EFFECTS OF TEMPERATURE ON THE PROPYLENE GLYCOL/ETHANOL (PGE) SOLUTIONS USED IN MOUNTAIN PRECIPITATION GAUGES WITH THE POLYSORBATE EMULSIFIER ADDITIVE

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ABSTRACT

The object of this study was to verify the earlier test to determine the temperatures at which various dilutions of equal proportions of propylene glycol and ethanol (PGE) with the addition of an emulsifier Polysorbate 20 (brand name Tween 20) would freeze. Earlier tests were conducted with straight mixture of 50 percent by volume of propylene glycol and 50 percent ethanol by volume without an emulsifier. This repeat study was to determine if the Tween 20 emulsifier had an effect on the freezing properties and specific gravity as tested in the earlier experiment. This experiment was also to observe if the 3 percent by volume Tween 20 would keep the 48.5 percent by volume propylene glycol and 48.5 percent by volume ethanol solution from separating at high temperatures which could occur at the remote site locations. (KEYWORDS: SNOTEL, propylene glycol/ ethanol (PGE), precipitation gauge, NRCS)

INTRODUCTION

The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) and others have developed methods to measure precipitation and snow fall events in remote mountainous locations. A common method is to capture and entire season of precipitation with a storage precipitation gauge as is the case at the NRCS SNOTEL stations (Figure 1.). In order to function properly at these remote locations were freezing conditions exist throughout much of the year, a storage gauge must have an initial charge of fluid which will prevent freezing and melt snow captured in the gauge and still mimic the specific properties of water at freezing conditions (USDA 1982). Over the years the products which have be utilized have ranged from adding calcium chloride salts to the fluid in the precipitation gauges, to using automotive style antifreezes to methanol based antifreezes. All these had drawbacks in that the mixture was corrosive to the gauge itself or that the product had environmental concerns of toxicity. Earlier research indicates that propylene glycol and ethanol (PGE) mixed in equal portions (McGurk, 1992) is appropriate mixture to replace other antifreeze solutions without the toxicity (Dow, 1981) or corrosive issues. This product still has the molecular mixing action, however when left still for long periods, (for instance inside of a precipitation gauge with no measurable precipitation activity), there are claims that the product tended to separate into layers of the principle ingredients. When this happened, the mineral oil which is used to prevent evaporation for these unattended gauges, which normally “floats” on top of the mixture of PGE would settle through the alcohol layer and thus allow evaporation. To counter this occurrence of separation, an emulsifier or binding agent is used to keep the products from separating.

METHODS

The purpose of this project was to verify that the binding agent, in this case Polysorbate 20, of which Tween 20 is a commercial trade name (Wikipedia, 2012), does in fact keep the product from separating, and if there is any change of the specific gravity or freezing properties with the use of the emulsifier. The focus of this study was to review the dilutions of the PGE in NRCS SNOTEL storage precipitation gauges, however, the results can be carried over to other styles of precipitation gauges or even snow pillows, if this same product is also utilized to fill them.

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Figure 1. NRCS SNOTEL Storage precipitation gauges containing PGE and cumulative precipitation.

To conduct this test, various concentrations of the recommended equal mixture of PGE were diluted with water to test response of the fluid thorough a range of temperatures, as would be experienced in the field by the fluid inside a storage precipitation gauge during a season of capturing rainfall.

Three gallons of the PGE were obtained from the NRCS Snow Survey Office in Portland, Oregon. The product from the manufacture was 48.5 percent by volume propylene glycol, 48.5 percent ethanol by volume and 3 percent Tween 20 by volume. The product was dyed red to help view fluid levels in operational use. Dilution factors ranging from pure PGE to pure water were calculated based on a final volume for testing of 400 ml. The samples were placed into 500 ml clear plastic water bottles (Figure 2), which could be capped with screw on caps. The clear plastic allowed the visual tests to be observed.   Table 1 reflects the various dilutions tested in this experiment.   For testing purposes, the PGE dilution rations of 3:1, 15:1 and pure water were replicated.

Figure 2. PGE fluid in dilution samples for testing.

DILUTION FACTS					PGE Dilution	Water Dilution
PGE (ml)	WATER(ml)	Total(ml)	% PGE	% water	ratio	Ratio
400	0	400	100	0	0.00	--.--
375	25	400	93.75	6.25	0.07	15.00
300	100	400	75	25	0.33	3.00
200	200	400	50	50	1.00	1.00
100	300	400	25	75	3.00	0.33
50	350	400	12.5	87.5	7.00	0.14
25	375	400	6.25	93.75	15.00	0.07
0	400	400	0	100	--.--	0.00

Table 1. Dilution factors

With the inclusion of the replicated samples, twelve samples for testing were developed.   The tests which would be conducted on the various samples in the clear bottles were 1): observe the samples over a range of temperatures for signs of fluid separation, 2): observe if the sample froze at the cooler temperatures and 3): measure the specific gravity (SG) of the solutions at the various temperatures.   An additional test was conducted on the 1:1 dilution ratio to see if a layer of mineral oil poured into the solution would sink and thus allow evaporation at an extreme temperature which might be encountered at the remote locations.

