Pilot Research Project on Alternative Substances for Rain Enhancement Operation

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TISTR

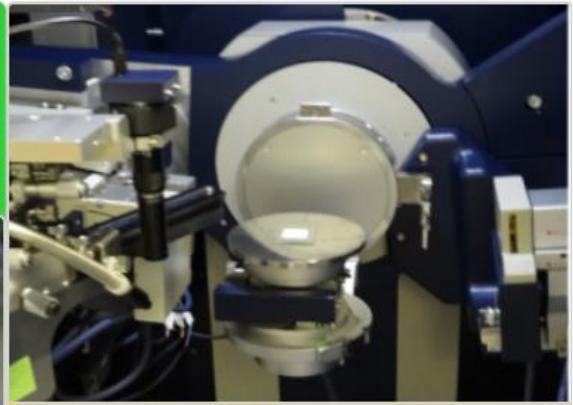
A state enterprise under the Ministry of Higher Education, Science, Research and Innovation

Vision

A leading organization in the integration of science, technology and innovation for the creation of a sustainable innovation-based society

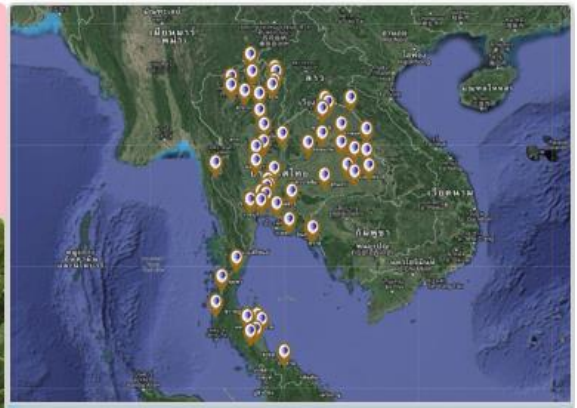
4 Guiding Principle

Bio Based Research



Appropriate Technology

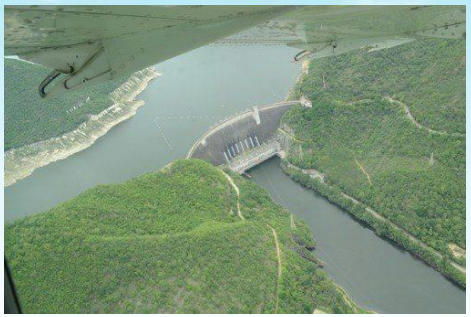
Total Solution Provider



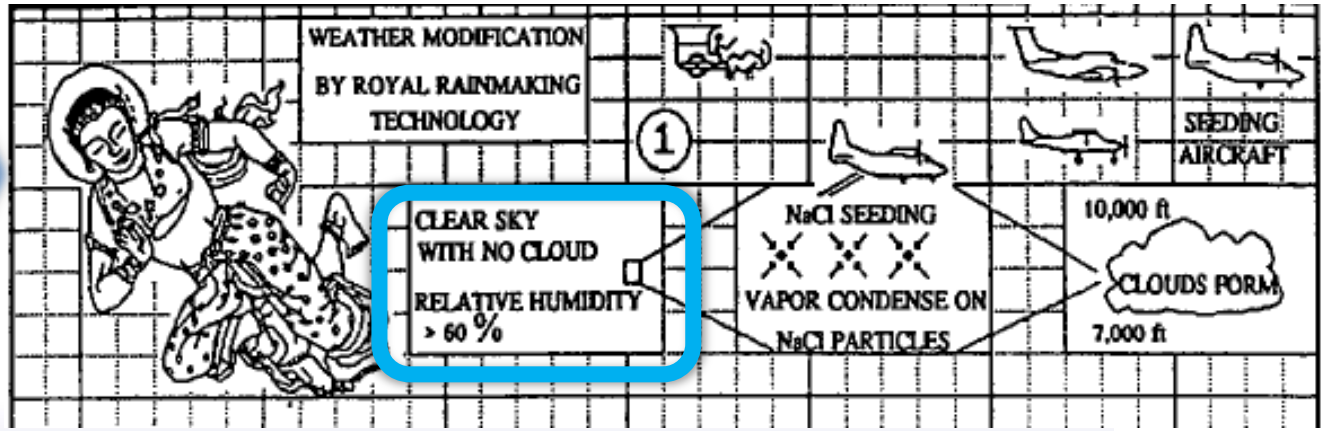
Community (Area Based)

UN Sustainable Development Goals (SDGs)

Royal Rainmaking Project



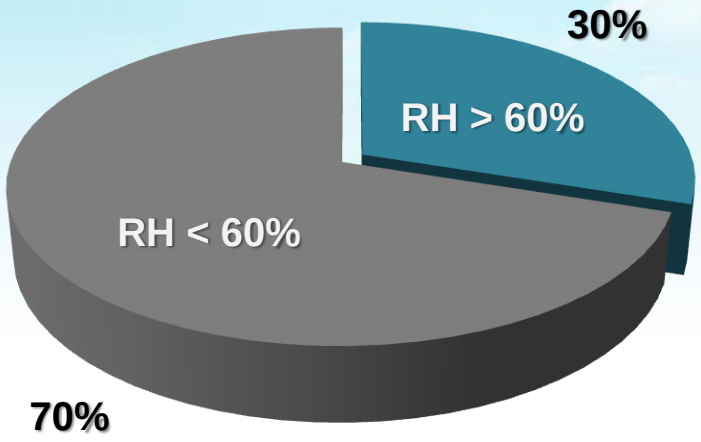
Step 1
Agitation
or
Triggering



Relative Humidity > 60%

Relative Humidity in the Dry Season

Percentage of day (Dry Season, Cha-am area)



Average Relative Humidity in 5 areas

In the dry season, there are only 30%-50% of the days with proper relative humidity.

