realistic predictions about the reliability of electronic devices, including systems that operate under extreme conditions. It also provides a specific tool for building and controlling reliability.

FIDES Guide 2009 consists of two parts, namely component reliability prediction and reliability process control and audit, and it provides reliability models for electrical, electronic, electromechanical and printed circuit components.

The mathematical model for calculating the failure rate of an electronic component according to the methodology FIDES Guide 2009 is as follows [8]:

$$\lambda = \lambda_{Physical}\pi_{PM}\pi_{Process}\,, \tag{9}$$

where $\lambda_{Physical}$ is the physical contribution, π_{PM} is the quality and technical control during production, $\pi_{Process}$ is the quality and technical control during development, production and operation.

Factor π_{PM} describes the quality of the item and it is expressed in mathematics as follows [8]:

$$\pi_{\mathrm{PM}} = \mathrm{e}^{\delta_1 (1 - Part\_Grade) - \alpha_1}, \tag{10}$$

where δ_1 and α_1 are correlation factors.

$$Part\_Grade = \frac{\left(QM_{\mathrm{manufaturer}} + QA_{\mathrm{item}} + RA_{\mathrm{component}}\right)\varepsilon}{36}, \tag{11}$$

$QM_{\mathrm{manufacturer}}$ is the quality assurance criterion of the manufacturer, QA_{item} is the quality assurance criteria, ε is the experience of purchaser with supplier, $RA_{\mathrm{component}}$ is the component reliability assurance.

Factor π_{Process} describes the quality and technical handling of processes that affect reliability throughout the product life cycle, and it is expressed mathematically as follows [8]:

$$\pi_{\mathrm{Process}} = \mathrm{e}^{\delta_2 (1 - Process\_Grade)}, \tag{12}$$

where *Process_Grade* is the signal that reflects process control, δ_2 is the correlation factor.

The mathematical model of physical contribution ($\lambda_{\mathrm{Physical}}$) is as follows [8]:

$$\lambda_{\mathrm{Physical}} = \left[\sum_{Physical\_Contributions} \left(\lambda_0 \pi_{\mathrm{acceleration}} \right) \right] \pi_{\mathrm{induced}} \tag{13}$$

where λ_0 is the basic failure rate, $\pi_{\mathrm{acceleration}}$ is the acceleration factor, π_{induced} is the induced factor.

The determination of specific value coefficient and input parameters for calculating failure rate is based on tables, relationships, and the recommendations in the handbook.

An example of the physical contribution to LEDs is shown in mathematics as follows [8]:

$$\lambda_{\mathrm{Physical}} = \sum_i^{Phase} \left(\frac{\mathrm{t}_{\mathrm{annual}}}{8760} \right)_i \left(\lambda_{0\mathrm{TH}} \pi_{\mathrm{Thermal}} + \lambda_{0\mathrm{TCyCase}} \pi_{\mathrm{TCyCase}} + \right. \\ \left. + \lambda_{0\mathrm{TCySj}} \pi_{\mathrm{TCySj}} + \lambda_{0\mathrm{RH}} \pi_{\mathrm{RH}} + \lambda_{0\mathrm{Mech}} \pi_{\mathrm{Mech}} \right)_i \pi_{\mathrm{induced}} \tag{14}$$

where t_{annual} is the time associated with each period per year, $\lambda_{0\mathrm{TH}}$, $\lambda_{0\mathrm{TCcase}}$, $\lambda_{0\mathrm{TCySj}}$, $\lambda_{0\mathrm{RH}}$, $\lambda_{0\mathrm{Mech}}$ are basic failure rate associated with cases, π_{Thermal}, π_{TCyCase}, π_{TCySj}, π_{RH}, π_{Mech} are factors contributing to physical stresses. These values are given from tables in FIDES 2009, for example, $\lambda_{0\mathrm{TH}} = 0.01$ (colour LED), $\lambda_{0\mathrm{TH}} = 0.05$ (white LED).

