Efficient Perforated Pyrotechnic Cartridges

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ABSTRACT

Efficient silver iodate pyrotechnic perforated cartridge is designed and developed which upon burning inside the cloud chamber, under simulated atmospheric condition emits optimum number of active seeding nuclei which speeds up and enhances the nucleation process. Fumigation from the perforated cartridge is 28% faster than that of non-perforated cartridge. Burning cartridge is to be released in cold region of cloud near to -19^0 C isotherm level so that its faster fumigation is almost complete by the time it falls till -3.7 0C isotherm. 190 to -3.7^0 C is the optimum temperature range for efficient ice nucleation. Hence, ideally the cartridge must completely burn off within ≈30 sec of free fall to disperse its fumes within this temperature range. Quick nucleation within available reaction time meets the needs of effective hail suppression.

Difference in quantity of seeding during artificial rain making and hail mitigation has also been explained prior to presenting the empirical formula for quantity of seeding for hail suppression (in warm and cold regions of the cloud). Moreover,' exact seeding', ' under seeding' and 'over seeding' have also been defined.

Keywords: *Pyrotechnic perforated cartridges, Silver iodate, Hail suppression, Exact seeding, under seeding, and over seeding.*

1. Introduction

Weather Modification and hail suppression efforts were started way back in 18th century with the invention of hail cannons. These cannons were developed in 1896 by Albert Stiger, an Austrian winegrower. Hail Cannon is basically a shock wave generator supposedly used to disrupt the formation of hailstones by burning acetylene gas (Chagnon and Ivens, 2019). An acetylene gas mixture is ignited in a lower chamber of the device which is connected to a large cone. As the energy is forced up the cone, it becomes a shockwave. This shockwave along with heat from the ignited gases is supposed to travel up and pass through storm clouds, which is expected to disrupt the formation of hailstones. But there is no scientific evidence in favour of the device and its methodology (Wieringa, 2006). Landmark discoveries made by General Electric scientists Langmuir, Schaefer and Vonnegut in 1940 ushered in the scientific approach to weather modification (Schaefer,1946; Schaefer,1949). In the six decades following their work, cloud seeding projects have proliferated across the world. A wide variety of scientific tests and operational weather modification experiments have been performed in many countries using various techniques for suppression of hail but failed to show efficient results. Weather modification operations include rain enhancement or dissipation, hail suppression, fog dissipation, increasing visibilities above airfields and roads, controlling forest wild fire etc (Changinon, 1977). They are done by means of airborne seeding, ground cannon shooting, salt spray system and launches of rockets, aircrafts, helicopters etc. Of late, DeFelic and Axisia (2017) suggested the same by drones. Kumar (2020, 2022a,b) proposed Early Duplex Vertical Seeding (EDVS) wherein pyrotechnic cartridges are ejected after vertically fired rockets from ground below the cloud, by the helicopter drones, reach specific height logged by ground positioning satellite(GPS). To ensure efficient seeding (Kumar, 2018), cartridges are ejected within cloud to fall down near the optimum temperature range of (-19^{0}C). It produces fumes while falling.

1.1. No Hailstorm over India during Monsoon Season

First of all, let us note the fact that no hailstorm is formed over Indian region during the monsoon season. Over India, the hailstorms are observed only during non-monsoonal months when mostly continental air mass prevails (Kumar, 2017) over the region and never during monsoonal months. Summarily, air masses originating from Arabian Sea, Bay of Bengal and Indian oceanic regions may be presumed to possess larger number of efficient CCN than those from continents, hence hailstorms are missing during monsoonal months in India. The regional progress of monsoon (no-hailstorm season) over Indian subcontinent is, therefore, observed in perfect consonance with the progress of oceanic-airmass. This information is significant in view of prevailing five methods of hail mitigation as prescribed in ANSI (2015). Aircraft measurements during CAIPEEX-I (Cloud Aerosol Interaction and Precipitation Enhancement Experiment-May to September) by Konwar et al. (2012) suggest that super micron size CCN or GCCNs enhance the rain from cumulus clouds when cloud droplet concentration near base is large (Hudson et al., 2009; Arthur et al., 2010; Reiche and Lasher-Trapp, 2010; Hudson et al., 2011). Thus GCCN (dry diameter > 1 µm) seeding in warm region and simultaneous seeding of subzero region of cloud by AgI pyrotechnic cartridge burning jointly meet the double objectives as laid down in 'beneficial competition' and 'early rain out' together in ANSI (2015).

