TECHNICAL BULLETIN

Susterra® Propanediol: Pump Performance provides a differentiating factor versus Propylene Glycol for Low Temperature Heat Transfer Fluids (LTHTFs).

Introduction

The purpose of this study is to highlight the pump performance property differences between a bio-based glycol Susterra® Propanediol, (1,3-Propanediol) and a traditional petroleum-based glycol, Propylene Glycol (PG), used as a secondary coolant in industrial distillery heat transfer heating and cooling systems. The use of Susterra® propanediol can deliver comparable performance to an ethylene glycol-based system with the safety and toxicity profile of a propylene glycol-based system allowing for approval for food contact (NSF International HTX-1 specification). The low-viscosity profile of Susterra® Propanediol at low temperature enhances pump power consumption, flow rates and pumping efficiencies, which can improve energy demands and maintenance costs for the overall heat transfer system when compared to Propylene Glycol.

Background

Susterra® Propanediol (1,3-propanediol) is a 100% bio-based, petroleum free diol that was developed and commercialized through a joint venture between DuPont and Tate & Lyle to create an alternative, high-performance product that uses plant-based feedstocks instead of petroleum-based feedstocks that protect the environment, reduce the world's dependence on petroleum. One of the many uses for Susterra® Propanediol is for use as a high performing, food safe heat transfer fluid in heating and cooling applications as an alternative to traditional petroleum-based glycols like ethylene and propylene glycol.

In addition to being renewably sourced, bio-based 1,3-propanediol is manufactured using a sustainable process that produces 47% less greenhouse gas emissions and consumes 49% less non-renewable energy than equivalent petroleum-based diols. At the manufacturing facility's full capacity, this is equivalent to taking 36,000 passenger cars off the road and turning off 1.3 million 100W incandescent lightbulbs for one full year.

Choosing the right fluid for your low-temperature applications

While water is almost the ideal heat transfer fluid, it is limited to temperatures above its freezing point. When the temperature drops below the 33^{o}F, alternative materials such as glycols must be considered to create aqueous solutions as plain water not only freezes but tends to be corrosive for chilling and freezing applications. **Table 1** compares the most common glycols used in low temperature heat transfer fluids (LTHTFs).

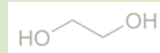
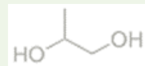
Common	Ingredient	CAS#	Formula	Structure	Mol. Wt.	BP, °C	MP, °C	Density
Ethylene Glycol	1,2-Ethanediol	107-21-1	C2H602		62.1	197.6	-12.7	1.116
Propylene Glycol	1,2-Propanediol	57-55-6	C3H802		76.1	187.3	-60	1.038
Propanediol	1,3-Propanediol	504-63-2	C3H802		76.1	214.0	-24	1.053

Table 1. Glycol comparison used for LTHTFs

In most low-temperature heat transfer applications ethylene glycol-based fluids are your best choice because of their superior heat transfer efficiency and its low-viscosity profile. Fluids with lower viscosities (or thinner) at lower temperatures contribute to the fluid's performance by reducing the power consumption for re-circulation pumps thus enables the system to achieve an overall lower minimum operating temperature. While ethylene glycol's viscosity profile at low temperature is an advantage, the high acute toxicity of ethylene glycol serves as a limitation for certain applications where incidental food or beverage contact is possible, like Industrial distilleries or breweries.

Propylene glycol is non-toxic alternative to ethylene glycol. Historically, propylene glycols are targeted for applications in which low acute oral toxicity is a requirement or freeze protection applications where food or beverage incidental contact is a possibility. Propylene glycol, however, does not have the same low-viscosity profile as ethylene glycol thus 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 higher risks including lowered freeze protection, increased corrosion potential, microbial growth or contamination since propylene glycols can readily biodegrade at lower concentrations.

Bio-based 1,3-propanediol is another non-toxic alternative to ethylene glycol, is approved for food contact (NSF International HTX-1 specification), and in some countries already approved as a food and beverage ingredient. Additionally, Susterra® has an advantage for over ethylene and propylene glycol fluids include higher boiling point and improved resistance to degradation. The viscosity profile is lower than propylene glycol but slightly higher than ethylene glycol (**Figure 1**). Theoretically, based solely on viscosity, heat transfer fluids using aqueous solutions of 1,3-propanediol would offer slightly less system efficiency as ethylene glycol and enhanced system efficiency compared to propylene glycol.

