Environment Canada Environnement Canada

Canada

Oil Comparison for Weighing Precipitation Gauges as used in Environment Canada

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Outline

1. Objective and background
2. Important factors
3. Evaluation criteria
4. Density
5. Kinematic viscosity
6. Evaporation comparison
7. Conclusions

Objective

Objective:

Establish principles and recommendations for the selection of oil in precipitation weighing gauges.

Current Meteorological Service of Canada usage, by Regions:

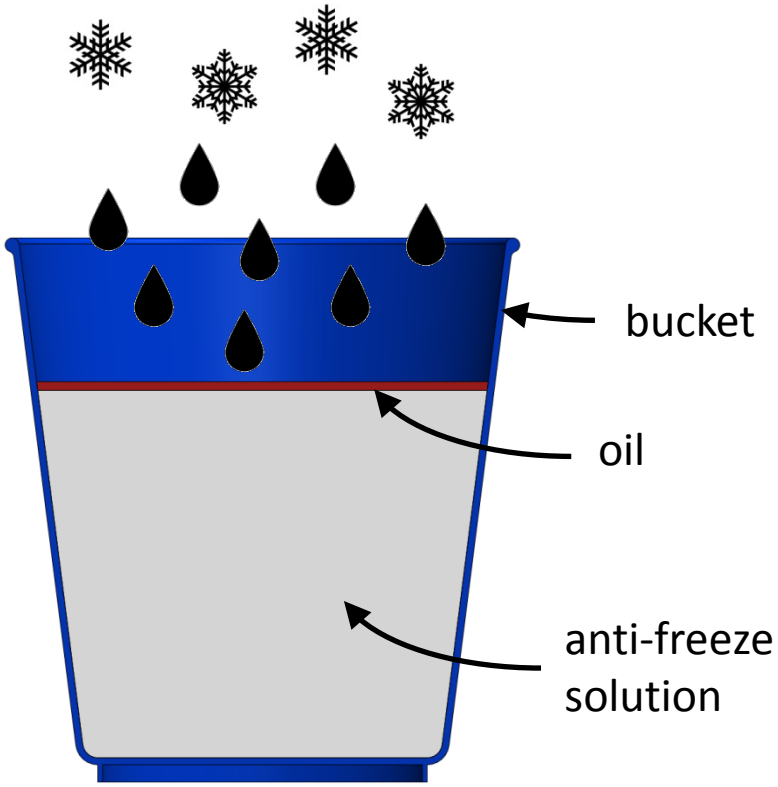
Region	Precipitation Gauge Oil
Pacific and Yukon	Mineral Oil, Baby Oil
Prairie and Northern	VoltEsso 35, Shell Diala Oil AX
Ontario	Bayol 35 (discontinued)
Quebec	Bayol 35 (discontinued), Isopar M
Atlantic	Bayol 35 (discontinued)

Antifreeze used: 60% Methanol & 40% Propylene Glycol

Desired outcome: identify oils that could be used operationally in the networks operated by the Meteorological Service of Canada

Important Factors

Precipitation (rain, snow, mixed)



Operational Temp: -40 °C to 60 °C

Oil Benefits:

- Limit evaporation of precip & anti-freeze
- Reduce splashing

Oil Requirements:

- Floats on precipitation & anti-freeze solution
- Enables light snow and rain penetration
- Does not evaporate and limits evaporation within bucket
- Does not mix with water
- Does not react with bucket or liquid mixture
- Is not harmful to human exposure
- Presence & condition is clearly visible
- Does not attract animals & insects

Evaluation Criteria

Purpose	Parameter	Evaluation Criteria
Oil floats on liquid	Density	ρ < Anti-freeze & precipitation mixture Low density is best
Oil enables light snow and water penetration	Viscosity & Surface Tension	Low viscosity is best Low surface tension is best
Oil does not evaporate	Evaporation rate	Low evaporation is best
Oil does not mix with water	Water solubility	Immiscible in water
Oil does not react with bucket or liquid mixture	Non-reactive	Must not react with plastic bucket & anti-freeze solution
Oil is not harmful to human exposure	Toxicity	Low toxicity for reduced health risks
Oil presence and condition is clearly visible	Colour	Visible to show oil presence, coverage and elevation within bucket
Oil does not attract animals & insects	Odor	Limited odor to not attract animals

