Fermilab

Particle Physics Division

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Title: Ethylene and Propylene Glycol Fluid and Thermal Properties

Author(s): Matthew L. Alvarez

Reviewer(s): Herman Cease

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Abstract Summary: The coolant for the monsoon crate, prime focus (pf) cage, and the chiller systems all contain different concentrations of propylene glycol. Brief descriptions of the application guidelines for ethylene and propylene glycol are contained in this document along with the thermal properties and fluid properties. Ethylene glycol fluid and thermal property tables are attached to this document as well.

Applicable Code: none

Propylene Glycol Fluid and Thermal Properties

Matthew Alvarez- FNAL
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INTRODUCTION

Three of the DECAM cooling systems, monsoon crate, pf cage, and chiller cooling systems, require the use of ethylene or propylene glycol to lower the freezing point of water. The monsoon crate and pf cage cooling systems must abide by the general operating conditions found in DES-doc 3819-v3 and 3763-v3. Both cooling systems require the 30% propylene glycol and 70% water (by mass). This concentration of propylene glycol allows the systems to operate below freezing, T= -5ºC, or in the coldest condition experienced in the mountains of Chile. These systems remove heat from the CCDs and electronic boards. The systems then transfer that heat to the chiller system, which consists of a 20kW water to air ethylene glycol heat exchanger located outside the building. This chiller system has a 50% propylene glycol and 50% water mixture. Therefore, the fluid and thermal properties for 30% & 50% propylene glycol are required to perform an accurate fluid dynamic and thermodynamic calculation.

BACKGROUND

Water is an effective coolant. However, it freezes at a relatively high temperature. Therefore, adding ethylene or propylene glycol to water lowers the freezing point at a cost. The following table displays the different concentrations of the glycol and its freezing point.

Propylene Glycol $C_3H_8O_2$

Propylene Glycol [Vol. %]	Freezing point [ºC]
10	-4.1
20	-10.6
30	-19.3
40	-27.8
42	-30
50	-45
60	<-50

Table 1[1]: Propylene Glycol Concentrations and Freezing Point

Ethylene or propylene glycol is slightly different than water. It has lower heat transfer efficiencies and it is denser than water. Therefore, the cooling system that uses glycols must operate at higher flow rates and require larger heat exchangers to transfer its heat. Because of the high flow rates required for a system that use glycols, the equipment within the system wears faster. In addition, the system requires more energy to operate efficiently than using 100% water.

[1] BOSCH: Tyfocor ® L "G" Propylene Glycol-based Solar Fluid (see pdf)

APPLICATION GUIDELINES

1. Corrosion[2]
    a. If ethylene or propylene glycol is exposed to air, acids begin to form that will corrode ferrous and non-ferrous metals- pH drops below 7. Corrosion inhibitors are added to counteract the formation of the acids.
2. Cleansing system of old glycol
    a. After removing glycol-water mixture from the system, the system must be cleansed with 1% to 2% solution of trisodium phosphate[3] for 2 to 4 hours. The phosphate must be flushed out of the system thoroughly prior to charging the system.
3. Desired Water Quality
    a. Water quality increases the heat transfer efficiency and prolongs the glycol life.
        i. Less than 50 ppm calcium
        ii. Less than 50 ppm magnesium
        iii. Less than 25 ppm chloride
        iv. Less than 25 ppm sulfate
4. Reactivity[4]
    a. Mass transfer of zinc into glycol occurs if any material is galvinized.
5. Mixing Glycols
    a. Do not mix ethylene and propylene glycols in the same system. Each glycol has different corrosion inhibitors. Therefore, mixing the two glycols in the same system will reduce the effectiveness of these inhibitors.
6. Life time
    a. 12 years on average
7. Other Considerations
    a. Do not use automotive-type glycols. They tend to gel because they are formulated with silicates. This reduces the heat transfer efficiency.

HAZARDS

(see Material Safety Data Sheet)

THERMAL AND ELECTRICAL PROPERTIES

In order to simulate the three cooling systems that use propylene glycol, fluid and thermal properties are required. Specific heat, density, thermal conductivity, and dynamic viscosity for 30% and 50% propylene glycol are needed to calculate the overall heat transfer coefficients, Reynolds number, or mass flow rate. The following equations are the curve fits in metric units for *only* propylene glycol. The input for the following equation is temperature in degrees Celsius.

