# DOWTHERM vs. DOWFROST

A Comparison of Ethylene Glycol and Propylene Glycol

Dow offers two basic types of low temperature heat transfer fluids: DOWTHERM* heat transfer fluids based on ethylene glycol (EG) and DOWFROST* heat transfer fluids based on propylene glycol (PG). Both types also contain water and corrosion inhibitors.

In terms of performance, both fluids are very similar. Both have demonstrated their effectiveness over 30 years of use in HVAC systems, food processing equipment, indirect line heaters, and other applications at moderate temperatures (less than 250° - 350°F, depending on the fluid's inhibitor system). Although there are differences in the physical properties of ethylene and propylene glycol-based fluids, it is not normally necessary to use different operating procedures with them.

There are, however, several important differences to keep in mind while determining which fluid will best meet your individual needs. Relative toxicity, regulatory impact, and heat transfer efficiency are among the differences discussed in this guide.

## Relative Toxicity

According to generally accepted guidelines, ethylene glycol has moderate toxicity if ingested (taken internally by mouth). Humans are much more sensitive to the toxic effects of ethylene glycol than are animals. It is estimated that a lethal dose (that dose which may result in death) of ethylene glycol for an average size person is about 100 milliliters or approximately 3 ounces (less than half a cup). In industrial settings, where workers may be exposed to ethylene glycol by inhalation, or by skin or eye contact, health concerns are relatively minor.

Conversely, propylene glycol exhibits low oral toxicity. Long-term use in food products and pharmaceuticals has demonstrated that humans are not more susceptible to any potential health risks than animals are, nor is potential industrial exposure generally of concern.

Although propylene glycol is lower in toxicity than ethylene glycol, fluids should be treated with equal precautions, regardless of their glycol content. Relative toxicity may be influenced by other fluid ingredients or by alterations to the fluid composition that may occur during use. For more information regarding potential hazards and safe handling recommendations refer to the product Material Safety Data Sheets.

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## Regulatory Considerations

***Superfund Amendments and Reauthorization Act (SARA):*** Ethylene and propylene glycol do not appear on the Environmental Protection Agency's (EPA's) list of "hazardous substances" or "extremely hazardous substances." However, due to its acute (short-term) oral toxicity, ethylene glycol is classified as a "toxic chemical" under SARA Title III, 1986 (40 CFR Part 372). Thus, DOWTHERM fluids that contain ethylene glycol are subject to the reporting requirements of this act.

***Comprehensive Environmental Response, Compensation and Liability Act (CERCLA):*** Ethylene and propylene glycol do not appear on the CERCLA list of "extremely hazardous substances" or "hazardous substances." However, ethylene glycol has been classified as a hazardous air pollutant in the Clean Air Act Amendments of 1990, and consequently has an environmental release reportable quantity (RQ) of 5,000 pounds.

Propylene glycol is generally recognized as safe (GRAS) by the Food and Drug Administration (FDA; 21 CFR 184.1666) for use in approved food and pharmaceutical applications when manufactured in accordance with FDA requirements.

Furthermore, propylene glycol is not subject to reporting requirements of SARA and CERCLA legislation, as is ethylene glycol.

## Heat Transfer Efficiency

Propylene glycol solutions are more viscous than are solutions of EG, particularly at temperatures below 0°F. As a result, there may be a loss of heat transfer efficiency when PG is used as a coolant. To know if PG will cause a heat transfer loss compared to EG, examine the overall heat transfer for an air-cooled heat exchanger:

$$\frac{1}{U} = \frac{1}{h_o} + \frac{1}{h_i} + r_w + r_f$$

| | | |
|---|---|---|
| $U$ | = | Overall heat transfer |
| $h_o$ | = | Outside heat transfer coefficient for air = 20 BTU/hr - ft$^2$ - °F |
| $h_i$ | = | Inside heat transfer coefficient for glycol (170°F, 7 ft./sec., 1 in. tube) |
| | = | 968 Btu/hr - ft$^2$ - °F for 50% EG |
| | = | 855 Btu/hr - ft$^2$ - °F for 50% PG |
| $r_w$ | = | wall resistance = .00048 hr - ft$^2$ - °F/Btu |
| $r_f$ | = | fouling resistance = .002 hr - ft$^2$ - °F/Btu |
| $U$ | = | 18.69 for EG coolant |
| $U$ | = | 18.64 for PG coolant |

Because the air cooling side of the exchanger controls the overall heat transfer, there is virtually no difference in heat transfer efficiency whether EG or PG is used as the coolant at the air-cooled heat exchanger.