1.2. Theoretical Concept of Hail Suppression

The effective weather modification operation requires ingestion of cloud condensing nuclei (CCN) or Ice Nuclei (IN), into clouds that are likely to produce hail, at an appropriate time while the cloud is growing. The large amount of nuclei increases the large number of small hailstones, rapidly reducing the amount of moisture available for further growth of hailstones. These small hailstones either further reduce in size to become innocuous or totally melt into drizzle or rain before reaching the ground.

Artificially ingesting CCN or IN within the cloud is known as seeding. There are various methods of seeding. "Sandwich" and "Super Sandwich" are different ways of weather modification. Sandwich cloud seeding targets "Warm Clouds" whose cloud top do not grow beyond the freezing level but no hails forms in this cloud. Hails form in mixed phase when clouds grow beyond the 0^0 C isotherms in vertical height. In this sandwich seeding and glaciogenic seeding are combined to control hail formation and is called supersandwich seeding. In this type of seeding Silver Iodide flares are released near growing cloud top in the cold cloud followed by dispersion of Sodium Chloride nuclei at mid cloud level below 0^0 C isotherms. Supersandwich seeding technique is beneficial for tropical countries where both warm and cold clouds are present (Adulyadej, 2004 and 2005).

Hailstone suppression can be effectively achieved by pyrotechnic cartridge burning inside the cold cloud which releases AgI flares. Pyrotechnics is the science of using materials capable of undergoing self-contained and self-sustained exothermic chemical reactions for the production of heat, light, gas, smoke (Gunn and Phillips, 1957; Simpson, 1970). AgI smoke particles obtained by cartridge burning are in the size range of 0.04 to 4 µm (Bristein and Anderson, 1954). These smoke particles act as nuclei for ice formation. In this paper attempt has been made to develop pyrotechnic cartridges which are faster in release of IN smoke and also economical in its use. Important point to be emphasized here is that during hail mitigation, one should do exact seeding (refer Appendix A) or slightly over-seeding. Details on the quantification of seeding are given in Appendix A.

2. Present Nuclei Delivery Methods

Presently There are three technical methods which are generally used for delivery of nucleating agents in cloud for suppression of hail formation. Brief details are mentioned below:

2.1. Ground-Based Seeding Generators ground based seeding (Figure 1) systems (Soulage and Admirat, 1968) are the oldest and most widely used seeding method. The most common seeding generator burns a solution of acetone in which a certain percentage by weight (usually 2-3%) of silver iodide has been dissolved. Remotely controlled silver iodide generators are frequently used at higher elevation locations. Ground-based generators normally disperse from 0.4-1.6 ounces (10-40 grams) of silver iodide per generator per hour of operation. At normal consumption rate of these solution-burning generators are of the order of 0.1-0.2 gallons (0.4-0.8 liter) of seeding solution per hour of operation. Although it is not very expensive, but the ability of ground-based generators to deliver seeding agents to the appropriate level in a moving cloud is low, except in situations where the clouds are being seeded to enhance snowfall in mountainous regions where the ground temperatures are already below freezing and the generators are, effectively, already within the clouds. These generators (Figure 1) are not efficient in seeding the clouds at right places and at the right time. Moreover, some seeding agents used in this method often get deactivated before reaching the target clouds for hail suppression (Chaudhry and Bari, 2003), hence it is not potentially viable.

Figure 1: Photos of ground-based cloud nucleating generators. Courtesy North American Consultants Inc.

2.2 Anti Hail Rockets

Anti Hail Rockets (Figure 2) techniques have been implemented in many countries like Bulgaria,Serbia (Ćurić and Janc, 2013), USA, Russia, Japan and china for hail suppression operation (Figure 2) but none of these efforts could gain appreciable success as they did not pay due cognizance to reaction time(Kumar P. Pati Debaprasad(2019). The efficiency of this technique got further constrained due to strict flight-safety regulations. on slant firing of the rockets which may cross several civil aviation routes endangering regular air traffic.

