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CLOUD SEEDING WITH THE TG-10 ROCKETS

by

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Abstract:

Efficency of hail suppression (HS) system is strongly affected by technical expedients in use, and the way they are used. In case of antihail action, it is necessary to inject the meteorological reagent in the seeding area, as soon as possible. Technical descriptions for rocket TG-10 are given, together with the metodology, which is based upon investigations of rocket operating in beams 25° wide, between -5° to -10° C isotherms on the front end of the Cb - clouds.

1. INTRODUCTION

The rocket TG-10 has been used in the operative program of the hail suppression since 1980 (Lipovšćak et al. 1980), as a result of many studies in the interdisciplinary fields of meteorology, ballistic and technology. Parallel with the methodology, evaluation of the rocket has been done.

Functional connection of the meteorology, TG-10 characteristics, and used seeding material, resulted in the construction of the six guide launcher, and quasi-horizontal, slightly scattered cloud seeding trajectories, (Gelo et al. 1978, Horvat et al. 80, Mozer et al. 81).

2. ANTIHAIL ROCKET TG-10

Hail suppression has been made possible due to a better understanding of the meteorological processes as well as the development of the antihail expedients.

TG-10 is a two part rocket, made of fibre-glass plastics. Motor part contains rocket propellant and container is filled with AgI based pyrotechnical mixture (reagent).

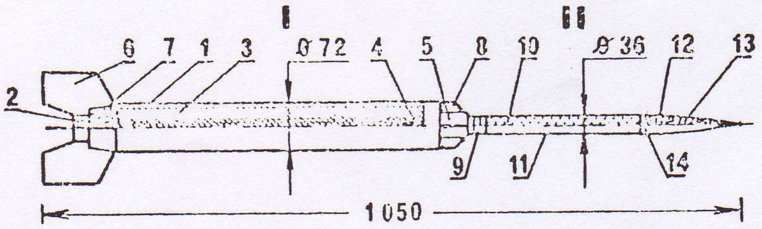


Figure 1 - Antihail rocket TG-10

I Motor part (booster): 1. motor; 2. nozzle; 3. propellant; 4. igniter; 5. connector; 6. fins; 7. self-destruction system,

II Container: 8. nozzle with fins and connection part; 9. timing system; 10. pyrotechnical mixture with AgI; 11. fiber-glass plastic body; 12. plastic nose cone; 13. ballast; 14. detonator.

2.1 Technical data:

throughout lenght	1050 mm	mass	4,35 kg
motor diameter	72 mm	propellant mass	1,50 kg
container diameter	36 mm	pyr.mix mass	0,40 kg
timing of the start of seeding		$5 \pm 0,5$ s to 25 ± 2 s max.	

seeding time 27 ± 2 s.

2.2 An antihail rocket TG-10 operation

Container should be timed before launching. Wiring is provided by inserting rocket into the launcher. El. current from the ignition box ignites the propellant and pyro-locker, freeing container from booster.

Motor works about 1.2 s and accelerates the rocket to 700 ± 50 m s^{-1}. When the propellant burns, container is separated due to the aerodynamical drag of the motor part, and flies freely. Motor part is disintegrated in harmless particles with 24 g detonating fuse, after 9 ± 2 s.

Speed-loss of the container is rather low due to the good aerodynamical properties and relatively great mass. At programmed time, the pyro-mixture (reagent) with AgI is ignited and dispersed through nozzle for 27 ± 2 s. In contact with cold atmosphere, AgI aerosol is formed. When the pyro-mixture has flown, detonator is activated which disintegrate the container in harmless particles.

2.3 Ballistic tables, isotherms and cloud-seeding

Because of the high speed (700 m/s) and good aerodynamical form, the container reaches $8,3 \pm 0,3$ km altitude at the 85° elevation.

According to experience, best results are obtained with cloud-seeding between -5° and -15° isotherms (English et al. 82, Sedunov et al. 79, Federer et al. 79), i.e., between 3 - 6 km altitudes (Sedunov et al. 79).

The destination of the cloud-seeding in Croatia is -10° isotherm, in the area of the first radar-echo. With quasi-horizontal trajectory, a long seeding path is obtained in a narrow temperature range. A steep trajectory should be avoided because a wide temperature range would then be seeded, and there then exists the possibility for amplification of the thermics by releasing latent heat. Safety of the air-traffic should be considered when using small elevations. The elevations used in Croatia are between 45° - 65°, because of the rocket ballistic properties and as a result of isotherm studies in the days of anti-hail actions.