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[2] Crown Solutions: Glycol Heat-Transfer Fluids Ethylene Glycol versus Propylene Glycol
[3] Trisodium phosphate: heavy duty cleanser: see MSDS
[4] BOSCH: Tyfocor ®L "G" Propylene Glycol-based Solar Fluid (see pdf)

Specific Heat [kJ/kg-K]

$$c_{p\,30\%} = 0.0028 \times T(°C) + 3.8041$$
$$c_{p\,50\%} = 0.0038 \times T(°C) + 3.4662$$

Density [kg/m^3]

$$\rho_{30\%} = 0.0026 \times T(°C)^2 - 0.3292 \times T(°C) + 1036.1$$

$$\rho_{50\%} = 0.0025 \times T(°C)^2 - 0.4372 \times T(°C) + 1055$$

Thermal Conductivity [W/m-K]

$$k_{30\%} = -5E-06 \times T(°C)^2 - 0.001 \times T(°C) + 0.4655$$

$$k_{50\%} = -3E-06 \times T(°C)^2 - 0.008 \times T(°C) + .3794$$

Dynamic Viscosity [N-s/m^2]

$$\mu_{50\%} = 3E-10 \times T(°C)^4 - 8E-08 \times T(°C)^3 + 8E-06 \times T(°C)^2 - 0.0004 \times T(°C) + .0082$$

$$\mu_{50\%} = -1E-12 \times T(°C)^6 - 4E-10 \times T(°C)^5 + 5E-08 \times T(°C)^4 - 3E-06 \times T(°C)^3 + 8E-05 \times T(°C)^2 - 0.001 \times T(°C) + .0159$$

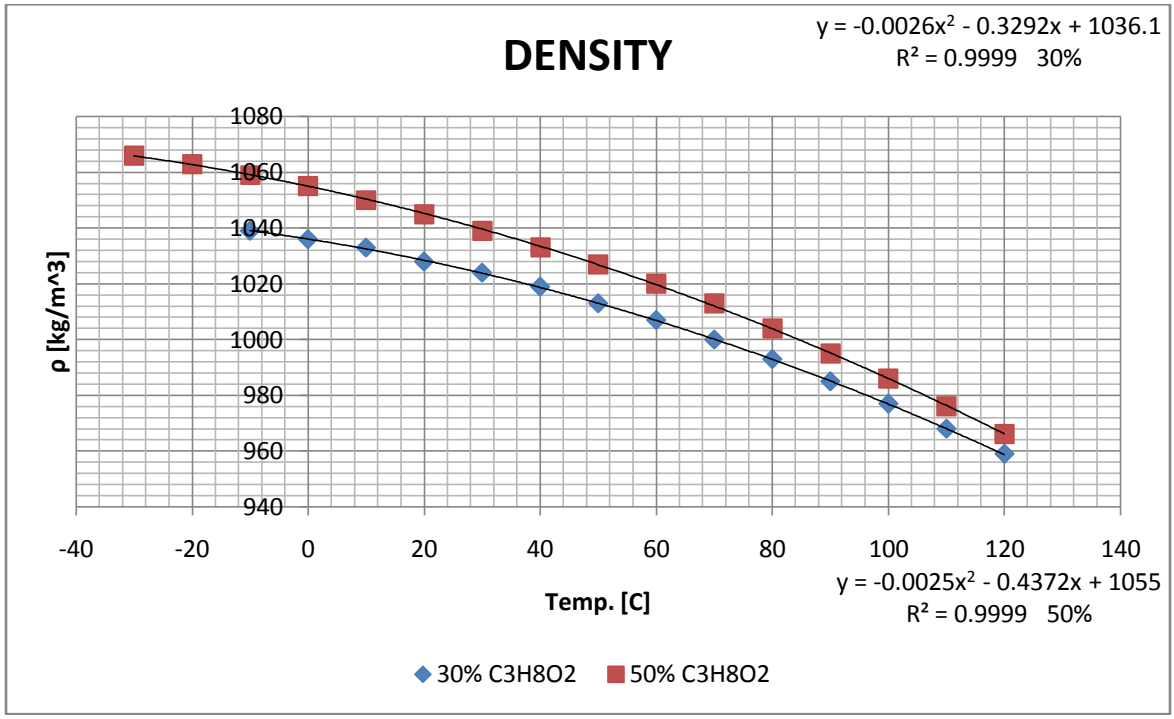
Also, **ethylene glycol** fluid and thermal property tables can be found in the ***APPENDIX*.**