Precipitation Gauge Oil Comparison Test Samples

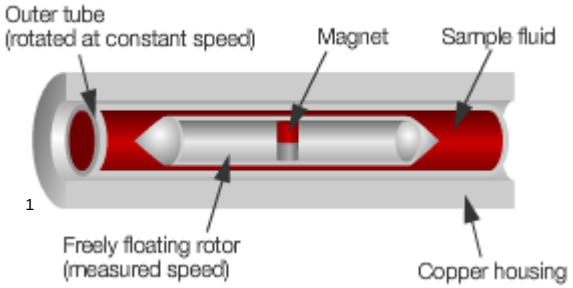
Oil Samples	
1	Clearco silicone oil, 2 mm^2/s
2	Clearco silicone oil, 5 mm^2/s
3	Clearco silicone oil, 10 mm^2/s
4	Bayol 35 (isoparaffinic hydrocarbon)
5	Isopar M (isoparaffinic hydrocarbon)
6	Mobil Aero HFA (hydraulic oil)
7	Univis HVI 13 (hydraulic oil)
8	Voltesso 35 (electrical insulating oil)
9	Baby oil (mineral oil base)
10	Raw linseed oil

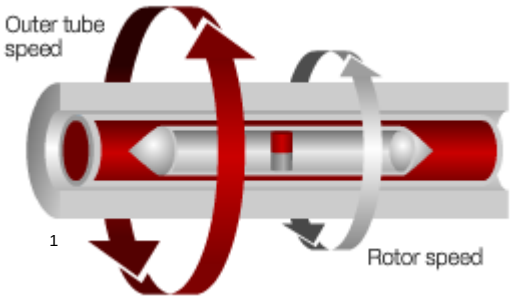
Anti-Freeze Samples	
1	Empty bucket [40% PG / 60% M]
2	Full bucket -20 °C mixture [16% PG / 24% M / 60% DW]
3	Full bucket -40 °C mixture [22% PG / 33% M / 45% DW]
4	Empty bucket alternative [75% PG / 25% DW]
5	Full bucket alternative [25% PG / 75% DW]

PG – Propylene Glycol
M – Methanol
DW – Distilled Water

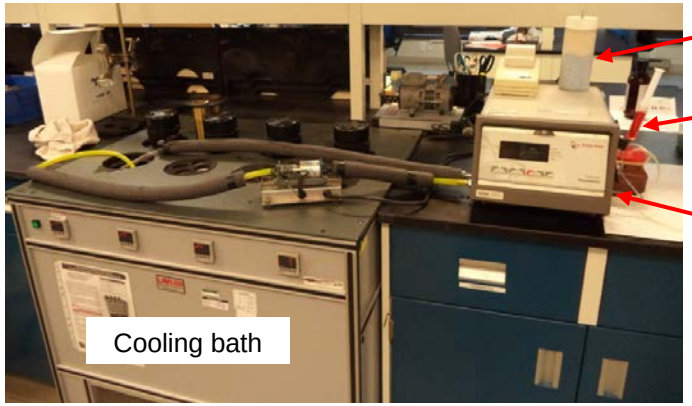
Viscosity μ (ASTM D 7042)

ASTM D 7042 - Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer





Test method for Newtonian fluids such as petroleum products and crude oils.