Table 1 compares these same 50% glycol fluids when used at lower temperatures. Notice that a drop of 4.7% ($\frac{18.69 - 17.82}{18.69}$) results for EG with a temperature change from 170°F to 25°F, but for PG the percentage difference is much greater, 11.7% ($\frac{18.64 - 16.46}{18.64}$) primarily due to the larger viscosity increase for the PG-based fluid.

Table 2 shows the effects that lower concentrations of EG and PG (increased water content) have on overall heat transfer.

## Table 1: Heat Transfer Comparison of 50% EG with 50% PG

| Temp °F | $Re_{EG}$ | $Re_{PG}$ | $hi_{EG}$ | $hi_{PG}$ | A† | $U_{EG}$ | $U_{PG}$ | B†† |
|---|---|---|---|---|---|---|---|---|
| 170 | 54,612 | 45,564 | 968 | 855 | 11.7 | 18.69 | 18.64 | 99.7 |
| 120 | 31,554 | 23,648 | 739 | 628 | 15.0 | 18.58 | 18.49 | 99.5 |
| 70 | 15,318 | 8,983 | 508 | 356* | 29.9 | 18.36 | 18.09 | 98.5 |
| 25 | 6,152 | 2,478 | 275* | 121* | 56.0 | 17.82 | 16.46 | 92.4 |
| 0 | 3,054 | 947 | 151* | --** | --** | 16.92 | --** | -- |

A† = $\frac{hi_{EG} - hi_{PG}}{hi_{EG}}$ (%)    B†† = $\frac{U_{PG}}{U_{EG}}$ (%)

Re = Reynolds number. For Re > 10,000 defines fully developed turbulent flow.

* Correction Factor Applied for Re = 2000 - 10,000 which defines partially developed turbulent flow.

** Calculation not valid for Re below 2000, which is basically laminar flow.

## Table 2: Heat Transfer Comparison of 30% EG with 30% PG

| Temp °F | $Re_{EG}$ | $Re_{PG}$ | $hi_{EG}$ | $hi_{PG}$ | A† | $U_{EG}$ | $U_{PG}$ | B†† |
|---|---|---|---|---|---|---|---|---|
| 170 | 81,009 | 72,931 | 1,361 | 1,282 | 5.8 | 18.79 | 18.78 | 99.9 |
| 120 | 50,426 | 42,432 | 1,065 | 977 | 8.3 | 18.72 | 18.69 | 99.8 |
| 70 | 26,677 | 18,987 | 760 | 648 | 14.7 | 18.59 | 18.51 | 99.6 |
| 25 | 11,898 | 6,585 | 496 | 331* | 33.3 | 18.35 | 18.02 | 98.2 |
| 0 | 6,443 | 3,035 | 314* | 172* | 45.2 | 17.97 | 17.16 | 95.5 |

A† = $\frac{hi_{EG} - hi_{PG}}{hi_{EG}}$ (%)    B†† = $\frac{U_{PG}}{U_{EG}}$ (%)

Re = Reynolds number. For Re> 10,000 defines fully developed turbulent flow.

* Correction Factor Applied for Re <10,000.

The percentage difference between EG (2.3%) and PG (4.0%) when going from 170° to 25°F is now much smaller, because of the lower concentration and consequently lower viscosity of the PG-based fluid.

## Physical Properties

Table 3 (Page 6) points out physical differences between EG and PG as concentrates and as 50% solutions. Some of these differences have already been noted as effecting heat transfer. Other differences also worth noting:

***Viscosity:*** PG solutions are more viscous than EG solutions. This difference becomes greater as solution concentration increases, and at colder temperatures. When operating under cooling conditions (~170°F) the viscosity difference is about 10% and generally not a concern. However, at temperatures below 0°F viscosity differences between EG and PG solutions become significant. Cold temperature start-up or running a system at very low temperatures with PG will require significantly more energy than EG because of viscosity and pressure drop differences. Because of this, the use of PG solutions greater than $50\%_V$ and at coolant temperatures below -28°F is not recommended.

***Freeze Point:*** Because of PG's higher molecular weight, it is not quite as efficient as EG in depressing the freeze point of water. An approximately 2% higher concentration of PG solution is needed to give the same freeze protection as an EG solution.

***Specific Gravity:*** The specific gravity of PG is very close to that of water. As a result, specific gravity cannot be checked for propylene glycol concentrations as can be done for EG solutions. This also means that a gallon of PG and its solutions will weigh less than a comparable amount of ethylene glycol.

