MEASUREMENTS OF VISCOSITY AND DENSITY OF ETHYLENE GLYCOL AND PROPYLENE GLYCOL SOLUTIONS

Fucheng Li

Polar Ice Coring Office
University of Alaska Fairbanks
Fairbanks, AK 99775-1710, USA

PICO
TR-93-5

August 1993

PICO is operated by the University of Alaska Fairbanks under contract to the National Science Foundation, Division of Polar Programs

MEASUREMENTS OF VISCOSITY AND DENSITY OF ETHYLENE GLYCOL AND PROPYLENE GLYCOL SOLUTIONS

INTRODUCTION

Viscosity and density measurements were carried out on solutions of ethylene glycol and propylene glycol.

The object of these measurements was to determine viscosity and density changes with respect to temperatures for two types of glycol solutions. These solutions may be considered as possible densifiers in ice boreholes for relief of a stuck ice core drill. Two characteristics of the densifiers are favorable to this purpose: 1) high density; and 2) low viscosity at low temperatures from 0°C to -50°C.

EQUIPMENT

The temperature of the glycol solution was changed and controlled with a 2095 Bath and Circulator in the Mineral Lab and with a freezer in the PICO Workshop. Both pieces of equipment can attain a low temperature of about -25°C. Density was measured with an electronic balance with a digital display and a resolution to the second decimal place in grams. For viscosity, a Lab-Line Instruments, Inc. Viscometer, Model 4537 (see Fig. 1, Ref. 1) was used. It has digital display in centipoise. The accuracy and the resolution are $\pm 1\%$ of full scale.

SAMPLES

The sample of ethylene glycol solution is a mixture of pure ethylene glycol and water in a ratio of 7:3 by volume. It has been shown by other experiments (Ref. 2) that the 70% ratio of the ethylene glycol solution gives the lowest freezing temperature and viscosity. Pure ethylene glycol was obtained for this investigation. For the sample of propylene glycol solution, the mixture ratio was 6:4 (P.G.:water) by