2.4. Telcordia SR-332 Predictive Method

The Telcordia SR-332 was created by the Telcordia Technologies, part of the Ericsson corporation [9]. Telcordia Technologies regularly updates this method every five years and the current version of the Telcordia SR-332 was published in 2016.

Even though the methodology in the standard is based on the principles outlined in the MIL-HDBK-217F, it reflects better the specifics of the telecommunications industry by supplementing the ability to consider data obtained from laboratories and from the actual operation. Telcordia SR-332 is mainly used for commercial electronic products and is very popular in the field of telecommunications.

Prediction reliability can be achieved by three different methods. Prediction method I predicts the reliability of the object in a way similar to MIL-HDBK-217F predictive method. Prediction method II is a combination of prediction method I and data from laboratories according to the specific criteria of Telcordia SR-332. Prediction method III uses field monitoring data collected and specific criteria of Telcordia SR-332 to predict failure rate of the object.

2.5. IEC/TR 62380 Predictive Method

The reliability data handbook IEC/TR 62380 was published in 2004 by the International Electrotechnical Commission (IEC). This standard was developed from French telecommunication standard which was created in 2000. The purpose of IEC/TR 62380 is to provide all information necessary for calculating reliability parameters of electronic components, especially for printed circuit boards (PCBs) and their parts [2]. IEC/TR 62380 builds models that take into account the influence of the environment and, in particular, element loads.

The methodology is based on statistical analysis of data from field operations in different environments. The operating environment mainly includes the following situations: the equipment is fixed on the ground in weather protected locations; the equipment is fixed on the ground in weather unprotected locations; the equipment is used in aircraft with benign conditions and the equipment is not fixed on the ground with the moderate conditions.

The methodology IEC/TR 62380 focuses on maximizing the reliability of the device even in the device design phase by providing different influencing factors. Therefore, the choice of values for the influencing factors is very important.

An example of a LED model from IEC/TR 62380 is as follows [10]:

$$\lambda = \lambda_0 \pi_t \cdot 10^{-9}, \tag{15}$$

where λ_0 is the failure rate from operational stresses, π_t is the temperature factor. The value of λ_0 depends on the module type, which can be found in the table in the standard.

Mathematical formula for π_t is (with activation energy of 0.35 eV) [10]:

$$\pi_t = \exp\left[4060\left(\frac{1}{343} - \frac{1}{t_j + 273}\right)\right], \tag{16}$$

$$t_j = t_c + R_{th} P, \tag{17}$$

where t_j is the junction temperature, t_c is the case temperature, R_{th} is the thermal resistance (default value of R_{th} is 150 °C/W), P is the applied power.

3. Comparison of Reliability Prediction Methods

Reliability predictions are performed for electronic components used in military vehicles with the same operating conditions and environmental conditions. The purpose of this work is to provide examples of reliability calculations using the predictive methods outlined above and to compare the results of these methods.

The samples used for the calculation are warm white LEDs in military vehicles. The electrical and optical characteristics of LEDs are: LED warm white 700 lm/90°; Luminous flux of 700-800 lm; Correlated colour temperature / Wavelength of 2900-3200 K/nm; Power dissipation of 9.45 W; Forward voltage of 9-11 V; Forward current of 750 mA; Thermal resistance of 10 °C/W; Operating temperature from −40 °C to +80 °C; Junction temperature of 115 °C; ESD sensitivity of ±2 000 V Human Body Model (HBM). The internal circuit diagram of LEDs is shown in Fig. 1.