2.3. Aerial Seeding

Aerial Seeding (Figure 3): Aerial seeding is a technique of seeding by dispersing the AgI through aerial mechanical plateforms such as aero plane, helicopter or drones. Aerial seeding is the second most common mode of seeding in existing operational hail suppression programs. This is the commonly used method of dispensing silver iodide using acetone/silver iodide fume generators mounted under each wing tip of aircraft. These generators hold approximately 8 gallons of a mixture of acetone and silver iodide. This mixture is ignited in the tail cone section of the generator, producing the desired silver iodide particles. Typical consumption rates of the solution are of the order of 2 gallons per hour per generator, which results in a release rate of approximately 4.2-6.3 ounces (120-180 grams) of silver iodide per hour. In fact, ground generators and aircraft seeding using silver iodide as the seeding agent is a frequently utilized as combination-seeding mode. The major drawback is the aviation hazards related to cumulus cloud moreover prolonged seeding is not possible by this technique. The several multiple clouds restrict the precision of seeding in space and time. This technique required large amount of seeding agent and hence quite expensive.

3. Existing Cartridges for Hail Suppression

Several types of pyrotechnic cartridges are available with different seeding agents. For completeness some basic types are briefly mentioned below:

3.1 AgI Ejectable Cloud Seeding Flares These types flares are mounted on the racks present on the

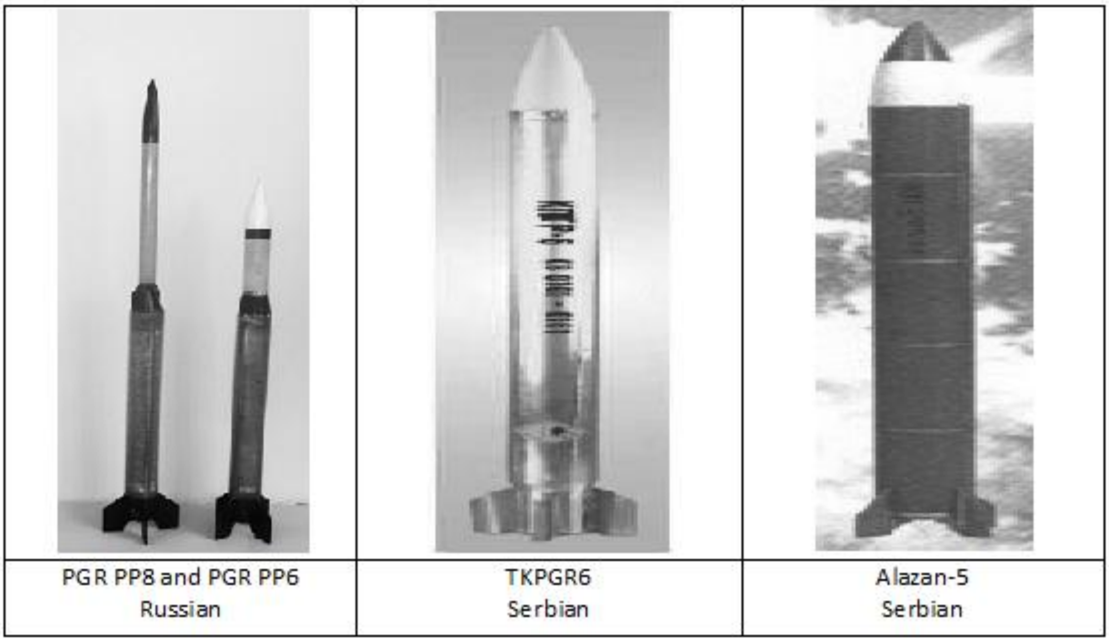

Figure 2: Anti hail rockets of Russia & Republic of Serbia.

AgI Flame generator mounted below the wings of the aircraft

NaCl Flame generator mounted below the wings of the aircraft

Figure 3: Flame generator mounted on the wings of the aircraft.

belly of the aircraft fuselage. Each rack holds 102 cartridges. When fired, the pyrotechnic is ignited and ejected from the aircraft (Figure 3).

3.2. AgI Burn-In-Place Cloud Seeding Flares

This type of flare was designed to produce the proper size and concentration of nuclei. Burn-in-Place flare is available in sizes of 75,100,125, or 150 grams of pyrotechnics per flare.

3.3 $CaCl_2$ Hygroscopic Burn-In-Place Cloud Seeding Flares: This pyrotechnic flare is designed for warm clouds. The aerosols produced by the hygroscopic flare are of the proper size to stimulate a particular cloud to start the rain process sooner and last longer. The main purpose of burn in place is rain enhancement only.

4. Key features of Economical and Efficient Pyrotechnic Cartridge

While attempting to modify the existing pyrotechnic cartridges to improve their efficiency in generating efficient Ice Nucleation (IN) following points were kept as paramount.