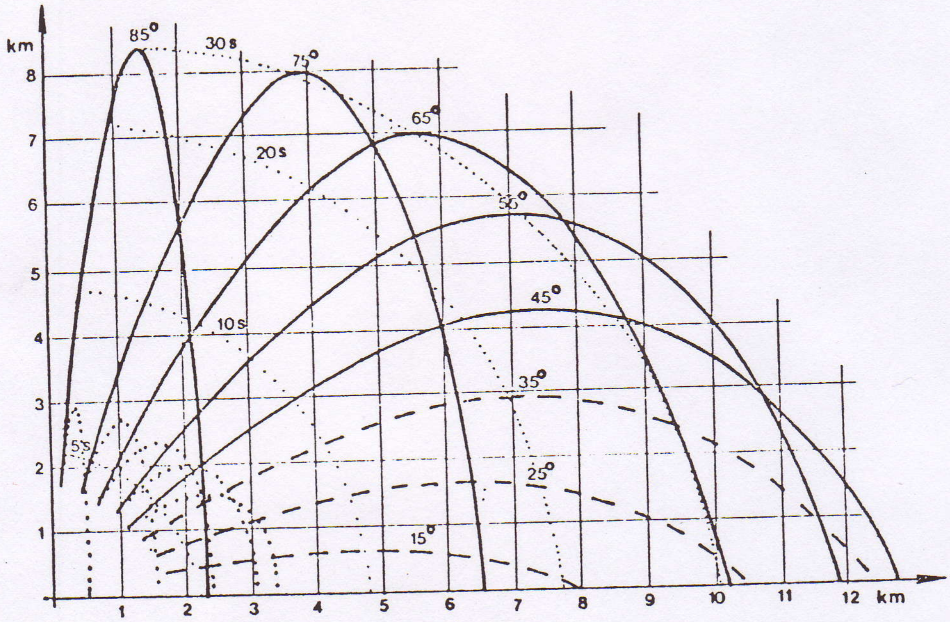


Figure 2 - Ballistic trajectories of the TG-10 container

When firing rockets, attention should be paid to the fact that the isotherms in seeding area are higher, compared with surrounded atmosphere, (Krastanov et Stantchev, 73).

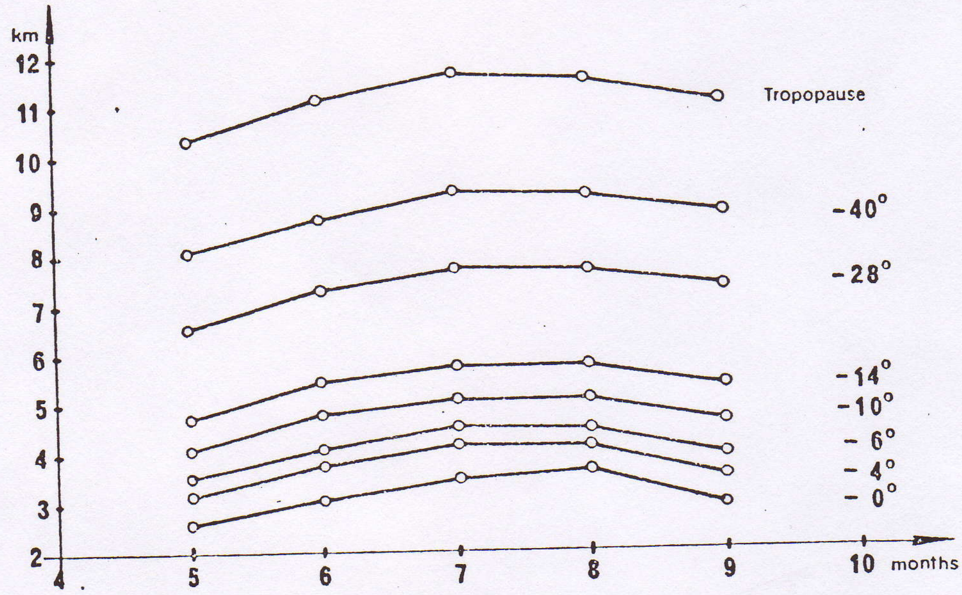


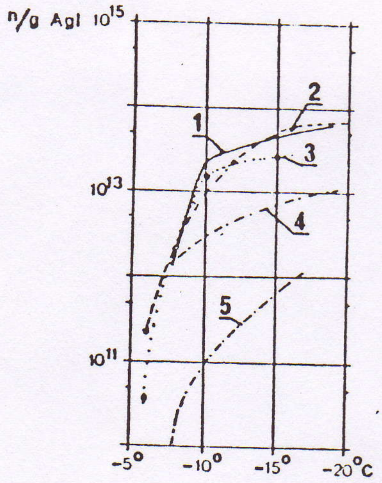
Figure 3 - Average altitudes of the isotherms in the days of anti-hail actions during the year, by soundings at 12°° and 00°° in the period of 1977-1981 year, (Peti and Huzjak, 82).