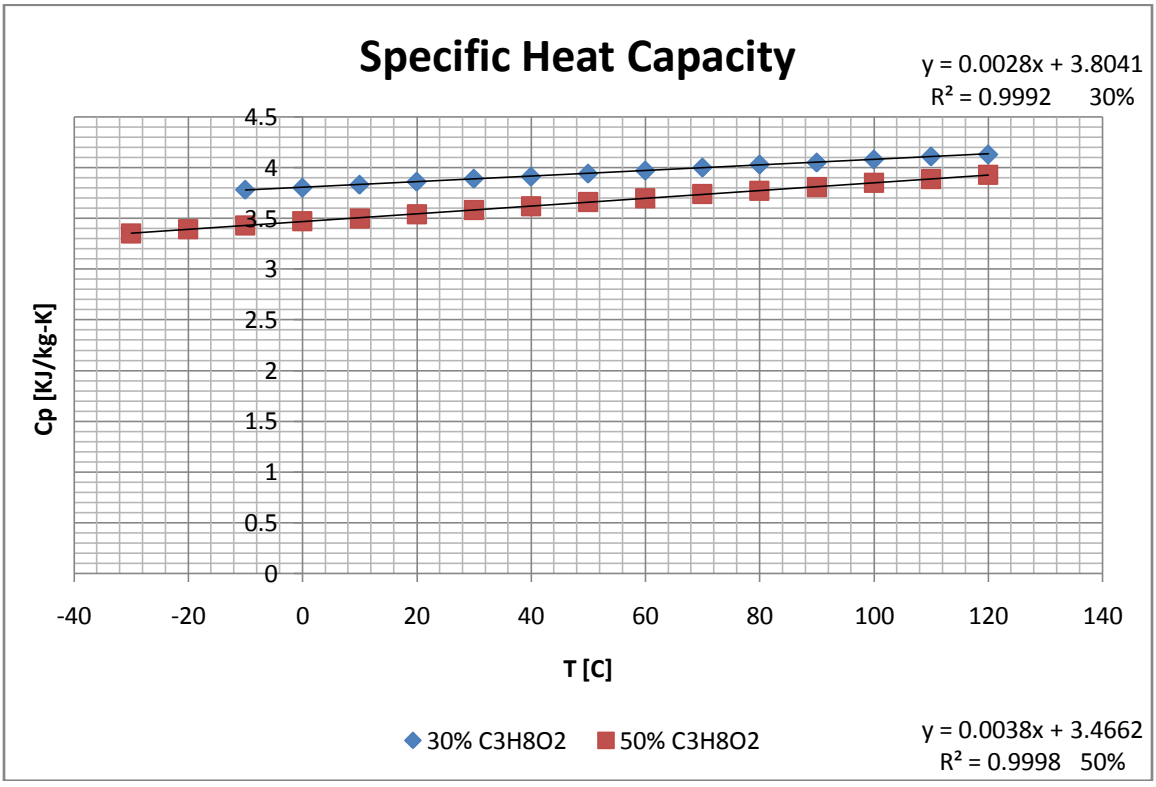
See charts in the ***APPENDIX*** to view the overall trend for each property.

