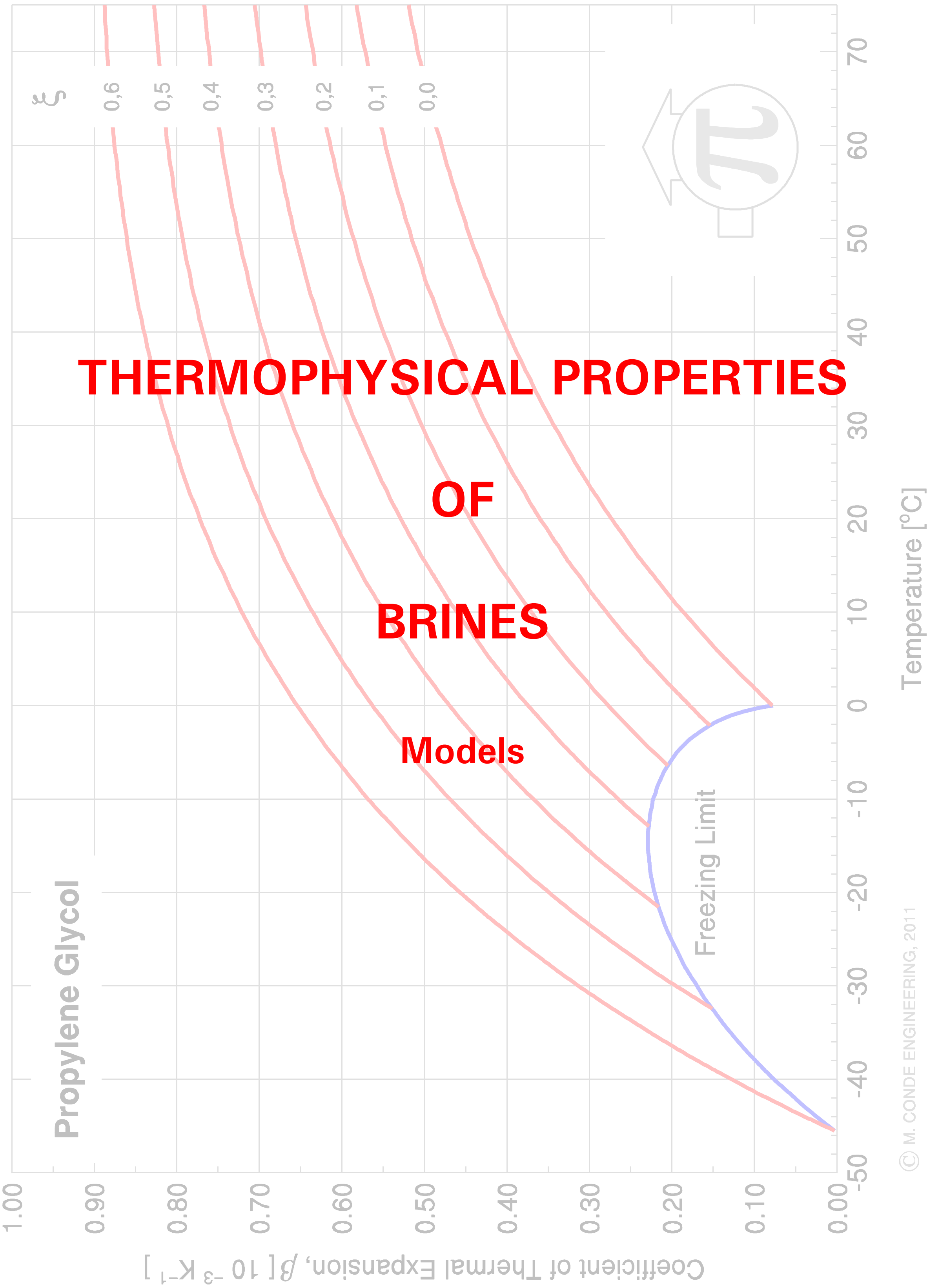

THERMOPHYSICAL PROPERTIES

OF

BRINES

Models

M. CONDE ENGINEERING, 2011

Secondary Fluids - Brines

Secondary refrigerants (brines) are used in refrigeration, air conditioning and heating plants whenever indirect heat transfer processes take place, particularly when the risk of freezing must be considered. There are a large number of products on the market, some to be used in aqueous solutions, some entirely without water. None represents a universal solution, and most present specific problems that must be properly addressed, in particular to avoid corrosion of pipes and fittings.

The thermophysical properties of the brines influence the energy transport processes and so affect the performance of plants and equipment. Thus, in the design and performance estimation of components, equipment and plants these external influences should be considered. For this purpose, mathematical models describing the thermophysical properties of brines were developed and are described in the following.

The brines considered here are aqueous solutions of *ETHYLENE GLYCOL* and of *PROPYLENE GLYCOL,* which happen to be two of the most common in refrigeration, heat pump, air conditioning and solar thermal applications.