Viscosity profiles for ethylene glycol, propylene and Susterra® propanefiol (1,3-propanediol) are illustrated in **Figure 1.** From this figure, Susterra® is more favorable than propylene glycol (1,2-propanediol) across the low temperature range making it an ideal option for low temperature heat transfer fluid (LTHTF) cooling system commonly found in industrial distilleries or breweries. In its inhibited form, 1,3 Propanediol has the same advantages of low corrosivity and low volatility of ethylene glycol, and the same safety advantages of propylene glycol, to which it is similar. Based on the glycol options evaluated, we will move forward with a comparison of propylene glycol and 1,3-propanediol.

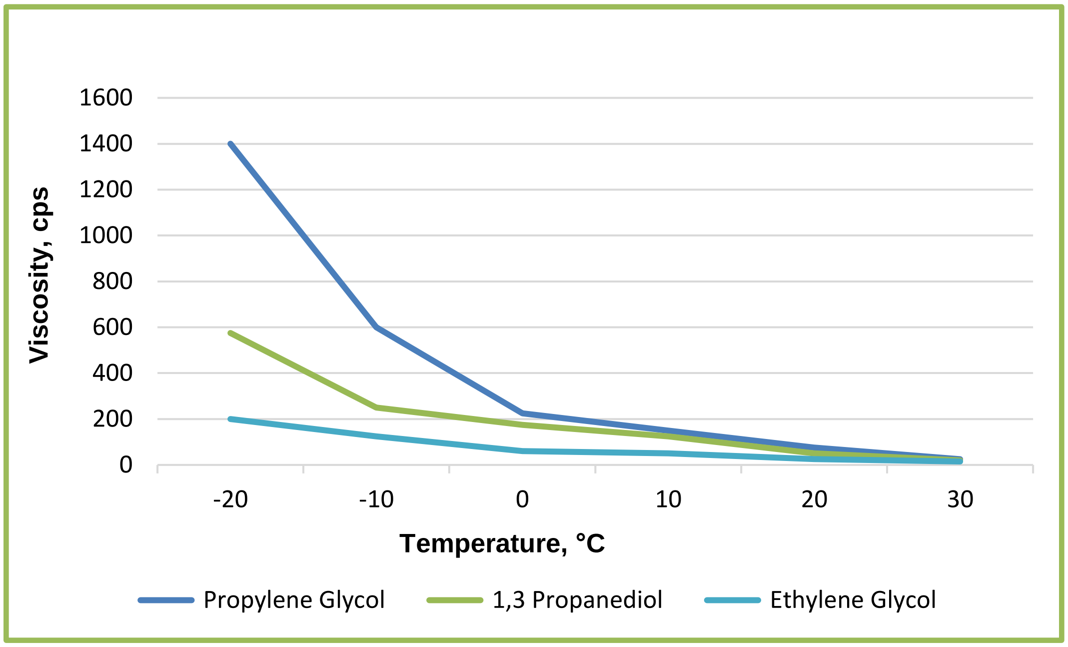


Figure 1: Viscosity profile of glycols as function of Temperature

Heat transfer coefficient, In-tube viscosity, and pressure drop.

To take this comparison one step further for understand the differences between propylene glycol and 1,3-propanediol used in a heat transfer cooling system, the movement of the LTHTF fluid through the tubes, pumps, heat exchanger and cooling jackets must be understood as well as the system's resistance to the fluid based on its thermal properties (friction, density, viscosity). Two ways to understand the thermal properties of a fluid is to evaluate it in terms of its heat transfer coefficient and pressure drop across a range of tube velocities.