In general, it could be said that every rocket has wider optimal elevations with lower max. range at 85° elev.

3. ACTIVITY PROBLEMS WITH AgI BASED REAGENTS

For the purpose of hail suppression a great variety of reagent are used in different parts of the world, (Federer et al.81, Fukuta 80, Bahlanov et al. 82). It seems that for relatively small rockets the best solution is AgI based mix.

Activity of the AgI based mixture is strongly affected by temperature. Dissipation of some types could cause deactivation of aerosol (Federer et al. 81). at temperatures from 0° to -5° C. However, dissipations at lower temperature (-15° C) in thermics could shorten the necessary time spent in the ice crystal growth zone.



1. SILVERSPARE A-2 (2% AgI), ETH
2. HAILLES (28% AgI), CSU
3. RTG-10 (20% AgI), PMF Beograd
4. NEI TG-1, CSU
5. NEI TB-1, ETH

Figure 4 - Activity versus temperature diagram for several types of the AgI based pyrotechnical mixture

Since the temperature affects the growth-speed and shape of the ice crystals (Fukuta 80) it seems the best results could be obtained at -5° to -10° isotherms according to the meteorological situation.

3.1 Dissipation of the AgI from a TG-10 container

TG-10 container is filled with 400 g AgI based reagent with 20% AgI. According to measurements, made at the University of Belgrade, AgI based mixture could release $4{,}1 \times 10^{12}$ activity nucleus per gram of mixture, i.e. $1{,}6 \times 10^{15}$ activity nucleus per container.

Dissipation duration is 27 ± 2 s at a 15 gr s^{-1}, i.e. 6×10^{13} activity nucleus per second. At average flight speed of 200 m s^{-1} there are 3×10^{11} activity nucleus per meter i.e. 0,015 gr AgI per meter.

3.2 Spreading of the reagent

One of the mechanisms of spreading is turbulent diffusion (Browning 77), Federer et al. 79). Turbulences in vertical streams of the Cb are very important for reagent spreading.

According to Browning (77), energy dissipation rate ϵ in the area of seeding could reach values between 500 - 1000 cm^2 s^{-3}.

Some measurements made in the USSR with Po^{210}, p^{32} and D_2O aerosols showed that the aerosol speed at the front zone (large drops) could reach 50 - 60 m s^{-1}, seeding speed of the central zone reaches 6 - 60 m s^{-1} in different directions. The explanation is that the spreading speed is probably affected by the electrical field inside and around Cb (Styra et al.76).

I could be said that the spreading speed of the reagent in the area of seeding has a value of 10 - 20 m s^{-1} in all directions.

3.3 Seeding with a single TG-10 rocket

For the seeding of the hail embryo growth zone, about 10^5 active nucleus are needed for 1 m^3.

Seeding tail of the TG-10 container is about 5,4 km long (50° elevation). Simple calculation shows that container at -10° C could seed about 16 km^3, 1 km around trajectory. By spreading, concentration of reagent decreases. With the assumed spreading speed of 10 - 20 m s^{-1}, the full volume is seeded in 1 - 3 minutes.

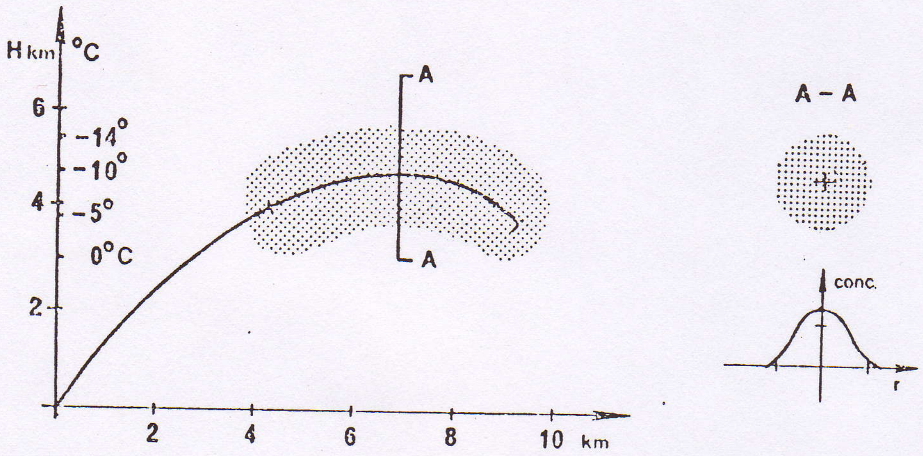


Figure 5 - Example of cloud seeding with single TG-10 rocket

3.4 Multi-rocket cloud seeding

Hail suppression action is a race against time. For efficient seeding, TG-10 rockets are fired simultaneously from the launcher in beams. Guides in launcher are inclined from central line as follows: -8°; -4°; 0°; +4°; +8° (Gelo et al. 78).