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GOAL

The alternative substances that can act as cloud condensation nuclei (CCN) at RH < 60% for agitation step in royal rainmaking operation

Overcome the limitation of relative humidity factors

Increase the chance of the Royal Rainmaking operation in the dry season

Critical Relative Humidity (CRH)

CRH is defined as the relative humidity of the surrounding atmosphere at which the material begins to absorb moisture from the atmosphere.

CRH of Pure Salt

Current Royal Rainmaking Substance

Salt	Critical Relative Humidity (%)
Calcium nitrate	46.7
Ammonium nitrate	59.4
Sodium nitrate	72.4
Urea	72.5
Sodium Chloride	75
Ammonium chloride	77.2
Ammonium sulfate	79.2
Diammonium phosphate	82.5
Potassium chloride	84.0
Potassium nitrate	90.5
Monoammonium phosphate	91.6
Monocalcium phosphate	93.6
Potassium sulfate	96.3

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CRH of the mixtures of salts

Mixtures of salts usually have lower CRH than either of the pure salts.

CRH of the mixtures of salts

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TABLE I: CRITICAL RELATIVE HUMIDITIES OF PURE SALTS AND MIXTURES AT 30°C (86°F)

CALCIUM NITRATE	AMMONIUM NITRATE	SODIUM NITRATE	UREA	AMMONIUM CHLORIDE	AMMONIUM SULPHATE	DIAMMONIUM PHOSPHATE	POTASSIUM CHLORIDE	POTASSIUM NITRATE	MONOAMMONIUM PHOSPHATE	MONOCALCIUM PHOSPHATE	POTASSIUM SULPHATE
46.7											
23.5	59.4										
37.7	46.3	72.4									
-	18.1	45.6	72.5								
-	51.4	51.9**	57.9	77.2							
-	62.3	-**	56.4	71.3	79.2						
-	59*	-	62*	-	72*	82.5					
<22.0	67.9**	66.9**	60.3	73.5	71.3**	70*	84.0				
31.4	59.9	64.5	65.2	67.9	69.2	-	78.6	90.5			
52.8**	58.0	63.8	65.2	-	75.8	78*	72.8**	59.8	91.6		
46.2	52.8	68.1	65.1	73.9	87.7	78*	-**	87.8	88.8	93.6	
76.1**	69.2**	73.3**	71.5	71.3	81.4	77*	81	87.8	79.0	-**	96.3

3 important criteria

1. The CRH of the alternative substance is below 60%.

2. The temperature difference of water after adding the alternative substance is not more than 5 ºC.

3. The surface tension of alternative substance aqueous solution should be high.

Conductivity

Flow Factor

pH

Safety

Not expensive

Easy to prepare and use

Experiment

Laboratory Test

- Lab scale preparation of Alternative substance

Properties

- Moisture Absorption
- Surface Tension
- Temperature Difference
- Flow Factor
- Conductivity and pH