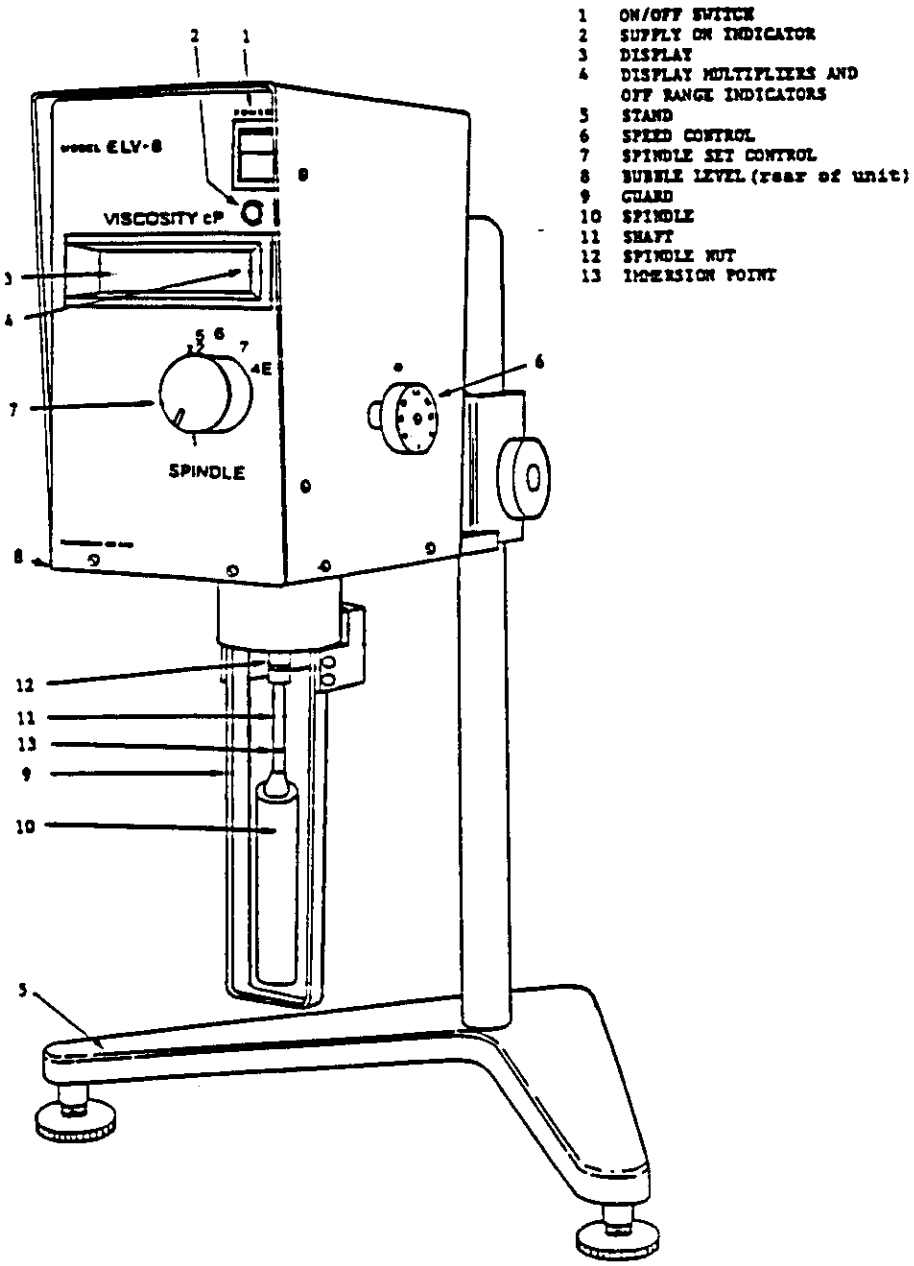

Figure 1. Sketch of the Viscometer Model 4537.

volume, which is recommended by the manufacturer for the best performance as an antifreeze.

METHODS

Approximately 800 ml of each sample was kept in a cooler (Bath and Circulator) for at least 24 hours before measurement at each controlled temperature. The viscometer spindle and guard were also kept in the same cup to maintain uniform temperature. At the time of a measurment, the viscometer was set up above the cooler, so that the samples were still in the cooler to avoid significant temperature disturbance. The samples were kept in the freezer for 24 hours at a given temperature before removing them for measurement. Because of restrictions in available conditions, the measurements were carried out in the workshop at a temperature of about 15°C. The samples were measured immediately after removal from the freezer for viscosity and density. This measurement takestwo minutes at most. It was hoped that the temperature disturbance to the samples had little effect on the observed results to our purpose.

On measuring viscosity, the Number 1 spindle was used during all measurements. The rotation speed was 60 RPM and 30 RPM, respectively, depending on viscosity measured. The Number 1 spindle has a small measuring range of 0 to 100 cp at 60 RPM and 0 to 200 cp at 30 RPM. Accuracies are ± 1 cp at 60 RPM and ± 2 cp at 30 RPM.

RESULTS

The results of the viscosity and density of ethylene glycol and propylene glycol solution samples are listed in Table 1 and Table 2, as well as in Figure 2 and Figure 3.

Table 1. Viscosity (in *cp*)

Temp. (°C)	14.5	7	0	-5	-10	-16	-18	-20	-24.5
E.G.	10	14	19		27	41	40	38	
P.G.	13	20	30	38		103		107	131

