Low-Temperature Heat Transfer Fluids – Newer Options

Introduction

Are you looking for the performance of an ethylene glycol-based system with the safety and toxicity performance of a propylene glycol-based system? Newer bio-based alternative fluids have advanced technical properties and functionality compared to petroleum-based counterparts giving newer options to the historical debate of which heat transfer fluid to use.

Megatrends across the globe have created a demand for bio-based solutions. Bio-alternative glycols have given more sustainable options to the heat transfer fluid market; however, newer bio-based fluids based on 1, 3 propanediol are offering sustainable fluids and showing improved pumping efficiencies across low-temperature heat-transfer applications.

For approximately the past decade bio-based propanediol has been entering the heat transfer fluid market. This material derived from natural corn starch and glucose has the same chemical formula as propylene glycol but has a slightly different structure as seen as Figure 1. This modification to the structure gives it thermal stability for high heat applications and a lower viscosity profile.

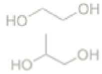
Common	Ingredient	CAS#	Formula	Structure	Mol. Wt.	BP, °C	MP, °C	Density
Ethylene Glycol	1,2-Ethanediol	107-21-1	C2H602		62.1	197.6	-12.7	1.116
Propylene Glycol	1,2-Propanediol	57-55-6	C3H802		76.1	187.3	-60	1.038
Propanediol	1,3-Propanediol	504-63-2	C3H802		76.1	214	-24	1.053

Figure 1. Chemical Structure and Property Comparison

Water, glycol or propanediol - choosing the right fluid for your low-temperature application

For most heat transfer applications water is the most efficient and cost-effective choice for your system. The problem is that water freezes. It is only when the temperature drops below 33 °F that alternative materials such as glycols and now propanediol have to be considered as plain water not only freezes but tends to be corrosive in chilling and freezing applications.

Heat transfer fluids are widely used in food processing, commercial refrigeration, geothermal, and other low-temperature heat-transfer applications that typically operate in a temperature range from 0°F to 42°F (-18°C to 6°C). Most heat transfer fluids have lower heat-transfer efficiencies than water and are denser, resulting in the needs for more surface area for the heat-exchanger or higher volumetric flowrates to maintain the same system temperature. The optimal heat transfer fluid would have a reduced viscosity at low temperatures and would not freeze as water does to maintain system efficiency.

In most low-temperature heat transfer applications ethylene glycol-based fluids are your best choice because of their superior heat transfer efficiency due to the low-viscosity profile. As the fluid is thinner at lower temperatures the fluid's performance also reduces the power consumption for re-circulation pumps and enables the system to achieves an overall lower minimum operating temperature.

While ethylene glycol is advantaged due to its low-viscosity profile, the high acute toxicity of ethylene glycol has served to limit its applications. Propylene glycol is non-toxic. Historically, propylene glycols are targeted for applications in which low acute oral toxicity is a requirement or for freeze protection applications where incidental contact with food or beverage products is possible.

Propylene glycols do not have the same low-viscosity profile as ethylene glycol negatively impacting pump power consumption, flow rates, and pump efficiency. This can be addressed in some cases with special equipment for circulation, by elevating operating temperatures or by lowering the glycol concentration below the manufacturer's recommended concentration limit. These concessions can lead to lowered freeze protection, increased corrosion potential, and microbial growth or contamination because propylene glycols can readily biodegrade at lower concentrations.

Bio-based propanediol is also non-toxic, approved for food contact, and in some countries already approved as a food ingredient. It was developed through a joint venture between DuPont and Tate & Lyle in an effort to create more sustainable solutions and move away from petroleum-based materials such as traditional glycols. The viscosity profile is lower than propylene glycol but higher than ethylene glycol. Figure 2. compares ethylene glycol, propylene glycol and propanediol low-temperature viscosities. Theoretically, based solely on viscosity, propanediol heat transfer fluids would offer slightly less system efficiency as ethylene glycol and enhanced system efficiency compared to propylene glycol.

