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Antifreeze and Oil Assessment

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Automatic precipitation gauges used to measure solid precipitation in cold climates typically use an initial charge of antifreeze and oil (Wolff 2012). The antifreeze solution is used to prevent freezing of the bucket mixture as precipitation accumulates within the bucket. The oil is used to reduce evaporation of the antifreeze and water mixture, particularly for volatile antifreeze mixtures. Freezing within the precipitation bucket can lead to damage of the bucket as well as inaccurate measurements and difficulty draining the gauge. Slush and ice and slush formation above the antifreeze can lead to unwanted evaporation and or sublimation loss of the exposed slush or ice.

The antifreeze and oil mixture should achieve the following performance characteristics:

- Enable penetration of light snow and water, even during cold temperatures;
- Encourage self-mixing and dissolve solid precipitation within the bucket; and
- Prevent freezing and slush formation of the antifreeze mixture.

Proper removal and disposal of the oil and antifreeze mixture is recommended for most mixtures to reduce environmental impact.

1.0 Precipitation Gauge Oil

In order to reduce evaporation within the bucket, the precipitation gauge oil must float on the antifreeze mixture with sufficient thickness to limit evaporation of the antifreeze mixture. Table 1 highlights the desirable oil characteristics for the precipitation gauge oil.

Table 1. Desirable precipitation gauge oil characteristics

Purpose	Parameter	Evaluation Criteria
Oil floats on antifreeze mixture	Density	Low density is best Less dense than antifreeze mixture and solid precipitation
Oil enables light snow and water penetration	Viscosity / surface tension	Low viscosity and surface tension is best
Oil does not evaporate	Evaporation	Low evaporation is best (Low vapor pressure, high molecular mass and higher boiling point generally correspond to lower evaporation)
Oil does not mix with water	Water solubility	Immiscible in water
Oil does not react with precipitation gauge bucket or antifreeze mixture	Non-reactive	Must not react with plastic precipitation gauge bucket and antifreeze mixture
Oil is not harmful to human exposure and the environment	Toxicity	Low toxicity for reduced health and environmental risks
Oil presence & condition is clearly visible	Colour	Visible to show oil presence and coverage above antifreeze mixture
Oil does not attract animals & insects	Odor	Limited odor to not attract animals

The density of a number of oil and antifreeze samples at 0 °C, -20 °C and -40 °C temperatures are shown in Figure 1. The descriptions of these samples are provided in Table 2. For reference, the density of hexagonal ice is 0.9167 g/cm^3 at 0 °C (2004) and the density of supercooled water is 0.9998 g/cm^3 at 0 °C (2004). The density of oil should be less than the density of ice to encourage solid precipitation to pass through the oil. The viscosity of the oil and antifreeze samples is shown in Figure 2. To put these viscosity values in perspective, the viscosity of water is 1.793 mPa·s at 0 °C and 100 kPa (2004) and the viscosity of honey is roughly 2000 mPa·s (2014). A low viscosity is desirable to allow solid precipitation to easily pass through the oil. From Figure 2 it is apparent that the oil viscosity is highly temperature dependent, with high viscosity values at low temperatures.

The Isoparaffinic Hydrocarbon oils (e.g. ExxonMobil, Isopar M) demonstrate the best combination of low density and viscosity of all of the oils tested. This oil type has been used in operations and is recommended for consideration for field use. Note that Bayol 35 production has been discontinued by Imperial Oil.

Table 2. Oil and antifreeze sample descriptions (Hoover et al. 2014)

Sample	Description
Clearco silicone oil, 2 cSt	Silicone oil
Clearco silicone oil, 5 cSt	Silicone oil
Clearco silicone oil, 10 cSt	Silicone oil
Bayol 35	Isoparaffinic Hydrocarbon
Isopar M	Isoparaffinic Hydrocarbon
Mobil aero HFA	Hydraulic fluid
Univis HVI 13	Hydraulic fluid
Voltesso 35	Electrical insulating oil
Baby oil	Mineral oil base
Raw linseed oil	Raw linseed oil
40% PG / 60% M	Antifreeze charge, empty bucket
16% PG / 24% M / 60% DW	Diluted -20 °C antifreeze mixture, full bucket
22% PG / 33% M / 45% DW	Diluted -40 °C antifreeze mixture, full bucket
75% PG / 25% DW	Antifreeze alternative charge, empty bucket
25% PG / 75% DW	Diluted antifreeze alternative, full bucket