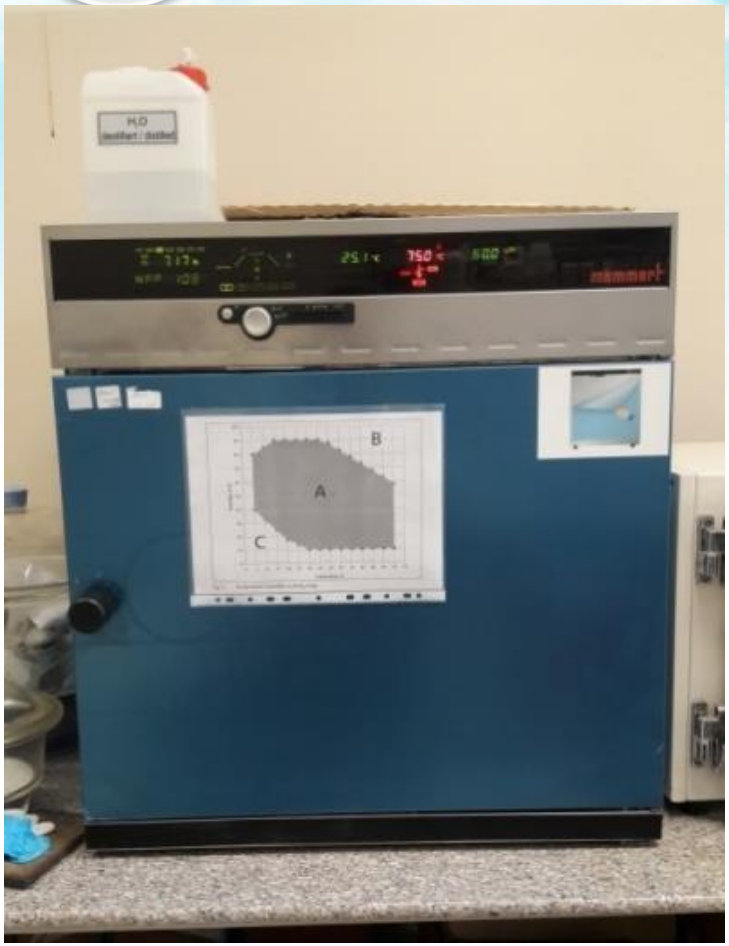
Field Test

- Pilot scale preparation of Alternative substance

Properties

- CCN
- Size of cloud droplet

Moisture Absorption



Temperature and humidity chamber

Digital Weight Scale

weigh Samples and put in aluminum containers for moisture

% Moisture absorption

$(W_{after}-W_{before})/W_{before} \times 100$

Different Temperature Test

Ratio 1:2

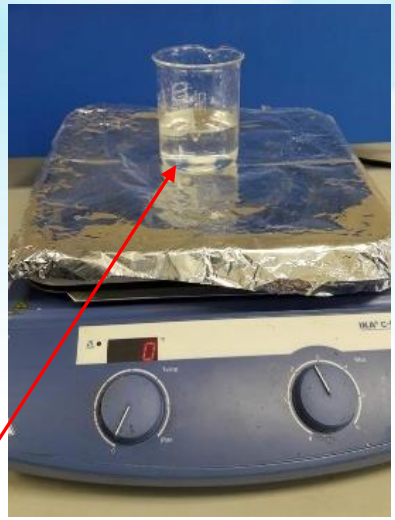
50 g (Alternative Substances) + 100 g (Distilled water)

stirring speed : 200-250 rpm

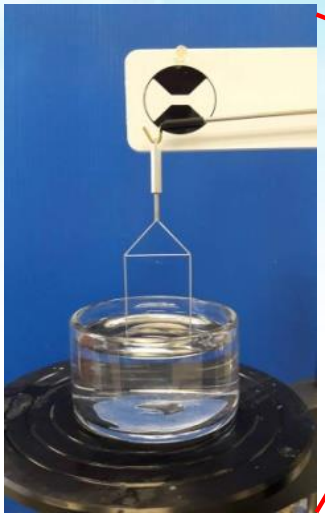
Measure temperature and store data at every 1 second.

*Until the solution does not change the temperature

Surface Tension Test

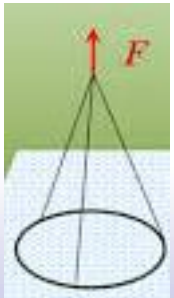


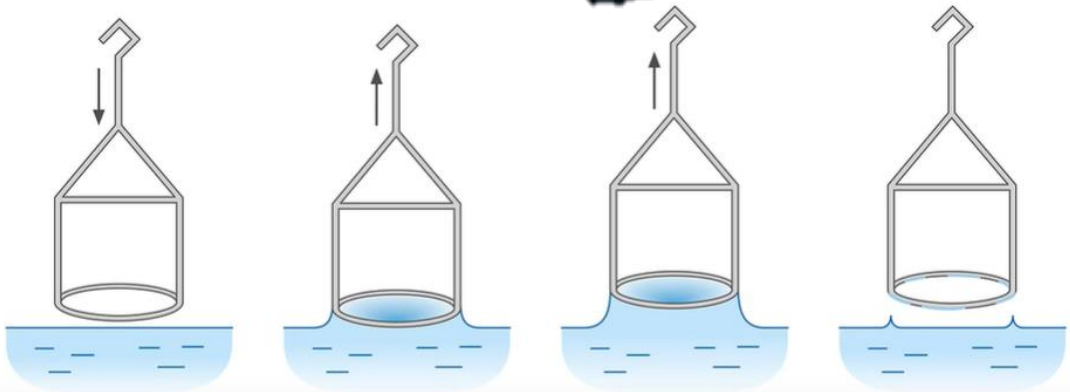
Alternative Substance Solution



$$S = F/A$$

S = Surface tension
F = Surface tension Force
L = Circle length





pH & Conductivity

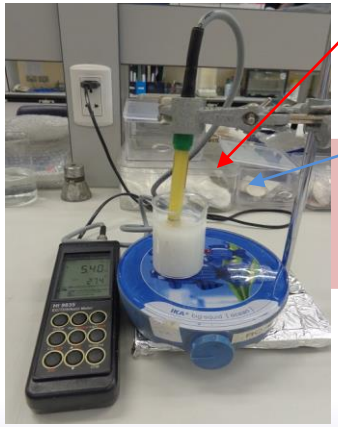
pH meter

8 g (Alternative Substances) + 40 ml (Distilled water)

