Test Program

Checking the Nanomotion Shutter Lifetime for a Rocket Application

Document No. RS08453000-00, Rev A

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AUTHORIZATION

Revision Approval	Name	Date approved	Signature (HC only)
Written/Edited by:	Boaz Slav	01/2019	
Checked by:	Einat Shperling	01/2019	
Approved by:	Nir Karasikov	01/2019	

REVISION HISTORY

ECO	Rev.	Description of Revisions	Changed by:	Date/Sign
	A	Initial release		01/2019

1 BACKGROUND

The NM RS-08 was validated for rockets and other ammunition applications. The lifecycle comprises 15 years storage and 1 year operational.

The test is according to accelerated test procedures as required by a specific NM customer.

2 THE PURPOSE OF THE TEST

The purpose of the test is to prove the mechanism is durable for the system lifetime as mentioned above.

3 DEFINITION OF THE TESTED ASSEMBLY

The NUC mechanism (Rotary Shutter) catalog number RS080350AA-01. Shutter Documentation is provided: Nanomotion Specifications. The mechanism contains a piezoelectric actuator, a metal flag, and a close loop control system. It should be noted, that the shutter comprises options: flag balance, change in the braid and connector, are not defined as risks for the system lifetime and therefore, changing them will not derogate the test results.

The mechanisms will be vibrated and placed in the temperature chamber using a dedicated Nanomotion jig.

4 LIFETIME TEST

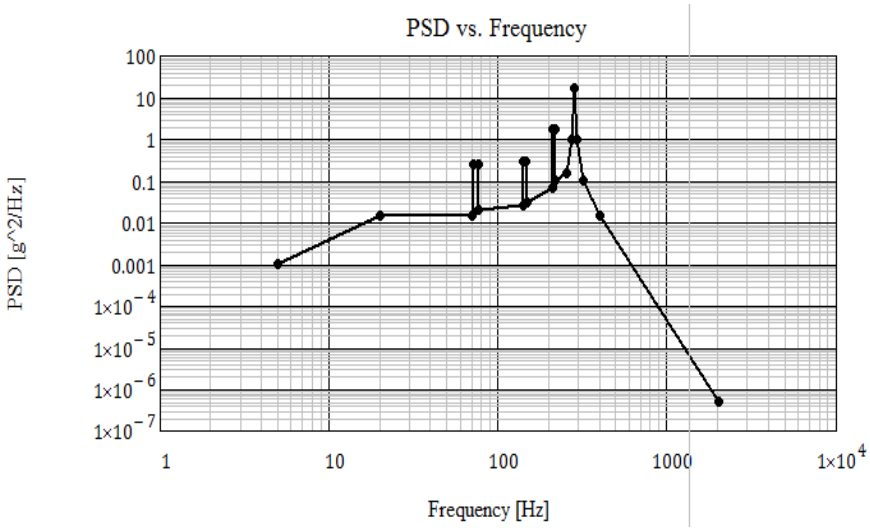
Full details and considerations for the tests are specified in the Customer's Environment Engineering Document. The Environmental Management Program Specification accounts for two stages in the product's lifecycle: storage (15 years) and operation (1 year). Before and after these stages vibration survivability test were conducted.

4.1 VIBRATION SURVIVABILITY

This vibration test validates the job profile and lifetime duration of the product in terms of fatigue and mechanical failure. The profile calculations are detailed per the customer's specs.

The system should survive without any permanent damage or degradation of performance after exposure to vibration conditions. Test time is 60 minutes.

Amplitude [G^2/Hz]	Freq[Hz]
0.001	5
0.015	20
0.015	70
0.25	71
0.25	76
0.02	77
0.025	140
0.3	141
0.3	146
0.03	147
0.07	210
1.8	211
1.8	216
0.1	217
0.15	255
1	270
17	280
1	290
0.1	320
0.015	400
5e-7	2000

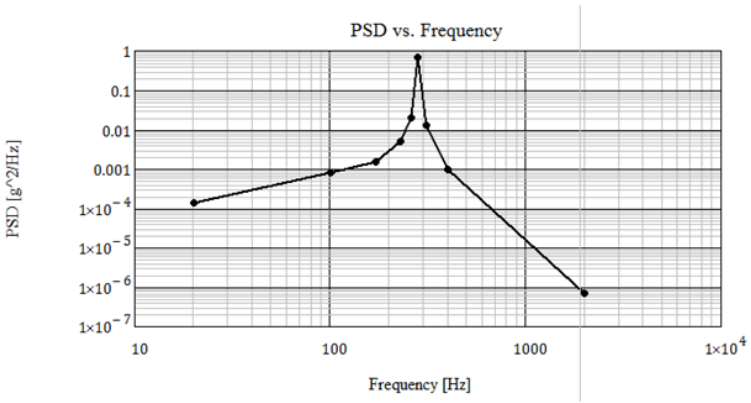


15.7Grms
Vibration for duration of one hour on each axis

4.2 VIBRATIONS - FUNCTIONAL

The system should operate without any degradation of performance during exposure to vibration conditions. Test time is up to 5 minutes.