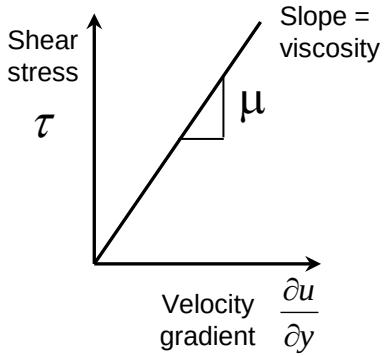


Drying agent

Test sample

Anton Paar SVM3000

Newtonian fluid:

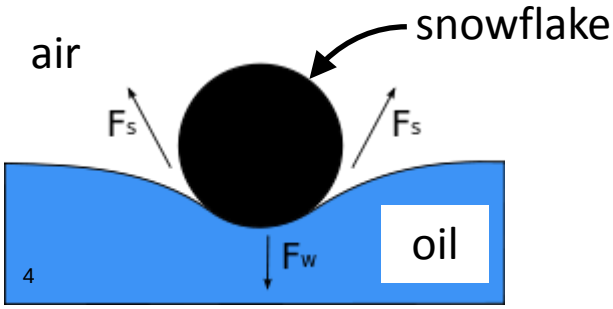


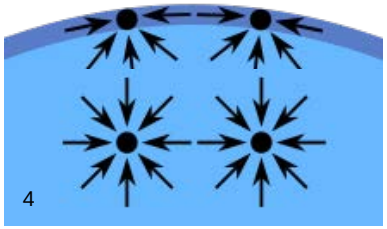
$$\tau = \mu \frac{\partial u}{\partial y}$$

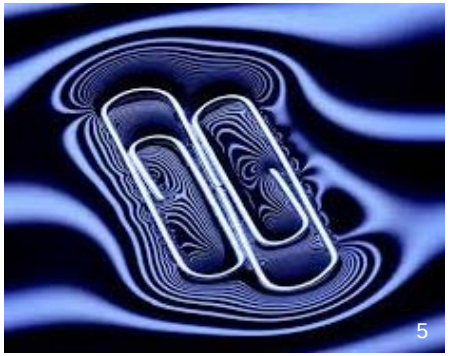
1. http://www.anton-paar.com/ca-en/products/group/viscometer/

Surface Tension γ

Will solid precipitation (dendrites, plates, needles...) pass through the oil surface at cold temperatures?