The heat transfer coefficient is a dimension that estimates how much heat is transferred. A higher value means more capacity for that fluid to transfer heat when in laminar or turbulent flow. The heat transfer coefficient can also be maximized in a heat exchanger by maximizing shell side (beer) and tube side (LTHTF) velocities. The ideal and recommended operating in-tube velocity range is 3-7 ft./sec. **Figures 2 and 3** show a comparison of 10% and 60% (v/v) 1,3-propanediol/water and propylene glycol/water solutions at various operating temperatures. This allows the heat exchanger to be optimized for the maximum amount of heat per unit area by generating as much turbulence as possible below given pump power limits. However, this is governed by the allowable pressure drop, a ratio of density/viscosity for the various LTHTF's at higher velocities, and directly affecting the Reynolds number for tube flow. In this case lower numbers are better for the in-tube pressure drop performance showing optimal fluid velocities. In-Tube Pressure drop for 10 and 60% (v/v) 1,3-propanediol-water and Propylene glycol-water solutions at various temperatures are presented in **Figures 4 and 5**. It should be noted that the primary function of a LTHTF is to be an effective heat transfer fluid; therefore, selecting a LTHTF based on that criteria should take precedence over the tube pressure drop. At low temperatures, the resulting viscosity of Susterra® is lower than propylene glycol and has less of an impact on pumping cost while maintaining heat transfer coefficients.