An environmental chamber operated by the NRCS Electronics Maintenance Facility (EMF) in Portland was utilized to conduct the tests. The chamber could accommodate the entire set of samples at one time and the temperatures could be controlled precisely. The test procedure would be to bring all 12 samples to an equilibrium temperature, starting about 15.5 degrees C (60 degrees F) and going up to 43.3 degrees C (110 degrees F).   At pre-selected temperature thresholds, the samples would be removed from the chamber, one at a time, observed if the fluid had separated, then the liquid sample would then be poured into a graduated cylinder and the specific gravity taken with a hydrometer. The fluid temperatures would be confirmed with a “mercury in glass” thermometer (Figure 3.). After all the samples were tested, the chamber was then lowered to the next temperature. Conversely, also beginning at 15.5C, the chamber was to be cooled to -17.8 degrees C (0 degrees F) and again at selected temperatures, the samples would be observed for fluid separation, signs of freezing, and the specific gravity measurement of the liquid samples was to be taken.

Time in the environmental chamber was scheduled around NRCS work load at EMF where the chamber is utilized to test pressure transducers at various temperatures. Staff from the Oregon Snow Survey office began the test on February 14, 2012. Beginning at room temperature, approximately 5 hours were required to bring the samples to the desired 43.3 C temperature and the specific gravity measured. One day would be utilized for the warm temperature tests, and another day would be utilized for the cool temperature tests. Unfortunately, the chamber malfunctioned and temperatures below 1.7C (35F) were not able to be reached. Once the chamber was back on-line, NRCS activities took priority for the time, and repeat tests were not able to be rescheduled.

At warm temperatures, it was discovered that the hydrometer went to the bottom of the graduated cylinder for the highest percentages of PGE mixture, thus not allowing a correct reading of the specific gravity. With the environmental chamber no longer available, a substitute test was developed to re-test the specific gravity at the warm temperature. A warm water bath was developed to bring the solutions to a stable 43.3C (110F), which would allow the time necessary to conduct the specific gravity readings. The specific gravity tests were then completed using a smaller graduated cylinder for the hydrometer. In addition, the -17.8C (“0 degree”) test was repeated in a freezer set to -18.3C. This extended test allowed the samples to spend a week at this temperature.

As a final test, a mixture of the 50% PGE/Tween 20 solution and 50 % water was heated in a water bath. In addition to the PGE/Water mixture, a ½ inch layer of mineral oil was added to mimic the oil level used in the storage precipitation gauges. This visual test was to insure that at warm temperatures, the fluid with the emulsifier would not separate and allow the oil to sink, and the allow fluid to evaporate. The fluid was brought to 54.4C (130F) F for 2 hours.

RESULTS

At all temperatures, there were no observed cases of the fluid separating into layers or becoming stratified. This also includes the 54.4C test on the 1:1 dilution test, where it was observer that the oil did not settle through the fluid, and the volume in the graduated cylinder remained the same throughout the test. As expected, all dilutions remained a liquid until the freezing temperatures were encountered. At -18.3C, the 3:1 dilution of PGE turned to slush. There was still liquid, but there were ice crystals in the solution. Dilutions of PGE 7:1 and greater were frozen solid after a week at -18.3C.

From the tests, it was observed that the specific gravity of PGE solution approaches that of water at the larger dilution ratios. This is true across all temperature ranges in this experiment. Also as the temperatures of the solutions cool, the specific gravity also approaches that of water. At cooler temperatures, there is little difference between the specific gravity of the fluids diluted greater than 7:1 and that of the pure water samples.

One of the observations noted during the tests was the formation of bubbles when solutions containing the Tween 20 were poured in to the graduated cylinder for conducting the specific gravity tests. This foaming has also been observed in field conditions, when the precipitation gauges are drained as part of the annual maintenance.

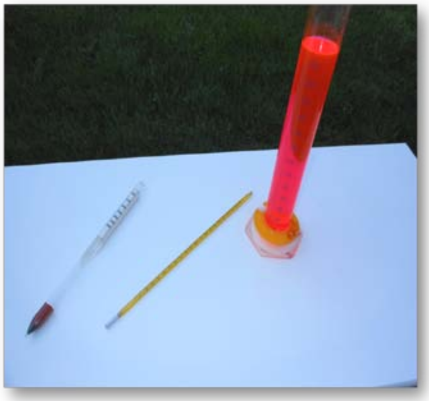

Figure 3. Thermometer and hydrometer for measuring specific gravity and temperature of PGE samples.