Before describing the models, a special mention of atmospheric air as a secondary fluid is necessary. Due to its particular properties and availability, air is only second to water as a secondary fluid. Due to the presence of condensable water vapour, a dedicated mathematical model is necessary for humid air. This model is decribed in detail in other documents on this site..

Mathematical model of the thermophysical properties of aqueous solutions of

ETHYLENE GLYCOL

and

PROPYLENE GLYCOL

The properties necessary in the calculation of the heat transfer processes include

- Density
- Specific thermal capacity
- Thermal conductivity
- Viscosity
- Prandtl number

and their variations with the operating conditions. Besides these, the freezing temperature and the upper limit of use are also required for a complete description and identification of application limits during simulations. This limit may as well represent the limitations of the data available. Furthermore, the coefficient of thermal expansion, β, is also required in order to size the expansion vessel in closed circuits.

Freezing Temperature

The temperature of freezing depends upon the concentration of the solution, and may be determined by an equation of the form

$$\frac{T_F}{273.15} = A_0 + A_1 \xi + A_2 \xi^2$$

Density, Thermal Conductivity and Specific Thermal Capacity

The density, thermal conductivity and specific thermal capacity may all be calculated by the same kind of equation. The property is here represented by P_x

$$P_x = A_1 + A_2\xi + A_3\frac{273.15}{T} + A_4\xi\frac{273.15}{T} + A_5\left(\frac{273.15}{T}\right)^2$$

Dynamic Viscosity and Prandtl Number

The same applies to the calculation of the dynamic viscosity and Prandtl Number, with a slightly different equation

$$LN(P_x) = A_1 + A_2\xi + A_3\frac{273.15}{T} + A_4\xi\frac{273.15}{T} + A_5\left(\frac{273.15}{T}\right)^2$$

These equations apply as well to pure water at the limit of null concentration.

Coefficient of Thermal Expansion

Since most applications of brines involve small to moderate temperature variations, it is necessary to provide some expansion volume (expansion vessel) to absorb the expansion and contraction of the brine volume due to these temperature oscillations. In order to estimate the volume required for the expansion vessel it is necessary to know the coefficient of thermal expansion, β, of the brine. This is defined as

$$\beta_{P,\xi} = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_{P,\xi} \equiv -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_{P,\xi}$$

The derivative is obtained from the equation for density.

Table I gives the parameters of all the equations for aqueous solutions of *ETHYLENE GLYCOL*.

Parameter Order	ρ [kg/m³]	Cp [kJ/kg K]	λ [W/m K]	μ [Pa s]	Pr [-]	T_F [K]
0						1.0
1	658.498 25	5.364 49	0.838 18	-4.630 24	3.969 51	-0.069 82
2	-54.815 01	0.788 63	-1.376 20	-2.148 17	0.700 76	-0.357 80
3	664.716 43	-2.590 01	-0.076 29	-12.701 06	-12.980 45	
4	232.726 05	-2.731 87	1.077 20	5.405 36	2.647 89	
5	-322.616 61	1.437 59	-0.201 74	10.989 90	11.589 00	

Table I - Parameters of the mathematical models of aqueous solutions of *ETHYLENE GLYCOL.*

The following figures depict charts of the thermophysical properties of aqueous solutions of *ETHYLENE GLYCOL.*