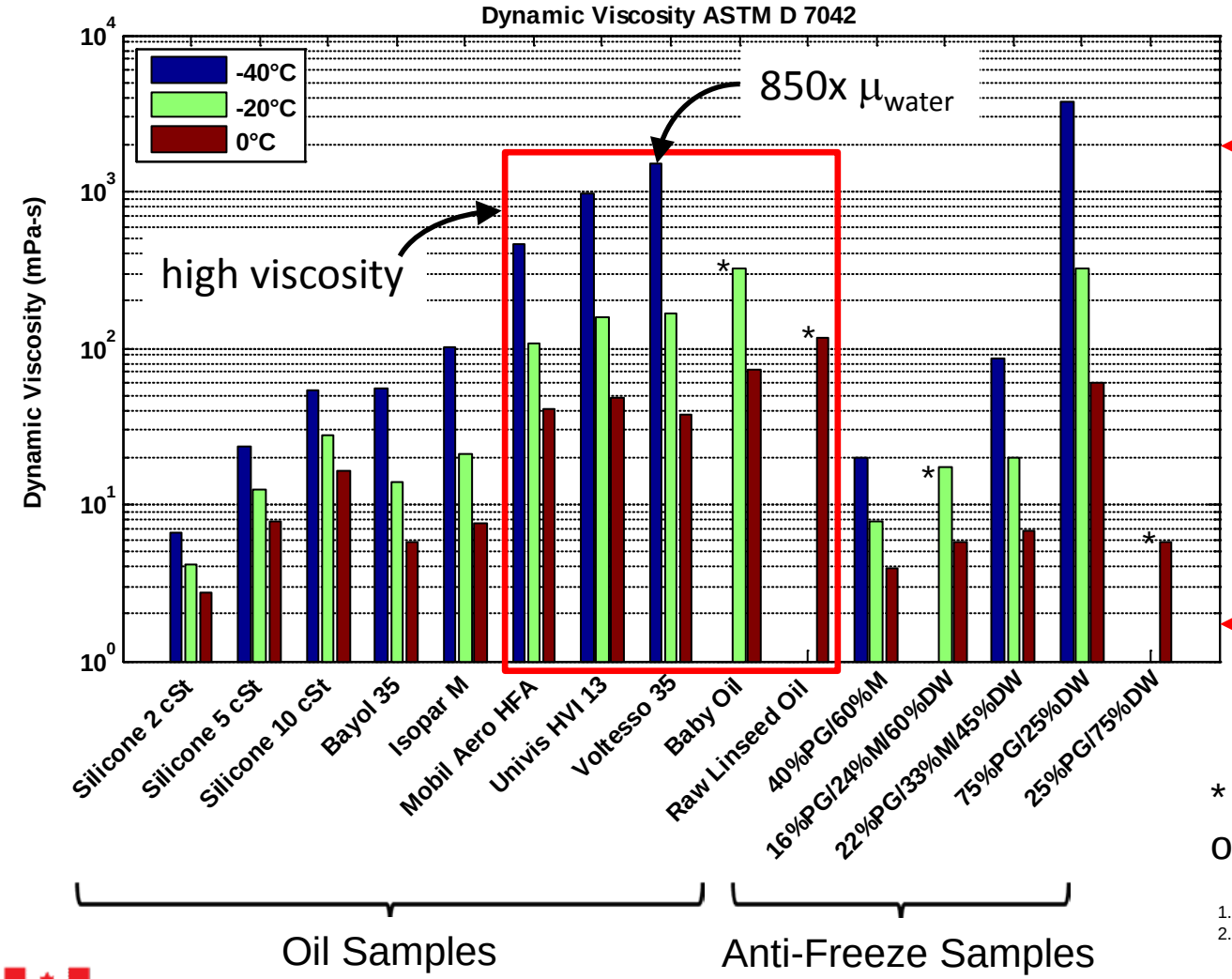
Liquid	Surface Tension (mN/m)
$Water_{0°C,\ 100\ kPa}$	75.64 [1]
Silicone oil 2 cSt	18.7 [2]

- Light object supported on surface by hydrostatic pressure and surface tension [3]
- Lower surface tension will have less ability to hold an object at its surface
- Degree of wetting of snow at snow-oil interface at cold temps?

1. CRC Handbook of Chemistry and Physics, 2004.
2. Clearco properties of polydimethylsiloxane fluids
3. Mansfield, E. H. Et al. Equilibrium and mutual attraction or repulsion of objects supported by surface tension, Phil Trans R Soc, May 1997.
4. http://en.wikipedia.org/wiki/Surface_tension
5. http://www.dpchallenge.com

Viscosity μ (ASTM D 7042)

Based on results from tests conducted by the Meteorological Service of Canada



* Product too viscous or solid to get a result

1. http://en.wikipedia.org/wiki/Viscosity, April 2, 2014
2. CRC Handbook of Chemistry and Physics, 2004