stirring time 10 min

Test pH of Alternative Substances

Conductivity meter



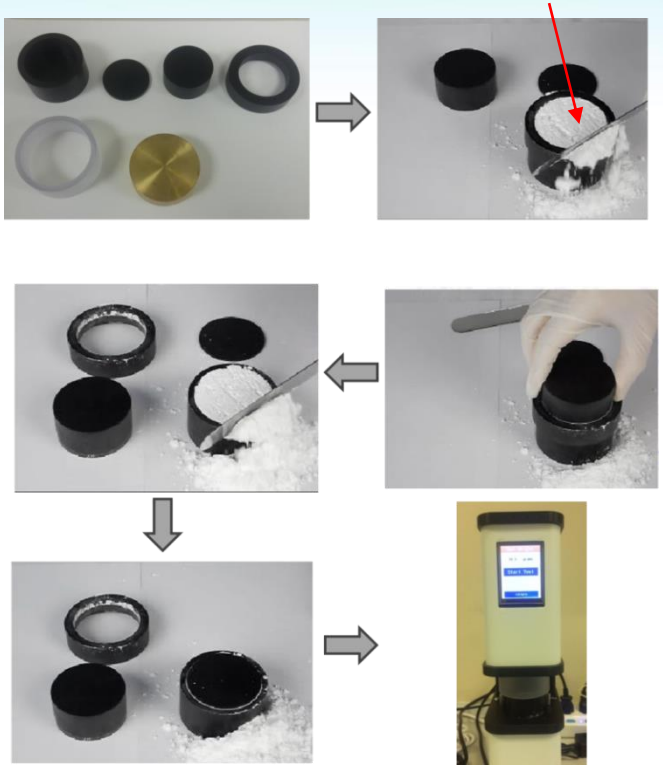
8 g (Alternative Substances) + 40 ml (Distilled water)

stirring time 10 min

Test conductivity of Alternative Substances

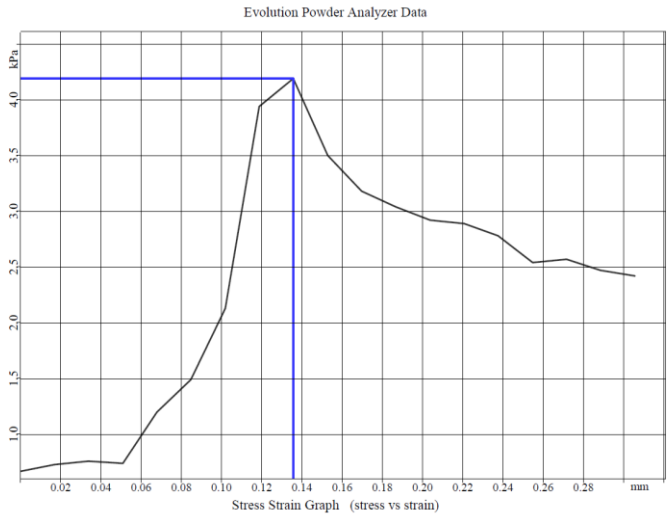
Flow Factor

Alternative Substances



Sample Graph

Evolution Powder Analyzer Data



Stress Strain Graph (Stress vs Strain)

Flow factor → **Type of Flows**

unconfined yield strength (UYS)

- Non Flowing (ff<1)
- Very Cohesive (1<ff<2)
- Cohesive (2<ff< 4)
- Easy Flowing (4<ff<10)
- Free Flowing (ff > 10)