4.1 Quick emission

As the reaction time plays a vital role in the hailstorm suppression process hence existing pyrotechnic cartridges should be modified to ensure faster smoke emission so that within the available reaction time optimum amount of active IN are generated. As per International Standard Atmosphere (ISA), the height difference between -19^{0}C level and -3.7^{0}C level may be taken as ≈ 11600 ft and hence approximate time during free fall is limited to ≈ 30 seconds only. For efficient seeding, therefore, quick emission of smoke is necessary.

4.2 Minimize the residue dust due to the burning of cover-casing

After pyrotechnic cartridges burning the residue dust particles should be minimum so that the emitted IN nuclei fumes do not get diluted with the casing-ash dispersion.

4.3 Cost reduction

The cost of pyrotechnic cartridges varies with seeding materials and quantity needed to seed. Hence it should be cheaper.

5 Method of Making Efficient AgI Cartridge Formulation in percentage

The AgI pyrotechnic formulation is shown in Table 1.

Table 1. Chemical Formulation of Pyrotechnic Cartridge.

Material	Percent by Weight
Silver iodate	45.0
Potassium perchlorate	27.0
Magnesium	20.0
Nitrocellulose	4.0
Triacetin	4.0

Keeping in mind the key features of Efficient AgI cartridges as mentioned in Section 13 the method of making Efficient AgI Cartridge is as under.

5.1. Step-I: Non-Reusable Cartridge Case' Filling

Cartridge case is made up of PVC pipe or Aluminum sheet (15 x 20 mm container) with perforation on the walls of the case (Figure 4). Each of pyrotechnic chemicals is finely grinded into fine powder (≈1 µm) with the help of pulverizer. The particle size plays very important role in the efficient burning of the cartridges. The fineness basically ensures the efficient burning. Hence the pulverized particles are analyzed with the help of Drying Laser Particle Size Analyzer (Figure 5).

Figure 4: Perforated pyrotechnic cartridge case made up of PVC.

Laser Particle Size Analyzer - Model ALPSW 3001 (MIT Hailstorm Laboratory,

Figure 5: Particle Size Analyzer (PSA) Sizer 3002. Measuring range: 0.02µm to 2000µm Accuracy: ≤0.5%. Typical measurement time: ≤ 10 second.

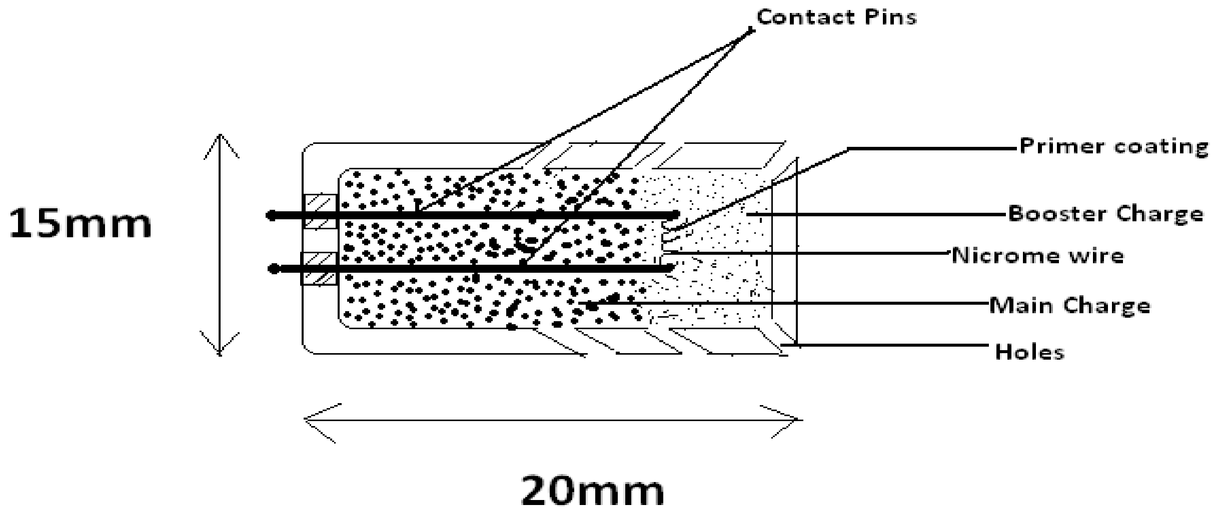

Figure 6: Igniter Design of the pyrotechnic cartridge.