E.G. - Ethylene Glycol, 70%; P.G. - Propylene Glycol, 60%

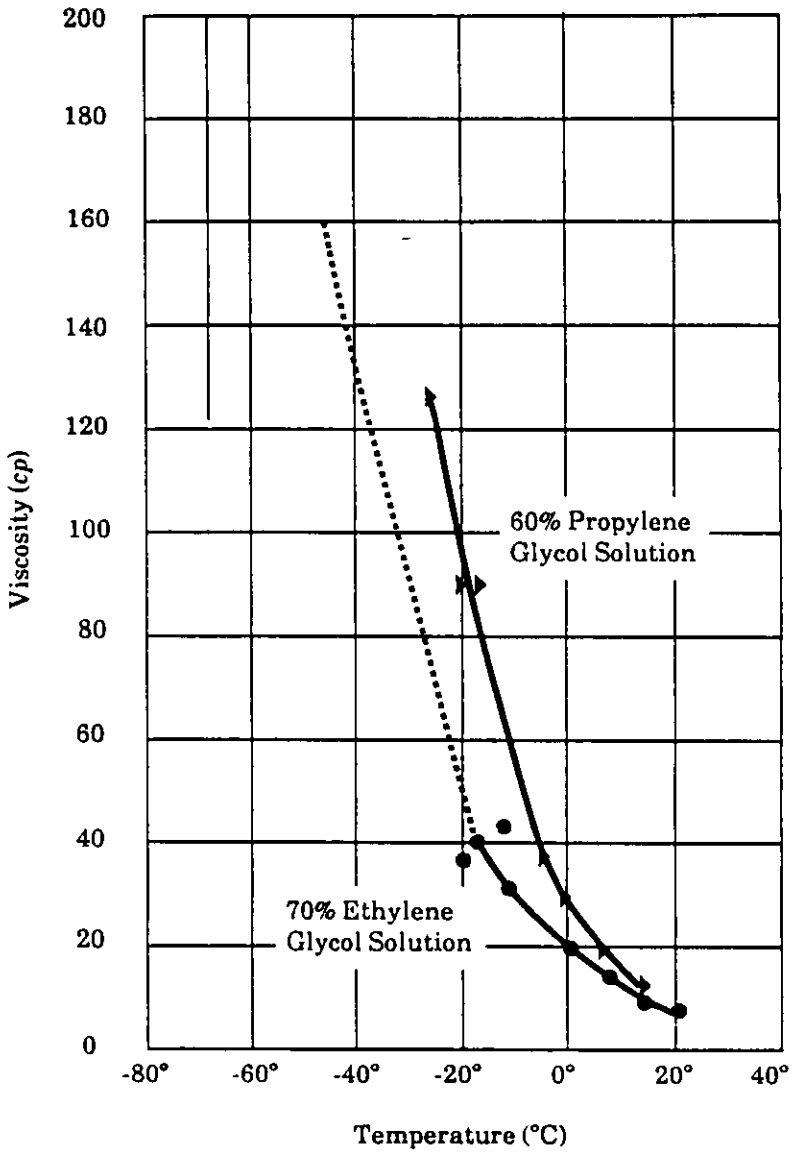

Figure 2. Vicoscity vs. Temperature. ● – 70% Ethylene Glycol solution; ▸ – 60% Propylene Glycol solution. It is difficult to work with ethylene glycol solution at -60°C.

Table 2. Density (in kg/m^3).

Temp. (°C)	27	7	0	-16	-18	-20	-24.5
E.G.	1079.3	1091.7	1096.0	1099.2	1090.0	1095.6	
P.G.	1035.0	1047.3	1051.1	1059.9		1059.2	1058.1