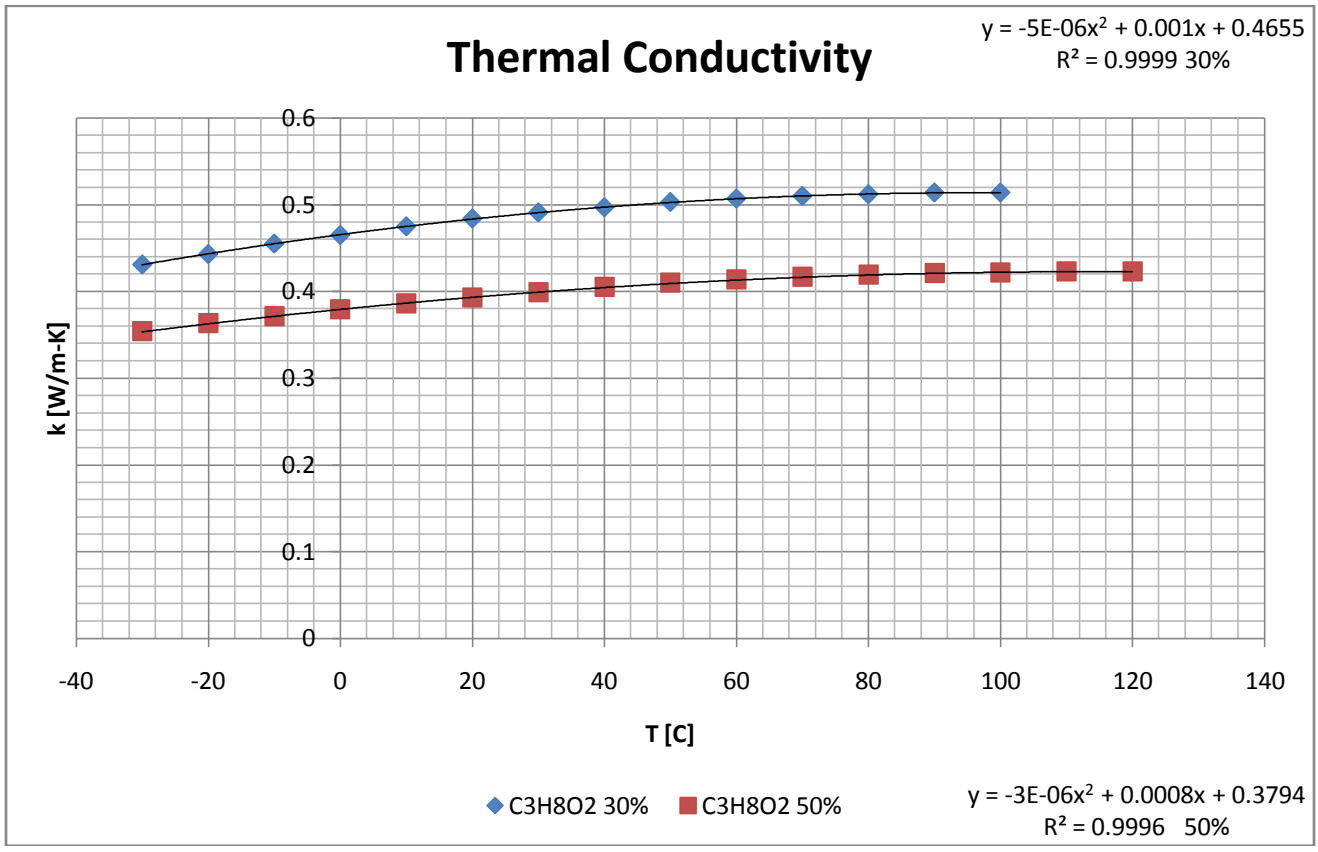
The **electrical conductivity** can be found in DOC-db 4584-v1 *Electrical Conductivity of Working Fluid in the Monsoon Crate cooling System*.