All the pyrotechnic chemicals are weighed and mixed properly. Firstly the fuel and additives are mixed properly and then the oxidizer is added to the composition. The composition is then filled into the tube and tightly packed using mechanical press. After all the materials are packed, about 2 cm remains vacant for filling fuse or primer.

5.2 Step-II: Making of Igniter

The total weight of the igniter is 25 grams within which the main charge is 12 grams. The contact pins are to be inserted in the case and connected with a Nichrome wire (26 gauge) which is coated with mercuric fulminate primer coating. The main charge is the black powder pellets of 5 to 10 mm size which is a mixture of 75% Potassium Nitrate, 15% charcoal and 10% sulphur. The booster charge is powder of 1 to 3 mm size. Igniter is carefully placed in the cartridge case. White cap/wooden stopper is plugged and sealed.

5.3. Step-III: Protection from moisture

The complete casing is wrapped by transparent laminated span using hot air so as to avoid the contact of atmospheric moisture with the pyrotechnic formulation.

The burning of cartridge is electrically initiated by passing voltage using batteries. Primer composition is capable to ignite the pyrotechnic composition due to its capacity to produce high flame temperature. As soon as the bridge wire gets red hot, the primer material will explode. This energy is picked up by booster charge and main charge in sequence, finally the hot gases will comes out through holes which will initiate the burning of AgI mixture, hence produces the fumes which are used for cloud seeding purpose (Figure 6).

Active seeding ice-nuclei rapidly increase with drop in temperature (Summers et al., 1972) [ranging from $\approx O(10^{10})$ to $O(10^{15})$ per gram]. With the perforated cartridge the process of ice nucleation also speeds up. Schematic in Figure 7 shows the sequence.

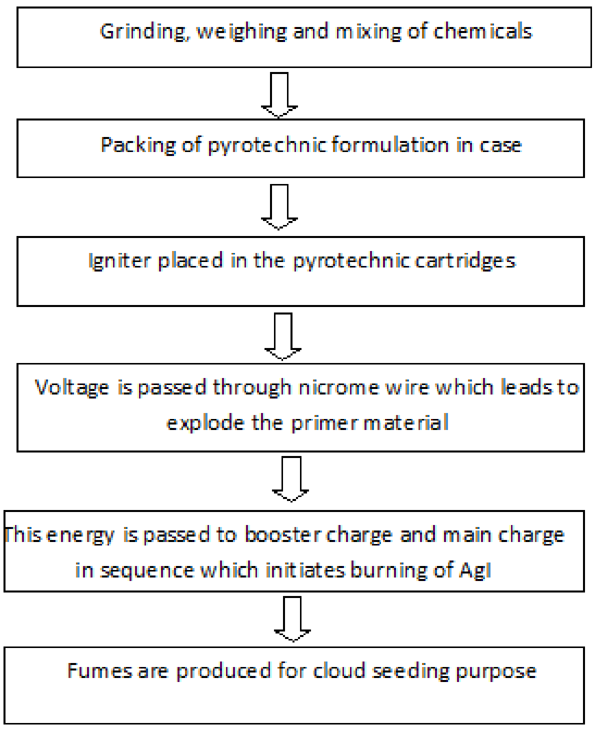

Figure 7: Schematic representation of construction of pyrotechnic cartridge.

6. Data Analysis of AgI Cartridges at Laboratory Scale inside the Cloud Chamber

A cloud chamber (Kumar, 2018) has been designed and developed for testing of pyrotechnic cartridges and performing various cloud seeding experiments at laboratory scale. 4’x4’x4’ cubic feet size cloud chamber Figure 8) is developed with features such as Humidity more than 98%, Temperature - +10 deg C to -15 deg C and Pressure of about 350 hPa. The chamber is also equipped with sensors for temperature, humidity, pressure and light. Light sensors (Luxmeter) present inside the chamber were used basically to measure the rate of emission of fumes of seeding agent (Figure 8).

Figure 8: Cloud chamber designed and developed under NICRA project. Top is closed chamber and bottom is open chamber.

It is based on the Hypothesis that The drop in luminosity (-d) on the right panel’s receiver (refer open chamber in Figure 8) is proportionate to the intervening net water mass (C_p) as below;

Drop in luminosity (-d) α C_p .