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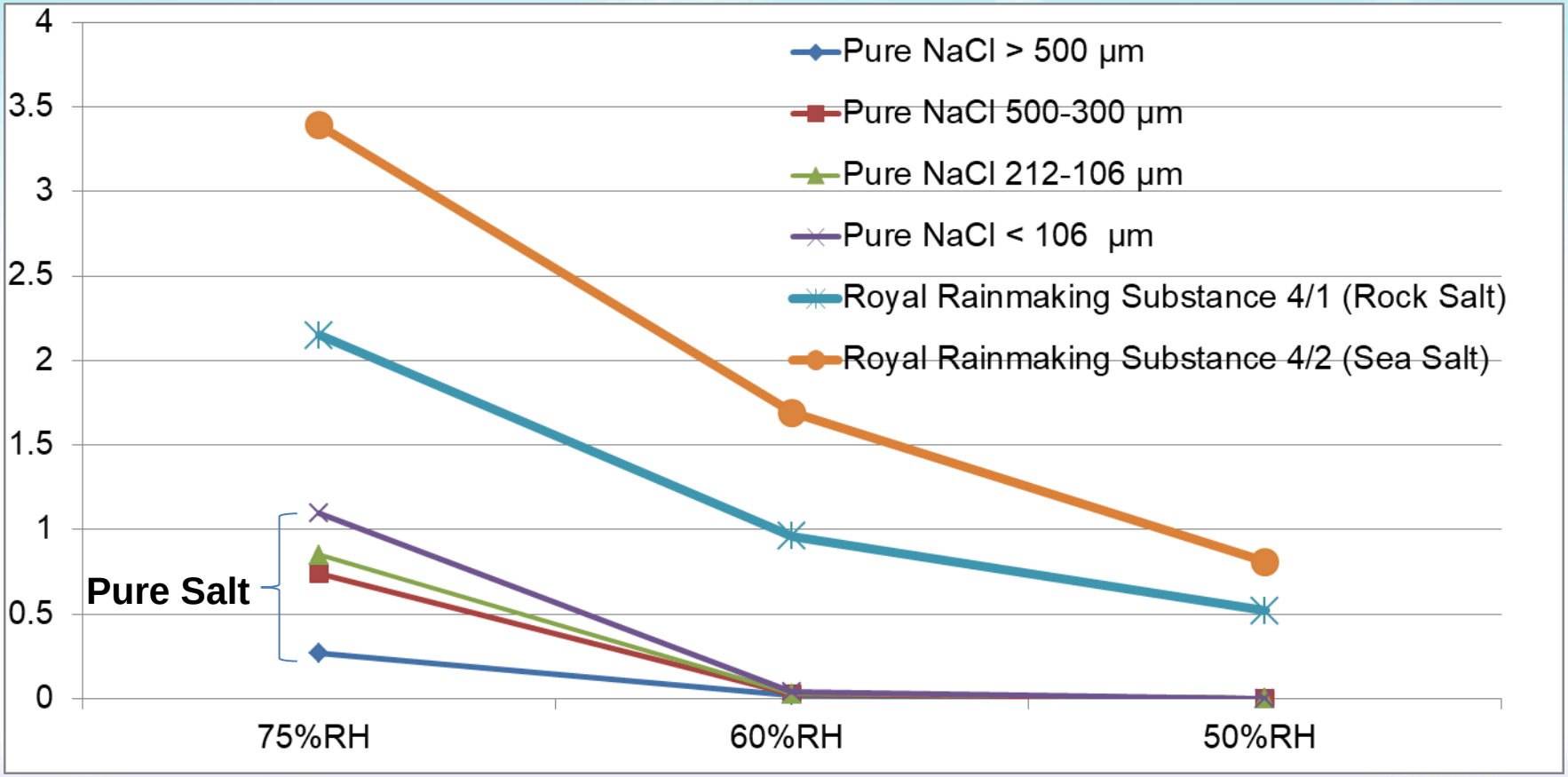
Moisture Absorption

Pure NaCl VS Royal Rainmaking Substance



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Preparation of the alternative substances

Laboratory Scale

Over 40 formulas have been prepared and tested their properties.

Laboratory Test

Moisture Absorption , Surface Tension, Temperature Difference, Flow Factor, Conductivity, pH

5 formulas : Pass all 3 criteria

$NaCl(0.35\%MgSO_4)$ + $CaCl_2$ +/- KCl or urea

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Safety

Not expensive

Easy to prepare and use

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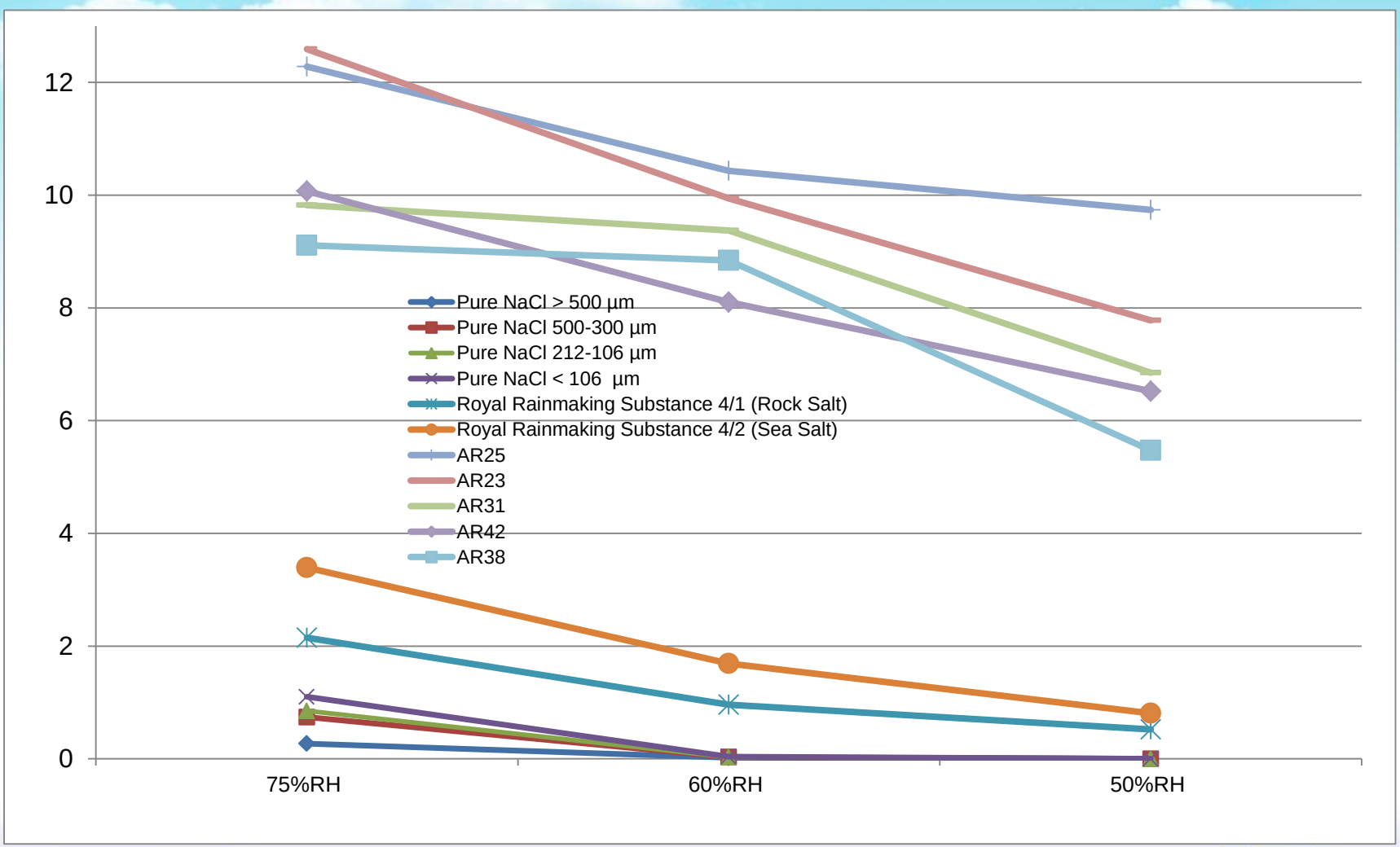
Moisture Absorption



