Effect of Temperature on Dielectric Liquids with and Without Nano Particles

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Abstract -Temperature plays a crucial role in determining the dielectric properties of liquids, which are fundamental in various electrical engineering applications. In this project, we investigate the effects of temperature on dielectric liquids, both with and without the addition of nanoparticles, using redwood experimental setup and simulation tools such as Mathematica 13.0 and Origin software. Conventional dielectric liquids exhibit temperature-dependent variations in viscosity, impacting their insulation performance. However, the introduction of nanoparticles into these liquids alters their behaviour significantly. Nanoparticles dispersed within the liquid enhance thermal conductivity, particularly at different temperatures. Simulations in Mathematica 13.0 and Origin software provide valuable insights into the behaviour of dielectric liquids. By integrating experimental results with simulation modelling, a comprehensive understanding of the conductivity mechanisms is achieved. This results-based approach enhances knowledge of dielectric behaviour and the relation between viscosity and temperature.

***Key Words*:** Dielectric liquids, Viscosity.

1.INTRODUCTION

Dielectric liquids, such as sun drop oil, mineral oil and other certain solvents, exhibit electrical conductivity due to the presence of ions or impurities. In this project sun drop oil, and mineral oil are used as dielectric liquids. Introducing nanoparticles into dielectric liquids can modify these temperature-dependent characteristics. Nanoparticles, such as metal oxides or carbon-based materials, when dispersed within the liquid matrix, can enhance dielectric strength and thermal conductivity. At elevated temperatures, the nanoparticles act as nucleation sites for gas bubbles, preventing the formation of large voids and mitigating partial discharge phenomena. This effect is particularly. crucial in high-voltage applications, where maintaining insulation integrity is paramount. Furthermore, the addition of nanoparticles can also influence the dielectric relaxation behavior of the liquid system, altering its response to alternating electric fields. The interfacial polarization of nanoparticles with the surrounding liquid molecules can enhance permittivity and reduce losses, leading to improved electrical performance across a range of temperatures. Various methods are employed to measure the temperature effect of dielectric liquids accurately. In this project red wood laboratory equipment is used to relate how temperatures vary over viscosity and conductivity and also mathematica 13.0 software used for simulate the behaviour of dielectric liquids.