E.G. - Ethylene Glycol, 70%; P.G. - Propylene Glycol, 60%

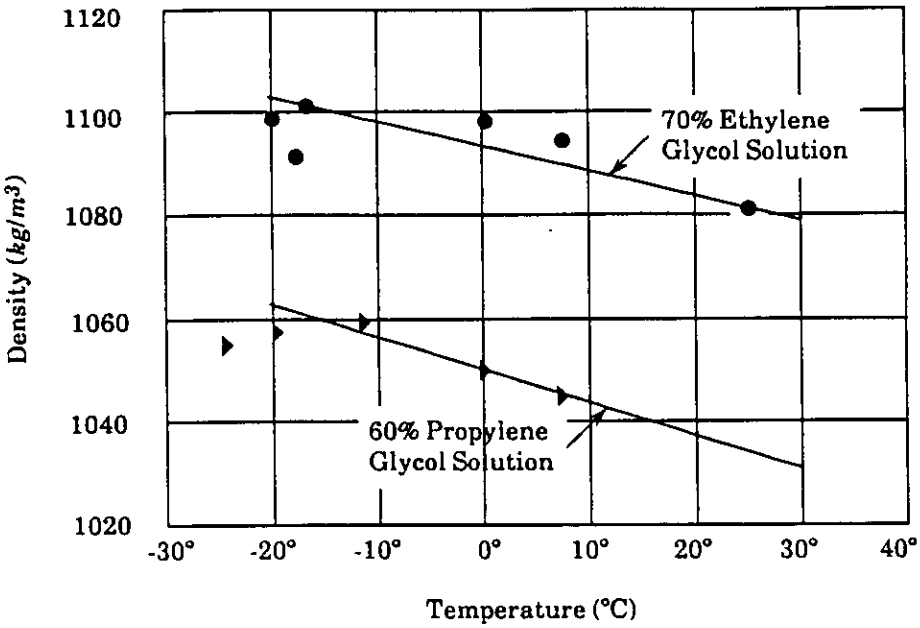

Figure 3. Density vs. temperature. ● – 70% ethylene glycol solution; and ▸ – 60% propylene glycol solution

In Table 2, there are some obvious anomalous density data for both ethylene glycol and propylene glycol solutions at low temperatures of around -20°C. These deviations are mainly measurement errors. At these low temperatures, the temperature difference between the samples and the surrounding environment increases, and an increased temperature disturbance to the samples is expected, which in turn, affects the measured results. This kind of error can also be found in the viscosity data of the ethylene glycol solution as shown in Figue 2. In the numerical interpolation, therefore, these data were abandoned. For viscosity of the ethylene glycol solution shown in Figure 2, an extended curve beyond the measurement range is also assumed for practical use based on the trend of viscosity. For density a linear regression was employed and the results are listed below:

1. For ethylene glycol (70%): $\rho(kg/m3) = 1093.68 - 0.47T(°C)$,
2. For propylene glycol (60%):$\rho(kg/m3) = 1050.95 - 0.58T(°C)$.

CONCLUSIONS

Measurements of viscosity and density were conducted on an ethylene glycol solution (70% volume) and a propylene glycol solution (60% volume). The viscosity of both solutions increases quickly as temperature decreases. For the ethylene glycol solution, the viscosity changes from about 10 cp at 20°C to about 30 cp at -10°C and decreases sharply as the temperature continues to decrease; whereas the viscosity of the propylene glycol solution decreases from about 10 cp at 20°C to about 70 cp at -10°C and decreases even more sharply as the temperature decreases from -10°C.

The density of the ethylene glycol solution and the propylene glycol solution increases as the temperature decreases, but this change is not a significant process compared to the density values of the two solutions themselves. For the measurement range from -16°C to 27°C, the relative change, $\Delta\rho/\rho$, is less than 2.5%, where $\Delta\rho$ means the maximum density difference and ρ the density at 27°C.

In general, the 70% ethylene glycol solution has a higher density and a lower viscosity, which are favorable for our purpose, compared to the 60% propylene glycol solution.

ACKNOWLEDGMENTS

The measurements described herein were supported by the UAF Polar Ice Coring Office through the Engineering Division. Thanks are given to Mr. Kerry Stanford, Manager of the Engineering Division, for his support and encouragement on this project and to Mr. Jesse Collins and Mr. Terry Gacke for their supply of materials.

REFERENCES

1. Operation Manual of Lab-Line Viscometers, Lab-Line Instruments, Inc., April, 1992.
2. Hansen, B. L. "Deep Core Drilling in the East Antarctic Ice Shelf, a Prospectus." *In* J. F. Splettstoesser (ed.) *Ice Core Drilling*, p 29-36. 1974.