Inside the chamber there are of special attachments called fumes generating pyrotechnic cartridges holding system, which will burn and generate fumes of silver iodide pyrotechnic cartridges inside the cloud chamber for the cloud seeding purpose (Figures 9 & 10)

Figure 9: Silver iodide cartridges testing (fume generating) device present inside the cloud chamber.

The objective of testing the pyrotechnic cartridges inside the chamber is to find out rate of emission of fumes . AgI cartridges are designed for generating huge amount of seeding nuclei [$\approx 10^{15}$ per gram(hence effective) and nucleating in shortest period of time = efficient] so that efficient suppression of hail formation can be done. This is first time a perforated rectangular pyrotechnic cartridge is designed and developed. The efficient AgI cartridges will be ejected from the rocket payload area after reaching desired height. The ignition of the pyrotechnic formulation will be done by ignition plug which comprises of battery, nicrome wire or nickel-copper wire (diameter of 0.2 mm), primer. These primer compositions have the capability to ignite the pyrotechnic composition due to produce high flame temperature.

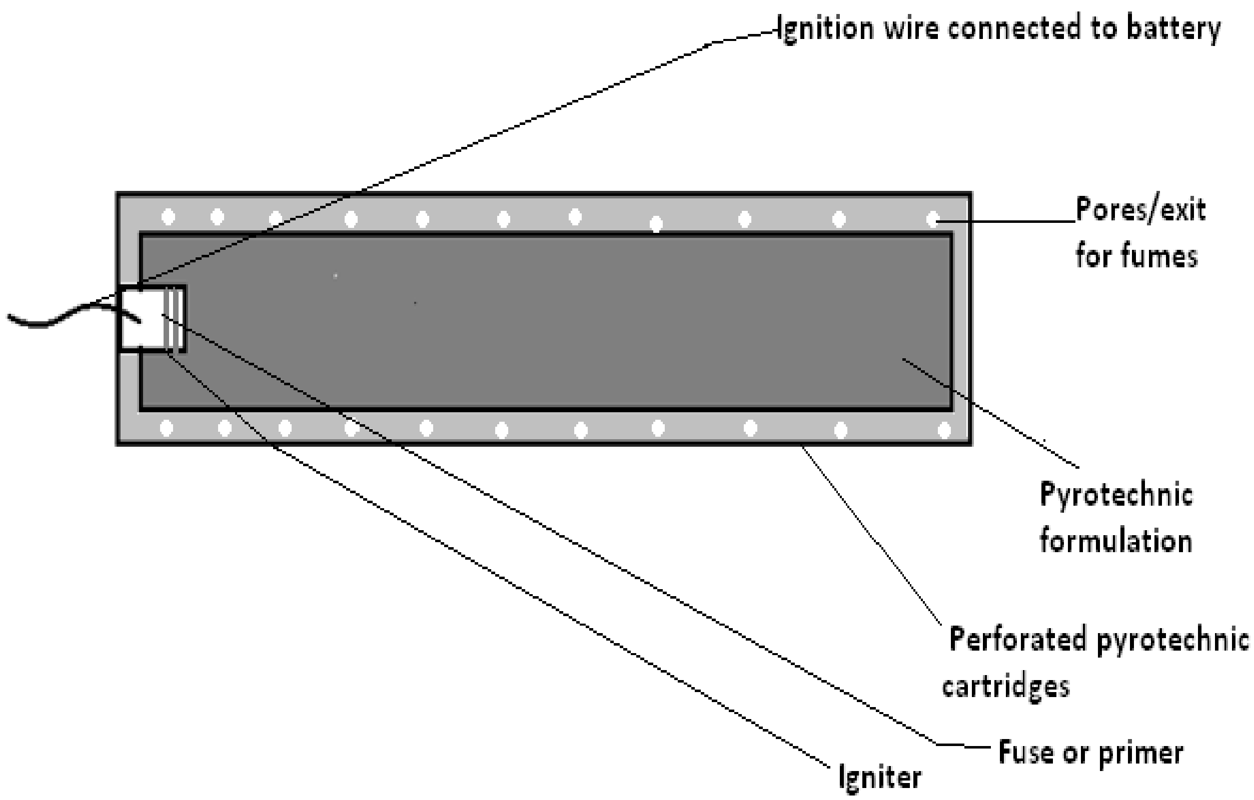

Figure 10: Perforated ejectable silver iodide cartridge.