The bubbles persist for some time, again making reading of the hydrometer somewhat problematic. Additionally, in a glass graduated cylinder, and using a glass hydrometer, there is trend for the hydrometer to want to “cling” to the side of the graduated cylinder, thus making a meniscus considerably higher than actual. This phenomenon was most noticeable when the 3:1 dilution slush was poured into the cylinder to have a specific gravity measurement made. The large layer of bubbles which formed and which were very slow to dissipate made a good hydrometer reading difficult to replicate. Consequently, those reading should be discounted. The results of the tests are presented in Table 2.

Table 2. 2012 PGE Test Results of Specific Gravity, Separation and Freezing

Sample Number.	PGE/H_2O Ratio	Specific Gravity At 43.3^oC	Specific Gravity At 32.2^oC	Specific Gravity At 18.9^oC	Specific Gravity At 5.0^oC	Specific Gravity At 1.7^oC	Specific Gravity At - 18.3^oC
1	400-0	0.905	0.925	0.935	0.950	0.946	0.950
2	375-25	0.935	0.935	0.944	0.960	0.954	0.960
3	300-100	0.945	0.956	0.966	0.973	0.975	0.975
4	200-200	0.967	0.977	0.986	0.983	0.995	1.000
5	100-300	0.987	0.995	0.999	0.987	foam	0.980*
6	100-300	0.983	0.996	0.996	0.987	foam	0.955*
7	50-350	0.988	0.996	0.999	0.990	1.004	***Frozen***
8	50-350	0.988	0.994	0.997	0.990	0.999	***Frozen***
9	25-375	0.990	0.995	0.997	0.995	0.999	***Frozen***
10	25-375	0.991	0.996	0.998	0.995	0.999	***Frozen***
11	0-400	0.993	0.996	0.998	1.000	0.999	***Frozen***
12	0-400	0.993	0.996	0.998	1.000	0.999	***Frozen***

❖ ** Note : sample 5 and 6 at -18.3C were also very foamy, results questionable*

DISCUSSION AND CONCLUSIONS

As was apparent in all the tests, the PGE with a polysorbate 20 emulsifier will not form layers at the temperatures tested. Additionally, even at 54.4C (130 F), the solution did not form layers, and the oil layer remained “floating” on the top of the solution.

The addition of the polysorbate 20 (as Tween 20) did not affect the freezing temperatures of the various dilutions of the PGE as the temperatures are similar to the results as presented in previous research. These results indicate that PGE with the emulsifier will work adequately as a fluid in storage precipitation gauges at remote locations. The PGE/Emulsifier does provide freezing protection, however, as the initial charge of the PGE/Emulsifier becomes more diluted with precipitation (as would happen as the precipitation season progresses and more water is captured in the gauge), the amount of freeze protection diminishes. This becomes especially critical if there has been large amount of precipitation early in the water year, followed with a minimal amount of snow, but with cold temperatures. Once the PGE fluid falls below a 3:1 ratio, freezing, in the formation of slush begins as the temperatures of the fluid approach -18.3C. The gauge, plumbing systems and pressure sensing devices could freeze, rendering them useless for collecting data, and possibly destroying the equipment as well. However, typically, as the snowpack builds in the early season, the snowpack tends to bury the lower portions of the precipitation gauge, thus, insulating the fluid in the precipitation gauge from extremely cold temperatures. As long as the temperature of the fluid stays near freezing, dilutions of 7:1 will still proved adequate freeze protection.

The results from this experiment also demonstrate that the PGE with the Tween 20 does not affect the specific gravity of the solution. The data for this test closely replicated the results from McGurk (1992). Although as noted in prior experiments, and as observed in this experiment, specific gravity measurements are sometimes problematic due to the difficulties in reading the hydrometer especially at cooler temperatures, as well as the foaming tendency which the Polysorbate 20 emulsifier produces on the fluids when poured, especially when slushy. However, with care, specific gravity measurements can be obtained. Also as noted in the results, that as the dilutions of the PGE/emulsifier solution become greater, the specific gravity approaches that of the water samples. This is becomes much more noticeable as dilutions approach 7:1.

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REFERENCES

1). US Department of Agriculture (1982) National Engineering Handbook, Section 22, Circular 1, Washington, D.C.

2). McGurk, B. J. 1992. Propylene Glycol and Ethanol as a Replacement Antifreeze for Precipitation Gauges: Dilution, Disposal, and Safety. 60th Proceedings of the Western Snow Conference, p. 56-65.

3). The Dow Chemical Company, A Guide to Glycols 1981 Form No. 116-1035-82

4). Wikipedia.org/wiki/ Polysorbate_20 accessed 2/14/2012