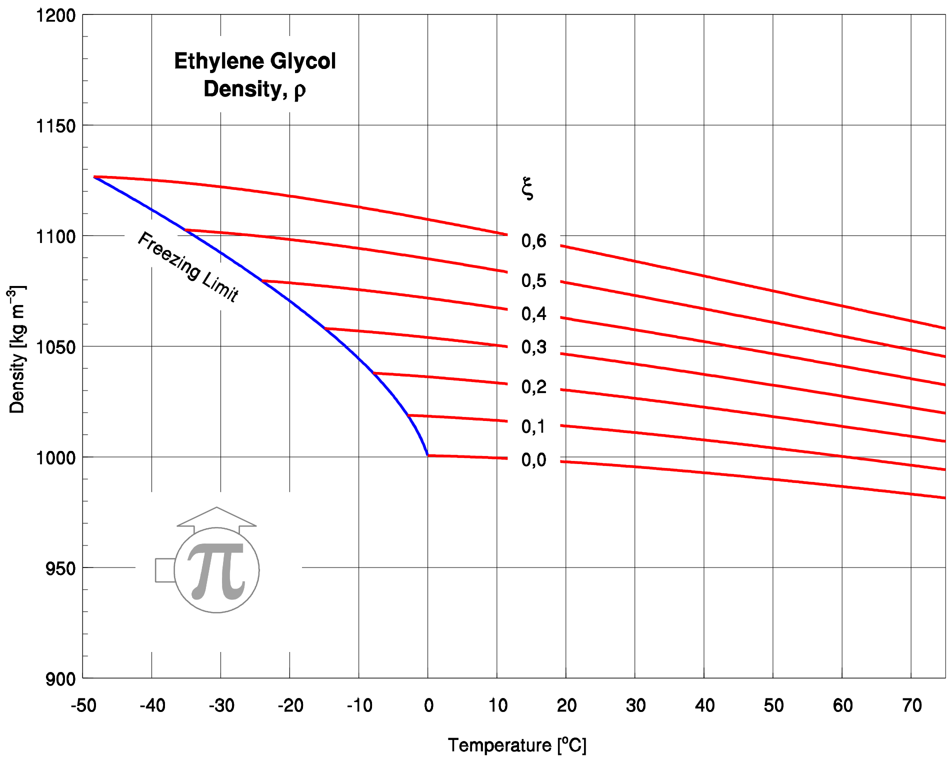

Fig. 2 - Density of aqueous solutions of *ETHYLENE GLYCOL.*

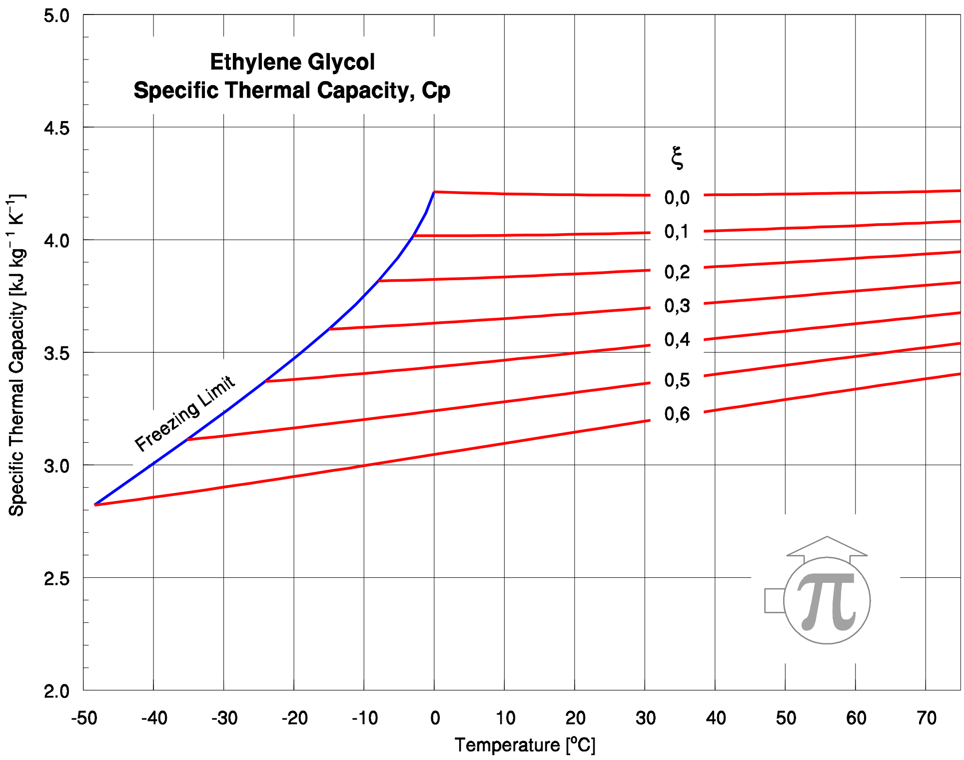

Fig. 3 - Specific thermal capacity of aqueous solutions of *ETHYLENE GLYCOL.*

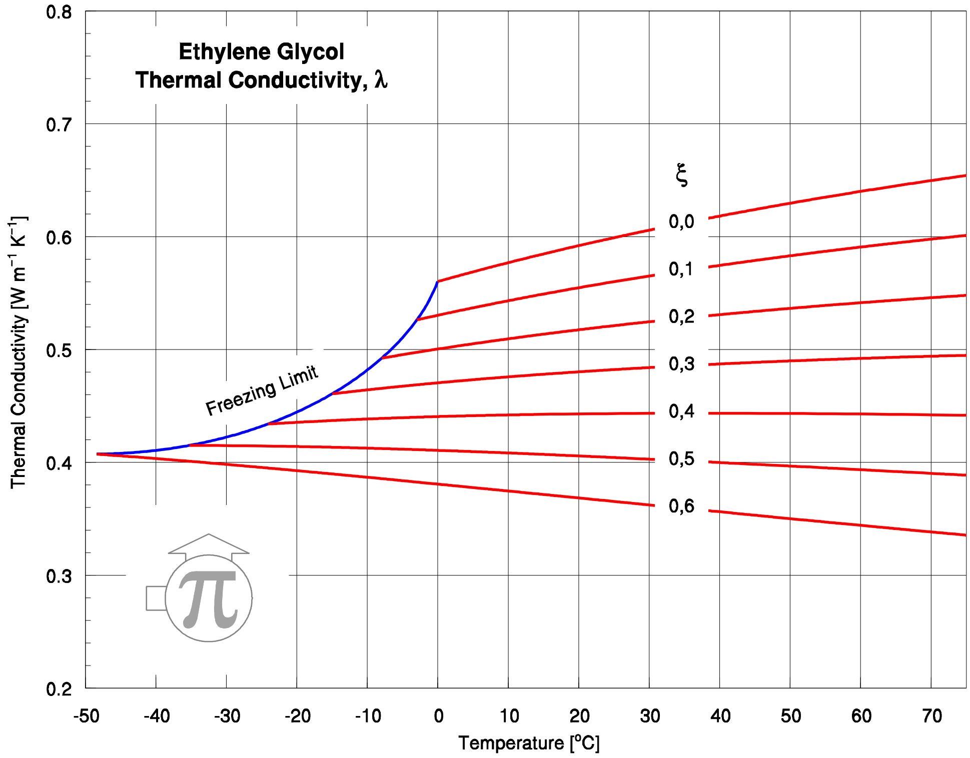

Fig. 4 - Thermal conductivity of aqueous solutions of *ETHYLENE GLYCOL.*

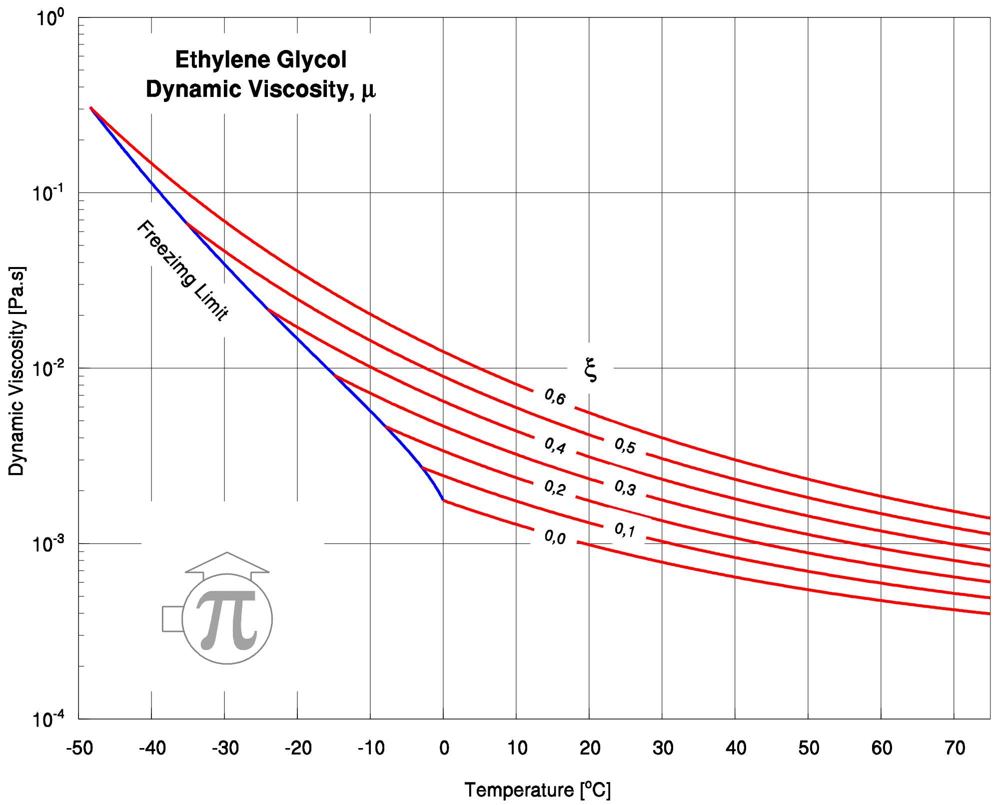

Fig. 5 - Dynamic viscosity of aqueous solutions of *ETHYLENE GLYCOL.*

