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# Approximation of the Vapor Pressure of Water

January 06, 2011

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# Introduction

- Water is an indispensable substance for life forms and also in industrial plants. It is used in various applications such as in solvents, cooling mediums, and heating mediums.
- Since water is an important and familiar substance, it is widely used as a standard for physical units, and knowing these values is also important for judging the validity of various calculation results.
- The vapor pressure of water is an extremely important physical property, but it is difficult to memorize approximate values because of its strong nonlinearity.
- In this section, we will introduce an approximate method for calculating the vapor pressure of water, which can be easily memorized and readily applied.

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# Antoine Equation

- In general, the vapor pressure is expressed by the Antoine equation or the Wagner equation, and parameters are given as physical property constants for each substance.
- The accuracy of these equations is high, but it is difficult to precisely memorize their parameters.

Kagaku Kogaku Binran (*in Japanese*: Chemical Engineering Handbook) Revised 3rd ed., 5th ed., 6th ed.

$$3^{rd}\text{ed.}: \log_{10} P[mmHg] = A - \frac{B}{C + t[^\circ C]}$$

$$5^{th}\text{ed.}: \log_{10} P[kPa] = A_5 - \frac{B_5}{C_5 + t[^\circ C]}$$

$$6^{th}\text{ed.}: \ln P[Pa] = A_6 - \frac{B_6}{C_6 + T[K]}$$

Antoine Constants of Water

| Kagaku Kogaku Binran | A | B | C |
|---|---|---|---|
| 3rd ed. | 7.8097 | 1572.53 | 219 |
| 5th ed. | 7.07406 | 1657.46 | 227.02 |
| 6th ed. | 23.1964 | 3816.44 | -46.13 |



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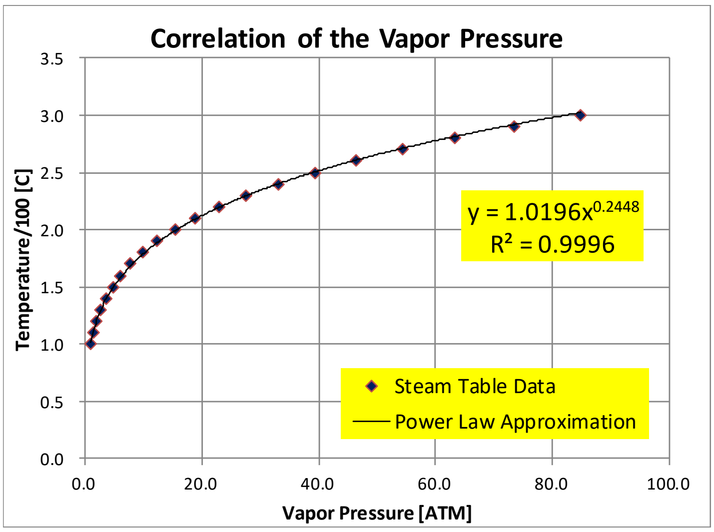
# Correlation of the Vapor Pressure

- We attempted to obtain to a simple regression based on measured data. The steam table (Japan Society of Mechanical Engineers, 1968) was used as data for comparison.

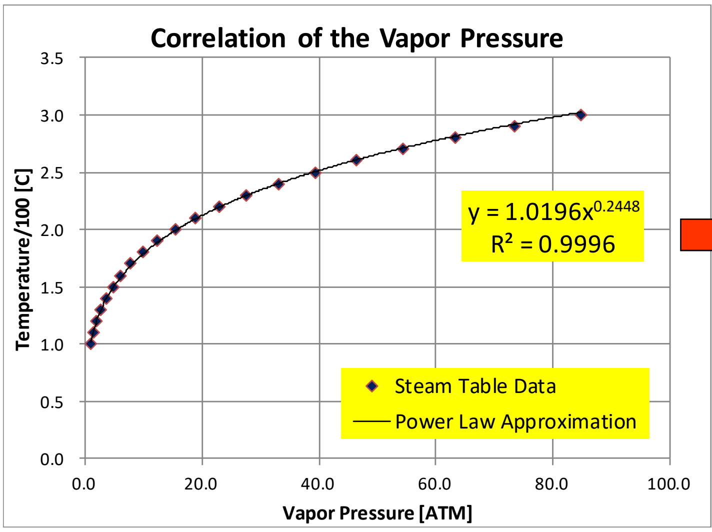
| | Measured Data | Measured Data | Measured Data | Measured Data |
|---|---|---|---|---|
| T [K] | t [C] | P [Kg/cm2] | P [ATM] | t/100 [C] |
| 373.15 | 100 | 1.03323 | 1.00000 | 1.0 |
| 383.15 | 110 | 1.46090 | 1.41392 | 1.1 |
| 393.15 | 120 | 2.02460 | 1.95949 | 1.2 |
| 403.15 | 130 | 2.75460 | 2.66602 | 1.3 |
| 413.15 | 140 | 3.68500 | 3.56650 | 1.4 |
| 423.15 | 150 | 4.85380 | 4.69771 | 1.5 |
| 433.15 | 160 | 6.30250 | 6.09982 | 1.6 |
| 443.15 | 170 | 8.07640 | 7.81668 | 1.7 |
| 453.15 | 180 | 10.22400 | 9.89521 | 1.8 |
| 463.15 | 190 | 12.79900 | 12.38740 | 1.9 |
| 473.15 | 200 | 15.85500 | 15.34513 | 2.0 |
| 483.15 | 210 | 19.45400 | 18.82839 | 2.1 |
| 493.15 | 220 | 23.65600 | 22.89526 | 2.2 |
| 503.15 | 230 | 28.52500 | 27.60768 | 2.3 |
| 513.15 | 240 | 34.13800 | 33.04017 | 2.4 |
| 523.15 | 250 | 40.56000 | 39.25565 | 2.5 |
| 533.15 | 260 | 47.86900 | 46.32961 | 2.6 |
| 543.15 | 270 | 56.14400 | 54.33849 | 2.7 |
| 553.15 | 280 | 65.46800 | 63.36265 | 2.8 |
| 563.15 | 290 | 75.92900 | 73.48724 | 2.9 |
| 573.15 | 300 | 87.62100 | 84.80324 | 3.0 |