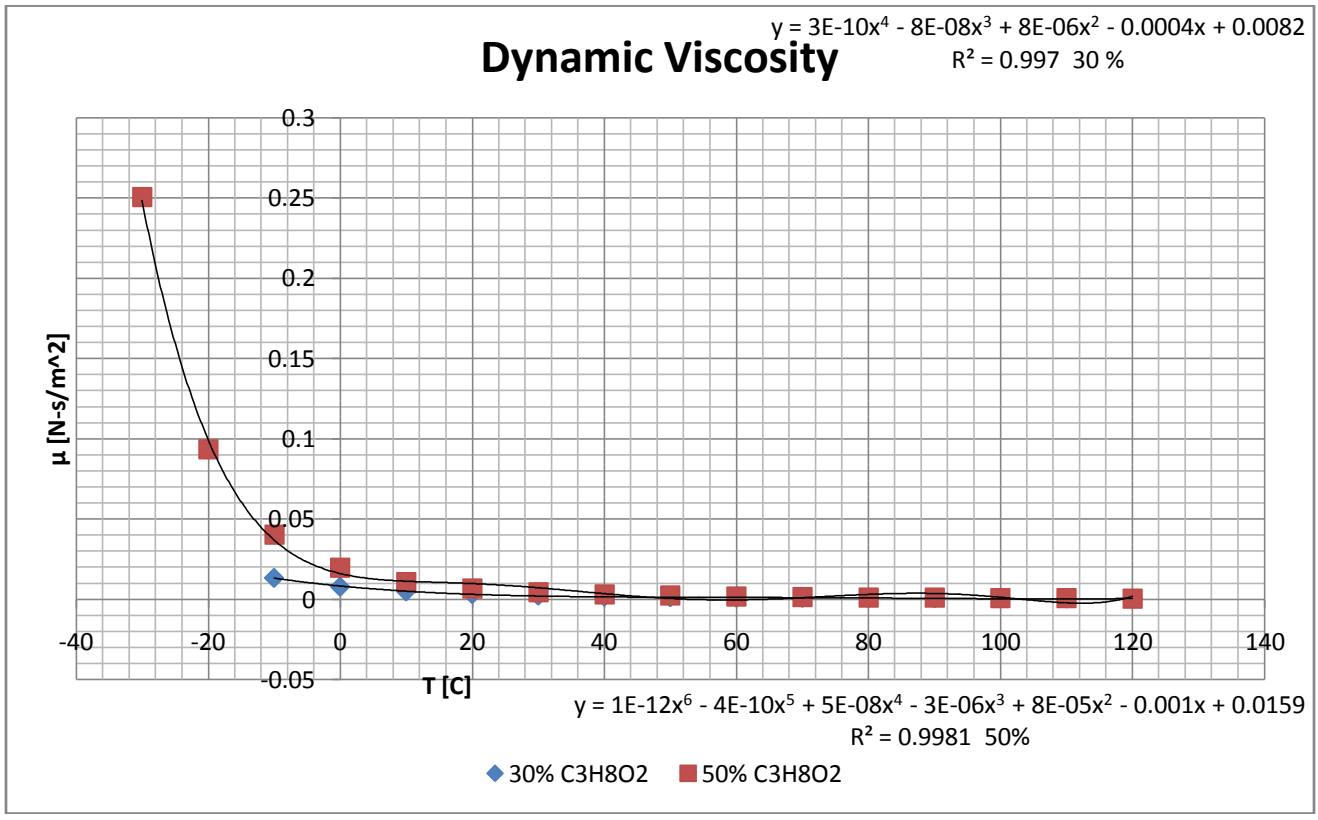
APPENDIX

The following figures were created using data from an engineering submittal sheet for propylene glycol.






Thermal Conductivity
y = -5E-06x² + 0.001x + 0.4655
R² = 0.9999 30%
k [W/m-K]
T [C]
C3H8O2 30%
C3H8O2 50%
y = -3E-06x² + 0.0008x + 0.3794
R² = 0.9996 50%


Dynamic Viscosity
y = 3E-10x⁴ - 8E-08x³ + 8E-06x² - 0.0004x + 0.0082
R² = 0.997 30 %
μ [N-s/m^2]
T [C]
y = 1E-12x⁶ - 4E-10x⁵ + 5E-08x⁴ - 3E-06x³ + 8E-05x² - 0.001x + 0.0159
R² = 0.9981 50%
30% C3H8O2
50% C3H8O2

The following figures were created using data *MEGLOBAL*[5] for ethylene glycol.

Density of Ethylene Glycol (% Mass) Metric Units												
		0.00%	*10.00%*	*20.00%*	*30.00%*	*40.00%*	*50.00%*	*60.00%*	*70.00%*	*80.00%*	*90.00%*	*100.00%*
T(ºF)	T(ºC)	ρ [kg/m^3]	ρ [kg/m^3]	ρ [kg/m^3]	ρ [kg/m^3]	ρ [kg/m^3]	ρ [kg/m^3]	ρ [kg/m^3]	ρ [kg/m^3]	ρ [kg/m^3]	ρ [kg/m^3]	ρ [kg/m^3]
-50	*-45.6*	1042.0	1041.6	1041.2	1040.8	1040.5	1040.1	1039.7	1039.3	1039.0	1038.6	1038.2
0	*-32.0*	1017.0	1016.8	1016.5	1016.3	1016.0	1015.8	1015.5	1015.2	1015.0	1014.7	1014.5
50	*-4.2*	999.5	999.3	999.1	999.0	998.8	998.6	998.5	998.3	998.2	998.0	997.8
100	*23.6*	1005.4	1005.3	1005.1	1005.0	1004.8	1004.7	1004.5	1004.4	1004.3	1004.1	1004.0
150	*51.3*	1018.4	1018.3	1018.1	1018.0	1017.9	1017.7	1017.6	1017.5	1017.4	1017.2	1017.1
200	*79.1*	1036.1	1036.0	1035.8	1035.7	1035.6	1035.5	1035.3	1035.2	1035.1	1035.0	1034.8
250	*106.9*	1056.9	1056.8	1056.7	1056.6	1056.5	1056.4	1056.3	1056.2	1056.0	1055.9	1055.8
300	*134.7*	1085.3	1085.2	1085.1	1085.0	1084.8	1084.7	1084.6	1084.5	1084.4	1084.3	1084.2
350	*162.4*	1119.4	1119.3	1119.2	1119.0	1118.9	1118.8	1118.7	1118.5	1118.4	1118.3	1118.2