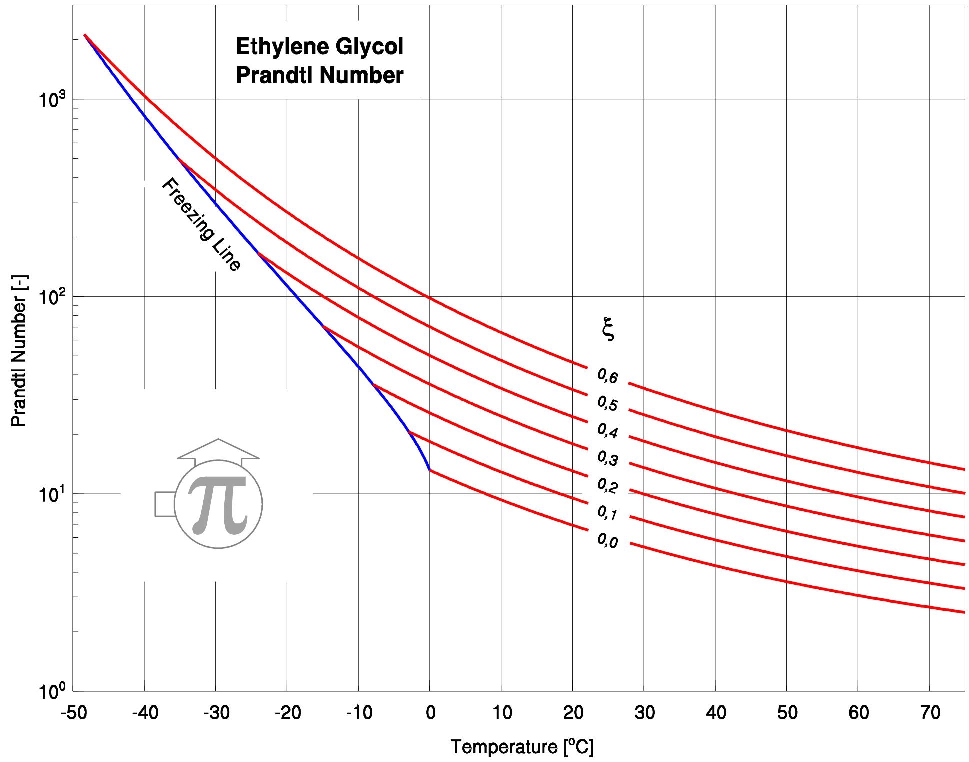

Fig. 6 - Prandtl number of aqueous solutions of *ETHYLENE GLYCOL.*

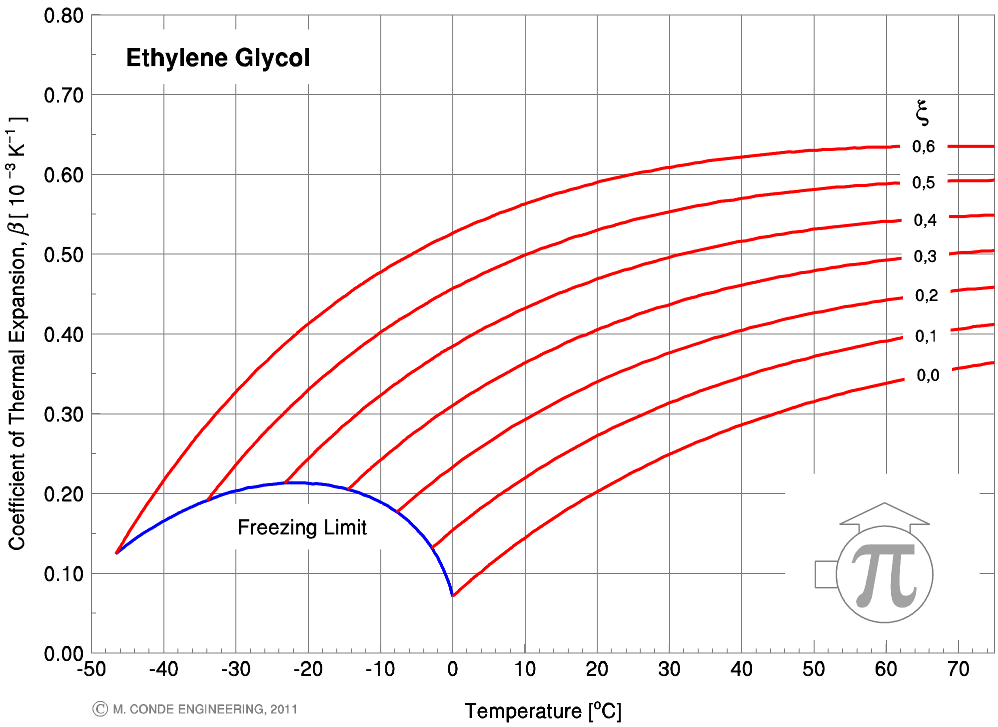

Fig. 7 - Coefficient of thermal expansion of aqueous solutions of *ETHYLENE GLYCOL.*

Table II gives the parameters of all the equations for aqueous solutions of *PROPYLENE GLYCOL*.

Parameter Order	ρ [kg/m^3]	Cp [kJ/kg K]	λ [W/m K]	μ [Pa s]	Pr [-]	T_F [K]
0						1.0
1	508.411 09	4.476 42	1.188 86	-1.027 98	6.661 39	-0.037 36
2	-182.408 20	0.608 63	-1.491 10	-10.032 98	-6.994 40	-0.400 50
3	965.765 07	-0.714 97	-0.696 82	-19.934 97	-18.551 14	
4	280.291 04	-1.938 55	1.136 33	14.658 02	12.046 40	
5	-472.225 10	0.478 73	0.067 35	14.620 50	14.477 35	

Table II - Parameters of the mathematical models of aqueous solutions of *PROPYLENE GLYCOL.*

The following figures depict charts of the thermophysical properties of aqueous solutions of *PROPYLENE GLYCOL.*