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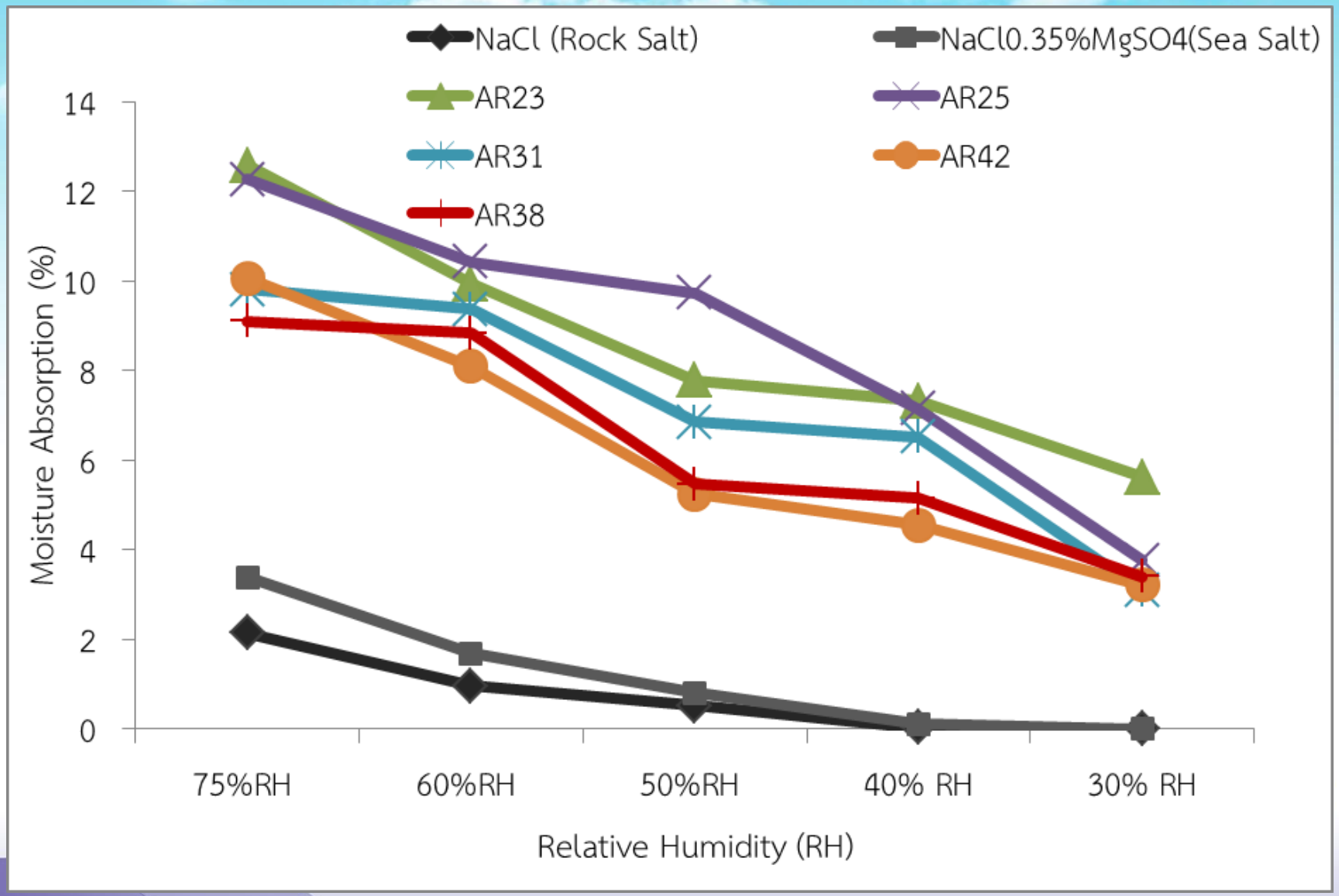