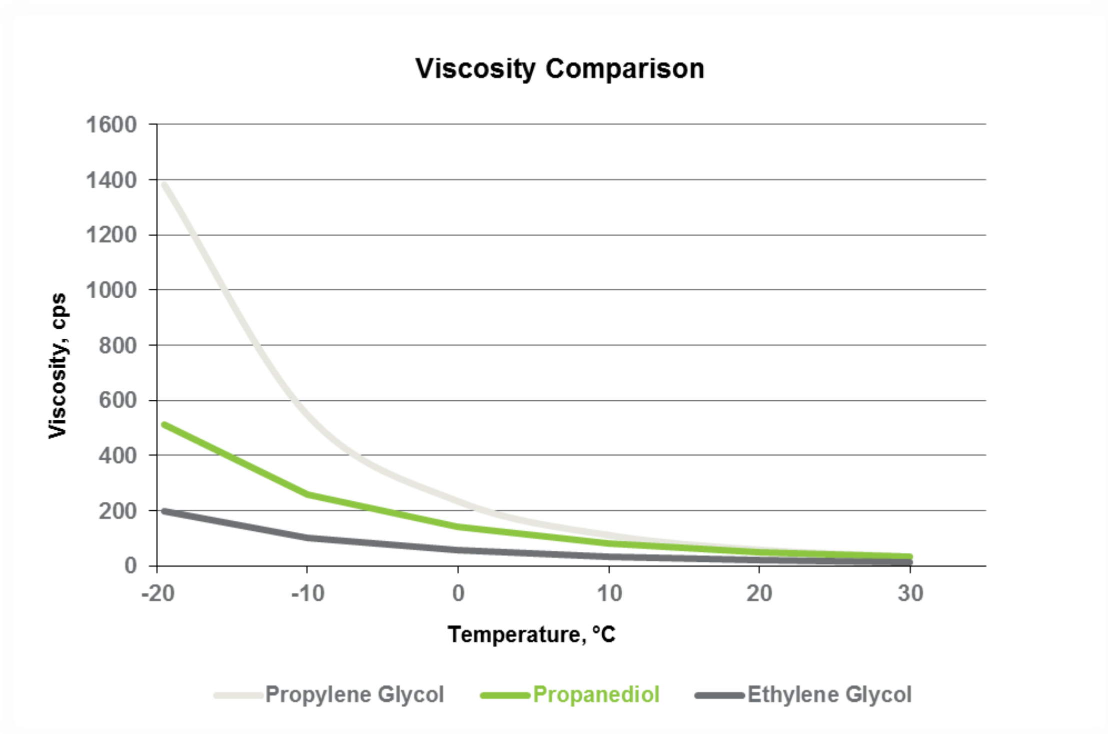


Figure 2. Low-temperature Viscosity Profiles

Low-Toxicity Fluid Comparison

A case study was completed to compare the performance and operating costs for a food refrigeration system using propanediol or propylene glycol as the heat transfer fluid. The food refrigeration system operated at 32ºF (0ºC) and used a 5 hp centrifugal pump that circulated a 30% solution by volume of propylene glycol or propanediol at a flow (Q) of 175 gallons per minute with a maximum head of 50 feet.

Pump characteristics are usually based on water at around a temperature of 20ºC, a density of pumped fluid of approximately 998 kg/m^3, and a kinematic viscosity of 1 centistrokes (cSt). However, the viscosities of some liquids such as antifreeze solutions increase with lower temperature. For example, aqueous mixtures of 50% propylene glycol (50% water) experience a change in viscosity by a factor of 10 when the temperature is lowered from approximately room temperature 20ºC to -20ºC. In this case, the viscosity of propanediol was 64% lower than propylene glycol under the same system operating conditions, which led to 8.9% reduction in power use as illustrated in Figure 3.

Property	Propanediol, 30%	Propylene Glycol, 30%
Freezing point, °F (°C)	9.4°F (-12.6°C)	9.2°F (-13°C)
Density (0°C), kg/m3	1026	1030
Kinematic viscosity, centistrokes	42	69
Power, (kW)	3.1	3.4
Power savings	0.089	- n/a -

Figure 3. Property Comparison of Propanediol and Propylene Glycol in Food Refrigerant System

Green and Sustainability

In most manufacturing environments whether or not a heat transfer fluid is "green" is more a question of color for leak detection versus determining if it is bio-based. However for the past 30 year, regulatory agencies around the world have been working to reduce greenhouse emissions. As more commercially viable bio-based alternatives are becoming more readily available in the marketplace companies are starting to evaluate their own manufacturing sustainability footprints. Considering a sustainable, bio-based heat transfer fluid would a step in supporting the reduction of greenhouse emissions.

Propanediol is manufactured through a proprietary process that uses glucose from natural raw materials instead of petroleum-based feedstocks. The basic materials can be derived from renewable, farm-grown sources including corn—making the promise of carbon neutrality and independence from petroleum a real possibility. From "cradle-to-gate," the production of DuPont Tate & Lyle BioProducts' bio-based 1,3 propanediol consumes 40% less energy and reduces greenhouse gas emissions by more than 40% versus petroleum-based 1,3-propanediol and propylene glycol."

Conclusion

If you have a system where temperatures are operating less than 33° F, than consider using a heat transfer fluid versus water. Early in your fluid selection process, you should consider what local requirements might impact your choice. Local regulations or a specific application may require that you decide between the use of a toxic material such as ethylene glycol or non-toxic materials such as propanediol or propylene glycol.

Then evaluate properties such as density, film coefficient, viscosity, pour point and thermal conductivity. Make sure the cooling capability charts offered by your distributor offer glycols and propanediols to select optimum system efficiency based on low-viscosity profiles. Also, consider your company's sustainability platform. Does a bio-based heat transfer fluid match the corporate direction of moving towards more sustainable solutions? Throughout this process remember now there are newer bio-based options such as propanediol added to decision process regarding which heat transfer fluid to use.

Footnote:

* DuPont Tate & Lyle Bio Products' bio-based 1,3 propanediol LCA data based on Loudon process design data; peer reviewed by Five Winds International