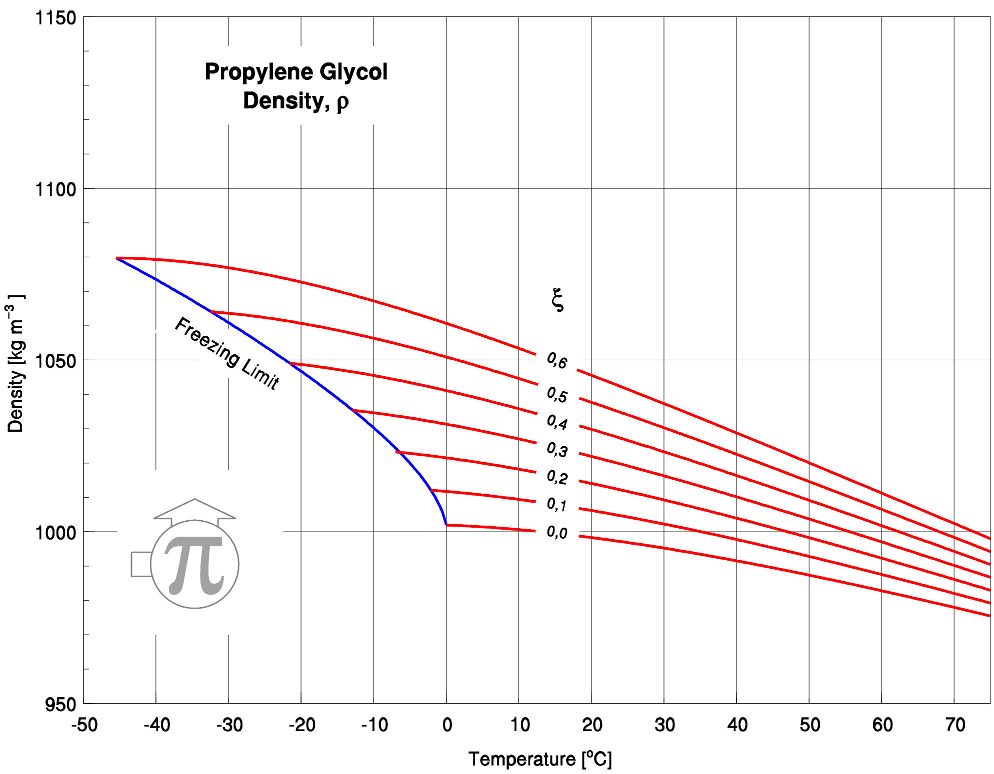

Fig. 8 - Density of aqueous solutions of *PROPYLENE GLYCOL.*

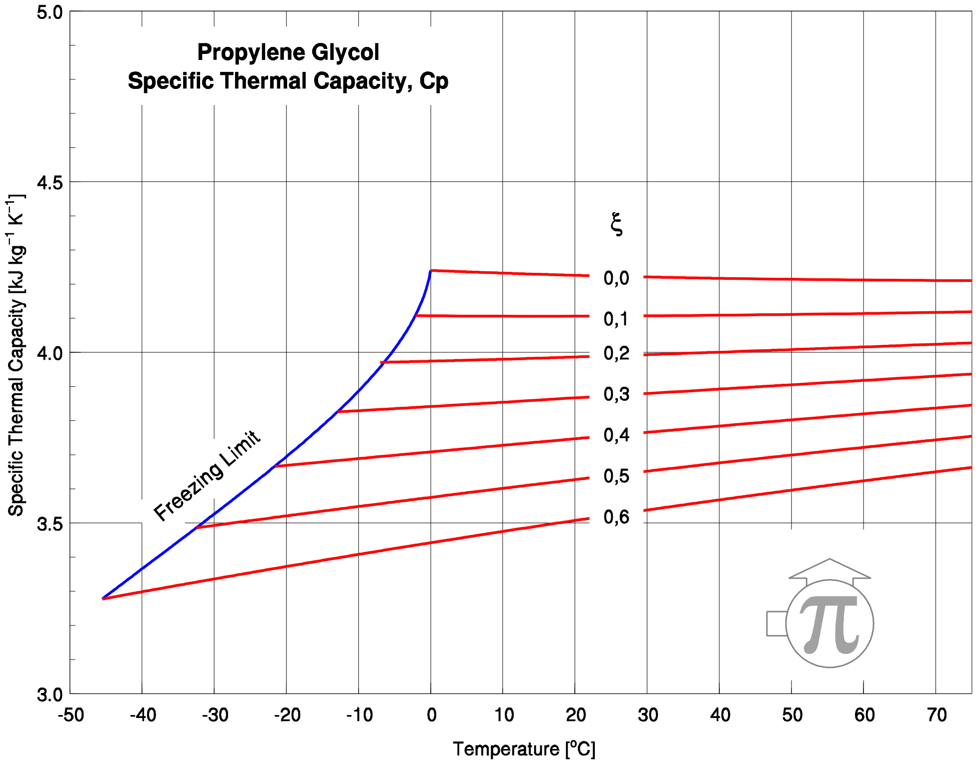

Fig. 9 - Specific thermal capacity of aqueous solutions of *PROPYLENE GLYCOL.*

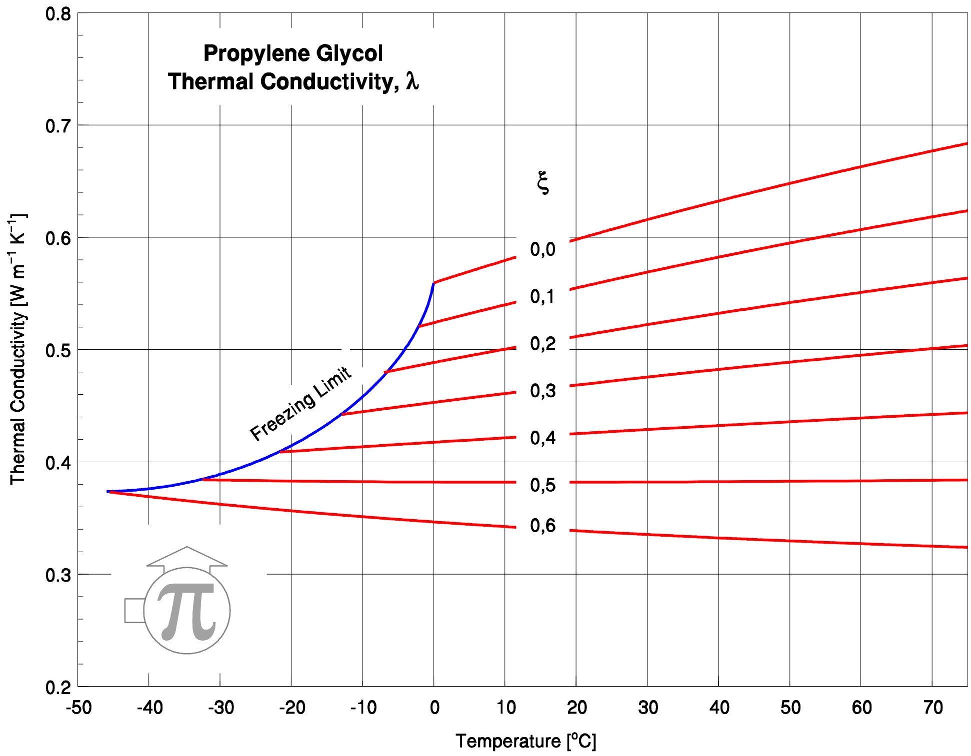