A highly accurate correlation can be obtained by plotting the temperature/100 [C] versus the vapor pressure [ATM] and using the power law approximation.

# Correlation of the Vapor Pressure

- Based on the form of the equation, it seems that it can be replaced by a simple correlation formula. The parameters can be rounded to perform a rough calculation.




$$t/100 \approx P^{0.25}$$

$$\therefore t/100 \approx \sqrt{\sqrt{P}}$$

$t$ : [C]

$P$ : [ATM]

This indicates that an approximate value of the saturated temperature can be obtained by taking the square root of the square root of the saturated vapor pressure in [ATM] , and then multiplying the result by 100 .



# Verification of Approximate Correlation Equation

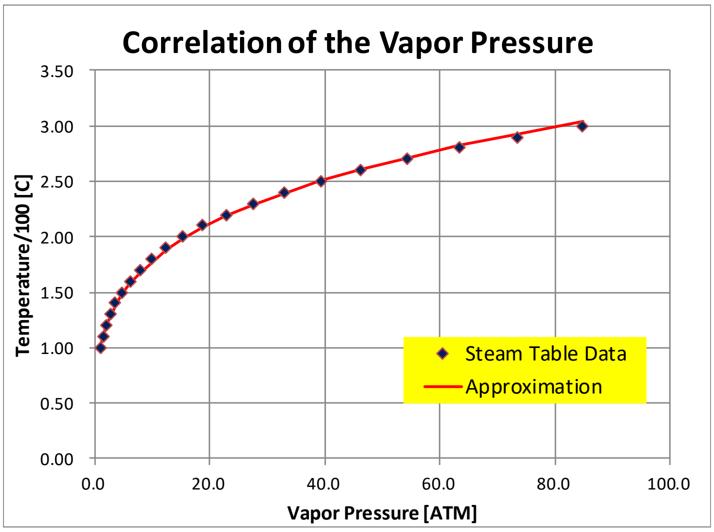
| Measured Data | Measured Data | Antoine Eq. | Approximation |
|---|---|---|---|
| P [ATM] | t/100 [C] | tA/100 [C] | tcal/100 [C] |
| 1.00 | 1.00 | 1.00 | 1.00 |
| 1.41 | 1.10 | 1.10 | 1.09 |
| 1.96 | 1.20 | 1.20 | 1.18 |
| 2.67 | 1.30 | 1.30 | 1.28 |
| 3.57 | 1.40 | 1.40 | 1.37 |
| 4.70 | 1.50 | 1.50 | 1.47 |
| 6.10 | 1.60 | 1.60 | 1.57 |
| 7.82 | 1.70 | 1.70 | 1.67 |
| 9.90 | 1.80 | 1.80 | 1.77 |
| 12.39 | 1.90 | 1.90 | 1.88 |
| 15.35 | 2.00 | 2.00 | 1.98 |
| 18.83 | 2.10 | 2.10 | 2.08 |
| 22.90 | 2.20 | 2.20 | 2.19 |
| 27.61 | 2.30 | 2.30 | 2.29 |
| 33.04 | 2.40 | 2.40 | 2.40 |
| 39.26 | 2.50 | 2.50 | 2.50 |
| 46.33 | 2.60 | 2.60 | 2.61 |
| 54.34 | 2.70 | 2.70 | 2.72 |
| 63.36 | 2.80 | 2.80 | 2.82 |
| 73.49 | 2.90 | 2.91 | 2.93 |
| 84.80 | 3.00 | 3.01 | 3.03 |
| 207.79 | 3.70 | 3.76 | 3.80 |

Vapor Pressure of Water Correlation Equation

$$t/100 \approx \sqrt{\sqrt{P}}$$

$t$ : [C]

$P$ : [ATM]




Below 300C [85 ATM], it can be seen that the deviation is around ± 1%.
Even in near the critical point, the deviation is 3% or less, which is not that much different than the Antoine equation.

# Conclusion

- When you want to estimate the saturated temperature of water from its saturated vapor pressure, simply remember to input the pressure in ATM units and press the root button twice on your calculator (deviation ± 1%).

Vapor Pressure of Water Correlation Equation

$$t/100 \approx \sqrt{\sqrt{P}}$$

$t$ : [C]

$P$ : [ATM]

- It is possible to calculate with relatively high accuracy up to near the critical point (370 C), but for precise calculations, the Antoine equation or other methods should be used.
- This formula does not apply for substances other than water.