PG – Propylene Glycol USP FCC, M – Methanol ACS, DW – Distilled Water ACS

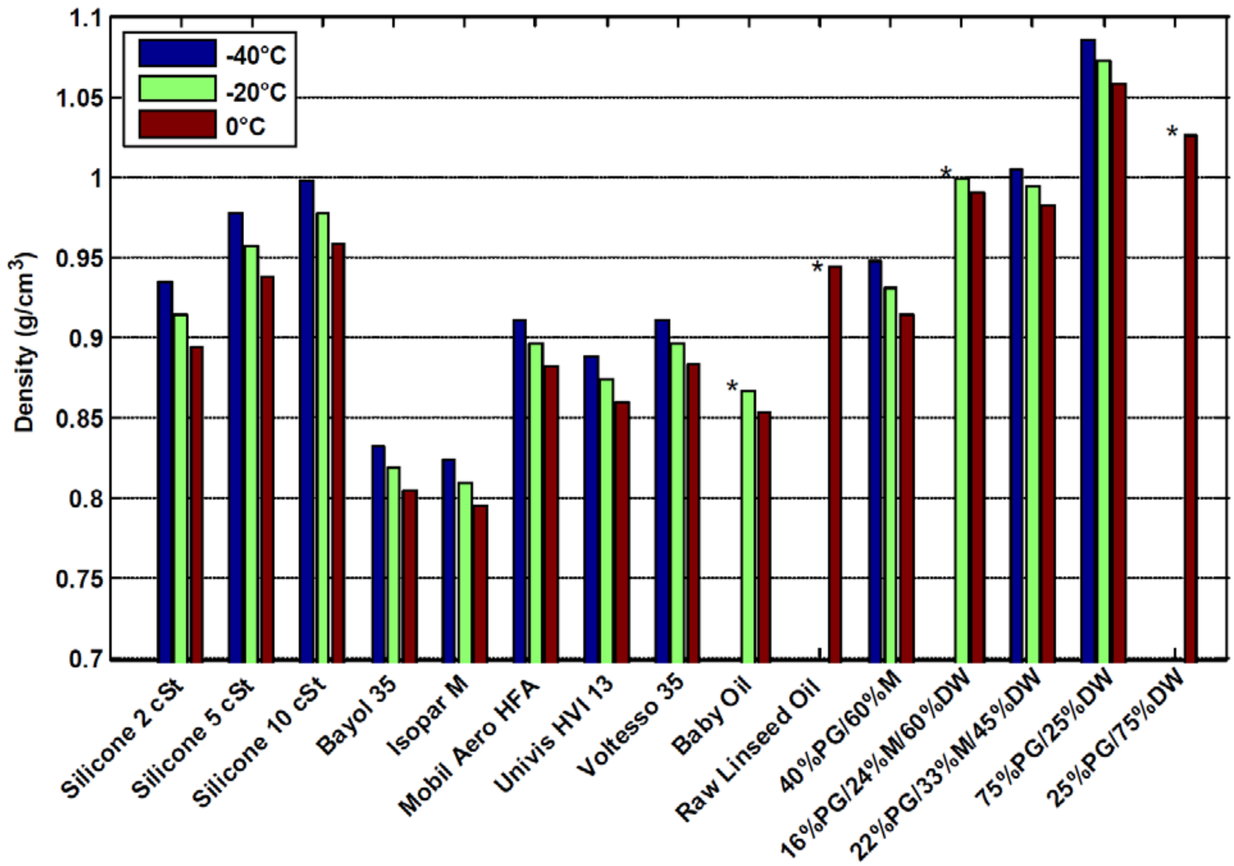

Figure 1. Density of oil and antifreeze samples by ASTM D 7042 Stabinger viscometer test method. Asterisks highlight samples where the product was too viscous or solid to obtain a low temperature result. (Hoover et al. 2014)