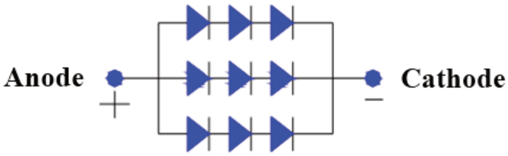

Fig. 1 Internal circuit diagram of LED

The operational conditions of military vehicles consist of two types of days:

- Non-operating day: 245 days per year with the average temperature change of 20-30 °C. The total time of the period is 5 880 hours per year (245 × 24 hours).
- Operating day: 120 days per year, with number of cycles of state change (on / off) 2 times per day. The total number of cycles of state change is 240 per year (2 × 120 cycles). When switching electronic systems on, the temperature changes from ambient temperature (25 °C) up to 60 °C. A cycle duration of 3 hours, the total time of the period is 720 hours per year (3 × 240 hours).

When switching electronic systems off, the temperature changes from 20 °C to 30 °C with the average temperature in this state of 25 °C. The total time of the period is 2 160 hours per year (18 × 120 hours). The total time in the off-state (including non-operating day) is 8 040 hours per year (2 160 hours + 5 880 hours). The temperature cycle profile for operating day is shown in Fig. 2.

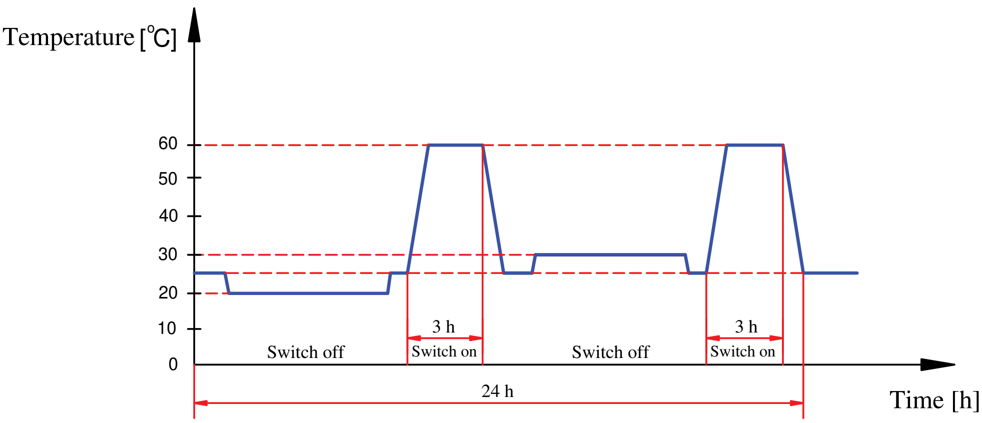

Fig. 2 Schematic of temperature cycle profile for operating day

Tab. 1 describes the operating conditions and the operating environment of electronic components in military vehicles. According to the Eqs (2)-(4), (7), (14)-(17), the result of calculating failure rate of LEDs with different methodologies is shown in Tab. 2.

As it can be seen from Tab. 2 below, the failure rate of LEDs widely differs with the use of various reliability prediction methods. These differences are due to the changes in statistical data sources, as well as the changes of model parameters. In MIL-HDBK-217F and IEC/TR 62380 models, the failure rate of electronic components is calculated as the number of failures per million operating hours; whereas, in RIAC-217Plus and FIDES Guide 2009, the parameter is calculated per million calendar hours. The reason is that in both RIAC-217Plus and FIDES Guide 2009 models, all types of time contributed to failure (operating, non-operating) are taken into account. Therefore, there are large differences in the failure rate of LEDs between the methodology MIL-HDBK-217F, IEC/TR 62380 and the methodology RIAC-217Plus, FIDES Guide 2009.

