Conformity assessment of anti-hail rocket RAG-96.00 with security requirements

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Abstract. In Romania at present a significant part of agricultural crops, vineyards, fruit trees, etc. are protected against hail by implementation / development of the anti-hail national system. The main component of this system is Anti-hail Rocket RAG 96.00, product manufactured by Electromecanica Ploiești, which falls under the category of explosives for civil use as specified in DIRECTIVE 2014/28/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014, on the harmonisation of the laws of the Member States relating to the making available on the market and supervision of explosives for civil uses, taken into national law by G.D. 197/2016. In order to be placed on the market / made available on the market, Anti-hail Rocket RAG 96.00 must comply with the essential safety and functioning requirements, thus providing, maximum safety for those using it, while at the same time achieving the purpose for which it was manufactured, in predictable safety conditions. The paper presents the results of the specific laboratory tests, that have been used as a reference in the conformity assessment process of this product.

1 Introduction

The Anti-hail Rocket RAG-96.00 is intended to combat hail formation in the "cumulus-nimbus" peak clouds, is evolving and reducing the amount of hail from the maturing clouds, in order to prevent hail falls and reduce the damage caused by fall hail. The anti-hail rocket introduces into the necessary area, determined with the help of the meteorological radar, in the clouds, substances with the role of an activated nuclear center "CNA" of microscopic dimensions, in order to fix the water drops. By significantly reducing the amount of liquid water not fixed in the clouds, it is transformed into a solid (ice), large size.

The Anti-hail Rocket RAG 96.00 shown in figure 1, consists mainly of propulsive installation (2 propellant charges and 2 delays assembly), useful section (active smoke cartridge + self-destruct control mechanism) and explosive charge system. The operation of the rocket is initiated with an electrical priming.

Technical specifications [1]:

- Diameter: 82.5mm;

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- Length: 1,4m;
- Total mass: 8,8kg;
- Main charge mass: aprox. 0,66kg;
- Maximum trajectory height: 9300m;
- Maximum horizontal distance: 12000m;
- The time between launching the rocket and destroying it: 38-47s.

Fig.1. Anti-hail Rocket

Launching of rockets RAG-96 is made from the beams of the launching ramp that provides the power supply needed to initiate the electrical priming, retaining the rocket on the ramp until reaching a level of traction (50daN) and guiding the rocket to the speed that will allow the stable flight.

The electrical priming powered by electricity (the guaranteed starting voltage at a DC voltage of $24 \pm 3V$ is 2 A) releases hot gases and hot particles during the operation of the rocket engine. At the same time the propellant charge and the first delay assembly are initiated. When the necessary traction force is achieved, the movement in the launch beam and the rocket flight begins. The burning time of the propellant charge in the starting step is $1.1 \div 1.9s$. The chain of fire is maintained by the delay assembly I for $4 \div 7s$, the flattening of the trajectory takes place and finally the beginning of the marching step by burning the black powder from the primer I. [2]

The rocket is further accelerated by combustion of the propellant charge and the delay assembly II. For sealing the marching step, as a safety measure, the delay assembly II burns $4 \div 6.5s$. Primer II is started that ignites the active smoke cartridge and the delayer to self-destructing control mechanism (MCA). The gases released by the active smoke cartridge "seed" the clouds, and the MCA prepares the rocket for self-destruction. After the delay time of the MCA, the explosive load system is initiated by its explosive components. Self-destruction is done at $38 \div 47s$ after launch, at a minimum height of 1700m. From a functional point of view, the total time of self-destruction is realized by a pyrotechnic chain whose events occur in series, the production of an event conditioning the next one. The realization of the self-destruct event and the achievement of the proposed purpose are conditioned by the correct functioning of each pyrotechnic element in the chain.

Anti-hail rocket RAG 96.00 and its main components are subject to certification in the areas covered by Directive 2014/28 / EU on civilian explosives (RAG 96.00 Anti-hail rocket, Self-destroy command mechanism, Explosive charges for self-destruction and Propellant charge) and Directive 2013/29 / EU regarding pyrotechnic articles (Delay assembly I and II, Priming and Active smoke cartridge). [3]

Directive 2014/28 / EU and Directive 2013/29 / EU, specify the essential security requirements with which products in the fields covered by the two directives must comply.

The instruments with which these conformities are verified are the harmonized European standards. In the absence of such standards, the directives allow the use of the national standards / internal procedures of the manufacturer, etc. as tools for verifying the compliance of explosives for civil use and pyrotechnic articles, with the essential security requirements applicable.

This situation is encountered in the RAG 96.00 Anti-hail rocket as well as certain components that enter its structure, for which the manufacturer Electromecanica Ploiesti has developed test procedures to verify the relevant essential safety requirements. The components of the anti-hail rocket as well as the rocket as a whole are addressed

individually, by evaluating the results of the tests at which harmonized standards were used (if elaborated), respectively testing procedures of the manufacturer Electromecanica Ploiesti.