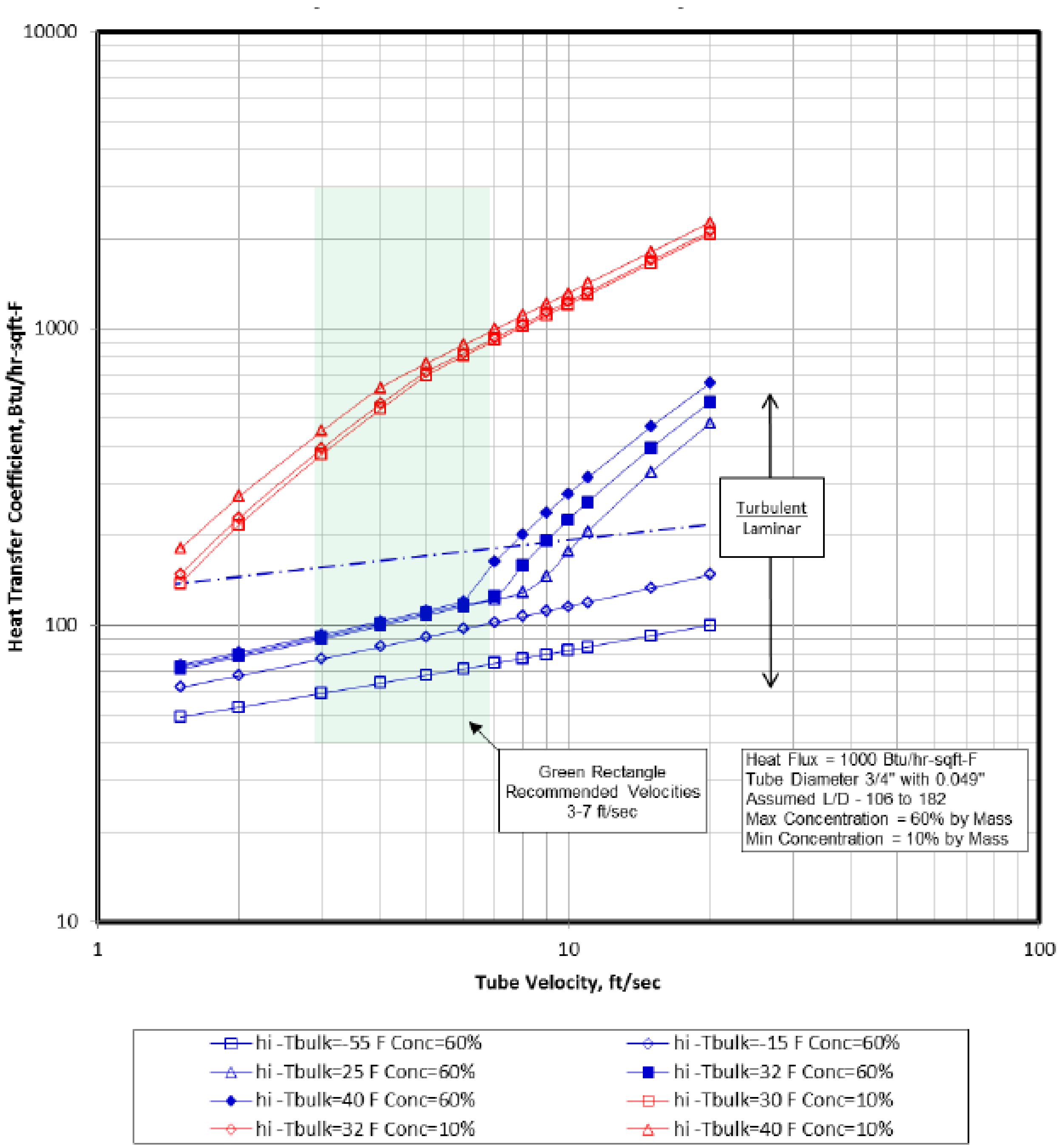


Figure 2. In-Tube Heat Transfer for Susterra® Propanediol-Water Solutions

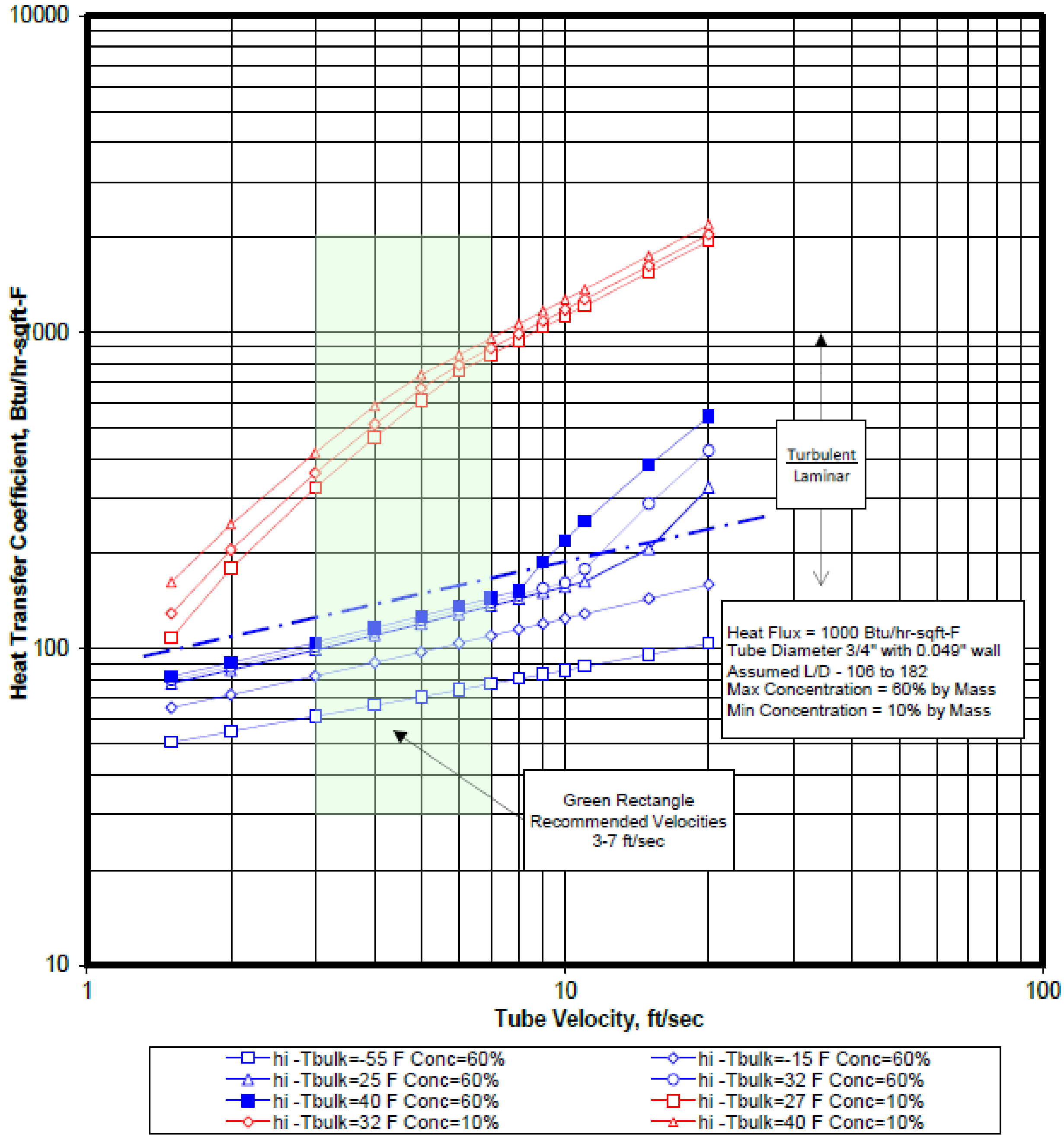


Figure 3. In-Tube Heat Transfer for Propylene Glycol-Water Solutions

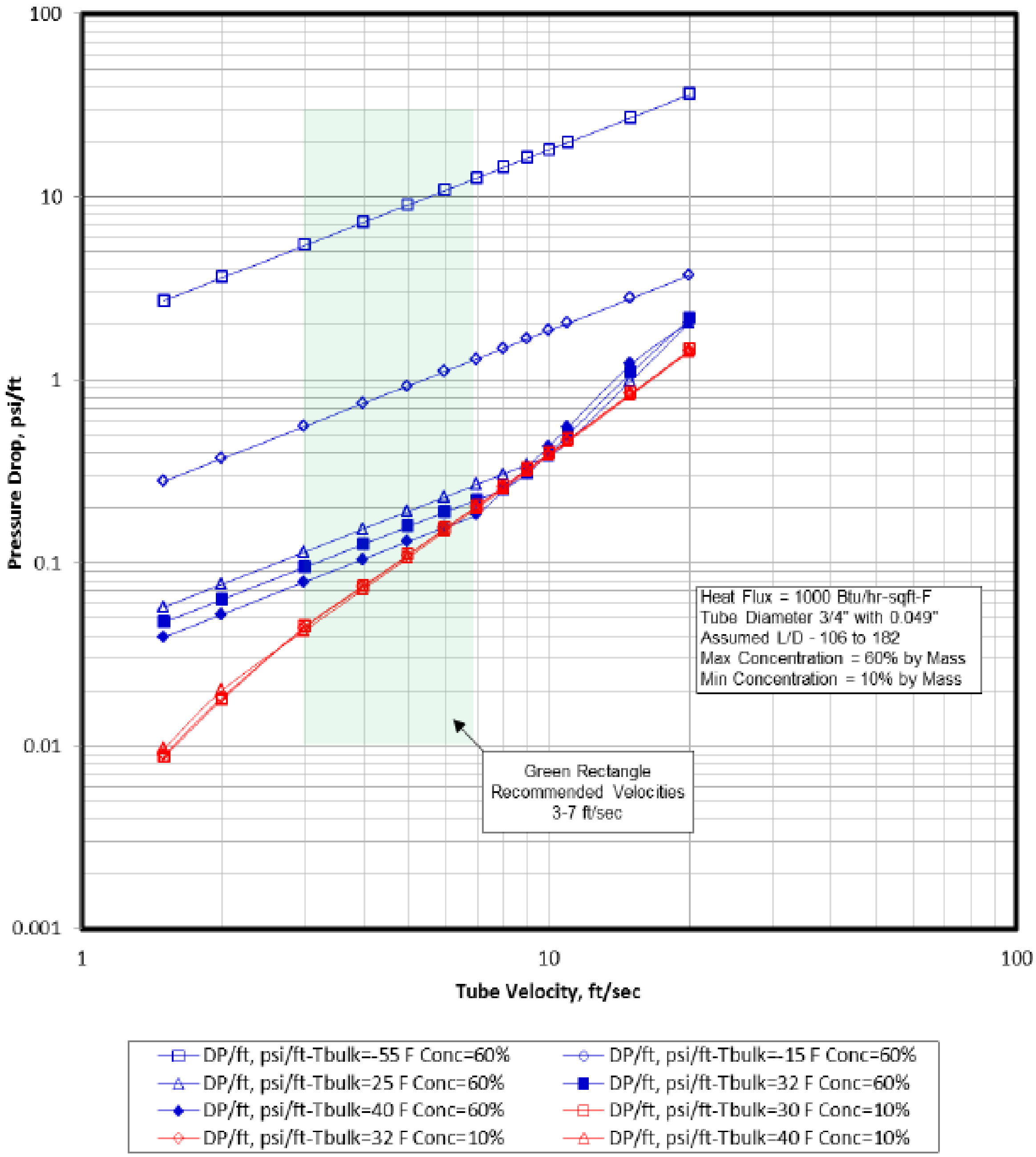


Figure 4. In-Tube Pressure Drop Susterra® Propanediol-Water Solutions

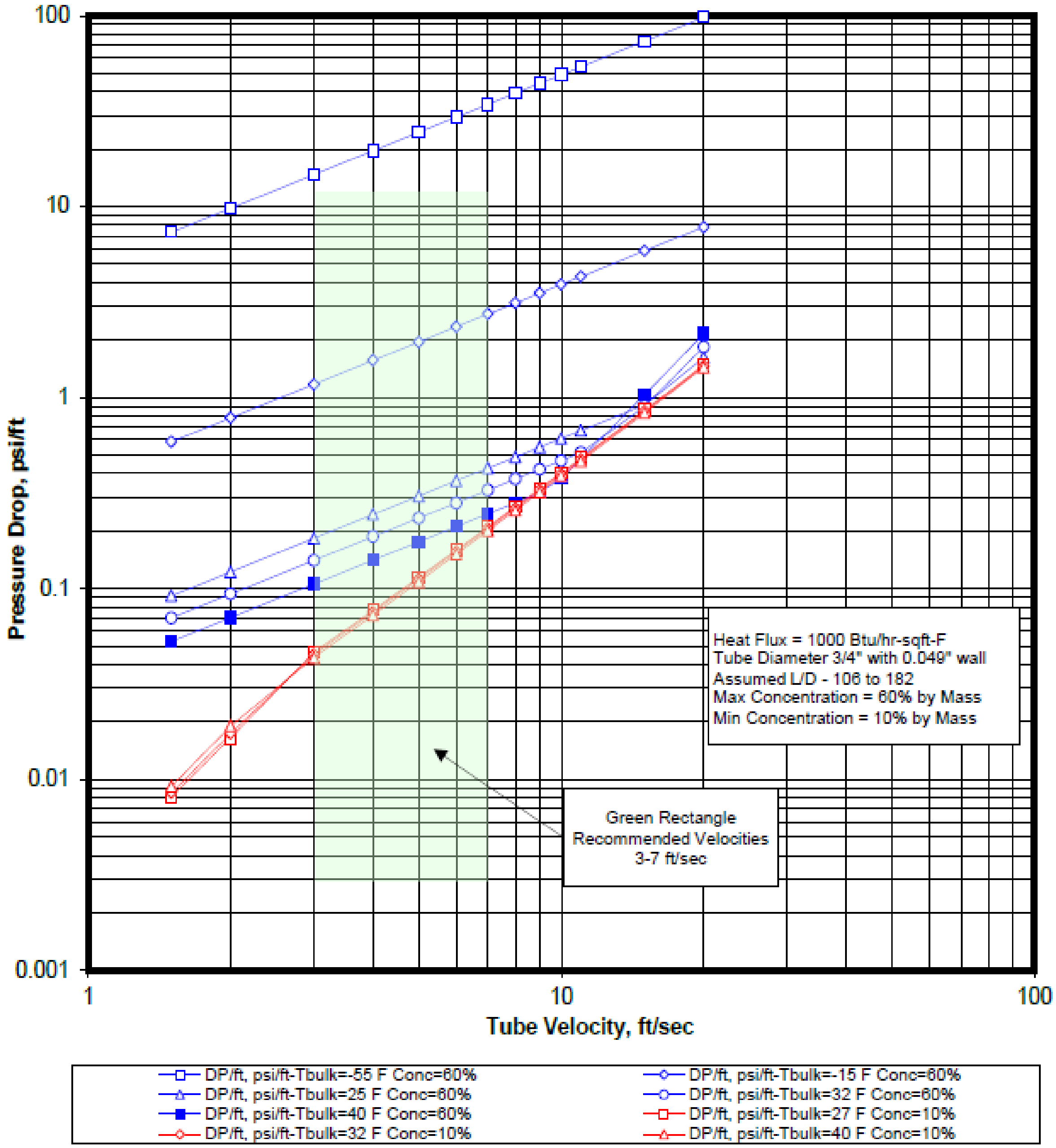


Figure 5. In-Tube Pressure Drop Propylene Glycol-Water Solutions

Power Pump Performance