Amplitude [G^2/Hz]	Freq[Hz]
0.00014	20
0.0008	100
0.0015	170
0.005	230
0.02	260
0.7	280
0.013	310
0.001	400
7e-7	2000
0.00014	20



Vibration 3.17Grms

4.3 SHOCK

The system should survive without any permanent damage or degradation of performance after exposure to the shocks specified in the following list:

Acceleration amplitude: 185[g]
Shock type: Half Sine
Shock duration: 15 [msec]
2 shocks in each direction (x,y,z)

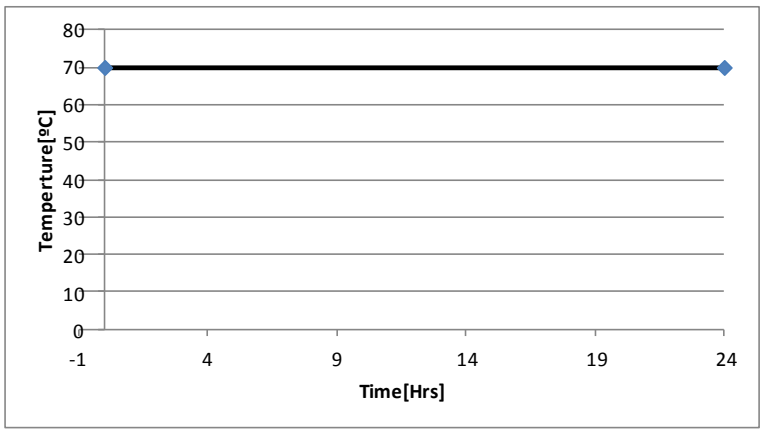
4.4 STORAGE AGING TEST

4.4.1 Life Cycle

The test simulates 15 years of storage in a rear base under controlled storage conditions at a constant temperature of 23 °C. A 80-hour accelerated trial simulates a year under controlled storage conditions.

4.4.2 Test Conditions

The tested shutters should be tested for 50 days (=15 years) at a constant temperature of 70 ºC as shown in the following Figure.



Time [hh:mm]	Temp [ºC]
00:00	70
24:00	70

4.5 HIGH AND LOW TEMPERATURE TEST (OPERATIONAL AGING TEST)

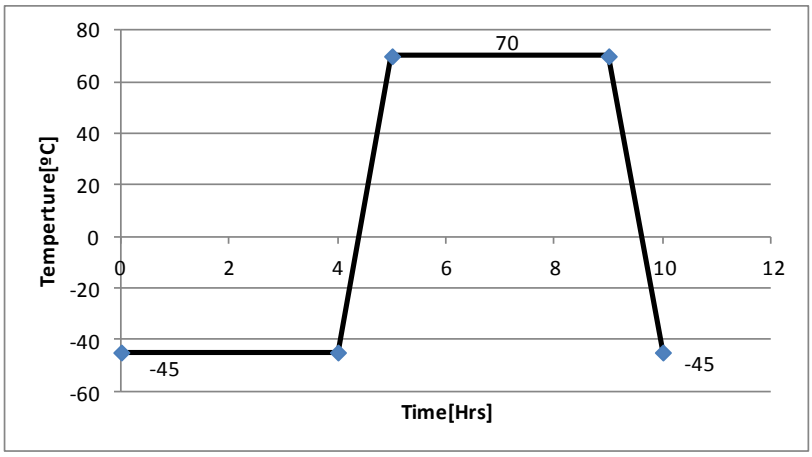
4.5.1 Life Cycle

The test simulates a year of storage in a front base under uncontrolled storage conditions – in total the test simulates 365 temperature cycles. Each cycle simulates daily temperature differences between the maximum daily temperature and the minimum daily temperature, of 20 °C.

5.5 cycles (55 hours) simulate a year of storage under uncontrolled conditions, per NM customer's protocol.

4.5.2 Test Conditions

The shutter should be tested in 5.5 temperature cycles as shown in the following Figure.



Time [hh:mm]	Temp [ºC]
00:00	-45
04:00	-45
05:00	70
09:00	70
10:00	-45

If the test ends in the middle of the cycle, the system will be removed from the temperature chamber after an hour at the room temperature.

5 TEST PROCEDURE

Ten shutter mechanisms were tested.