Viscosity of Ethylene Glycol (% Mass) Metric Units												
T [ºF]	T[ºC]	*0%*	*10%*	*20%*	*30%*	*40%*	*50%*	*60%*	*70%*	*80%*	*90%*	*100%*
		μ [N-s/m^2]	μ [N-s/m^2]	μ [N-s/m^2]	μ [N-s/m^2]	μ [N-s/m^2]	μ [N-s/m^2]	μ [N-s/m^2]	μ [N-s/m^2]	μ [N-s/m^2]	μ [N-s/m^2]	μ [N-s/m^2]
-50	*-45.56*	3.72E-02	3.73E-02	3.74E-02	3.74E-02	3.75E-02	3.76E-02	3.77E-02	3.78E-02	3.79E-02	3.80E-02	3.81E-02
-40	*-40.00*	2.21E-02	2.21E-02	2.21E-02	2.21E-02	2.21E-02	2.21E-02	2.24E-02	2.24E-02	2.25E-02	2.25E-02	2.26E-02
-30	*-34.44*	1.41E-02	1.41E-02	1.41E-02	1.41E-02	1.41E-02	1.41E-02	1.43E-02	1.43E-02	1.44E-02	1.44E-02	1.44E-02
-20	*-28.89*	9.34E-03	9.37E-03	9.37E-03	9.37E-03	9.37E-03	9.37E-03	9.48E-03	9.50E-03	9.53E-03	9.55E-03	9.57E-03
-10	*-23.33*	5.77E-03	5.79E-03	5.79E-03	5.79E-03	5.79E-03	5.79E-03	5.87E-03	5.88E-03	5.90E-03	5.91E-03	5.93E-03
0	*-17.78*	4.63E-03	4.64E-03	4.64E-03	4.64E-03	4.64E-03	4.64E-03	4.69E-03	4.71E-03	4.72E-03	4.73E-03	4.74E-03
10	*-12.22*	3.36E-03	3.37E-03	3.37E-03	3.37E-03	3.37E-03	3.37E-03	3.41E-03	3.42E-03	3.43E-03	3.43E-03	3.44E-03
30	*-1.11*	1.92E-03	1.92E-03	1.92E-03	1.92E-03	1.92E-03	1.92E-03	1.95E-03	1.95E-03	1.96E-03	1.96E-03	1.97E-03
50	*10.00*	1.26E-03	1.27E-03	1.27E-03	1.27E-03	1.27E-03	1.27E-03	1.28E-03	1.29E-03	1.29E-03	1.29E-03	1.30E-03
100	*37.78*	6.75E-04	6.76E-04	6.76E-04	6.76E-04	6.76E-04	6.76E-04	6.83E-04	6.85E-04	6.86E-04	6.88E-04	6.89E-04
150	*65.56*	4.30E-04	4.30E-04	4.30E-04	4.30E-04	4.30E-04	4.30E-04	4.34E-04	4.35E-04	4.36E-04	4.37E-04	4.37E-04
200	*93.33*	3.03E-04	3.04E-04	3.04E-04	3.04E-04	3.04E-04	3.04E-04	3.06E-04	3.07E-04	3.07E-04	3.08E-04	3.08E-04
250	*121.11*	2.30E-04	2.30E-04	2.30E-04	2.30E-04	2.30E-04	2.30E-04	2.32E-04	2.32E-04	2.33E-04	2.33E-04	2.33E-04
300	*148.89*	1.85E-04	1.85E-04	1.85E-04	1.85E-04	1.85E-04	1.85E-04	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1.88E-04
350	*176.67*	1.53E-04	1.53E-04	1.53E-04	1.53E-04	1.53E-04	1.53E-04	1.54E-04	1.54E-04	1.54E-04	1.55E-04	1.55E-04