Fig. 10 - Thermal conductivity of aqueous solutions of *PROPYLENE GLYCOL.*

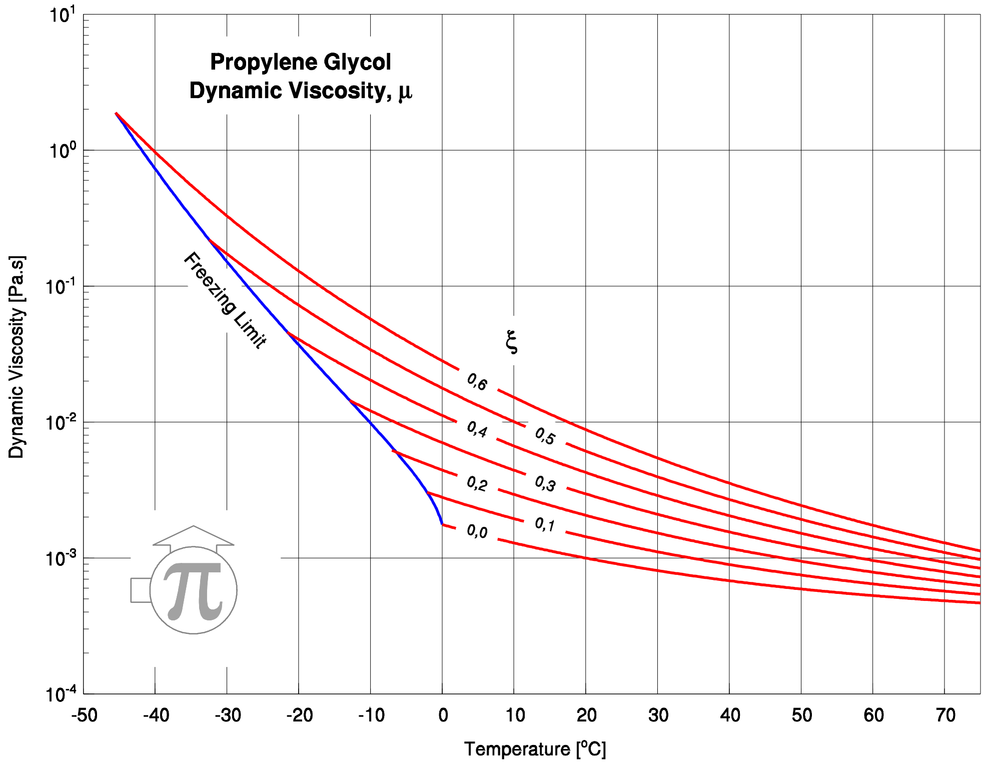

Fig. 11 - Dynamic viscosity of aqueous solutions of *PROPYLENE GLYCOL.*

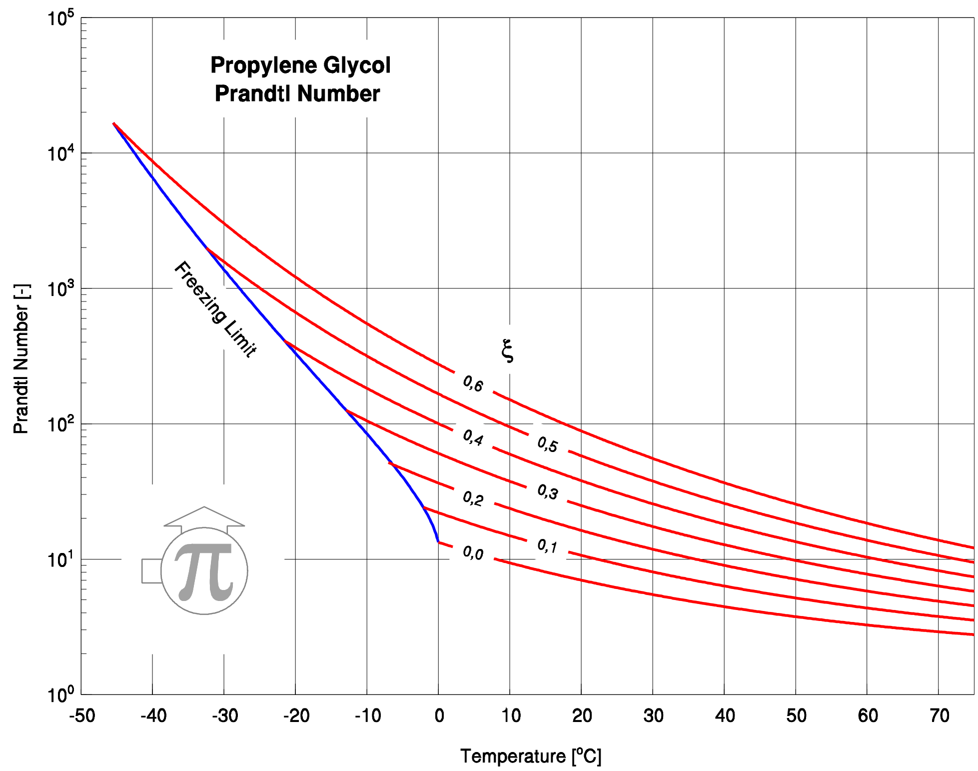

Fig. 12 - Prandtl number of aqueous solutions of *PROPYLENE GLYCOL.*