STAGE A: VIBRATION/SHOCKS

Ten mechanisms were vibrated/shocked as described in Par. 4.1,4.2,4.3.

STAGE B: TEMPERATURE SOAK IN CHAMBER AT HIGH TEMPERATURE

The test was performed in the temperature chamber. The numbered mechanisms were placed in the temperature chamber, while at each exit point 2 mechanisms were pulled out to be checked by Nanomotion.

STAGE C: TEMPERATURE SOAK IN CHAMBER WITH TEMPERATURE CYCLES

The test was performed in the temperature chamber that allows pre-programing temperature cycles. The remaining 4 mechanisms were placed in the temperature chamber and at the end of the test were inspected by Nanomotion.

# Exit point	Stage	Duration of the test	The corresponding stage in the product's lifetime
1	B	400 hours (17 days)	5 years in the storage
2	B	800 hours (34 days)	10 years in the storage
3	B	1200 hours (50 days)	15 years in the storage
4	C	1255 hours (52.3 days)	15 years in the storage + 1 year in operation

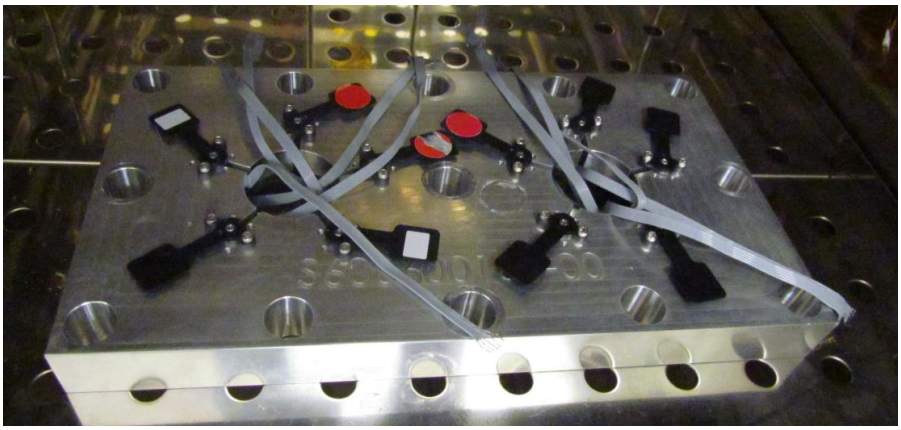
The purpose of the fifth exit point is to check the robustness of the mechanisms by checking it for two additional years in operation.

6 TESTING THE MECHANISMS

Prior to conducting the test, 10 mechanisms passed the ATP test and the results were recorded by Nanomotion. After pulling out the mechanism at each stage as described in Par. 5, a repeated ATP test was conducted. The mechanisms' parameters before and after the test, were compared.

7 RESULTS

The test was carried out according to the plan as detailed in Par. 4 – Vibration, Aging and Temperature Cycles.



For Vibration, to simulate the weight of the system's flag, 1-gram metal discs were mounted in place of the original Nanomotion flags. After the Vibration test these flags were removed and the Nanomotion's original flags were reinstalled. Three of the mechanisms were damaged by improper mounting onto the plate; therefore, the plastic grids were replaced with the plastic restraints of –55 degrees.
Compared to the original ATP, **the flags passed the test**.
The following is the Test Summary Table:

# Exit Point	Test Duration	The corresponding stage in the product's lifetime	The date of pulling out of the temperature chamber	Serial numbers of the mechanisms
1	400 hours (17 days)	5 years in storage	31.7.17	24170004 24170011
2	800 hours (34 days)	10 years in storage	20.8.17	24170006 24170009
3	1200 hours (50 days)	15 years in storage	3.9.17	24170001 24170008
4	1255 hours (52.3 days)	15 years in storage + 1 year in operation	28.9.17 + year in operation 1.2.18	24170003 24170012 24170010 24170007

The following is the ATP Table of the mechanisms.

