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FORCES AFFECTING DEFENCE PRODUCT PARTS IN THE CONDITIONS OF SERVICE MANIPULATION

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Abstract: *The present work studies the forces influencing defence products and their parts in the conditions of service manipulation – related to transportation, loading unloading, accidental fall, charging, etc. It presents a classification of possible overloads on the parts, as well as the impact of these forces on the safety and performance of the final product. For this purpose, a modern chemical source of electricity has been developed and it is intended for use in defence products. Attention is focused on the overload and impact forces which may affect the power source and its components.*

Keywords: service manipulation, chemical power sources, overload,

1. Introduction

The process of exploitation of special purpose defence products /industrial explosive devices, fuzes, etc./ is conditionally divided into the following main periods: service manipulation, shot, flight /along a trajectory/ and barrier encounter. Each of these operating periods is characterised by the impact of different forces on the component parts of the product. These forces are of different direction and value and continue to be studied.

The report presents the results obtained when testing an independent chemical source of electricity which is considered as a part for defence products. Some of the tests were related to determining its safety and working capacity after the impact of the forces acting upon service manipulation. To evaluate these forces, the overloading of the parts and the entire product was used.

Overloads that work on product details under the terms of service manipulation can be divided into two groups:

- overloads repeated thousands and millions of times;
- overloads which are relatively rare /from ten to one hundred times/.

The first group includes vibrations and impulse overloads, and the second one – the impacts and quasi-static overloads.

2. Overloading during transportation

The focus here is on overloads which may occur when land or air transport is used.

2.1. Vehicle transportation

Measurements of vibrations and impulse overloads have been carried out during transportation in a vehicle, with a load of 10 to 50 % of the nominal load when travelling on different roads, mostly in poor condition /broken asphalt road, paving, dirt road, etc./, at a speed of 20 to 60 km/h.

Vibrational overloads have been measured with a sensor firmly attached to the platform floor of the vehicle. The measurements show that four vibration modes appear in vehicle transportation (Table 1).

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Table 1 Characteristics of vibrational overloads [2]

Frequency, Hz		Maximum overload
Designation	**Value**	
f_1	1.7 – 4.5	5.0
f_2	6.7 – 13.5	2.5
f_3	14 - 37	0.6
f_4	67 - 87	0.3

The frequencies f_1 и f_2 characterise the fluctuations of the platform /from the suspension/ of the vehicle. Frequency f_3 designates the forced fluctuations caused by engine operation. Frequency fluctuations f_4 represent floating fluctuations of the elements of the platform itself [2].

At the same time, vibrational overloads under the same conditions are also influenced by the specific location of the load on the platform /centre, corners, etc./, and depend on the load of the vehicle. The biggest overloads have been found at the back of the platform, especially in the corners. Increasing the load by 10 to 50 % of the nominal load leads to a 30 to 40 % reduction.

Impulse overloads have been measured when driving a vehicle on roads in poor condition and in a single pass over pits or holes along the road at a speed of 20 and 30 km/h. These uneven places are selected so that when passing through them, the highest possible impulse overloads are obtained without damaging the vehicle. Wooden boxes are placed on the platform of the vehicle freely or fixed with ropes or boards which limit their bouncing. The tests that have been carried out showed that the bouncing of the boxes and their striking onto the platform in all cases resulted in overloads that did not differ significantly in value.

The height of the jump of an unfixed trunk, subject to the admissible technical norms for vehicle operation, is about 20 cm – this height is now considered the maximum possible [2]. Consequently, it is assumed that overloads of about 40 units are the maximum under these conditions. When the vehicle load is increased to 50 % of the nominal load, the impulse overloads occurring in the course of unevenness on the road are substantially reduced and not more than 20 units.

The percentage of impulse overloads by value recorded in a single passage of a vehicle through a pit or hole on the road is presented in Table 2.

Table 2 Ratio of impulse overloads in percent relative to their value [2]

Overload value	Percentage ratio
from 1 to 10	59 %
from 10 to 20	27 %
from 20 to 30	9 %
from 30 to 40	5 %

It should be noted that the aforementioned impulse overloads have been obtained when the vehicle passed through pits without any speed reduction in order to result in higher jumps of the boxes /containers/, i.e. greater values of overload. In real conditions, the number of such jumps of the containers is very small compared to the number of small /inappreciable/ overloads.