[5] MEGlobal: Ethylene Glycol

Specific Heat Capacity (%Mass) Metric Units												
T [ºF]	T[ºC]	*0%*	*10.0%*	*20.0%*	*30.0%*	*40.0%*	*50.0%*	*60.0%*	*70.0%*	*80.0%*	*90.0%*	*100.0%*
		cp [Btu/lb-F]	cp [Btu/lb-F]	cp [Btu/lb-F]	cp [Btu/lb-F]	cp [Btu/lb-F]	cp [Btu/lb-F]	cp [Btu/lb-F]	cp [Btu/lb-F]	cp [Btu/lb-F]	cp [Btu/lb-F]	cp [Btu/lb-F]
-50	***-45.56***	4.2684E+03	4.0417E+03	3.8416E+03	3.6652E+03	3.4752E+03	3.2720E+03	3.0553E+03	2.8251E+03	2.5816E+03	2.3247E+03	2.0543E+03
-40	***-40.00***	4.2579E+03	4.0448E+03	3.8509E+03	3.6772E+03	3.4898E+03	3.2890E+03	3.0746E+03	2.8467E+03	2.6053E+03	2.3504E+03	2.0819E+03
-30	***-34.44***	4.2481E+03	4.0480E+03	3.8602E+03	3.6891E+03	3.5044E+03	3.3060E+03	3.0940E+03	2.8683E+03	2.6290E+03	2.3761E+03	2.1095E+03
-20	***-28.89***	4.2390E+03	4.0513E+03	3.8695E+03	3.7011E+03	3.5189E+03	3.3231E+03	3.1134E+03	2.8899E+03	2.6527E+03	2.4018E+03	2.1370E+03
-10	***-23.33***	4.2306E+03	4.0548E+03	3.8788E+03	3.7131E+03	3.5335E+03	3.3401E+03	3.1328E+03	2.9115E+03	2.6764E+03	2.4275E+03	2.1646E+03
0	***-17.78***	4.2229E+03	4.0584E+03	3.8881E+03	3.7251E+03	3.5481E+03	3.3571E+03	3.1521E+03	2.9331E+03	2.7001E+03	2.4532E+03	2.1922E+03
10	***-12.22***	4.2158E+03	4.0622E+03	3.8974E+03	3.7371E+03	3.5626E+03	3.3741E+03	3.1715E+03	2.9547E+03	2.7239E+03	2.4789E+03	2.2198E+03
30	***-1.11***	4.2038E+03	4.0702E+03	3.9160E+03	3.7611E+03	3.5918E+03	3.4082E+03	3.2102E+03	2.9979E+03	2.7713E+03	2.5303E+03	2.2749E+03
50	***10.00***	4.1944E+03	4.0789E+03	3.9346E+03	3.7851E+03	3.6209E+03	3.4423E+03	3.2490E+03	3.0411E+03	2.8187E+03	2.5817E+03	2.3301E+03
100	***37.78***	4.1829E+03	4.1030E+03	3.9810E+03	3.8450E+03	3.6938E+03	3.5274E+03	3.3459E+03	3.1491E+03	2.9372E+03	2.7102E+03	2.4679E+03
150	***65.56***	4.1883E+03	4.1307E+03	4.0275E+03	3.9049E+03	3.7666E+03	3.6126E+03	3.4427E+03	3.2571E+03	3.0558E+03	2.8387E+03	2.6058E+03
200	***93.33***	4.2107E+03	4.1622E+03	4.0740E+03	3.9649E+03	3.8395E+03	3.6977E+03	3.5396E+03	3.3651E+03	3.1743E+03	2.9672E+03	2.7436E+03
250	***121.11***	4.2501E+03	4.1974E+03	4.1205E+03	4.0248E+03	3.9123E+03	3.7829E+03	3.6365E+03	3.4731E+03	3.2929E+03	3.0957E+03	2.8815E+03
300	***148.89***	4.3064E+03	4.2362E+03	4.1670E+03	4.0848E+03	3.9852E+03	3.8680E+03	3.7333E+03	3.5811E+03	3.4114E+03	3.2242E+03	3.0194E+03
350	***176.67***	4.3797E+03	4.2788E+03	4.2134E+03	4.1447E+03	4.0580E+03	3.9532E+03	3.8302E+03	3.6891E+03	3.5300E+03	3.3527E+03	3.1572E+03