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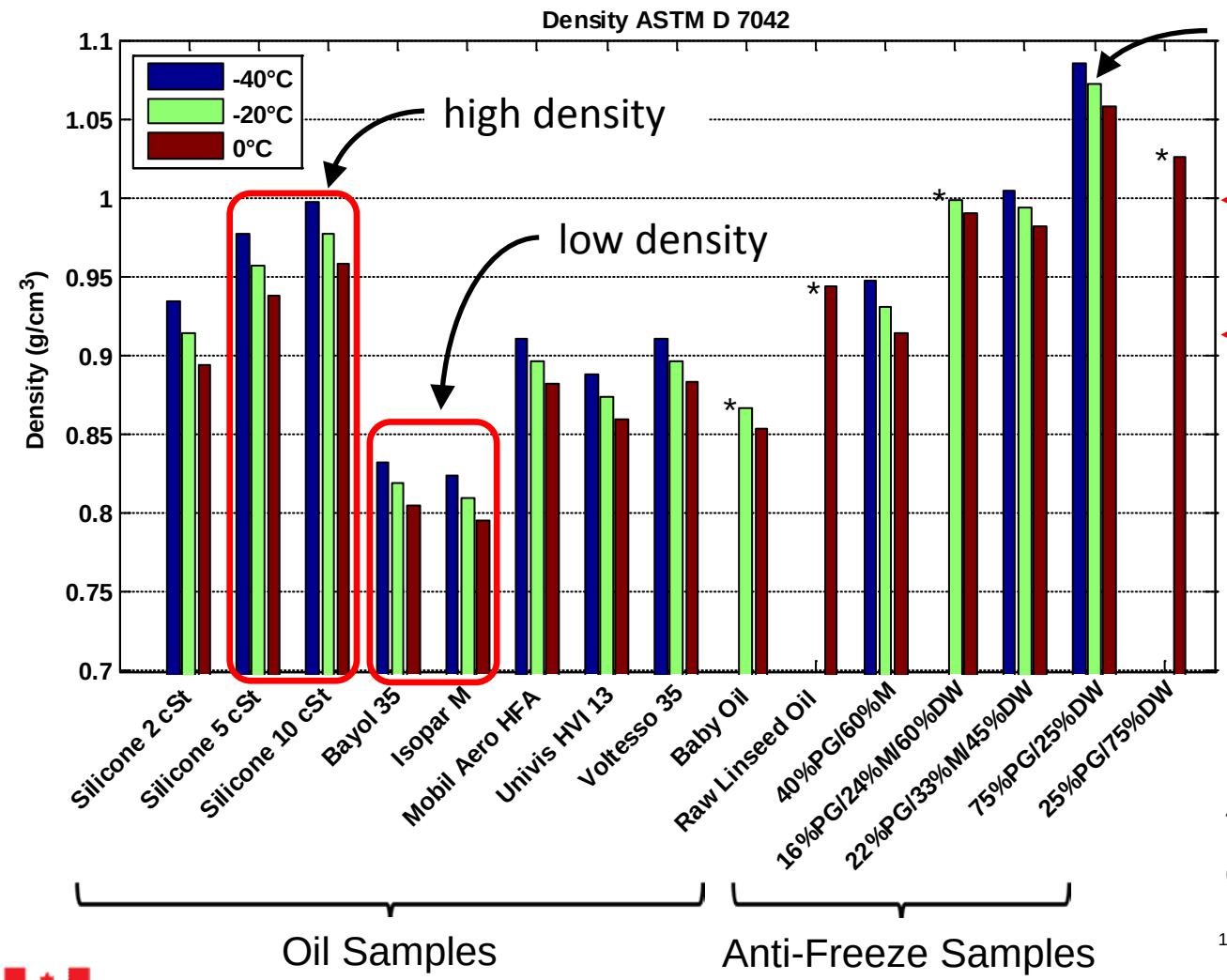
Density (ASTM D 7042)

Based on results from tests conducted by the Meteorological Service of Canada



Propylene glycol mix is denser than water

$\rho_{water\ 0\ °C\ 100\ kPa}$ = 0.99984 g/cm^3 [1]

$\rho_{ice\ 0\ °C}$ = 0.9167 g/cm^3 [1]