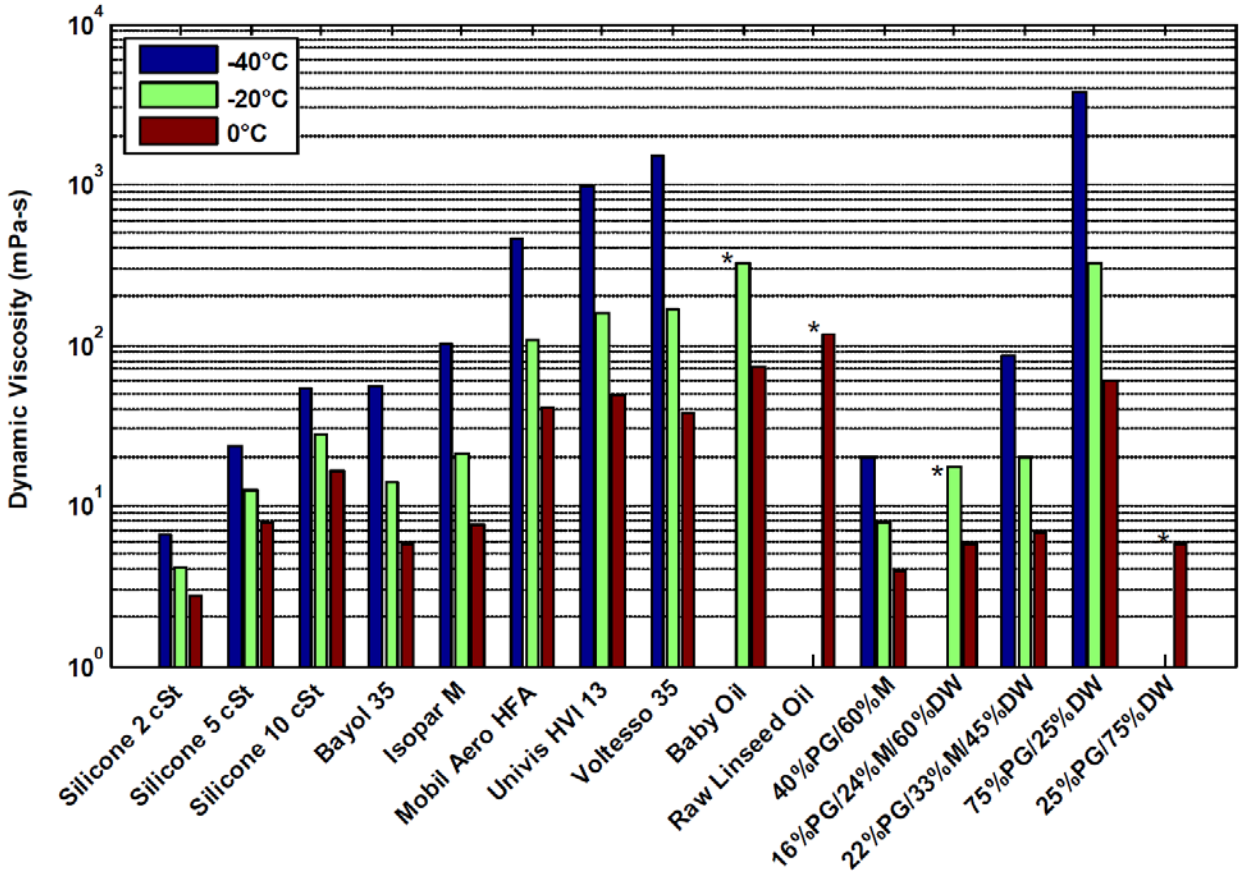

Figure 2. Dynamic viscosity of oil and antifreeze samples by ASTM D 7042 Stabinger viscometer test method. Asterisks highlight samples where the product was too viscous or solid to obtain a low temperature result. (Hoover et al. 2014)

2.0 Precipitation Gauge Antifreeze

A summary of desired antifreeze characteristics are provided in Table 3. The diluted antifreeze mixture with the anti-freeze charge and precipitation must prevent freezing and ice or slush accumulation above the antifreeze mixture. The density of the antifreeze mixture should be lower than the density of water to encourage self-mixing of precipitation within the antifreeze mixture (Mayo 1971). The viscosity of the antifreeze mixture should also be low to encourage rapid mixing within the bucket. This will limit stratification and slush or ice accumulation above the antifreeze mixture.

Table 3. Desirable antifreeze characteristics

Purpose	Parameter	Evaluation Criteria
Antifreeze and precipitation mixture will not freeze	Freezing point	No slush or ice formation in anti-freeze mixture to prevent damage and evaporation / sublimation
Antifreeze mixture rapidly mixes with solid precipitation even at cold temperatures	Density / viscosity	Low density and viscosity is best Less dense than water to encourage mixing
Antifreeze does not evaporate (if oil is not added)	Volatility	Low volatility is best
Antifreeze mixes with water	Water solubility	Soluble in water
Antifreeze does not react with precipitation gauge bucket or oil mixture	Non-reactive	Must not react with plastic precipitation gauge bucket and oil mixture
Antifreeze is not harmful to human exposure and the environment	Toxicity	Low toxicity for reduced health and environmental risks
Antifreeze does not attract animals & insects	Odor	Limited odor to not attract animals

As shown in Figure 1, the density of the propylene glycol and water antifreeze solution is denser than water. This will encourage stratification and freezing of precipitation on top of the propylene glycol antifreeze mixture (McSaveney 1979). Freezing results have been observed using a Powercool DC 924-PXL antifreeze mixture as well (Lejeune et al. 2014). Many users use an antifreeze mixture of Methanol combined with Ethylene Glycol or Propylene Glycol. This type of antifreeze mixture can achieve a density less than water, which will encourage self-mixing of precipitation within the bucket (Mayo 1971). This anti-freeze solution is highly volatile and should be used with oil to prevent the loss of methanol from the anti-freeze mixture (Hoover et al. 2014).