				Testing the appropriate script					Dynamic Force							
Module SN	Test Date	FW version	Frequency after calibration **[KHz])**	Check after unplugging Variable 33	Open Time Variable 12 **[0.1 mSec]**	ADC1 value in open status	Close Time Variable 12 **[0.1 mSec]**	ADC1 value in close status	Dynamic Force /open [N]	Dynamic Force/close [N]	Current Test **[mA]**	Current in Power Safe Enable **[mA]**	Movement Range	Leaf Jig	Delta ADC **[0.1 mSec]**	**Pass/fail**
Initial ATP																
24170006	14-Jun-17	1.1.0.23	127	45	865	772	707	1870	0.04	0.34	62	2.7	1	1	1098	PASS
24170003	14/06/2017 18:46	1.1.0.23	132	45	769	779	855	1870	0.038	0.04	70	2.7	1	1	1091	PASS
24170007	15/06/2017 06:10	1.1.0.23	130	45	653	776	607	1892	0.04	0.038	54	2.9	1	1	1116	PASS
24170010	15/06/2017 06:11	1.1.0.23	132	45	801	729	721	1708	0.038	0.04	52	2.9	1	1	979	PASS
24170011	15/06/2017 06:12	1.1.0.23	132	45	781	729	713	1712	0.04	0.038	54	2.9	1	1	983	PASS
24170009	15/06/2017 06:13	1.1.0.23	132	45	719	761	881	1854	0.048	0.055	80	2.9	1	1	1093	PASS
24170012	15/06/2017 06:13	1.1.0.23	129	45	799	765	831	1856	0.038	0.04	54	2.9	1	1	1091	PASS
24170008	15/06/2017 06:14	1.1.0.23	132	45	791	713	805	1715	0.04	0.04	60	2.9	1	1	1002	PASS
24170001	14/06/2017 18:48	1.1.0.23	132	45	971	783	869	1859	0.04	0.042	70	2	1	1	1076	PASS
24170004	14/06/2017 18:48	1.1.0.23	129	45	929	828	897	1863	0.038	0.034	83	2.8	1	1	1035	PASS
After Vibration and Shock																
24170010	21-Jun-17	1.1.0.23	132	45	949	743	763	1757	0.046	0.05	71	2.8	2	1	1014	PASS
24170007	21-Jun-17	1.1.0.23	130	45	797	668	681	1739	0.046	0.032	70	2.8	2	1	1071	PASS
24170011	21-Jun-17	1.1.0.23	132	45	921	817	889	1852	0.038	0.032	78	2.8	2	1	1035	PASS
24170003	21-Jun-17	1.1.0.23	124	45	781	794	817	1899	0.038	0.048	82	2.8	2	1	1105	PASS
24170001	21-Jun-17	1.1.0.23	132	45	889	653	855	1683	0.034	0.042	80	2.4	2	1	1030	PASS
24170009	21-Jun-17	1.1.0.23	132	45	917	765	993	1843	0.04	0.05	89	2.4	2	1	1078	PASS
24170004	21-Jun-17	1.1.0.23	132	45	960	772	905	1838	0.034	0.04	95	2.8	2	1	1066	PASS
24170006	22/06/2017 08:43	1.1.0.23	132	45	955	686	815	1861	0.038	0.042	85	2.8	1	1	1175	PASS
24170008	22/06/2017 09:14	1.1.0.23	132	45	919	704	947	1735	0.038	0.038	80	2.8	1	1	1031	PASS
24170012	22/06/2017 09:17	1.1.0.23	132	45	969	693	839	1679	0.038	0.044	86	2.8	1	1	986	PASS
After Vibration + Aging																
24170011	22/08/2017 09:24	1.1.0.23	132	45	737	734	787	1737	0.032	0.034	64	2.8	2	1	1003	PASS
24170009	04/09/2017 08:35	1.1.0.23	124	45	849	497	911	1735	0.038	0.036	63	2.8	1	1	1238	PASS
24170001	05/11/2017 17:36	1.1.0.23	132	45	801	639	869	1701	0.068	0.058	86	2.8	1	1	1062	PASS

24170004	14-Aug-17	1.1.0.23	132	55	1243	412	1245	1780	0.034	0.052	70	2.7	2	2	1368	PASS
24170006	04/09/2017 08:43	1.1.0.23	132	55	967	473	791	1825	0.034	0.054	90	2.8	1	1	1352	PASS
24170008	05/11/2017 17:40	1.1.0.23	132	55	1227	410	1221	1703	0.042	0.056	80	2.8	1	1	1293	PASS
After Vibration + Complete Aging Period (Temperature Chamber)																
24170003	28/02/2018 11:27	1.1.0.23	132	45	771	754	825	1789	0.046	0.046	96	2.7	2	2	1035	PASS
24170012	28/02/2018 11:55	1.1.0.23	132	45	801	700	741	1742	0.07	0.078	72	3	2	2	1042	PASS
24170010	28/02/2018 12:01	1.1.0.23	132	45	873	704	665	1737	0.046	0.042	70	2.7	2	2	1033	PASS
24170007	28/02/2018 13:40	1.1.0.23	132	45	755	626	707	1746	0.044	0.042	80	2.8	2	2	1120	PASS

8 CONCLUSION

The NM RS-08 has successfully passed a series of the Environmental Management System Tests: vibration, temperature, and lifetime, and meets the Environmental Management System requirements.

The shutters could be used for ammunition applications and will function well after 15 years storage.