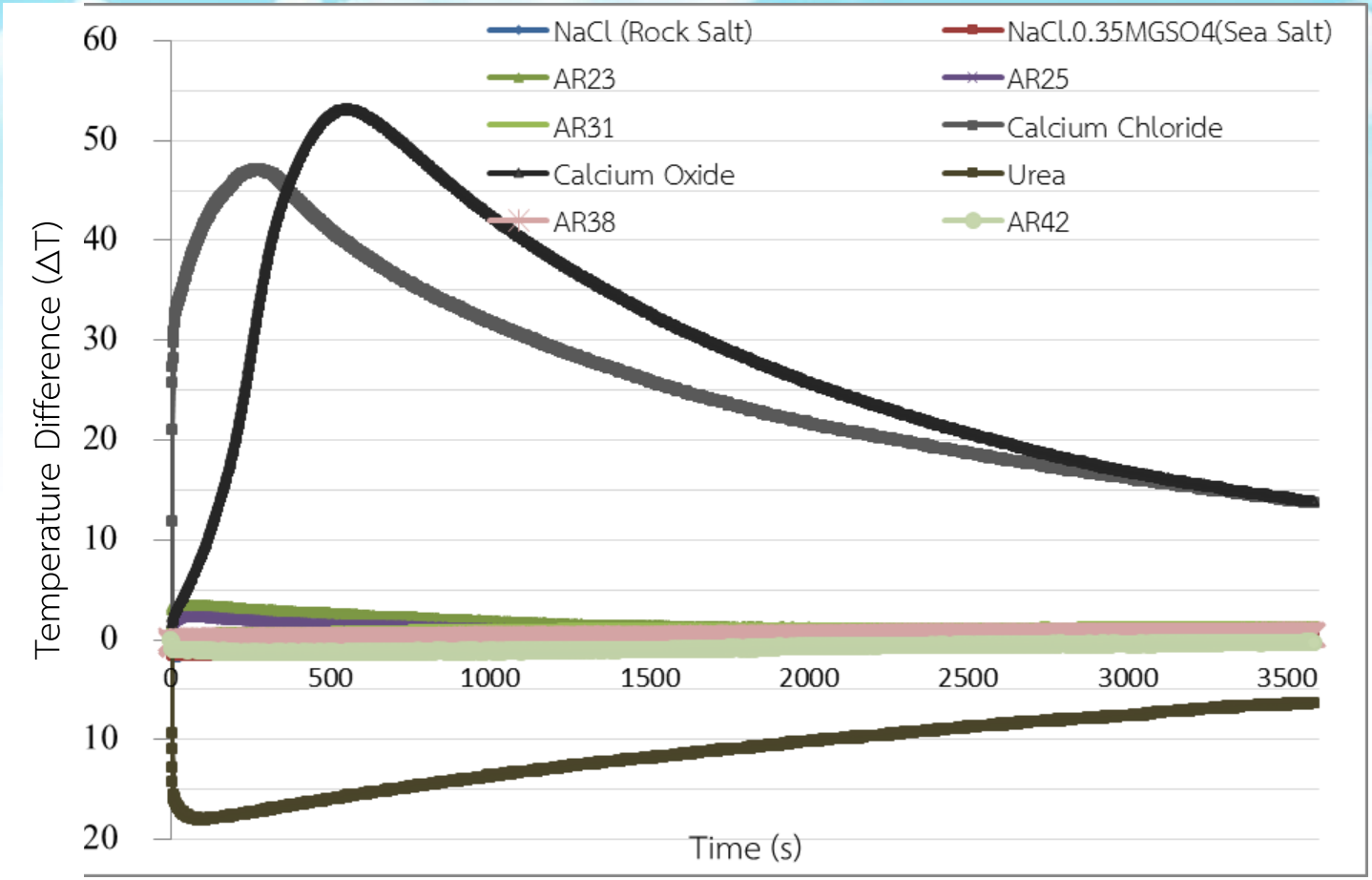
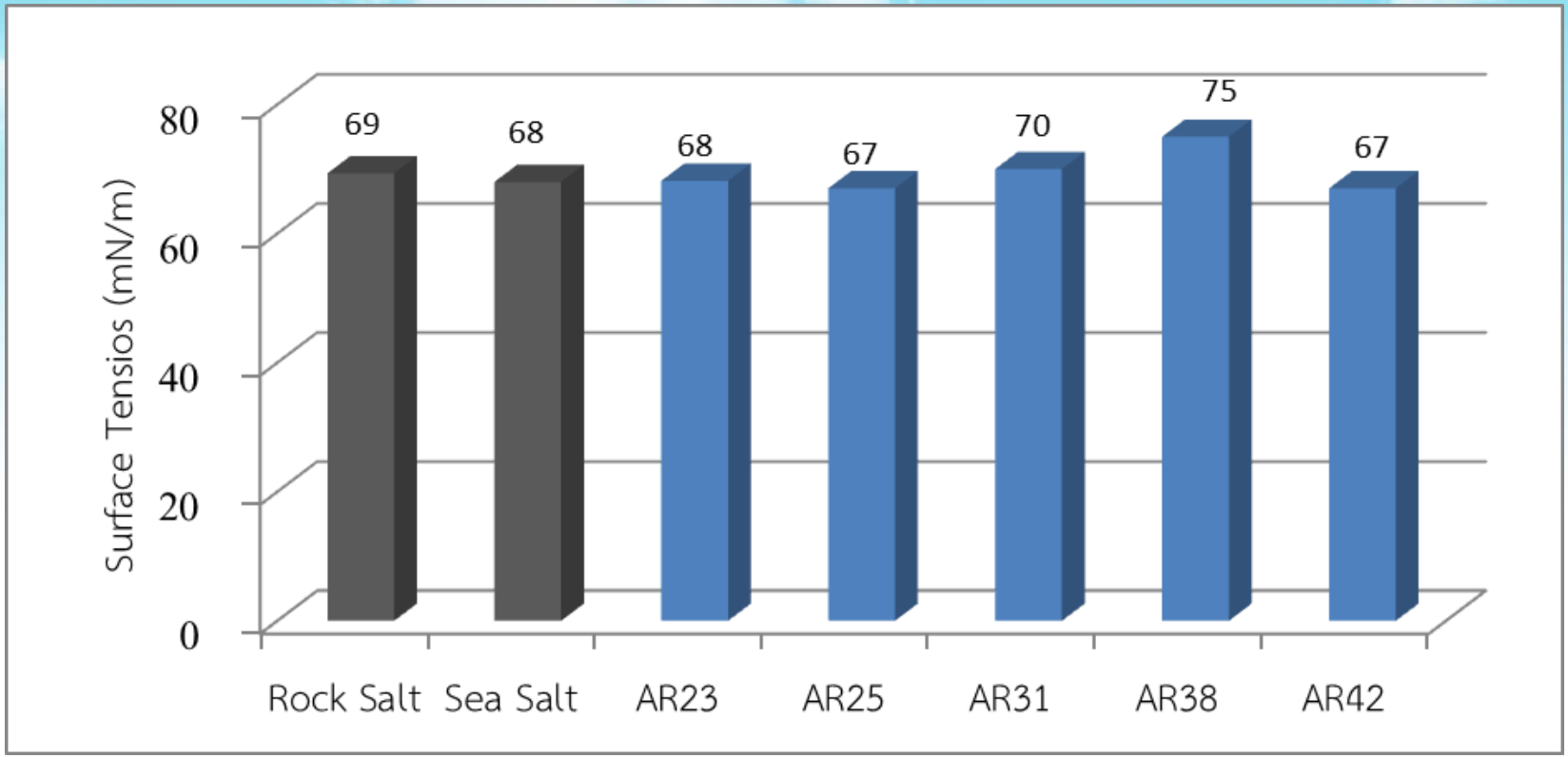
Moisture Absorption



