

Thermophysical properties of industrially important fluids on the saturation line: Cresols

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THE PREPARATION OF THIS DATA ITEM

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THERMOPHYSICAL PROPERTIES OF INDUSTRIALLY IMPORTANT FLUIDS ON THE SATURATION LINE: CRESOLS

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THERMOPHYSICAL PROPERTIES OF INDUSTRIALLY IMPORTANT FLUIDS ON THE SATURATION LINE: CRESOLS

1. INTRODUCTION

This Item, which is one of a series concerned with the thermophysical properties of industrially important fluids, gives equations representing the thermophysical properties of *o*-cresol, *m*-cresol and *p*-cresol on the saturation line, together with tabulated values calculated from the equations.

The data on which the recommended values of the fluid properties are based are considered to be the best available and the range covered for the saturation line properties is from the melting temperature to within at least 75 kelvin of the critical temperature.

All quantities are expressed in SI units or their multiples (see Section 2) but, for users who require them in other units, conversion factors are provided in Appendix A. Equations representing the fluid properties are given in Section 3 and Section 4 gives an explanation of the Tables and Figures in the Data Item.

2. NOTATION AND UNITS

b_1, b_2, b_3, b_4, b_5	constants in Equations (3.1) to (3.14)	*
c	specific heat capacity	kJ/kg K
h	specific enthalpy	kJ/kg
M	molecular weight (relative molecular mass)	—
p	vapour pressure	kPa
T	kelvin temperature	K
t	Celsius temperature, $(T - 273.15)$	°C
u	specific internal energy	kJ/kg
V	molar volume	cm ³ /mol
v	specific volume, $v = 1/\rho$	m ³ /kg
η	dynamic viscosity	mN s/m ² or $\mu\text{N s/m}^2$
θ	temperature dependent variable in Equation (3.10)	—
λ	thermal conductivity	mW/m K
ρ	density	kg/m ³
σ	surface tension	mN/m
ω	acentric factor	—

* The constants b are dimensionless except for the following: Equations (3.4) and (3.6), kJ/kg (all); Equations (3.7) and (3.9), kJ/kg K (all); Equation (3.8), kJ/kg K (b_1); Equation (3.10), K (b_3), mN s/m² (b_4); Equation (3.11), $\mu\text{N s/m}^2$ ($\exp(b_1)$); Equations (3.12) and (3.13), mW/m K (b_1 and $\exp(b_1)$ respectively); Equation (3.14), mN/m (b_1).

State descriptors

(g)	value for gas or saturated vapour
(l)	value for saturated liquid
Δ	denotes property difference between two states

Subscripts

b	value at normal boiling point
c	value at critical point
m	value at normal melting point
p	value at constant pressure
r	denotes reduced quantity, <i>e.g.</i> $T_r = T/T_c$
sat	value at saturation (defined in Appendix B, Section B1)
v	value at constant volume
vap	denotes evaporation.

3. EQUATIONS FOR PROPERTIES

3.1 Vapour Pressure

Data for the vapour pressure are represented by Equation (3.1).

$$\log_e \left(\frac{p}{p_c} \right) = \frac{1}{T_r} [b_1(1 - T_r) + b_2(1 - T_r)^{3/2} + b_3(1 - T_r)^3 + b_4(1 - T_r)^6]. \quad (3.1)$$

3.2 Density of the Saturated Liquid

Data for the density of the saturated liquid are represented by Equation (3.2).

$$\log_e \left(\frac{\rho(l)}{\rho_c} \right) = b_1(1 - T_r)^{1/3} + b_2(1 - T_r)^{2/3} + b_3(1 - T_r) + b_4(1 - T_r)^{4/3}. \quad (3.2)$$

3.3 Density of the Saturated Vapour

Data for the density of the saturated vapour are represented by Equation (3.3).

$$\log_e \left(\frac{\rho(g)}{\rho_c} \right) = b_1 \left(\frac{1}{T_r} - 1 \right)^{1/3} + b_2 \left(\frac{1}{T_r} - 1 \right)^{2/3} + b_3 \left(\frac{1}{T_r} - 1 \right) + b_4 \left(\frac{1}{T_r} - 1 \right)^{4/3} + b_5 \left(\frac{1}{T_r} - 1 \right)^{5/3}. \quad (3.3)$$

3.4 Specific Enthalpy of the Saturated Liquid

Data for the specific enthalpy of the saturated liquid are represented by Equation (3.4).

$$h(l) = b_1(1 - T_r)^{1/3} + b_2(1 - T_r)^{2/3} + b_3(1 - T_r) + b_4(1 - T_r)^{4/3}. \quad (3.4)$$