In the following are presented methods applied to verify some essential indicators and the operating parameters of the RAG 96.00 anti-hail rocket components, respectively the propellant charges and the delays assembly I and II.

2 Material and method

In order to determine certain ballistic parameters, the manufacturer has a specific test infrastructure, which consists of a stand specially designed for tests for anti-hail rockets and their components.

The diagram of the assembly designed to determine the parameters that highlight the correct functioning of the propellants charge and of the two delays assembly in the composition of the anti-hail rocket, is shown in figure 2. [4]

Fig.2. Assembly diagram

The assembly is called "propulsive installation" and consists of the initiation means, respectively the priming, propellant charges (2 pcs.), Delay assembly I and delay assembly II, which is fixed after assembly on the special stand, after which the pressure and force sensors are mounted, resulting in the assembly shown in figure 3.

Fig.3. Assembly for testing

The test method is applied to the pressure test and the traction test in order to verify the following functional characteristics:

- A. Ballistic parameters of the propulsive installation, [5] with the specified values:

- Maximal pressure ($p_{\max}$): $\leq 70\text{bar}$;
- Average pressure (p_m): $40\div 57\text{bar}$;
- Burning time (t_{ef}): $1.1 \div 1.5\text{s}$;
- Total impulse (I_{tot}): $\text{min.}270 \text{ daNs}$;
- B. Burning time in the real engine, Delay assembly I: $4\div 7,5\text{s}$;
- C. Burning time in the real engine, Delay assembly II: $4\div 6,5\text{s}$.

During the tests, data of the tracked parameters are acquired, which after processing can be graphically represented in the forms shown in figure 4, for the pressure sensor records TP1 and TP2, respectively figure 5, for the force sensor records.

Fig.4. The pressures and times graph

- Where: $P_{1\max}$ = maximum engine start pressure (step I);
 $P_{2\max}$ = maximum pressure in gear motor (step II);
 $P_{1\text{med}}$ = average pressure in engine start (step I);
 $P_{2\text{med}}$ = average pressure in gear motor (step II);
 T_{11} = realization time 10% din $P_{1\max}$ at starting engine start (step I);
 T_{14} = realization time 10% din $P_{1\max}$ at the end burning engine start (step I);
 T_{21} = realization time 10% din $P_{2\max}$ at gear engine start-up (step II);
 T_{24} = realization time 10% din $P_{2\max}$ at the burning end gear engine (step II);
 T_{25} = firing time primer II from Delay II.

It is possible to determine the operating time intervals for [6,7]:

$$\text{Delay assembly I: } \Delta T_1 = T_{21} - T_{14} \quad (1)$$

Condition of compliance with the operation $4\text{s} \leq \Delta T_1 \leq 7,5\text{s}$

$$\text{Delay assembly II: } \Delta T_2 = T_{25} - T_{24} \quad (2)$$

Condition of compliance with the operation $4\text{s} \leq \Delta T_2 \leq 6,5\text{s}$

Propulsive installation having the conditions of conformity to operation

$$11\text{s} \leq T_{25} \leq 17\text{s}$$

$$1,1\text{s} \leq T_1 = T_{11} - T_{14} \leq 1,9\text{s}$$

$$1,1\text{s} \leq T_2 = T_{21} - T_{24} \leq 1,9\text{s}$$

$$P_{1\max} \leq 70 \text{ bar}$$

$$P_{2\max} \leq 70 \text{ bar}$$

$$40\text{bar} \leq P_{1\text{med}} \leq 57\text{bar}$$

$$40\text{bar} \leq P_{2\text{med}} \leq 57\text{bar}$$

Fig. 5. Traction forces graph.

The tensile force is the force generated by the propulsion system of the anti-hail rocket and appears as a result of the action and reaction principle following the combustion of the propellant charges and the expulsion of the flue gases through the nozzles.

The condition of compliance for the propulsive installation in terms of total impulse [6,7] (obtained by the integral of the force) for step I and step II, respectively the total impulse:

$$I_{t1} > 275 \text{ daN s}$$

$$I_{t2} > 275 \text{ daN s}$$

$$I_t > 550 \text{ daN s}$$

3 Results and discussion

Applying the configuration of figure 1, tests were carried out in the laboratory belonging to Electromecanica Ploiesti, to verify the conformity of the components of the anti-hail rocket RAG 96.00, respectively the propellant charge and the delay assembly I and II, constituted in an assembly called propulsive installation.

Considering substances that take care of the composition of the products, the temperature and the vibration can influence the safety characteristics of the products, which can have a direct impact in the predictable and safe operation of an anti-hail rocket RAG 96.00 as a whole.