2. EXPERIMENT

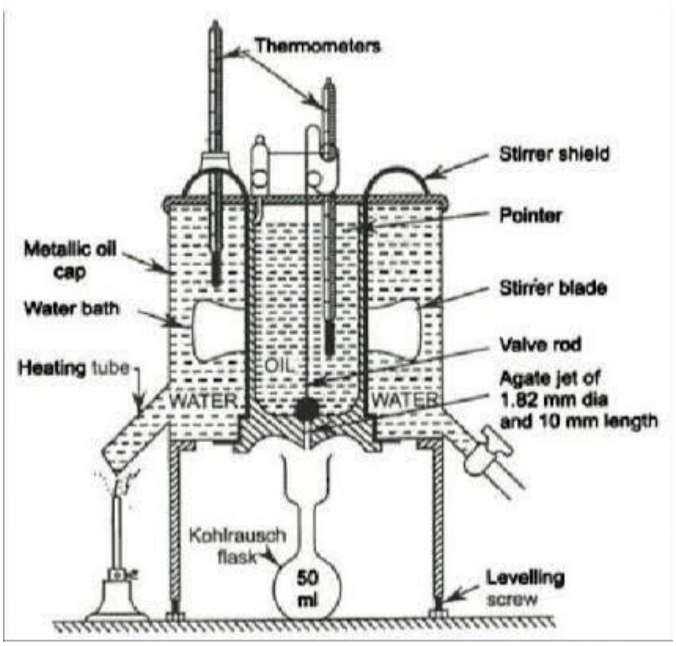


Figure 1 diagram for Red Wood Viscometer

The Redwood viscometer is a vital instrument in the field of fluid mechanics, particularly for measuring the viscosity of dielectric liquids. This instrument operates on the principle of measuring the time it takes for a fixed volume of fluid to flow through a small-diameter tube under the force of gravity. The theory behind the Redwood viscometer involves understanding the relationship between viscosity, fluid flow, and gravitational force. When a sample is poured into the viscometer, gravity pulls it downward through the tube. Viscosity, the resistance to flow within the fluid, influences the speed at which the fluid moves. Higher-viscosity fluids flow more slowly, while lower viscosity fluids flow more quickly. By measuring the time it takes for the fluid to pass a certain point, the Redwood viscometer provides valuable data on the viscosity of the sample. The cylindrical container that holds the sample liquid. The cup has a standardized capacity and is made of materials that resist corrosion and temperature variations. Jet Orifice is Located at the bottom of the oil cup, the jet orifice allows the liquid to flow out. The diameter of the orifice is standardized to ensure consistent results. Heating Bath is Surrounding the oil cup, the heating bath controls the temperature of the sample. The bath is equipped with a heating element and a thermostat to maintain the desired temperature. The water bath with an oil cup is supported on a tripod stand with leveling screws.

2.1 SPECIFICATIONS

Type	Redwood viscometer
Model	IP 70
Oil cup	Silver-plated Brass
Heating	Electric heating
Temperature measurement	Mercury in glass thermometer
Supplements	Silver-plated ball valve, spirit level and cover, thermometer clip and receiver
Safety	Overheat protection, manual shut-off
Power supply	230 V, 50 Hz Single phase, AC

2.2. Procedure for Redwood viscometer Experiment

i. Clean the oil cup with a solvent preferably C.T.C (Carbon Tetrachloride) and wipe it dry thoroughly with a paper napkin or a soft cloth (do not use cotton waste) and the orifice jet with a fine thread.
ii. Keep the water bath with an oil cup on the stand and level it.
iii. Pour water into the water bath up to 15 to 20mm below the top portion.
iv. Keep the ball (valve) in position and pour a clean filtered oil sample (use a strainer not coarser than BS 100 mesh) to be tested into the oil.
v. Take a clean dry 50ml flask and place it under the orifice jet of the oil cup and center it.
vi. Adjust the receiving flask so that the oil stream hits right at its neck to prevent any foaming on the surface. When you reach the 50ml mark, stop that watch and note down how long it took in seconds.
vii. Adjust the receiving flask (50ml) in such a way that the oil string coming out of the jet strikes the neck of the flask to avoid foaming (formation of air bubbles) on the oil surface.
viii. Wait till the oil level touches the 50 ml mark stop the watch and record the time in sec.
ix. Repeat the experiment at different temperatures above ambient.
x. Plot the relevant graphs.

2.3 Formulae used

ρ = (m2-m1/50*1000)106 kg/m^3

v = [0.22R -1.79/R]10-4 m^2/sec

μ = ρ* v N/m^2

3. SIMULATION

3.1 MATHEMATICA 13.0

Mathematica 13.0 simulation software offers a comprehensive solution for investigating the viscosity of dielectric liquids and understanding how it is affected by temperature variations. we can utilize its mathematical and computational tools to construct models describing viscosity-temperature relationships. Through numerical simulations and data visualization, researchers can explore how viscosity changes with temperature and compare different liquids. Mathematica 13.0 enhances understanding of dielectric fluid behaviour, aiding decision making in fields in electrical engineering.