At 50° elevation, wider beam is used: -12.3°; -6.2°; 0°; 0°; +6,2°; +12,3° (Mozer et al. 81). Guides are numbered from 1 to 6. Seeding possibilities

(55° el) are showed.

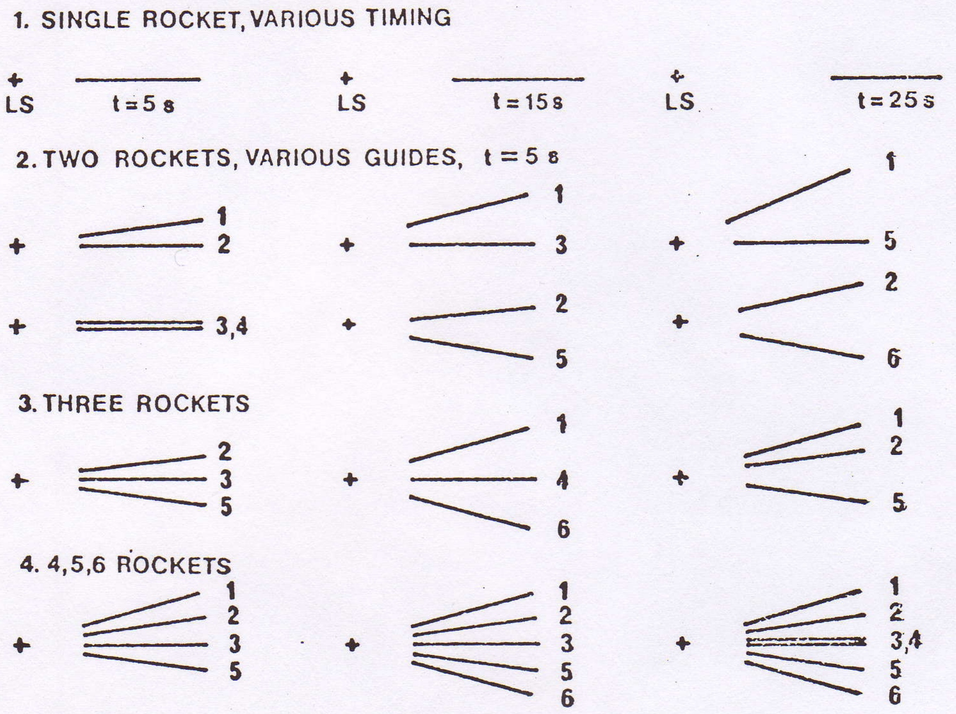


Figure 6 - Example of seeding possibilities

It is evident, that a great volume can be seeded in a short time.

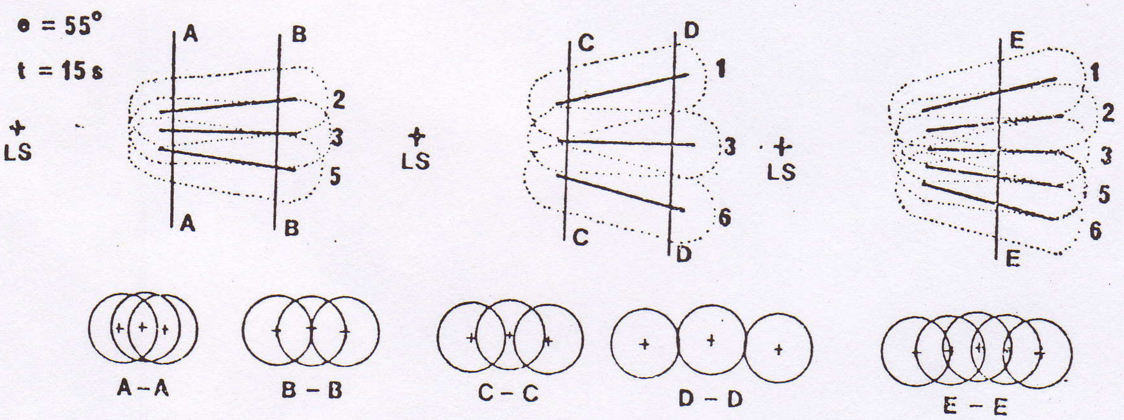


Figure 7 - Seeding area expected 1-2 minutes after firing

3.5 Cloud possibilities of a single launching station (LS)

Using 45° - 65° elevations, every LS can seed toroidal-shaped space with radius from 1.5 - 10 km and 1.5 - 6.5 km altitude, (Gelo et al. 78, Horvat et al.81).