3.5 Latent Heat of Vaporisation (Specific Enthalpy of Vaporisation)

Data for the latent heat of vaporisation are represented by Equation (3.5).

$$\Delta_{\text{vap}} h = h(g) - h(l). \quad (3.5)$$

3.6 Specific Enthalpy of the Saturated Vapour

Data for the specific enthalpy of the saturated vapour are represented by Equation (3.6).

$$h(g) = b_1(1 - T_r)^{1/3} + b_2(1 - T_r)^{2/3} + b_3(1 - T_r) + b_4(1 - T_r)^{4/3}. \quad (3.6)$$

3.7 Isobaric Specific Heat Capacity of the Saturated Liquid

Data for the isobaric specific heat capacity of the saturated liquid are represented by Equation (3.7).

$$c_p(l) = b_1(1 - T_r)^{-2/3} + b_2(1 - T_r)^{-1/3} + b_3(1 - T_r)^{1/3} + b_4(1 - T_r)^{2/3}. \quad (3.7)$$

The significance of $c_p(l)$ as a representation of specific heat capacity is fully explained in Appendix B, Section B1.

3.8 Isobaric Specific Heat Capacity of the Saturated Vapour

Data for the isobaric specific heat capacity of the saturated vapour are represented by Equation (3.8).

$$c_p(g) = b_1[1 + b_2(1 - T_r)^{-2/3} + b_3(1 - T_r)^{-1/3} + b_4(1 - T_r)^{1/3} + b_5(1 - T_r)^{2/3}]. \quad (3.8)$$

The significance of $c_p(g)$ as a representation of specific heat capacity is fully explained in Appendix B, Section B1.

3.9 Specific Heat Capacity at Saturation of the Saturated Liquid

Data for the specific heat capacity at saturation of the saturated liquid are represented by Equation (3.9).

$$c_{\text{sat}}(l) = b_1(1 - T_r)^{-2/3} + b_2(1 - T_r)^{-1/3} + b_3(1 - T_r)^{1/3} + b_4(1 - T_r)^{2/3}. \quad (3.9)$$

The significance of $c_{\text{sat}}(l)$ as a representation of specific heat capacity is fully explained in Appendix B, Section B1.

3.10 Dynamic Viscosity of the Saturated Liquid

Data for the dynamic viscosity of the saturated liquid are represented by Equation (3.10).

$$\eta(l) = b_4 \exp[b_1(\theta - 1)^{1/3} + b_2(\theta - 1)^{4/3}] \quad (3.10)$$

where $\theta = (T_c - b_3)/(T - b_3)$.

3.11 Dynamic Viscosity of the Saturated Vapour

Data for the dynamic viscosity of the saturated vapour are represented by Equation (3.11).

$$\log_e \eta(g) = b_1 + b_2 \left(\frac{1}{T_r} - 1 \right)^{1/3} + b_3 \left(\frac{1}{T_r} - 1 \right)^{4/3}. \quad (3.11)$$

3.12 Thermal Conductivity of the Saturated Liquid

Data for the thermal conductivity of the saturated liquid are represented by Equation (3.12).

$$\lambda(l) = b_1 [1 + b_2(1 - T_r)^{1/3} + b_3(1 - T_r)^{2/3} + b_4(1 - T_r)]. \quad (3.12)$$

3.13 Thermal Conductivity of the Saturated Vapour

Data for the thermal conductivity of the saturated vapour are represented by Equation (3.13).

$$\log_e \lambda(g) = b_1 + b_2(1 - T_r)^{-2/3} + b_3(1 - T_r)^{-1/3} + b_4(1 - T_r)^{1/3} + b_5(1 - T_r)^{2/3}. \quad (3.13)$$

3.14 Surface Tension

Data for surface tension are represented by Equation (3.14).

$$\sigma = b_1(1 - T_r)^{b_2} [1 + b_3(1 - T_r)]. \quad (3.14)$$

4. EXPLANATION OF THE TABLES AND FIGURES

Tables 6.1, 6.4 and 6.7 provide values of the physical constants for *o*-cresol, *m*-cresol and *p*-cresol respectively and constants for use in the equations given in Section 3, that represent the fluid properties in the SI units* of the Notation, Section 2. Although the saturated liquid and vapour enthalpies tend to the same value as the critical point is approached, the saturated liquid enthalpy values calculated from Equation (3.4) for all the cresols pass through a physically unrealistic maximum so that the slope of the saturated liquid enthalpy curve tends to $-\infty$ at the critical temperature, not ∞ as required.