3.2 Mathematical formulation

Infinite layer of fluid that doesn't squish at all and it's packed with tons of electric energy. Picture a steady flow of electricity running through it from top to bottom..let's forget about the temperatures - they're keeping things stable on both ends. The equations controlling how this dielectric fluid behaves are pretty complex, involving stuff like velocity, pressure, temperature, and more.

$$\nabla \cdot \vec{q} = 0,$$

$$\rho_0 \left[\frac{\partial \vec{q}}{\partial t} + (\vec{q} \cdot \nabla)\vec{q} \right] = -\nabla p + \rho_0 [1 - \alpha(T - T_0)]\vec{g} + \mu \nabla^2 \vec{q} + \vec{f}_e$$

$$\frac{\partial T}{\partial t} + (\vec{q} \cdot \nabla) T = \kappa \nabla^2 T .$$

Assuming the free charge density is negligible small, the relevant Maxwell equations are

$$\nabla \cdot (\varepsilon \vec{E}) = 0 ,$$

$$\nabla \times \vec{E} = 0 \text{ or } \vec{E} = -\nabla \phi ,$$

$$\varepsilon = \varepsilon_0 [1 - \eta (T - T_0)],$$

where $\vec{q} = (u, v, w)$ the velocity vector, $\vec{g} = (0, 0, -g)$ the gravitational acceleration, T the temperature, p the pressure, ρ_0 the density at reference temperature $T = T_o$, κ the effective thermal diffusivity, μ the fluid viscosity, $\vec{E} = (0, 0, E_z)$ the applied AC electric field, $\alpha (> 0)$ the thermal expansion coefficient, η (>0) the analog for dielectric constant of thermal expansion coefficient, ε_0 the dielectric constant at reference temperature $T = T_o$, ϕ the root mean square velocity of the electric potential and $\nabla^2 = \partial^2/\partial x^2 + \partial^2/\partial y^2 + \partial^2/\partial z^2$ the Laplacian operator. The last term of Eq.(2) is the force of electrical origin which can be expressed in the form

$$\vec{f_e} = \rho_e \vec{E} - \tfrac{1}{2}(\vec{E}\cdot\vec{E})\nabla\varepsilon + \tfrac{1}{2}\nabla\left[\rho\left(\frac{\partial\varepsilon}{\partial\rho}\right)_T \vec{E}\cdot\vec{E}\right]$$

where the electrical body force eE r , known as the Coulomb force is neglected since there are no free charges. When we analyze all these factors together using some mathematical magic called linear stability analysis, we end up with these nifty equations that tell us if things are going haywire or staying calm and collected. It's like predicting whether your favorite sports team will win or lose – except with electric currents and fluid dynamic

$$\begin{bmatrix} (D^2-a^2)^2 & -a^2(R_t+R_{ea}) & a^2R_{ea}D \\ 1 & D^2-a^2 & 0 \\ 0 & -D & D^2-a^2 \end{bmatrix}\begin{bmatrix} W \\ \Theta \\ \Phi \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

where $D \equiv d/dz$ the differential operator, $a = \sqrt{\ell^2 + m^2}$ the horizontal wave number, $R_t = \alpha g \Delta T d^3/\nu\kappa$ the thermal Rayleigh number and $R_{ea} = \eta^2\varepsilon_0 E_0^2(\Delta T)^2 d^2/\mu\kappa$ the electric Rayleigh number. Equations (8a,b,c) forms an eigenvalue problem for R_t or R_{ea} and is to be solved using below boundary conditions.

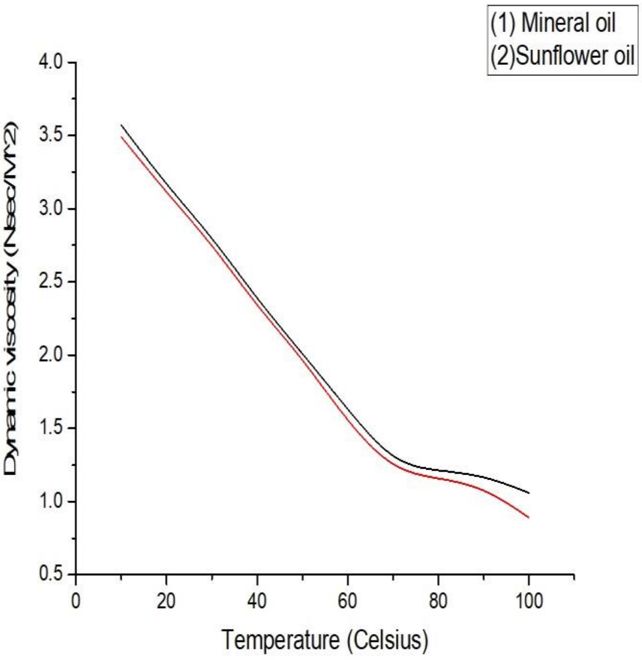
i. Lower rigid-upper free boundaries:

$$W = DW = \Phi = 0, \quad \Theta = 0 \text{ or } D\Theta = 0 \quad \text{at} \quad z = 0$$

$$W = D^2W = D\Theta + Bi\,\Theta = D\Phi = 0, \quad \text{at} \quad z = 1$$

3.3 Output

TEMPERATURE in C	DYNAMIC VISCOSITY	
	Sun drop oil	Mineral oil
10	3.57	3.49
20	3.16	3.11
30	2.81	2.76
40	2.38	2.33
50	2.01	1.98
60	1.63	1.54
70	1.26	1.21
80	1.21	1.16
90	1.18	1.10
100	1.06	0.89



3.4 ORIGIN SOFTWARE

Origin simulation software offers a comprehensive solution for analyzing the viscosity of dielectric liquids and understanding how it is influenced by temperature variations. This software provides advanced graphing and data analysis tools that enable researchers to explore the nature of viscosity-temperature relationships effectively. By inputting experimental data into Origin, we can generate various types of graphs to visualize viscosity trends over different temperature ranges.

By plot, the temperature and viscosity values in the origin software of dielectric liquids, select the range of temperature in which we have to get the graphs of the specific liquids.

4.METHODOLOGY

1. Experimental Setup (Redwood Experimental Setup): The experiment begins with the setup of the Redwood experimental apparatus, specifically designed for measuring the effect of temperature on dielectric liquids with and without adding nano particles. The setup typically includes electrodes immersed in the dielectric liquid, with provisions for controlling temperature and applying voltage.
2. Selection of Dielectric Liquids: Various dielectric liquids are chosen for experimentation, representing a range of electrical properties and chemical compositions. These liquids may include mineral oil, sun drop oil.
3. Preparation of Experimental Samples: Each chosen dielectric liquid is prepared according to the experimental requirements, ensuring purity and consistency. Any necessary additives or contaminants are carefully controlled to study their effects on conductivity.
4. Experimental Procedure: The prepared dielectric liquid samples are carefully poured into the Redwood experimental setup, ensuring uniformity and proper electrode immersion. The temperature of the liquid is controlled using the apparatus's temperature control system.
5. Data Collection: Conductivity measurements are recorded systematically, varying parameters such as temperature, voltage, and composition of the dielectric liquid. Each measurement is repeated multiple times to ensure accuracy and reliability.
6. Plotting graph using the experimental values, plot a graph for viscosity versus temperature.
7. Simulation using Mathematica 13.0 and Origin: In addition to the experimental work, simulations are performed using Mathematica 13.0 and Origin software. The simulations aim to model the electrical behaviour of dielectric liquids based on theoretical principles and known physical properties.
8. Analysis of Results: The experimental data and simulation results are analyzed comprehensively, considering factors such as temperature dependence, voltage effects, and the influence of additives or contaminants on conductivity. Statistical analysis and graphical representations are employed to visualize trends and correlations.
9. Comparison and Interpretation: The experimental results are compared with simulation outcomes to validate the accuracy of the models. Discrepancies and agreements between experimental and simulated data are examined to gain insights into the underlying conductivity mechanisms in dielectric liquids.
10. Conclusion and Implications: Based on the experimental and simulated findings, conclusions are drawn regarding the electrical conductivity of dielectric liquids. The implications of the study for industrial applications, such as electrical insulation and capacitor design, are discussed, highlighting avenues for further research and optimization.