* Product too viscous or solid to get a result

1. CRC Handbook of Chemistry and Physics, 2004

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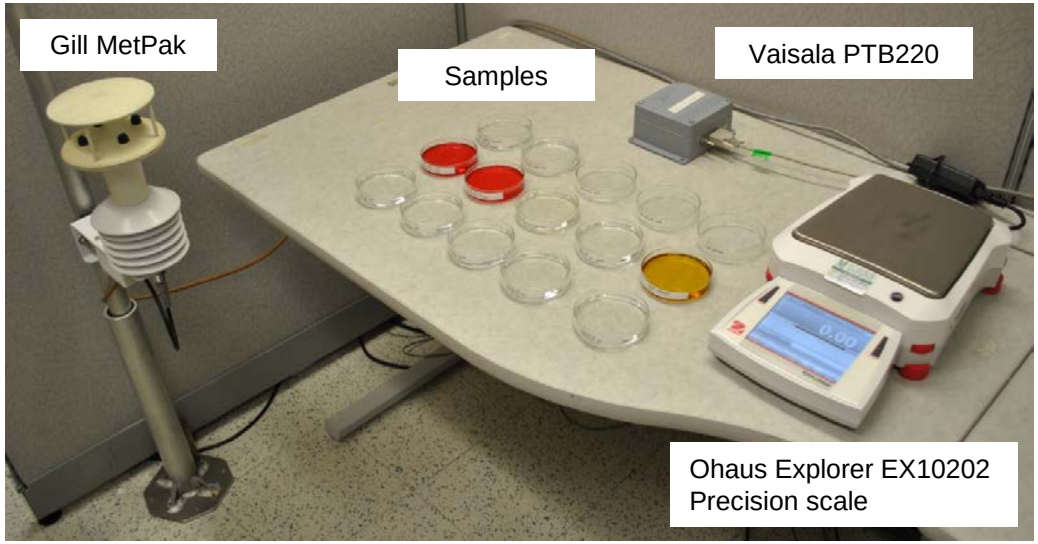
Evaporation (Lab Experiment)



- Samples added to petri dish up to fill line
- Petri dish area estimated from x, y measurements
- Measurements of sample mass over 1 week period
- Testing performed indoors
- Lights were on during business hours

Samples	
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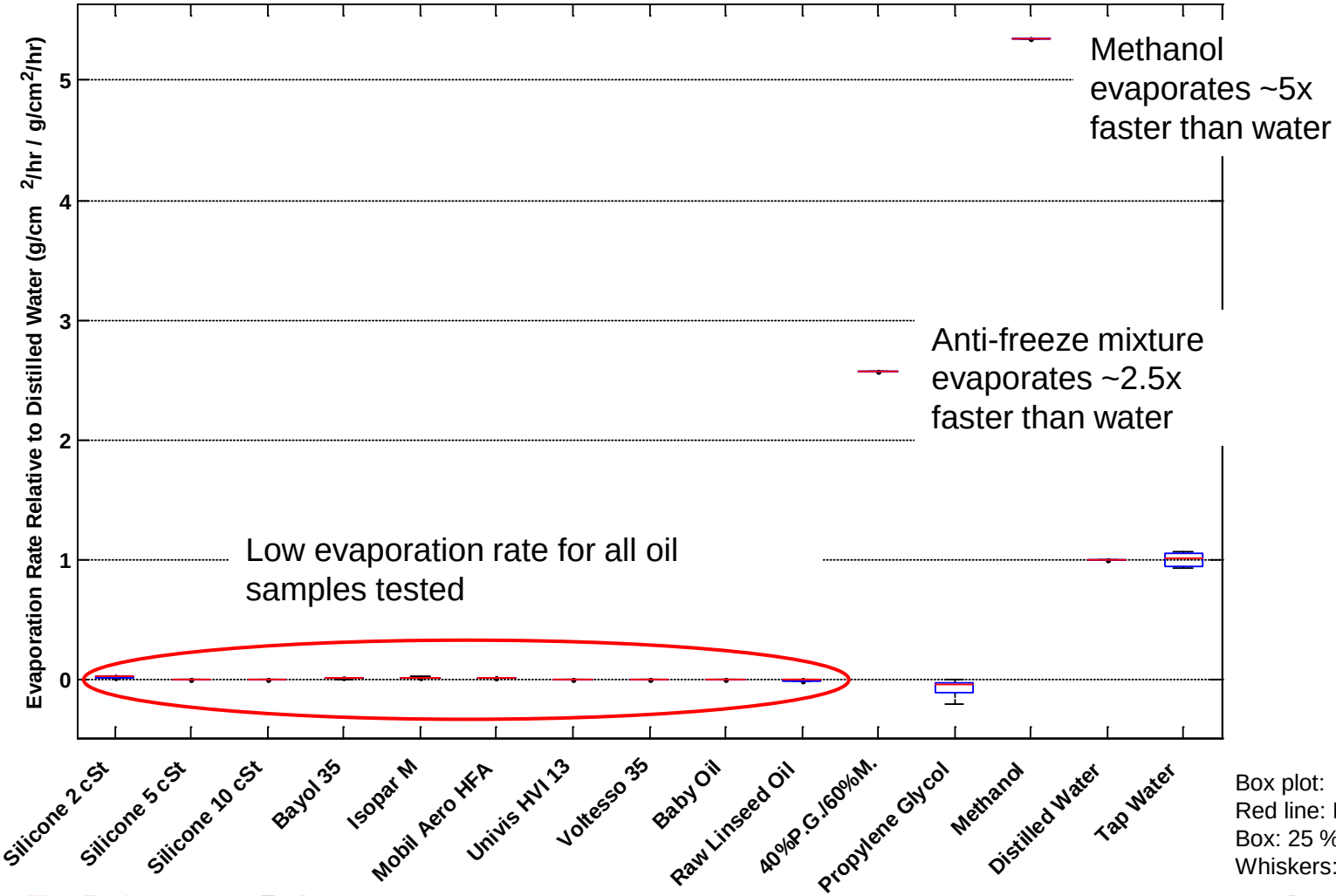
6	Mobil Aero HFA (hydraulic oil)
7	Univis HVI 13 (hydraulic oil)
8	Voltesso 35 (electrical insulating oil)
9	Baby oil (mineral oil base)
10	Raw linseed oil
11	Anti-freeze [40% PG / 60% M]
12	Propylene Glycol USP FCC
13	Methanol ACS
14	Distilled Water ACS
15	Tap Water