Modern theory requires the isobaric heat capacity, viscosity and thermal conductivity to tend to infinity as the critical point is approached; this theoretical limit has been included where appropriate in Tables 6.3, 6.6 and 6.9. However, for all the cresols, Equations (3.8), (3.10), (3.11), (3.12), (3.13) do not conform with theory in this respect; Equation (3.8) approaches $-\infty$, Equations (3.10), (3.11), (3.12) approach a finite value and Equation (3.13) goes to zero at the critical temperature. Although the remaining equations – apart

* Appendix A gives conversion factors to other units.

from Equation (3.5) for *o*-cresol – Equations (3.1), (3.2), (3.3), (3.5), (3.6), (3.7), (3.9), (3.14) extrapolate in a physically realistic manner, users should not extrapolate any of the equations in Section 3 outside the temperature limits specified in Tables 6.1, 6.4 and 6.7.

The variation with temperature of all the fluid properties for *o*-cresol is shown in Figures 1 to 7. The dashed lines show the extrapolated behaviour of some of these equations between the upper temperature limits in Table 6.1 and the critical temperature. The corresponding variations of fluid properties for *m*-cresol and *p*-cresol are not plotted since they are very similar in form to those for *o*-cresol.

The values derived from the equations applying on the saturation line are presented in: Tables 6.2 and 6.3 (*o*-cresol); Tables 6.5 and 6.6 (*m*-cresol), and Tables 6.8 and 6.9 (*p*-cresol). The temperature range covered is from the melting temperature to approximately $T_r = 0.90$, except for Equations (3.1), (3.2), (3.3) and (3.14) which are valid to the critical temperature and Equations (3.11), (3.12) and (3.14), which are valid to approximately $T_r = 0.97$.

The specific enthalpies of vaporisation in column 7 of Tables 6.2, 6.5 and 6.8 were calculated directly from Equation (3.5) with subsequent rounding to the desired number of significant figures. Small differences, usually in the last figure may occur therefore, between these values and those obtained by subtraction of the specific enthalpies in column 5 from those in column 6, since the values generated thereby are the differences between two rounded numbers.

The data used in developing the constants for the equations are those considered to be the best available and the equations themselves introduce no significant fitting errors. For some properties, however, where experimental data are few or lacking it has been necessary to estimate values and these are indicated in the Tables by the use of parentheses.

5. DERIVATION

The Derivation lists selected sources that have assisted in the preparation of this Data Item.

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6. TABLES

C₇H₈O o-CRESOL
CAS Reg. No: 95-48-7

**TABLE 6.1 Physical constants of o-cresol and constants
for Equations (3.1) to (3.14)**

<i>Physical Constants</i>	<i>Symbol</i>	<i>Value</i>
Molecular Weight	M	108.14
Critical Temperature	T_c	697.55 K (424.40 °C)
Critical Pressure	p_c	5005.0 kPa
Critical Density	ρ_c	384.0 kg/m ³
Critical Molar Volume	V_c	281.6 cm ³ /mol
Normal Boiling Temperature	T_b	464.19 K (191.04 °C)
Normal Melting Temperature	T_m	304. K (30.85 °C)
Acentric Factor	ω	0.437

Constants used in Equations (3.1) to (3.14)

Property	Equation in Section 3	b_1	b_2	b_3	b_4	b_5	Range of Applicability °C
p	(3.1)	-9.10170	3.63546	-6.68055	-2.61550	-	31 to 410
$\rho(l)$	(3.2)	0.62430	2.23205	-2.64071	0.94363	-	31 to 410
$\rho(g)$	(3.3)	-2.10740	-4.09299	2.60275	-2.47611	-2.92759	31 to 410
$h(l)$	(3.4)	2972.72	-7201.58	5142.25	-2120.84	-	31 to 350
$h(g)$	(3.6)	2714.17	-3187.52	-1535.05	1731.04	-	31 to 350
$c_p(l)$	(3.7)	1.03141	-2.62899	12.2279	-9.18505	-	31 to 350
$c_p(g)$	(3.8)	-13.1282	0.03069	-0.35663	-1.66117	0.97841	31 to 350
$c_{sat}(l)$	(3.9)	0.77368	-1.87014	10.540	-7.9288	-	31 to 350
$\eta(l)$	(3.10)	1.9590	0.4624	180.	0.0381	-	31 to 410
$\eta(g)$	(3.11)	3.1989	-1.03526	-0.11882	-	-	31 to 410
$\lambda(l)$	(3.12)	87.261	3.5	-8.1	6.0	-	31 to 350
$\lambda(g)$	(3.13)	-23.1226	-0.832335	7.855947	40.78388	-24.2072	31 to 400
σ	(3.14)	69.61	1.1355	0	-	-	31 to 410