Ethylene Glycol (%Mass) Metric												
T [ºF]	T[ºC]	*0%*	*10.0%*	*20.0%*	*30.0%*	*40.0%*	*50.0%*	*60.0%*	*70.0%*	*80.0%*	*90.0%*	*100.0%*
		k [W/m-K]	k [W/m-K]	k [W/m-K]	k [W/m-K]	k [W/m-K]	k [W/m-K]	k [W/m-K]	k [W/m-K]	k [W/m-K]	k [W/m-K]	k [W/m-K]
-50	***-45.56***	4.4270E-01	4.3354E-01	4.3211E-01	4.1344E-01	4.0216E-01	4.0216E-01	3.9100E-01	3.4951E-01	3.6616E-01	3.5285E-01	2.6933E-01
-40	***-40.00***	4.5429E-01	4.4233E-01	4.3644E-01	4.1739E-01	4.0417E-01	4.0417E-01	3.9116E-01	3.5176E-01	3.6359E-01	3.4930E-01	2.7357E-01
-30	***-34.44***	4.6550E-01	4.5080E-01	4.4078E-01	4.2115E-01	4.0604E-01	4.0604E-01	3.9123E-01	3.5394E-01	3.6098E-01	3.4574E-01	2.7781E-01
-20	***-28.89***	4.7632E-01	4.5896E-01	4.4511E-01	4.2473E-01	4.0775E-01	4.0775E-01	3.9121E-01	3.5607E-01	3.5835E-01	3.4217E-01	2.8204E-01
-10	***-23.33***	4.8675E-01	4.6680E-01	4.4944E-01	4.2811E-01	4.0931E-01	4.0931E-01	3.9109E-01	3.5814E-01	3.5568E-01	3.3859E-01	2.8628E-01
0	***-17.78***	4.9680E-01	4.7433E-01	4.5378E-01	4.3131E-01	4.1073E-01	4.1073E-01	3.9088E-01	3.6015E-01	3.5299E-01	3.3500E-01	2.9052E-01
10	***-12.22***	5.0646E-01	4.8155E-01	4.5811E-01	4.3432E-01	4.1199E-01	4.1199E-01	3.9057E-01	3.6210E-01	3.5026E-01	3.3140E-01	2.9476E-01
30	***-1.11***	5.2463E-01	4.9506E-01	4.6678E-01	4.3976E-01	4.1408E-01	4.1408E-01	3.8966E-01	3.6583E-01	3.4471E-01	3.2417E-01	3.0323E-01
50	***10.00***	5.4126E-01	5.0731E-01	4.7544E-01	4.4445E-01	4.1556E-01	4.1556E-01	3.8838E-01	3.6931E-01	3.3904E-01	3.1691E-01	3.1170E-01
100	***37.78***	5.7608E-01	5.3246E-01	4.9711E-01	4.5286E-01	4.1667E-01	4.1667E-01	3.8350E-01	3.7699E-01	3.2433E-01	2.9857E-01	3.3289E-01
150	***65.56***	6.0126E-01	5.4979E-01	5.1877E-01	4.5654E-01	4.1404E-01	4.1404E-01	3.7624E-01	3.8318E-01	3.0884E-01	2.7999E-01	3.5407E-01
200	***93.33***	6.1680E-01	5.5931E-01	5.4044E-01	4.5549E-01	4.0768E-01	4.0768E-01	3.6660E-01	3.8789E-01	2.9259E-01	2.6116E-01	3.7526E-01
250	***121.11***	6.2270E-01	5.6101E-01	5.6211E-01	4.4971E-01	3.9760E-01	3.9760E-01	3.5457E-01	3.9111E-01	2.7556E-01	2.4210E-01	3.9644E-01
300	***148.89***	6.1896E-01	5.5489E-01	5.8377E-01	4.3920E-01	3.8378E-01	3.8378E-01	3.4017E-01	3.9285E-01	2.5776E-01	2.2279E-01	4.1763E-01
350	***176.67***	6.0559E-01	5.4095E-01	6.0544E-01	4.2396E-01	3.6624E-01	3.6624E-01	3.2339E-01	3.9311E-01	2.3919E-01	2.0323E-01	4.3882E-01