5.RESULT

Conducting an experiment using a redwood viscometer entails measuring the viscosity of a fluid sample, typically mineral oil, sunflower oil, engine oil. The process involves setting up the viscometer as per manufacturer guidelines, which includes filling it with the sample fluid and heating it to a specific temperature. This experiment is complete, and all the respective values are noted. Additionally, simulations using software tools like Mathematica 13.0 and Origin can be used to model the fluid flow and calculate viscosity based on known fluid properties and viscometer geometry. In Mathematica, parameters such as viscosity, density, temperature, and viscometer dimensions are defined, and fluid flow equations are still being solved to simulate the flow dynamics and find the relationship curve.

5.1 Tabular column of Dielectric liquids without adding nano particles:

1.Sun drop oil:

Temp° (c)	Dynamic Viscosity(μ)
35 °	2.863NS/m²
50 °	1.78NS/ m²
70 °	1.18NS/ m²
90 °	1.07NS/ m²

2.Mineral oil:

Temp° (c)	Dynamic Viscosity(μ)
35°	2.8569 NS/m²
50°	1.876 NS/m²
70°	1.189 NS/m²
90°	0.876 NS/m²

5.2 Tabular column of Dielectric liquids with adding nano particles:

1.Sun drop oil (0.091):

Temp° (c)	Dynamic Viscosity(μ)
35 °	2.99NS/m²
50 °	1.83NS/ m²
70 °	1.15NS/ m²
90 °	0.821NS/ m²

2.sun drop oil (0.91):

Temp° (c)	Dynamic Viscosity(μ)
35°	3.01 NS/m²
50°	1.59 NS/m²
70°	1.10 NS/m²
90°	0.74 NS/m²

3.sun drop oil (0.455):

Temp° (c)	Dynamic Viscosity(μ)
35°	2.76 NS/m²
50°	1.83 NS/m²
70°	1.16 NS/m²
90°	0.95 NS/m²

4.Mineral oil (0.0827):

Temp° (c)	Dynamic Viscosity(μ)
35°	0.928 NS/m²
50°	0.733 NS/m²
70°	0.554 NS/m²
90°	0.542 NS/m²

5.Mineral oil (0.827):

Temp° (c)	Dynamic Viscosity(μ)
35°	0.96 NS/m²
50°	0.68 NS/m²
70°	0.56 NS/m²
90°	0.47 NS/m²

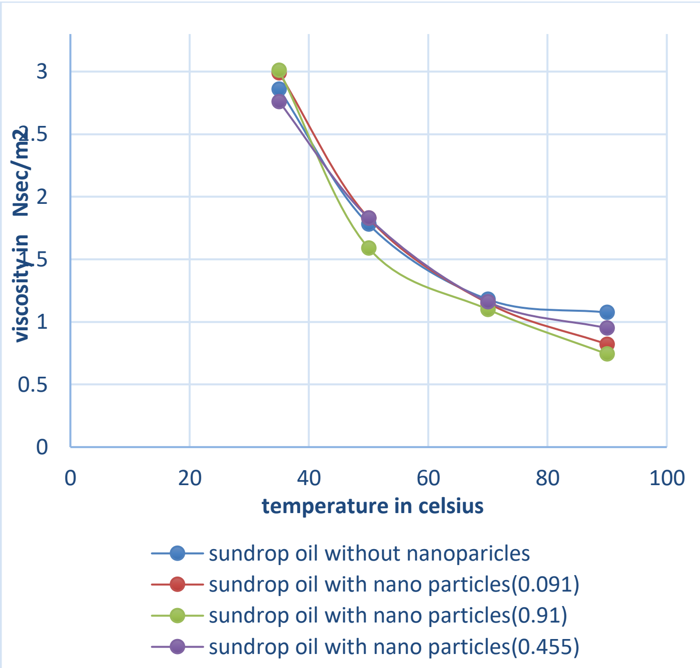
6.Mineral oil (0.4135):

Temp° (c)	Dynamic Viscosity(μ)
35°	0.88 NS/m²
50°	0.70 NS/m²
70°	0.60 NS/m²
90°	0.51 NS/m²

Where ( ) denotes the concentration of Nano particles(titanium dioxide).