Temperature Difference (ΔT)



Surface Tension

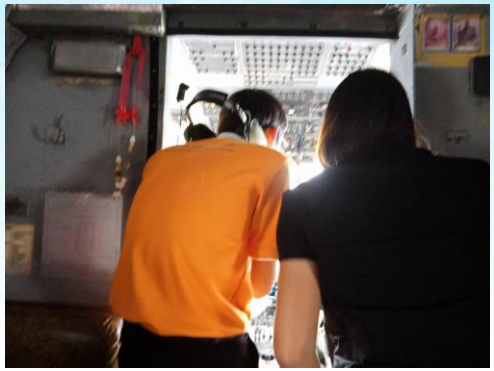


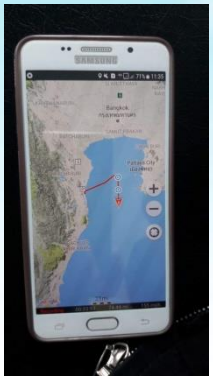
Preparation of the alternative Substances in Pilot scale

More than 2000 kg per formula have been prepared under temperature and relative humidity control (<25 °C, RH <35%).

Field Test

Hua-Hin and Phitsanulok Station



Field Test

Dispersing the alternative substance from the CARAVAN aircraft at RH < 60% and the CCN and cloud droplet were measured after seeding and after seeding + 25 min by Super King Air 350

4 experiments for each formula

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Field Test

Condition :

- **Average RH 5,000-10,000 = 40-60%**
- **Wind Speed < 20 kts**
- **Lifed Index < 0**
- **CCL High < 9,000 ft.**

Data from Balloon Radiosounde

Field Test Preliminary Results

The results showed that the use of AR23 or AR 38 or AR42 after seeding 25 minutes exhibited more CCN and cloud droplet than the control area (nonseed area).

Conclusion

The results from laboratory and preliminary field test showed positive results of using alternative substance under 60%RH. However, more field test should be done in the future in order to get the accurate and reliable results.

Acknowledgment

Department of Royal Rainmaking and Agricultural Aviation

Agricultural Research Development Agency

Thank you

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