Pump power ratio is a method that allows one to compare the performance of the two different glycols in the same system, under the same conditions as it relates to the energy needed to operate a pump using a process system equipment including the heat exchanger, heat flux, head pressure load, and tube diameter. The pump power ratio compares the pressure drop coefficient as well as the heat transfer coefficient. The equation for the pump power ratio (**Figure 6**), is expressed as a relationship between density (ρ), specific heat (c_p), thermal conductivity (k) and kinematic viscosity (μ) at a given temperature.

$$PPR_{12} = \left(\frac{\mu_1}{\mu_2}\right)^{1.95} \left(\frac{\rho_1}{\rho_2}\right)^{-0.05} \left(\frac{k_1}{k_2}\right)^{-2.3} \left(\frac{c_{p1}}{c_{p2}}\right)^{-1.05}$$

Figure 6. Power Pump Ratio

Pump Power Reduction was determined by comparing 25-50% (v/v) solutions of Susterra® Propanediol-Water and Propylene Glycol-Water at various temperatures while at constant flow (**Figure 7**) and at a 2% flow reduction (**Figure 8**). The pump power reduction and reduction in required flow depends on the superior viscosity (**Figure 1**) and density (**Table 1**) properties of Susterra® Propanediol when compared to Propylene Glycol. Power reduction for Susterra® is observed to be 0.5-7% at -10°C at constant flow and 6-12% at -10°C at 2% reduced flow   It is noted that a reduction in required flow occurs because of these superior properties; however, even with no reduction in flow, there is a power reduction observed for Susterra® Propanediol versus Propylene Glycol due to its lower viscosity at low temperature. This power reduction translated into reduced energy demand, energy savings and potential lower maintenance cost.

