

## ACCELERATED TESTS TIME OF ELECTRONIC PARTS USED IN MILITARY VEHICLES

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Received on 09 December 2012; accepted in revised in April 2013

*This article tackles the accelerated reliability tests of electronic parts used in military vehicles and operated within the Army of the Czech Republic and the Czech Republic. Basic military parameters for newly acquired military vehicles are based on electronic parts, the reliability of which is essential for completing a mission successfully. In military conditions reliability evaluation tests observe the standard methods only. At present the relevant information about the reliability of electronic parts used in military vehicles along with the data on the trends of reliability measures development are not available at all. In the civilian sector (electrical and motor industry) the accelerated test time are used for showing the reliability measures of electronic parts. These processes have been developed in terms of statistics and standards. For military purposes it is possible to apply these civilian procedures of accelerated tests to the electronic parts of military vehicles, thereby minimizing the lack of information about the reliability of electronic parts used in military vehicles.*

**Keywords:** *electronics, military vehicles, maintenance, accelerated tests, reliability*

### INTRODUCTION

At present modern battle, purpose, or logistic vehicles are equipped with digitally controlled electronic systems which have a direct impact on the functionality of vehicles. Military systems design, used materials, production quality and the application of digital electronic parts increase the durability of a military vehicle.

When dealing with electronic systems, the high values of parameters of reliability performance are difficult to prove because the tests are very expensive and time consuming, therefore accelerated test methods are used.

As for the electronic elements for commercial application, the standardized procedures of accelerated tests have been already available and they might be applied also to the electronic parts of military vehicles: electronic parts act in the same way no matter whether for military or civilian purposes. In order to specify the type of environ-

mental stress for an accelerated test time, it was necessary to select representative military electronic parts and carry out their design analysis, location in a military vehicle and their environmental stress analysis during common use. To measure the environmental stress, experiments on selected military electronic parts were performed.

## 1. TESTS EXECUTION

At present no data is available on how electronic parts used in military vehicles will act when put under the different types of environmental stress. When performing the accelerated tests of commercial electronic equipment, the following types of stresses are used:

- constant temperature – resulting temperature value is the evaluated parameter;
- thermal cycling;
- vibrations/strokes;
- voltage (overvoltage/low voltage);
- combination of single stress types.

Different stress types have a different effect on the load of an electronic part and its susceptibility to failure, which is manifested both in an accelerating factor value for a given stress and in the real duration of an accelerated test.

The electronic parts of military vehicles are usually placed inside the vehicle out of an engine-gear sector, and, as compared with common commercial electronic parts, they are generally expected to be subject to higher levels of stress, mainly vibrations, strokes, voltage (overvoltage/low voltage), dustiness and humidity. Therefore, the placement of electronic parts in protecting cases hermetically sealed is also dealt with.

When choosing the proper stress of electronic parts, we focused on thermal cycling and temperature. Both types of stress load electronic parts without exception, no matter whether it is a commercial product or a military one. When deciding which type of stress to use for an accelerated test, it is necessary to perform an experiment, the results of which help us to specify that. Based on the analysis of electronic parts used in military vehicles, representative electronic parts intended for experiments have been selected.

The experiments proved that the temperature of electronic parts placed in military vehicles does not differ that much between switching on/switching off (10 up to 12.3°C), and also changes in temperature are not that quick (to 0.14 °C/min). On the basis of the experiment results, we selected the thermal stress and used it for the accelerated test of the electronic parts placed in military vehicles. Following the performed analyses, we determined accelerated test parameters using the Arrhenius equation of reaction rate:

$$A_{S\_Arrh} = e^{\frac{E_a}{k_B} \left( \frac{1}{T_{Use}} - \frac{1}{T_{Test}} \right)} \quad (1)$$

where:

$T_{Use}$  and  $T_{Test}$  are operating temperature at normal conditions and test temperatures in degrees of Kelvin;

$E_a$  – activation energy (eV);

$k_B$  – Boltzmann constant =  $8.617\ 3324E^{-5}$  eV/K;

$A_{s\_Arrh}$  – acceleration factor.

To set the value of activation energy, a wide range of technical literature and standards might be used [1, 4]. For the electronic parts utilizing standard miniaturization technology we applied the value of activation energy 0.6 eV [1].

## 2. OPERATING CONDITIONS OF ELECTRONIC PARTS PLACED IN MILITARY VEHICLES

To apply the standard methods of accelerated tests, it is necessary to specify at what real thermal operating conditions a military vehicle is used. The average temperatures of electronic parts in military vehicles depend on military conditions.

Military equipment is used according to the standard [3]:

- 1) Free state, during which the electronic parts are switched off – up to 95% of operating life time;
- 2) Operating state, during which the electronic parts are switched on – up to 10% of operating life time.

Ad 1) During the switch off state the electronic part of a military vehicle is stressed by ambient temperature. Depending on the season of the year, the idle state does not have a profound effect on an average annual temperature. When specifying thermal conditions in the switch off state, we use the values of average temperature for the Czech Republic in single months. The values are described as long-lasting average temperature.