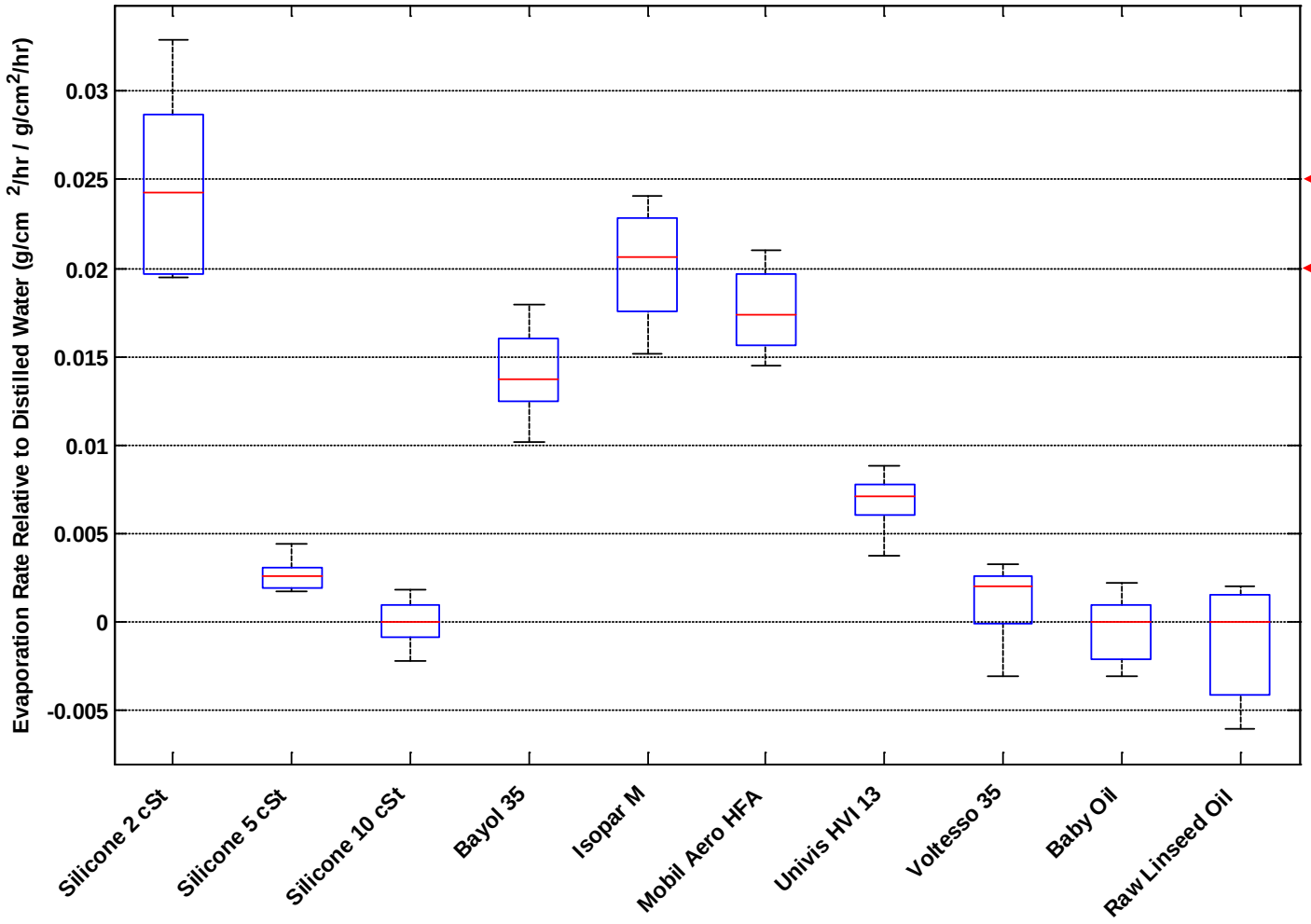
PG – Propylene Glycol USP FCC
M – Methanol ACS