In the cases of vehicle transportation, rarely repeated impulse overloads of more than 40 units may occur. These values are obtained in a collision between a vehicle and an obstacle, which may cause overloads of 80 to 100 units and more /up to 150 units/. These are perceived as impact overloads and their number is relatively small /collision with an obstacle, car crash/

compared to the total number of impulse overloads during transportation; they are considered as incidents.

2.2. Transportation in tracked vehicles

When transported in tracked vehicles, vibration and impulse overloads impact the product details. In the most common cases, when transported on roads in bad condition, the following fluctuations /vibrations/ occur:

- free hull fluctuations, depending on its mass, the moment of inertia and the hardness of the springs, at a frequency of 1 to 4 Hz;
- forced fluctuations of the hull and its components at a frequency dependent on the engine performance in the range of 13.5 to 37 Hz;
- fluctuations of the elastic elements which the hull is made from with a frequency dependent on the elasticity of these elements up to 250 Hz.

The greatest vibrational overloads occur in the free fluctuations of the hull. The maximum values of these overloads are from 0.7 to 1.6 units.

In the presence of obstacles on the road at a sufficiently high speed, when the amplitude of the free fluctuations of the hull is greater than the admissible, a shock occurs in the rigid restrictors of the hull movement, resulting in impulse overloads of 4 to 6.5 units. It has been found that the fluctuations of the hull elements under the specified conditions have a frequency of 7 to 250 Hz and maximum vibration overloads of 3 to 9 units.

2.3. Transportation in trains

When transporting goods by rail, vibrational overloads occur due to the free and forced fluctuations of the wagons caused by their passage through the rail spikes, the eccentricity of the wheels, etc.

According to scientific resources, the maximum vibrational overloads at a speed of 90 km/h are not greater than ± 0.45 units in a vertical direction and ± 0.5 units in a horizontal direction with a frequency of fluctuations of 1.8 to 15 Hz. The maximum vibrational overload is equal to 0.25 units for passenger carriages and 1.0 for freight wagons with a frequency of fluctuations in two ranges – 1 - 2 and 3 - 5 Hz. In the case of sudden jerks of the wagons, overloads with an impulse character of no more than 10 units appear [2].

2.4. Transportation on airplanes

Products are transported by airplane in a special package. It is usually placed in the fuselage of the plane. The maximum vibrational overloads in the fuselage of the airplane occur at take-off and landing. Overloads depend on the type of aircraft and equal 2 - 3 units. The frequency of freight fluctuations is in the range of 20 to 200 Hz.

2.5.Quasi-static overloads in transportation

Quasi-static overloads in typical manoeuvres of land transport are very small and may be neglected. It has been found that when a car is accelerated, they have a value of 0.08 - 0.25 units and for a lorry – 0.04 - 0.20 units. The overloads when the vehicle is stopped are somewhat larger.

Manoeuvre overloads of rail wagons are generally not more than 0.2 units when stopping, and 0.075 units when travelling along a curved section of the road. In the case of sharp braking, sharp bends, etc. quasi-static overloads may be greater than a unit. They are the greatest in air transport, and depending on the speed and direction of movement they can reach values of 5.7 - 8 units.

2.6. Impact overloads

Impact overloads are impulsive in nature and have a relatively high value. They can occur at all stages of product service manipulation. It is characteristic for them that they are usually caused by accidental reasons /unexpected collision with an obstacle on the road, falling, rollover, etc./. Impact overloads are rarely observed compared to vibrational and impulse overloads.

3. Impact of overloads on the performance of a power source designed for use as a defence product

A new type of chemical power source has

been developed, which is made up of electrochemical elements interconnected with a rigid connection. Its technical parameters are pre-set and it must provide a voltage without load of 12 V and under load – of more than 6 V for not less than 10s. Physical samples of the power source were constructed and their features were compared. In order to determine their work capacity and safety under service manipulation conditions, they underwent overloads characteristic of this stage of operation. The power sources subject to the experimental study have identification numbers.