5.3 Relationship curves between viscosity of dielectric liquids versus temperature

5.3.1. Sun drop oil



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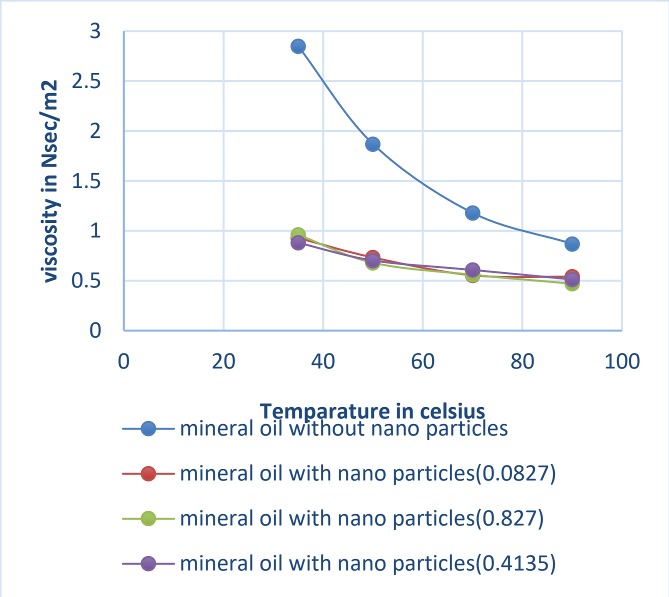
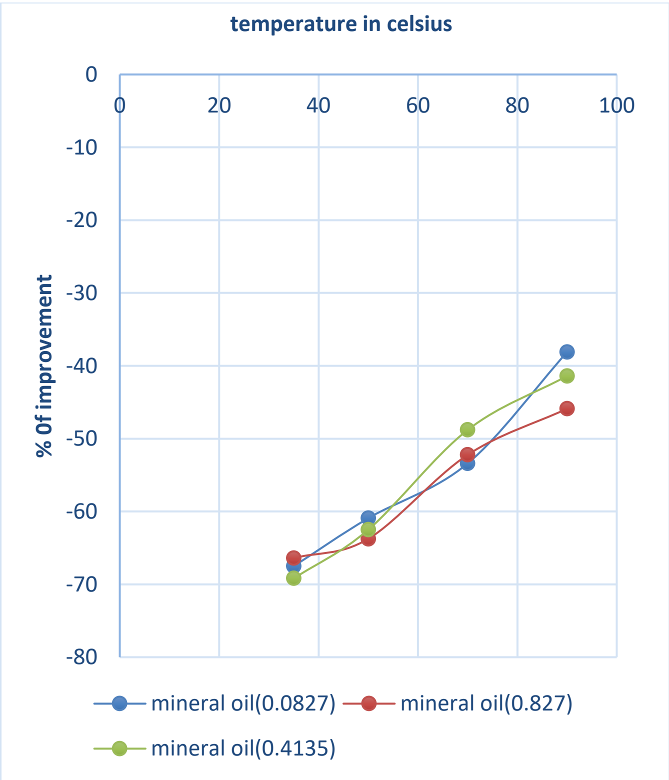
5.3.2 Mineral Oil



5.4 Relationship curve between percentage of improvements of dielectric liquids versus temperature



5. CONCLUSION

The study concluded that temperature significantly affects the viscosity of dielectric liquids. With increasing temperature, viscosity decreased due to reduced intermolecular forces. However, adding nanoparticles to dielectric liquids improved their thermal stability, resulting in a slower decrease in viscosity. Both experimental results and Mathematica simulations confirmed that nanoparticles help maintain higher viscosity levels at elevated temperatures. Thus, incorporating nanoparticles enhances the thermal resilience of dielectric liquids, ensuring more stable and reliable performance across varying temperature conditions.

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