Evaporation (Lab Experiment)



Box plot:
Red line: Median
Box: 25 % & 75 %
Whiskers: Min & Max

Evaporation (Lab Experiment)



~40x slower than water

~50x slower than water

Box plot:
Red line: Median
Box: 25 % & 75 %
Whiskers: Min & Max

Isopar M Oil Performance Summary

Purpose	Parameter	Evaluation Criteria	Performance
Oil floats on liquid	Density	ρ < Anti-freeze & precip mix Low density is best	ρ= 0.82 g/cm^3 @ -40 °C (ASTM D 7042) Lower than other oil types tested
Oil enables light snow and water penetration	Viscosity & Surface Tension	Low viscosity is best Low surface tension is best	μ = 100.9 MPa·s @ -40 °C (ASTM D 7042) Lower viscosity than other oil types tested
Oil does not evaporate	Evaporation rate	Low evaporation is best	~ 50x slower evaporation than water
Oil does not mix with water	Water solubility	Immiscible in water	Immiscible in water
Oil does not react with bucket or liquid mixture	Non-reactive	Must not react with plastic bucket & anti-freeze solution	Non-reactive with plastic, methanol, & propylene glycol
Oil is not harmful to human exposure	Toxicity	Low toxicity for reduced health risks	HMIS Hazard ID: Health 1, Flammability 1, Reactivity 1
Oil presence and condition is clearly visible	Colour	Visible to show oil presence, coverage and elevation within bucket	Colourless. Dye can be added to achieve desired color.
Oil does not attract animals & insects	Odor	Limited odor to not attract animals	Odorless

Conclusions

- Bayol 35 & Isopar M oil provide the best combination of low density and low viscosity for use in operations (compared with the other oils tested)
- The addition of oil for all gauges using volatile anti-freeze solutions such as 40 % Propylene Glycol / 60 % Methanol, would ensure the performance of the anti-freeze solution.
- The hygroscopic propylene glycol and water antifreeze solution exhibits high viscosity and density at low temperatures, which may lead to stratification and slush and ice accumulation at the surface.

Precipitation Gauge Oil Comparison

Thank-you

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