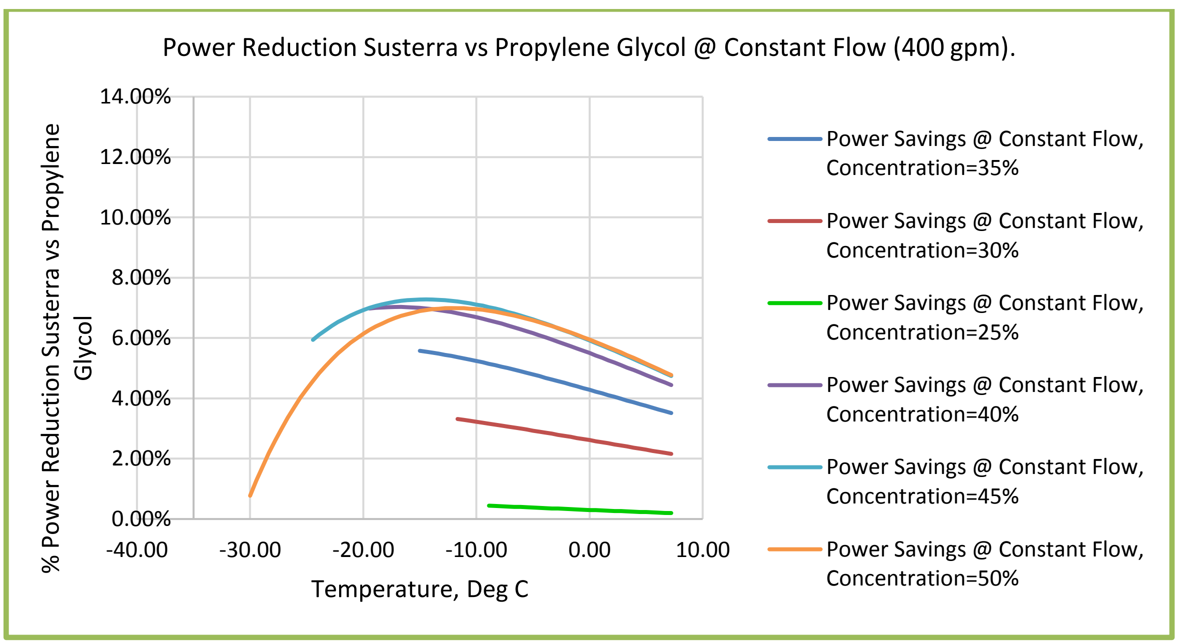


Figure 7. Pump Power Reduction: Susterra® Propanediol-Water vs Propylene Glycol-Water at Constant Flow

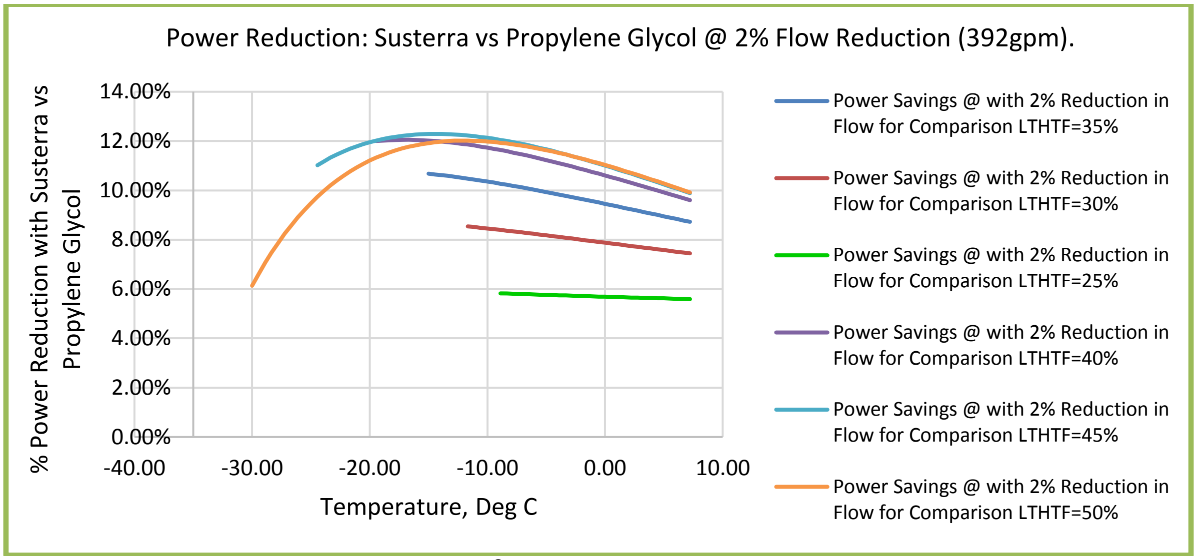


Figure 8. Pump Power Reduction: Susterra® Propanediol-Water vs Propylene Glycol-Water Solutions at 2% Flow Reduction.

Conclusions

- Susterra® Propanediol can deliver comparable performance to an ethylene glycol-based system with the safety and toxicity profile of a propylene glycol-based system allowing for approval for incidental food contact, NSF International HTX-1 specification.
- Susterra® Propanediol aqueous solutions has the same advantages of low corrosivity and low volatility of ethylene glycol, and the same safety advantages of Propylene Glycol.
- Susterra® Propanediol aqueous solutions have a lower viscosity at low temperature versus Propylene Glycol aqueous solutions.
- Due to Susterra® Propanediol's superior viscosity and density properties in comparison to Propylene Glycol, a pump power reduction is observed for both constant flow and a reduced flow.
- Susterra® Propanediol aqueous solutions offers an opportunity to enhance pump power consumption, flow rates and pumping efficiencies, which can improve energy demands and maintenance costs.
- Susterra® Propanediol is a 100% bio-based, renewably sourced alternative to petroleum-based Propylene Glycol for low temperature heat transfer fluids (LTHTFs); Susterra® Propanediol provides a reduced environmental footprint based on a peer reviewed Life Cycle Analysis (LCA).

References

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