3.1. Vibration testing of experimental samples

Aim: The test aimed to model the impact of vibration during transport on the power source. The test conditions were based on the vibration range /vibration overload/ referred to in Point 2.

Carrying out the test: The tested power sources were firmly attached to the platform of the experimental vibration device without being deformed, but also in a way which allowed the vibrations to be transmitted as accurately as possible. The tested physical samples were subject to sinusoidal vibrations [1].

Requirements: There had to be no loss of mass, electrolyte leakage, air leakage, transient short circuit, destruction, explosion or incineration in the process of testing the physical samples of the power source.

Course of the test: The developed physical samples of the power source were subject to vibrational overload. They were subjected to tests beyond the required range to determine their performance capacity with greater loads. A vibration bench ST-5000 - 300/1 was used to perform the experiment and the samples were axially tested under the following conditions:

1. Vibrations – 10 Hz – 2.5 kHz;
2. Acceleration – G = 2.5 m/s^2;
3. Amplitude – 1.5 mm in both directions.

The Bulgarian standard БДС EN 60068-2-6: 2007 was also used in the study. This standard refers to the environmental impact test: Part 2-6: Tests. Fc test: Vibration /sinusoidal/. Each of the power sources was subjected to two cycles of vibrational impact, each of the cycles lasting for 16 minutes. The consecutive undergoing of two test cycles was intended to aggravate the conditions under which the test samples were placed. This method provides a standard procedure for determining the capability of the developed samples to withstand certain effects caused by sinusoidal vibrations. It is also assumed that the overload is greater when conducting the test with unpacked parts.

The suspected problems that could be simulated during the experiment are divided into two types: external and internal, and each of them affects the efficiency of the power source and, accordingly, leads to a change in the amount of energy it delivers. Vibrational overload is used to prove the mechanical strength of the samples and/or to study their dynamic behaviour.

The tested power sources were numbered and indicated by their type as follows:

Alkaline Maxell LR44:	***Silver Maxell SR V357:***	***Lithium CR – 1/3 N***
(12.06.1.00012)	(12.03.2.00007)	(13.01.3.00001V)
(12.06.1.00008)		(13.01.3.00002S)
(12.06.1.00010)		

The outer part of the power sources that were used in the test was examined. In the absence of any visible damage to the outer casing and/or changes in their integrity, the measurement of their electrical voltage was carried out.

For the correct reading of the vibration effect results, the voltage of the power sources was first measured without load. They were then subjected to an electrical resistance of 120 Ω for 10 s.

Results obtained: The variation of the voltage after two cycles of vibrational impact is presented in Table 3 and Figure 1.

Table 3 Values of the voltage after the conducted vibrational impact

Power source №	VOLTAGE			
	Without load [V]	Voltage with load 120 Ω - beginning [V]	Voltage with load 120 Ω/10 s – end [V]	Change in the working voltage in %
(12.06.1.00012)	12.280	8.590	7.911	7.90
(12.06.1.00008)	12.449	9.300	8.650	6.99
(12.06.1.00010)	12.443	9.300	8.525	8.33
(12.03.2.00007)	12.785	9.903	9.767	1.37
(13.01.3.00001V)	12.257	10.560	10.043	4.88
(13.01.3.00002S)	12.270	10.310	9.770	5.24