Ad 2) During the operation of military equipment the electronic parts are switched on and by their function they generate their own heat. After switch of the equipment it reaches its operating temperature. The resulting temperature of an electronic part depends then on the ambient temperature at which the electronic part is switched on. In order to find out the operating temperatures of electronic parts placed in military vehicles, an experiment has to be performed.

When calculating the resulting temperature, it is necessary to know how long the single temperatures [5, 6, 7] were affecting the electronic parts. Therefore, it is essential to find out the time of the switch on/off of the electronic parts during at least one year. Those modern military vehicles used in the Army of the Czech Republic which are equipped with electronic parts are able to record and archive the time of switch on/off including an hour, a day and a year.

A detailed analysis was performed in order to select a representative electronic part. Following this analysis, three electronic parts (two processors and a display) commonly used in the military vehicles of the Army of the Czech Republic were chosen. To

specify the operation of electronic parts, the annual operation of 30 military vehicles were evaluated.

The evaluation of real annual operation showed the average use at the level of 3.6% per year capacity (8766 hours), the average amount of switching on/off of one electronic part during each month, and the average time of switching on/off of an electronic part. The values of average electronic parts operation which were established can be further specified using the operation values of a larger amount of electronic parts placed in military vehicles during next years. At present only these statistical data are available since we have just started to tackle this issue.

### 3. APPLICATION OF AN ELECTRONIC PART ACCELERATED TEST

On the basis of the experiment it was confirmed that when switching on electronic parts at different ambient temperatures it reaches different maximum operating temperatures. At negative temperatures (in Celsius) the power input of control units processor increased, therefore the values of final temperatures got higher. At positive temperatures (in Celsius) the power input fell down, which resulted in lower values of final temperatures. Owing to the thermal regulation of single electronic parts, the amount of time required for stabilizing maximum temperature changes at different ambient temperatures results of the experiments represented in the graph.

Figure 1 shows the operating temperatures of switched on electronic parts for ambient temperatures obtained during single months. The final annual temperature of one switched on/off electronic part is acquired by a weighted mean, where the weight is the operation measured in hours during a given month. The final value of the (weighted) average annual temperature of switched on electronic parts was within the range of 20.6°C to 21.3°C, and regarding switched off parts, it was 7.5°C. The manufacturer of electronic parts placed in military vehicles specifies maximal thermal environmental conditions for operation +70°C. At higher ambient temperatures the electronic part of a military vehicle has to be switched off. The established values then used in the Arrhenius model of a reaction rate, and using the above formula, the calculation of acceleration factor can be performed.

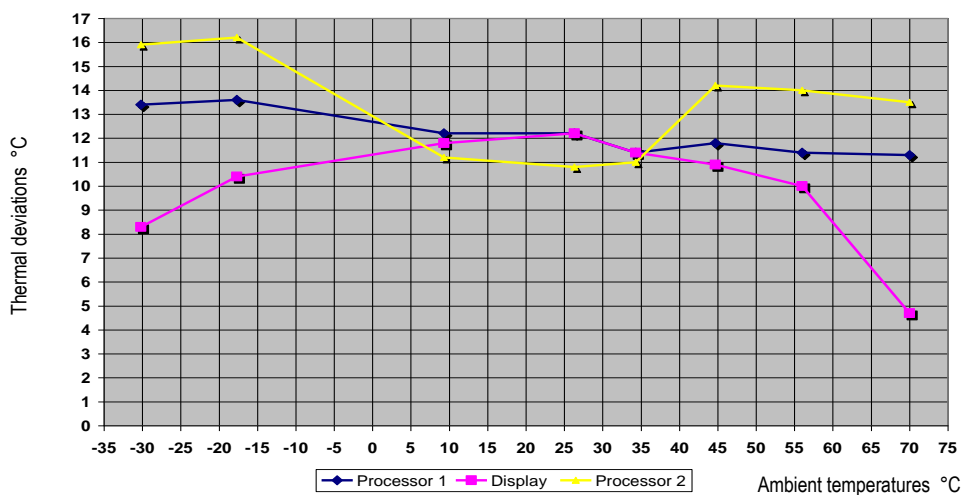


Fig. 1. Thermal deviations of electronic parts

Source: Own elaboration

The value of acceleration factor is used in the equation for calculating:

$$T_C = \frac{\chi_C^2(\nu)MTBF}{2A_S_{Arrh}} \quad (2)$$

where:

$T_C$  - accumulated test time;

$\chi_C^2(\nu)$  - chi square distribution value for confidence C and  $\nu$  of degrees of freedom;

C - required confidence for reliability evaluation (90%);

$\nu$  - the amount of degrees of freedom:  $\nu = (2r + 1)$  (it is assumed that the set of evaluated data will be always of censored set nature.