Table 2. Description of Pyrotechnic Cartridges.

Non perforated AgI cartridges with 2gm formulation(type-1)		**Perforated AgI cartridges with 2 gm formulation(type-2)**	
Material	Percent by Weight	Material	**Percent by Weight**
Silver iodate	45.0	Silver iodate	45.0
Potassium perchlorate	27.0	Potassium perchlorate	27.0
Magnesium	20.0	Magnesium	20.0
Nitrocellulose	4.0	Nitrocellulose	4.0
Triacetin	4.0	Triacetin	4.0
Result: 47 lux (±2)		Result: 65 lux (±2)	

The area inside the cloud chamber is very small as compared to the environment hence proportionally very small size pyrotechnic cartridges were tested inside the chamber for observing the rate of emission of the fumes after burning.

inside the cloud chamber for observing the rate of emission of the fumes after burning of pyrotechnic cartridges. Two types of AgI cartridges were developed perforated and non-perforated with chemical formulation listed in the table-2 shown below. These pyrotechnic cartridges were tested inside cloud chamber for observing rate of emission of fumes. The cloud chamber for performing this test was set at Temperature -11^{0} C, Pressure 378 mmHg and humidity 97%. Luxmeter was used to measure the drop in transparency due to fast fumigation from cartridge and also artificial cloud formation within the cloud chamber. The testing of pyrotechnic cartridges showed huge amount of emission of fumes which were white in color. Rate of emission of fumes were observed on the basis of lux meter readings. As we used PVC pipes for testing purpose inside the cloud chamber very little deformation of the pyrotechnic cartridges shell were observed after complete burning.The initial reading of the lux meter was 388 lux. Within 15 seconds, due to burning of perforated cartridge, the luxmeter reading dropped by 65 lux (± 2) whereas in case of non perforated cartridge it dropped only by 47lux(± 2). The experiment clearly demonstrated that the emissions of fumes were ≈ 28% more in case of perforated type pyrotechnic cartridges (type-2) (Refer table-2). As the reaction time is crucial for hail suppression hence if rate of emission of fumes is increased the faster nucleation process will facilitate seeding completion within reaction time to meet the objective of hail suppression.

Drying Laser Particle Size Analyzer - Model ALPSW 3001 with Measuring range: 0.02µm to 2000µm; Accuracy: ≤0.5% (Figure 6), was used to measure the smoke particle sizes range of .04 µm 4 µm during fumigation of cartridge.

7. Summary

The advantages of modified pyrotechnic cartridges are summarized below while the complete cartridge is presented in Figure 10.

(i) If the cartridge is permitted free fall at then −19 °C it may completely burn off by the time (≈30 sec) it falls down to the level of -3.7^0 C within cloud with maximum fumigation. This is optimum ice-nucleation temperature range (Kumar, 2018).

(ii) Pyrotechnic perforated cartridge fumigates 28% more within fixed time hence it is faster in fumigation. More fumes in shorter time makes it efficient.

(iii) As the reaction time (Kumar and Pat, 2019) is crucial for hail suppression hence if rate of emission of fumes is increased the condensation process will be within the reaction time to meet the objective of hail suppression.

(iv) Perforation also makes the cartridge lighter in weight.

Appendix – A

Quantification of Seeding; Artificial Rain Making and Hail Mitigation

The total mass concentrations near sea surface over the Arabian Sea during monsoon months were measured by Vijaykumar et al. (2008) with mean value 16.7 ± 7 μg m^{-3}. About 50% of it is in the coarse mode (with radii >1 μm,) i.e. ≈ 8 μg m^{-3}. Concentration monotonically decreases with height over oceanic surface and is confined to 3 km there but over Indian continental region the concentrations initially increase from the surface to about 1 km before decreasing towards higher altitudes confined to 6.0 Km during monsoon months(Kala et al. 2021). Scavenging by rain drastically further reduces the concentration. There is debate as to the quantity of scavenging of CCN. Larger particles scavenge faster than smaller ones. Over ‘other than Indian region’ it has been observed that lager inorganic salts could be scavenged up to 85% (Sellegri et. al., 2003) though Henning et.al., 2002 found it only ≈ 50%. Hence on taking the vertical average, keeping in mind the vertical aerosol distribution and scavenging together in coarse mode, the efficient-CCN concentration over Indian region during monsoon months may be taken as of the order of ≈ 0.5 to 1.0 µg/m^3 (Mean = 0.75kg/Km^3) which could be the reference amount in atmosphere to inhibit the hail-growth. Examining overseeding effects were initially attempted by Elliot ((1970). However, in present discussion seeding is being defined under three broad categories; (i) Under seeding (ii) Exact Seeding (iii) Over seeding. Ingestion of seeding agents within cloud at the rate of 0.75kg/Km^3 may be defined as exact seeding density whereas less than 0.5 µg/m^3 may be defined as ‘under-seeding’ and more than 1.0 µg/m^3 could be defined as ‘over-seeding’ (Kumar, 2017).