***Solubility Parameter:*** Propylene glycol has a greater affinity for oil-like materials than EG as reflected in its lower solubility parameter. This means that PG acts as a slightly better solvent. It can have a greater effect on some plastics and elastomers when operating at high temperatures.

## Table 3: Physical Property Comparison

| | Ethylene Glycol 100% | Propylene Glycol 100% | Ethylene Glycol Sol. 50%v | Propylene Glycol Sol. 50%v |
|---|---|---|---|---|
| **Molecular Weight** | 62.1 | 76.1 | | |
| **Freeze Point** (°F) | 8 | -71 ($T_g$) | -34 | -29 |
| **Specific Gravity** | 1.110 | 1.033 | 1.082 | 1.050 |
| **Density** ($lb/ft^3$ @ 70°F) | 69.12 | 64.32 | 67.05 | 65.14 |
| **Flash Point** (°F) | 240 | 220 | None | None |
| **Boiling Point** (°F) | 387 | 369 | 225 | 222 |
| **Vapor Pressure** | | | | |
| (mm HG @ 77°F) | .12 | .22 | 16 | 21 |
| (psia @ 170°F) | .07 | .14 | 4.6 | 5.2 |
| **Surface Tension** | | | | |
| (dynes/cm @ 77°F) | 47 | 36 | 56 | 45 |
| **Solubility Parameter** | 17.1 | 15.0 | Not Available | Not Available |
| **Viscosity** | | | | |
| (cps @ 77°F) | 16.5 | 44.0 | 3.4 | 5.4 |
| -30°F | —— | ~20,000 | 64 | 263 |
| 170°F | 3.5 | 4.5 | 1.04 | 1.20 |
| **Pressure Drop** | | | | |
| (psi/100 ft.) (1 in. pipe – 7 ft/sec.) | | | | |
| -30°F | —— | —— | 28.11 | 48.64 |
| 170°F | 12.5 | 12.6 | 10.61 | 10.43 |
| **Biodegradation** (20 day) | | | | |
| part oxygen/part glycol | 1.15 | 1.45 | | |
| % of theoretical oxygen demand | 89 | 86 | | |

## Corrosion

Table 4 shows rates of corrosion for inhibited and uninhibited glycol solutions compared to water. Without inhibitors, EG solutions have much higher corrosion rates than do the comparable PG solutions. Neither uninhibited solution gives acceptable corrosion protection, however. With the DOWTHERM and DOWFROST fluid inhibitor packages, both EG and PG provide excellent corrosion protection.

### Table 4: Corrosion Effects of Fluids on Common Metals (Corrosion Rate[1] –mils per year)

| Metal | Plain Water | Uninhibited Propylene Glycol | Inhibited Propylene Glycol | Uninhibited Ethylene Glycol | Inhibited Ethylene Glycol |
|---|---|---|---|---|---|
| Copper | 0.08 | 0.16 | 0.20 | 0.16 | 0.12 |
| Solder | 3.14 | 34.7 | 0.03 | 56.5 | 0.14 |
| Brass | 0.22 | 0.20 | 0.16 | 0.46 | 0.11 |
| Steel | 9.69 | 9.8 | 0.04 | 44.5 | 0.03 |
| Cast Iron | 21.2 | 16.2 | 0.15 | 55.7 | 0.13 |
| Aluminum | 13.2 | 1.8 | 0.26 | 19.8 | 0.44 |

*[1]Based on corrosion test ASTM D1384; 190°F - 2 weeks; standard ASTM test metals 30% glycol in deionized water; air bubbling.*

***Note:*** *The test data information is intended for screening purposes only. Rates in excess of 0.5 mpy (2.5 mpy for aluminum) are generally not considered adequate for corrosion protection.*

## Compatibility

Ethylene glycol and PG are physically compatible with each other, and mixtures of the solutions are often used when making a transition from one glycol to the other. Keep in mind that a mixture of the glycols will result in a blend of the characteristics discussed in this report as well as make field analysis of glycol solutions misleading.

## Summary

Inhibited EG- or PG-based heat transfer fluids have been successfully used for many years in many different HVAC applications. The choice of which glycol to use is an individual decision based on the specific needs of each location. This report is meant to point out the differences between EG- and PG-based fluids and emphasize which differences are of practical importance. PG-based DOWFROST fluids should be considered by locations facing regulatory restrictions on EG.

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**For further information, call toll-free 1-800-447-4369.**
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