Tab. 1 Operating conditions of electronic components in military vehicles

Parameter	Phase title	Switch off	Switch on
Calendar time [h]	t_{annual}	8040	720
Ambient temperature [°C]	T_a	25	60
Relative humidity [%]	RH	80	60
Temperature change [°C]	ΔT	10	35
Number of cycles per year	N_{cy_annual}	365	240
Cycle duration [h]	θ_{cy}	22.03	3
Maximum temperature in the cycle [°C]	$T_{max\_cycling}$	30	60
Vibration [G]	W	—	5

Tab. 2 Comparison of results for different methods

T_a [°C]	**MIL-HDBK-217F(N2)** ($f/10^6$ operating hours)	**IEC/TR 62380** ($f/10^6$ operating hours)	**RIAC 217Plus** ($f/10^6$ calendar hours)	**FIDES Guide 2009** ($f/10^6$ calendar hours)
25	0.180	0.214	0.0012	0.0025
40	0.243	0.331	0.0021	0.0034
60	0.350	0.562	0.0047	0.0055

All models show a strong influence of ambient temperature to failure rate of LEDs used in military vehicles. This effect on failure rate is the exponential function (Figs 3, 4). In addition, Fig. 5 shows that in FIDES Guide 2009, the influence of temperature cycling on the failure rate is considerable; whereas, in RIAC-217Plus, the influence seems to be negligible. Neither MIL-HDBK-217F methodology, nor IEC/TR 62380 methodology considers the influence of temperature cycling.

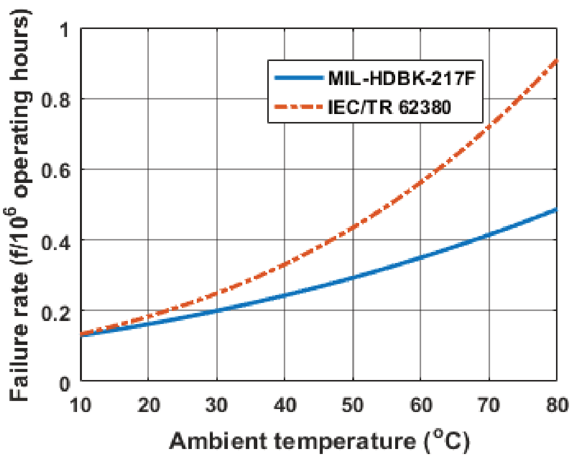

Fig. 3 Influence of ambient temperature (MIL-HDBK-217 and IEC/TR 62380)

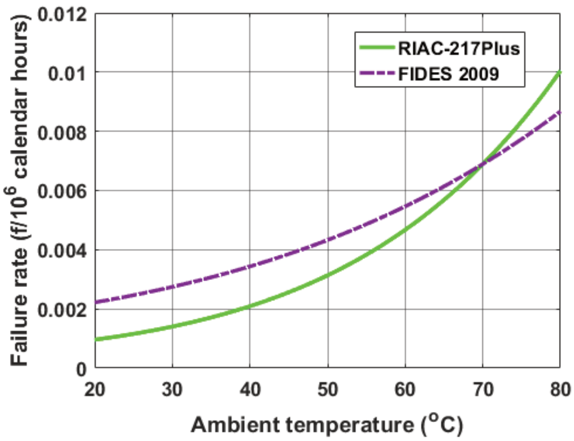

Fig. 4 Influence of ambient temperature (RIAC-217Plus and FIDES)

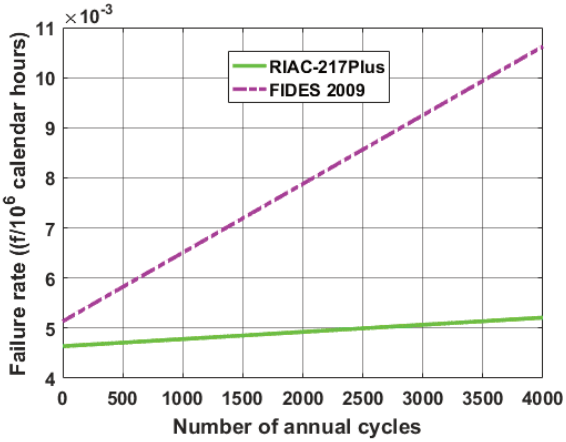

Fig. 5 Influence of number of temperature cycling (RIAC-217Plus and FIDES)