Excessive quantity of CCN (IN) density (>>1.0 µg/m^3) severely enhances the nucleation number per unit volume which restricts the larger size growth of droplets. To achieve rain (as is the objective of artificial rain making campaigns) one needs to ensure that final CCN(IN) density after seeding must be ≈ 0.5 to 1.0 µg/m^3 so that drop diameter is ≈ 1.5 to 3mm. If the final CCN (IN) density after seeding is more than 1.0 µg/m^3 then precipitation could be smaller in size e.g. drizzle, virga (generally the drop diameter is ≤ 1.5mm) or else if seeding is less than 0.5 µg/m^3 then precipitation size might be larger e.g. rain-shower (generally the drop diameter ≈ 3 to 8 mm) or may be hails (Hudson and Yum,2001; Hudson and

Mishra, 2007; Freud et al., 2008). Hence the quantity of artificial seeding in particular airmass has to be strictly precise in all the artificial rain making operations. On the other hand all the hail-mitigation campaigns have only one objective i.e. 'to get rid of damaging hail fall – partially or fully'. Therefore exact or 'little-over-seeding' of the cumulus cloud still would squarely meet the objective.

Nevertheless, from farmers point of view 'excessive-over-seeding' in hail-mitigation might also not be welcomed as another fear, beside the objective of hail-mitigation, of rain scarcity **(**Nataraj, 2017) looms due to possibility of ensuing drizzle or virga. At the same time if under-seeding is carried out in such missions then instead of decreasing the hail formation it may increase the same. It was observed by Detwiler (2015), though its cause was not explained. Stringency of exact seeding quantity, therefore, in case of artificial rain making is much more rigorously needed than in case of hail-mitigations. Hence 'at least no under seeding rule' of seeding marks hail-mitigation operation relatively simpler than artificial rain making campaigns which needs exact seeding.

A quick estimate of exact quantity of seeding agents (QSA) is crucial for the success of proposed hail-mitigation operation. If estimated volume of the warm and cold parts of the cloud is (x+y) Km^3 where x km^3 is volume from lifting condensation level(LCL) to 0^0C isotherm(warm region) and y km^3 is the volume the cloud above 0^0C isotherm to top of the cumulus cloud(cold region) then the empirical formula for the QSA is as under

QSA = 0.75x kg of NaCl powder salt (coarse mode) + 0.75y kg AgI - based seeding agent (1)

Following definition may be used for seeding:

(i) Exact seeding: In this type of operation the amount of CCN dispersed is exactly 0.75 Kg/Km^3 in clouds. This will generate normal rain/shower of size 0.5–6mm

(ii) Under seeding: In under seeding operation the amount CCN dispersed are less than 0.5 Kg/Km^3 in clouds. This will result in a few droplets of rain/shower.

(iii) Over seeding: In over seeding operation the amount CCN dispersed are more than 1.0 Kg/Km^3 in clouds. This will result in formation of small graupel or drizzle or virgo (smaller than 0.5 mm in diameter). If graupels, as they are very small in size they melt before reaching the ground and turn into drizzle and the purpose of controlling the size of hail is served.

Hail suppression, therefore, can be done by exact or little over seeding of the clouds. It is important that seeding is done in a thunderstorm before hailstones have formed. It is the cloud state when the radar reflectivity crosses 45 dBZ (Singh Hari, 2010). There may be variations in its value by ± 3 dBZ from region to region. The interval when the cloud reflectivity begins growing from 20dBZ till it reaches to 45dBZ is defined as the "Reaction time". If the seeding is done during the reaction time then only we can hope to restrict the growth of hailstorm. If cloud is seeded after its growing reflectivity has crossed the 45 dBZ mark then it is of little avail as the large-hailstones which have already formed will come down and cause damage.

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