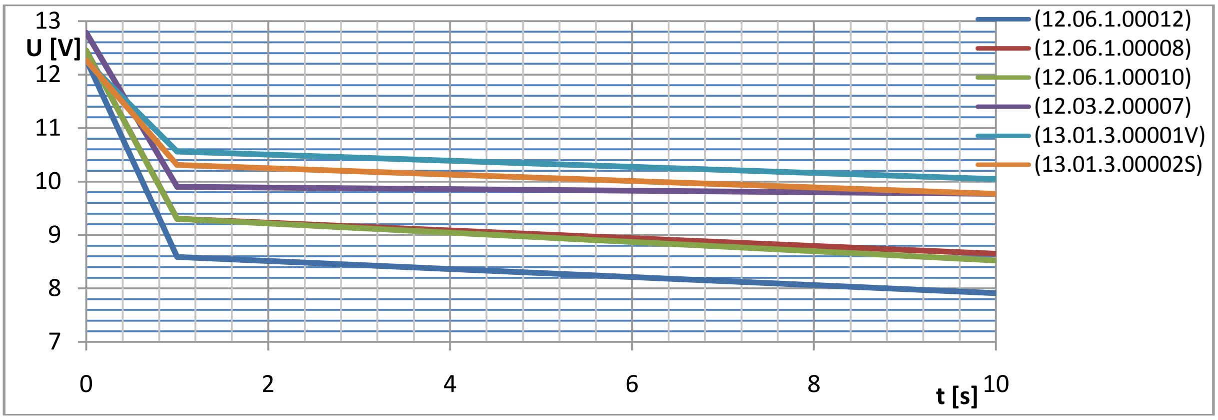

Figure 1 Graphic dependence of the change in the working voltage after the conducted vibrational impact

The vibration overload did not change the nominal voltage of the tested power sources. This proved the lack of mechanical deformation inside the power source. The measured operating voltage values were over 6 V for 10 s. The change of the working voltage within the specified time interval was within the permissible value below 10 %.

3.2. Test of the performance of the test samples under mechanical overload

Aim: The test modelled a sharp mechanical impact on the power source during transport. These overloads are relatively rare, but they can be initiated not only during transport but also in case of improper manipulation with the product or its frequent loading and unloading activities, etc.

Test procedure: The power sources had to be firmly attached to the test unit by fixing all the mounting surfaces of each of the elements. They were subjected to three strikes with a force of 150 N in the three reciprocally perpendicular mounting positions.

Requirements: There had to be no mass loss, electrolyte leakage, air leakage, transient short circuit, destruction, explosion and burning in the process of testing the power sources.

Course of the test: In laboratory conditions, the physical samples of the power source were subjected to mechanical overload. Three series of samples were used. The first and second series consisted of alkaline and silver electrochemical systems, and the third one – of the power sources stored for one year without being placed under special conditions.

Alkaline Maxell LR44:	***Silver Maxell V357:***	***The first made PS:***
(12.01.1.00008)	(12.03.2.00007)	(11.08.1.00001)
(12.01.1.00010)	(12.03.2.00009)	(11.08.1.00005)
(12.01.1.00012)		

Results obtained: The tested power sources successfully passed the mechanical stress of 150 N in the three mutually perpendicular mounting positions. No visible external defects were observed. Table 4 shows the measured values of the voltage of the power sources before and after the mechanical load.

Table 4 Values of the voltage after mechanical load

Power source №	**Voltage without load [V]**	
	Before the strike test	**After the strike test**
(11.08.1.00001)	12.740	12.770
(11.08.1.00005)	12.700	12.700
(12.03.2.00007)	12.450	12.810
(12.01.1.00008)	12.370	12.370
(12.03.2.00009)	12.440	12.520
(12.01.1.00010)	12.400	12.180
(12.01.1.00012)	12.830	12.830

When comparing the values obtained for each of the power sources, the operating voltage was maintained within the expected 12 V. Part of the tested power sources showed higher values after the mechanical overload. This was due to an increase in the contact surface between the electrodes in the chemical source of electricity after the mechanical impact.

4. Conclusions:

1. At the stage of service manipulation, vibrational and impulse overloads had an impact on the product parts. They were originally mechanical forces related to solving important safety and reliability issues of fundamental mechanisms.
2. The conducted test for the impact of typical vibrational sinusoidal overloads at the stage of service manipulation proved the safety and operability of the test samples, which retained their nominal and working voltage after the experiment.
3. The designed power source samples successfully passed the mechanical overload of 150 N in the three reciprocally perpendicular mounting positions /axes/ and maintained their nominal voltage of 12V.
4. The obtained information on the behaviour of the constructed power sources in service manipulation conditions could be employed when a decision is made on their use as a defence product part.

References

[1]. Bulgarian Standard БДС EN 60068-2-6:2007. Environmental Testing. Part 2-6: Tests. Test Fc: Vibration (Sinusoidal).

[2]. Petkov, B. M. Artillery Fuzes. Theory, Estimate and Structures. Saint George MoD Publishing House, Sofia, 1994.