4. Conclusions

This paper presents methodologies for predicting the reliability of electronic components which can be applied to the calculation of the failure rates for LEDs in military vehicles. Although methodology MIL-HDBK-217 has not been updated since 1995, it is very frequently used in both military and commercial industries. The methodology Telcordia SR-332 has modified MIL-HDBK-217 for a better use of many electronic component types in telecommunication applications. The methodology RIAC 217plus was published in 2006 to replace MIL-HDBK-217, and its models of reliability calculations are completely different from the methodology MIL-HDBK-217 and Telcordia SR-332. The methodology RIAC 217plus considers different basic failure rates corresponding to the type of failure mechanism and it supports the user in better understanding the model, thereby reinforcing the validity and credibility of the RIAC-217 model. The methodology IEC/TR 62380 provides calculation models for various electronic components, especially for PCBs and their parts. The methodology FIDES Guide 2009 was developed by analysing data from a variety of sources (e.g. military, aviation); therefore, this methodology focuses on realistic reliability prediction of electronic component and systems under different conditions.

The failure rate of LEDs use in military vehicles is according to the methodology MIL-HDBK-217 and the methodology IEC/TR 62380 mainly due to the temperature; according to the methodology RIAC 217Plus, it is due to the temperature and electrical overstress. According to the methodology FIDES Guide 2009, the failure rate of LEDs is ascribed to the temperature and temperature cycles. Based on these calculations, it is not possible to conclude that this methodology is superior to other methodologies because these methodologies have not explored the root causes of failure of electronic components. More accurate comparison of reliability models generally requires additional data, which can be obtained through LEDs reliability testing.

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References

[1] LEE, S.W. and LEE, H.K. Reliability Prediction System Based on the Failure Rate Model for Electronic Components. *Journal of Mechanical Science and Technology*, 2008, vol. 22, no. 5, p. 957-964. DOI 10.1007/s12206-008-0212-4.

[2] VINTR, Z. and VINTR, M. Reliability Prediction for Components of Robotic Systems. *Advances in Automation and Robotics*, 2011, vol. 2, p. 463-470. DOI 10.1007/978-3-642-25646-2_60.

[3] SOUZA, F.A., PEREIRA, P.C.T., DE PAULA, H., BRAZ FILHO, J.C. and ROCHA, A.V. Motor drive systems reliability: Impact of the environment conditions on the electronic component failure rates. In *2014 IEEE Industry Application Society Annual Meeting*, 2014, p. 1-8. DOI 10.1109/IAS.2014.6978463

[4] THADURI, A., VERMA, A.K. and KUMAR, U. Comparison of Reliability Prediction Methods Using Life Cycle Cost Analysis. In *Proceedings of Reliability and Maintainability Symposium (RAMS) 2013*. Orlando, 2013, p. 1-7. DOI 10.1109/RAMS.2013.6517747.

[5] MIL-HDBK-217F-N2. *Reliability Prediction of Electronic Equipment.* Washington: US Department of Defense, 1995, 80 p.

[6] HELD, M. and FRITZ, K. Comparison and Evaluation of Newest Failure Rate Prediction Models: FIDES and RIAC 217Plus. *Microelectronics Reliability*, 2009, vol. 49, no. 9-11, p. 967-971. DOI 10.1016/j.microrel.2009.07.031.

[7] RIAC. *Handbook of 217Plus Reliability Prediction Models*. New York: Defense Technical Information Center, 2006, 182 p.

[8] FIDES Guide. *Reliability Methodology for Electronic Systems*. FIDES Group, 2009, 465 p.

[9] Telcordia SR-332 Issue 2. *Reliability Prediction Procedure for Electronic Equipment*. Telcordia, 2006.

[10] IEC TR 62380. *Reliability Data Handbook – Universal Model for Reliability Prediction of Electronics Components, PCBs and Equipment*. IEC, 2004, 96 p.