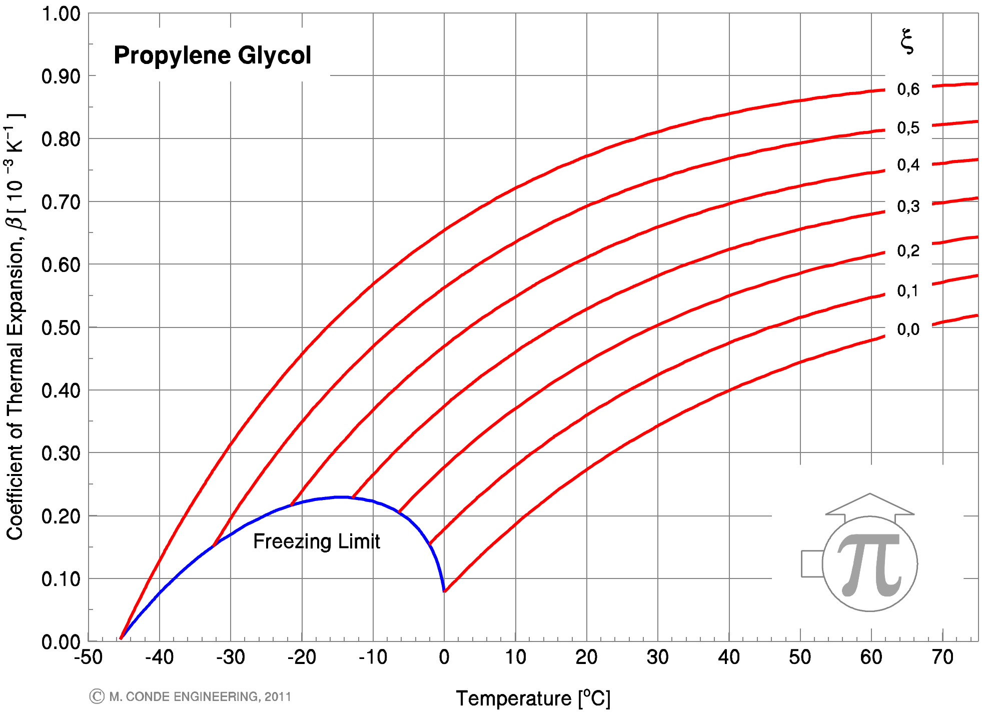

Fig. 13 - Coefficient of thermal expansion of aqueous solutions of *PROPYLENE GLYCOL.*

Nomenclature

ξ is the mass fraction of the glycol in solution

T is the absolute temperature in K.

Literature

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