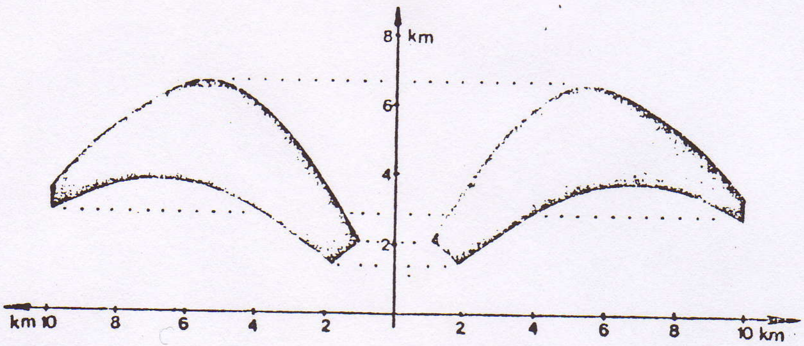


Figure 8 - Single LS seeding possibility

After firing at LS, distance between rockets increases with time. Due to wind influence, the deviation from trajectory is increased with the distance from launcher, while the elevation influences the reagent activity.

Therefore, good results are obtained at distances of 3-9 km, and the best ones are at 4-8 km. Firing rockets in the precipitation areas should be avoided.

Figure 9 shows some cloud seeding areas for single launching station.

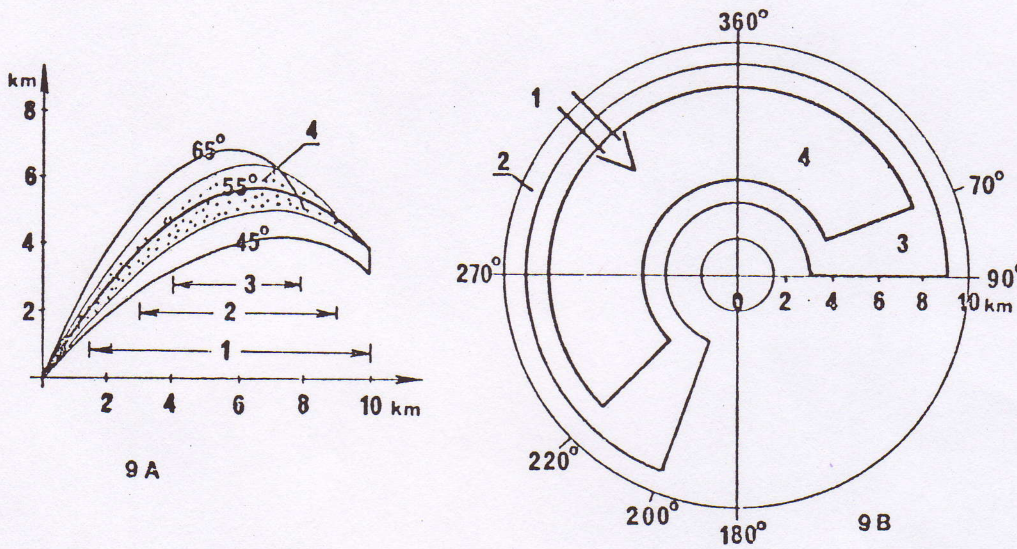


Figure 9 - Optimization of the cloud seeding areas for single LS

9. A 1. Possible seeding area; 2. acceptable area; 3. optimal area; 4. optimal elevations.

9. B 1. Direction of the incoming thunderstorm (mostly NW); 2. possible seeding area; 3. acceptable area (in the case shown NW direction); 4. optimal area.

4. CONCLUSION

The investigations of ballistic properties show that optimal elevations for rocket TG-10 are from 50° to 55°. For cloud seeding in temperature zones between -5° to -10° C six guide launcher are set to 50° elevation, beam width 25° (from -12,3° to +12,3° of null direction at elevation 50°).

Every launching station could seed the toroidal shape space 1,5 to 10 km in radius.

The best place to seed is front end of the arriving Cb cloud. The possible seeding area is optimized according to meteorological influence to the rocket as well as the quality of the reagent.

The TG-10 rocket is an innovation among antihail expedients. Low mass, ultimate precision and great range are prerequisites for easy handling and reliability in use.

However, better understanding of atmospheric processes requires further development of methodology and technology of hail suppression.

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