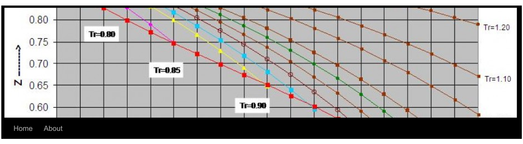

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Handy equations to calculate Heat of Evaporation and Condensation of Water/Steam

Posted on January 8, 2019 by conceptualplan

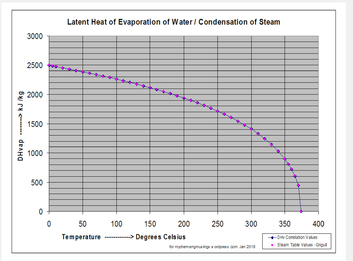
This post features short and handy equations for the heat of evaporation DeltaHvap for water (steam condensate) as a function of (saturation) temperature. These equations can come in handy. For example when one needs to determine the duty of an exchanger heating a process stream with steam. The steam's heat of condensation in the equipment is exchanged with the process stream. To calculate the heat exchanger's 'duty' (in kWatts) one need the heat of vaporization/condensation at the particular temperature the exchanger is working at. Note that in general the total heat duty by the exchanger consists of the condensation heat released plus the de-superheating of the incoming steam if applicable and the sub-cooling duty of the exiting steam condensate.

The heat of evaporation can be calculated from the following equation that is valid over a very wide temperature range : from 10 deg. Celsius to 365 deg. Celsius and with the small average percentage error of 0.15% ! As usual in this blog the equation's formula is written in 'excel' style format: the symbol'^' is used for multiplication and the accent circonflex '^' for raising to the power. With as symbol 'DHv' for the heat of evaporation and 't' as symbol for the temperature of condensation (in contrast with 'T' for the absolute temperature) the equation reads:

DHv = 193.1 – 10950 * Ln((374 – t)/647) * (374 – t)^0.785 /(273+ t)

'DHv' heat of condensation is expressed in kJ/kg ; t in degrees Celsius ; 'Ln' stands for the

This equation can be easily implemented in an excel spreadsheet as above equation is noted in 'excel style' formula format. Please note that of course no additional 'inputs' like absolute saturation Pressure or vapor compressibility are necessary! The following Chart shows the above equation's results compared with steam table data : (click to enlarge)



Latent Heat of Evaporation/Condensation of Water as function of temperature

Fig. The latent heat of evaporation of water as function of temperature in degrees Celsius

Steam system generally work in the temperature range where the DHvap is changing strongly witstanding temperature.

Handy short cuts: linear relations around a 'fixed' operating temperature point.

The strength of the above correlation is it covers a very wide range of temperatures and is still able to predict the heat of evaporation with very good accuracy of 0.15% on average. The equation is also compact enough so one can easily implement it in one cell of a spreadsheet or in a VisualBasic program line. The wide range and good accuracy make it eminently suitable for design studies, or revamp studies or study the effects of operating on far off-design conditions without having to worry about the validity of the numbers used for the heat of condensation generated by the equation.

When working with an existing installation of exchangers or condensers and one wants to quickly and repeatedly evaluate the performance or the duty of a particular exchanger that usually is operating and controlled at a certain temperature and hence its temperature varies within a narrow range, a 'local range' shortcut relation of DHv and temperature would be handy . In such cases one can use the above full-range equation to devise one's own "local model" , a shortcut linear relation to calculate the heat of condensation for your chosen small temperature range around the operating temperature you are interested in.

For example, assume you are interested in the operating temperature around 240 degrees Celsius and chose a + / – 20 degrees Celsius range. You can devise a simple equation that you even can use even on a handheld calculator. The resulting equation reads:

DHv = 2924 – 4.84 * t ; e.g. for 240 deg.C the heat of condensation is 1762.4 kJ/kg

and as long as you stay within your chosen temperature range for which the shortcut is regressed the answers will stay within the 0.12% error compared to answers from the full range correlation!!!

Spreadsheet with data on the Heat of Evaporation / Condensation plus Correlation formulas for both full temperature range and local range short cut formula example. *Please find spreadsheet here:* **deltahvap correlation and shortcut calc – publ 8 jan 2019**

The basis for the above the Heat of Evaporation equation is an corresponding states correlation

The very first above full-range correlation with the temperature expressed in deg. C at the top of this post is based on an equation using 'reduced temperatures' that is formulated it in a 'corresponding states' type way. The equation in this form was developed in detail and reported in an earlier post of September 3 in 2013. In that post this development was step wise presented and appeared as such until the very end of the long post. For completeness sake I will repeat it here:

DHv * MW / (R * Tc) = A * Ln(1- Tr) * (1-Tr)^n / Tr + B

DHv = heat of evaporation / condensation in kJ/kg ; MW = water Mol Weight is 18 ; R is the universal gas constant is 8.31451 kJ/kmol/oK ; Tc = critical temperature of water is 647.15 Degr. Kelvin ; A = -9.11 ; Ln = natural Logarithm ; Tr = reduced temperature is T/Tc ; n = exponent 0.785 ; B = 0.646

References.

See post chemengmusings.wordpress.com of Sept 3 2013

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About conceptualplan

I am a retired chemical engineer. Certain areas always had my special interest, like physical properties, design of physical and chemical processes and more, that I can now delve a bit deeper into and through this blog can share with you!
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1 Response to *Handy equations to calculate Heat of Evaporation and Condensation of Water/Steam*

Anonymous *says:*
January 6, 2021 at 9:14 pm

Thank you very much for the post! I'm building a Excel xlam file to provide functions to calculate steam properties, this is very helpful!

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