A common antifreeze mixture is 40 % Propylene Glycol and 60 % Methanol with the desired initial charge volume to prevent freezing. The freezing point results for this antifreeze mixture are shown in Figure 3 by Smith and Watson (Smith and Watson 2014) for different gauge charge quantities. For example, a 6.0 L antifreeze charge will remain liquid with 6.0 L of precipitation (300 mm) at approximately -40 °C. A 4.0 L antifreeze charge will remain liquid at approximately -20 °C with 8.0 L of precipitation (400 mm). For additional information on anti-freeze charge quantities, readers are directed to the work of Smith and Watson (Smith and Watson 2014), Mayo (Mayo 1971), and the Geonor manual (Geonor 2010).

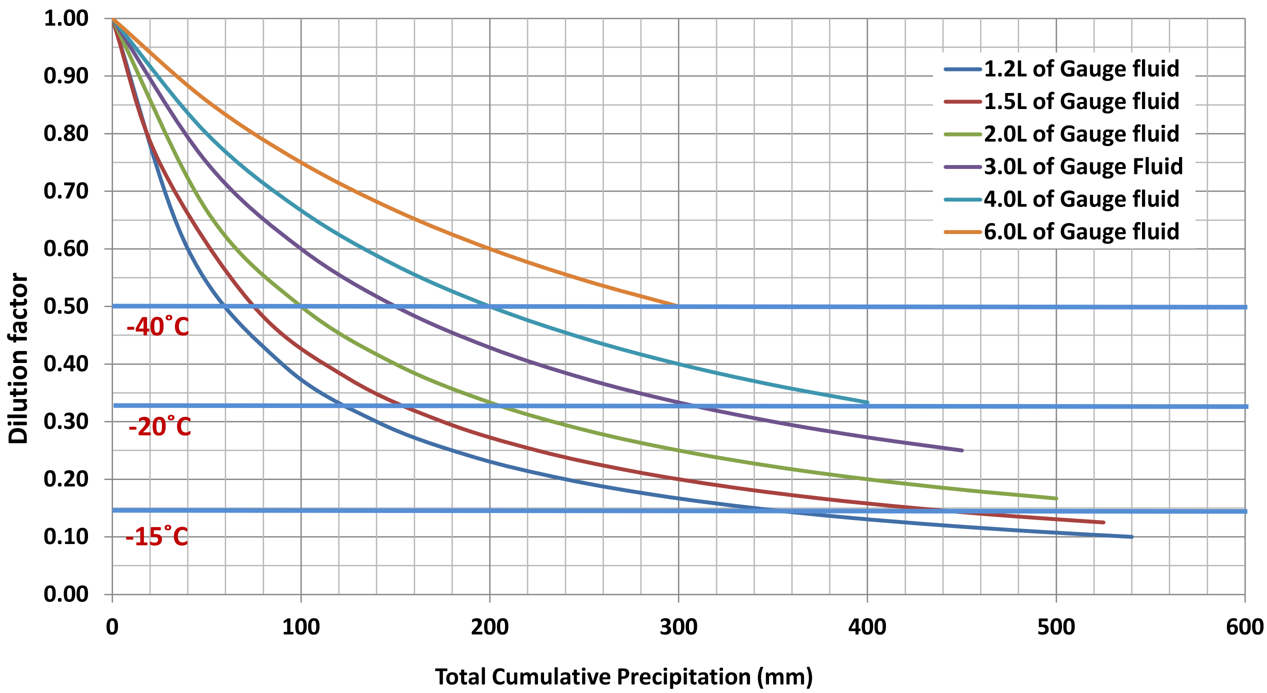

Figure 3. Antifreeze freezing points (approximate) based on initial antifreeze charge and dilution due to the addition of precipitation. The antifreeze charge is 60 % Methanol and 40 % Propylene Glycol. The charge volume corresponds to a 600 mm capacity gauge with a 200 cm^2 orifice. (Smith and Watson 2014)

References

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