The manufacturer considered this aspect and included in the test procedure, the thermal and mechanical conditioning of these products, before testing on the stand. [8]

In order to carry out the tests, there were 7 assemblies (propulsive installations) as well:

- Assembly 1 and 2: Propellant charge (2 pieces) / set, Delay assembly I and Delay assembly II / set, conditioned at 0°C for 6 hours;
- Assembly 3: Propellant charge (2 pieces), Delay assembly I and Delay assembly II, conditioned at 45°C for 6 hours
- Assembly 4: Propellant charge (2 pieces), Delay assembly I and Delay assembly II, conditioned at 20°C for 6 hours;
- Assembly 5,6,7,8: Propellant charge (2 pieces)/set, Delay assembly I and Delay assembly II / set, all delays being conditioned to mechanical shocks, deceleration of 490 m/s^2 ($-50 / + 100 \text{ m/s}^2$), frequency of $1 \pm 0.1 \text{ Hz}$ for 1 hour;

All assemblies were initiated with priming.

The results obtained in the laboratory tests are centralized in tables 1 and 2.

Table 1. Results obtained when testing the assemblies 1,2,3 and 4. [9]

No.	Measured / determined parameter - Component	Measured / determined values			
		Assembly/ Propulsive Installation)			
		1	2	3	4
1	Delay time – Delay assembly I (T_1,s)	5,88	5,98	5,56	6,59
2	Delay time - Delay assembly II (T_2,s)	5,90	5,49	5,84	5,55
3	Maximum pressure - Propellant charge 1 (P_{1max},bar)	52,13	53,07	57,10	69,32
4	Medium pressure - Propellant charge 1 (P_{1med}, bar)	45,24	47,67	49,01	48,85
5	Maximum pressure - Propellant charge 2 (P_{2max},bar)	53,70	47,22	51,3	54,13
6	Medium pressure - Propellant charge 2 (P_{2med}, bar)	48,65	46,11	49,15	49,66
7	Impuls ($I_1, daN s$)	310,6	311,4	312,2	307,9
8	Impuls ($I_2, daN s$)	335,9	304,9	320,7	310,5
9	Total Impuls ($I_t, daN s$)	646,6	616,3	633,0	618,4
10	Realization time 10% from P_{1max} (T_{14}, s)	1,51	1,47	1,37	1,39
11	Realization time 10% from P_{2max} (T_{24}, s)	1,52	1,50	1,40	1,42
12	Burning time primer II from Delay a. II (T_{25}, s)	14,86	14,50	14,21	15,01

Table 2. Test results of assemblies 5,6,7 and 8. [10]

No	Measured / determined parameter - Component	Measured / determined values			
		Assembly/ Propulsive Installation			
		5	6	7	8
1	Delay time - Delay assembly I (T_1,s)	6,59	6,26	7,12	6,03
2	Delay time - Delay assembly II (T_2,s)	5,55	5,74	5,65	6,16
3	Maximum pressure - Propellant charge 1 (P_{1max}, bar)	69,5	55,47	69,00	70,0
4	Medium pressure - Propellant charge 1 (P_{1med}, bar)	48,85	49,30	49,87	49,57
5	Maximum pressure - Propellant charge 2 (P_{2max},bar)	54,13	50,02	49,53	48,95
6	Medium pressure - Propellant charge 2 (P_{2med}, bar)	49,66	50,2	50,10	44,60
7	Impuls ($I_1, daN s$)	307,9	308,3	308,2	306,7
8	Impuls ($I_2, daN s$)	310,5	315,4	309,7	308,9
9	Total Impuls ($I_t, daN s$)	618,4	623,7	618,0	615,6
10	Realization time 10% from P_{1max} (T_{14}, s)	1,39	1,42	1,37	1,37
11	Realization time 10% from P_{2max} (T_{24}, s)	1,42	1,45	1,42	1,42
12	Burning time primer II from Delay a. II (T_{25}, s)	15,01	14,88	15,61	15,03

4 Conclusions

The verification procedures are developed for each component of the RAG 96.00 anti-hail rocket and are designed to highlight the compliance / non-compliance of these products with the relevant safety requirements.

Test methods are applied to monitor critical parameters in the proper functioning of the RAG 98.00 anti-hail rocket, respectively delay times / operation of the I and II delays

assembly, the pressures developed by the operation of the propellant charges and the traction forces produced during the firing of the pyrotechnic train.

The test method is appropriate for the purpose proposed following the conformity of the products with the safety and operating requirements.

The test results are within the range of values designed so that the RAG 96.00 anti-hail rocket perform the trajectory performance in order to trigger, at a given moment, the distribution of the active substance in the area for which it was launched.

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