MTBF the operating time of an electronic part placed in a military vehicle is supposed to be 15 years, i.e. 131 490 hours.

Table 1 shows the times necessary for the accelerated test of given electronic parts at 90% confidence. At higher confidence the accelerated test of electronic parts will be longer.

Table 1. The time of accelerated test of an electronic part placed in a military vehicle according to the equation (2)

Electronic Unit		Operation Temperature $T_{Use}$ [K]	Test Temperature $T_{Test}$ [K]	Acceleration Factor $A_S$	Test Time [h]	Total Test Time [h]	Total Test Time [day]
Process or 1	Switched on	294.45	354.45	54.75085	115.370	1989.19	82.883
	Switched off	280.65	343.15	91.71234	1873.820		
Display	Switched on	293.85	347.85	39.5815	159.584	2033.40	84.725
	Switched off	280.65	343.15	91.71234	1873.820		
Process or 2	Switched on	293.75	356.65	65.38641	96.604	1970.42	82.101
	Switched off	280.65	343.15	91.71234	1873.820		

Source: Own elaboration

## CONCLUSION

Following the evaluation of electronic parts operation it might be stated that the value of military operation is gaining on the operation of commercial electronic parts. The procedure for calculation time accelerated examination commercial electronic parts is state in [6]. The accelerated test of an electronic part placed in a military vehicle using thermal stress takes basically the same time as the accelerated tests intended for the electronic parts of commercial automotive equipment. The accelerated test method of electronic elements provided in commercial industry can be applied or modified for use on electronic elements of military vehicles after a detailed analysis.

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## PRZYSPIESZONA ANALIZA NIEZAWODNOŚCIOWA CZĘŚCI ELEKTRONICZNYCH UŻYWANYCH W POJAZDACH WOJSKOWYCH

### Streszczenie

*Artykuł przedstawia przyspieszoną analizę niezawodnościową dla części elektronicznych stosowanych w pojazdach wojskowych eksploatowanych w Armii Republiki Czeskiej.*

*Podstawowe parametry dla nowo nabywanych pojazdów wojskowych określone są na poziomie niezawodności części elektronicznych, która gwarantuje skuteczną realizację misji. Ocena ta bazuje obecnie w warunkach wojskowych jedynie na standardowych metodach. Nie ma przy tym dostępu do istotnych informacji dotyczących niezawodności części elektronicznych stosowanych w pojazdach wojskowych, a w tym brak jest danych dotyczących trendów w rozwoju metod i sposobu pomiaru niezawodności. W cywilnych sektorach przemysłu elektrycznego i samochodowego stosuje się przyspieszone testy niezawodności komponentów elektronicznych, dla których zostały opracowane dane statystyczne i standardy. Również dla potrzeb wojskowych możliwe jest zastosowanie cywilnych procedur realizacji przyspieszonych testów niezawodności części elektronicznych, dzięki czemu można uniknąć braku informacji o niezawodności omawianych komponentów stosowanych w pojazdach wojskowych.*

**Słowa kluczowe:** *elektronika, pojazdy wojskowe, eksploatacja, testy przyspieszone, niezawodność*

## BIOGRAPHICAL NOTE

**Prof. Ing. Zdenek VINTR, CSc., dr.h.c.** – is a professor at the Faculty of Military Technology, the University of Defence in Brno, where he has taught dependability,

safety and security of complex systems for over 24 years. The core of his scientific and technical activity lies in the development of dependability, safety and security theory of complex technical systems and its applications. He is the author or co-author of 16 monographs and manuscripts, and more than 250 articles in scientific journals and proceedings. He cooperates closely with industrial companies in the area of dependability, safety and security of technical systems.

**Lt. Col. David VALIS, PhD, Associate Professor** – he has worked at the Department of Combat and Special Vehicles of the Defence University in Brno since 2005. He is a representative of the Czech Republic in the IEC/ISO Technical Commission 56 – Dependability and in ISO 262 on Risk Management. His extensive technical, research and publishing activity addresses especially the area of development of safety, risk and dependability analyses in the complex technical systems, and applied research in the fields mentioned above. He focuses on the area of reliability simulation, analyses, events description, defining the causes and consequences of events, specification and measures description of events, consequences of events verification, implementation of the obtained results into analyses, or dependability and safety assessment of complex systems. During the last five years he published more than 30 technical papers.

**Ing. Jiří CHALOUPKA, Ph.D.** he has worked at the Department of Combat and Special Vehicles of the Military Technical Institute Ground Forces in Vyškov since 1993. His extensive technical, research and publishing activity addresses especially the area of development of safety, risk and dependability analyses in the complex technical systems, and applied research in the fields mentioned above. In the team of research workers he focuses on the area of accelerated testing, reliability analyses, events description, defining the causes and consequences of events, specification and measures description of events, consequences of events verification, implementation of the obtained results into analyses, or dependability and safety assessment of complex systems. During the last five years he published more than 30 technical papers.