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**CONFIDENTIAL**

SET A

# UNIVERSITI KUALA LUMPUR

## MALAYSIA FRANCE INSTITUTE

## FINAL EXAMINATION

## JANUARY 2011 SEMESTER

| | | |
|---|---|---|
| SUBJECT CODE | : | FRB 10602 |
| SUBJECT TITLE | : | APPLIED REFRIGERATION COMPONENTS |
| LEVEL | : | BACHELOR |
| DURATION | : | 3.30pm – 5.30pm<br>( 2 HOURS ) |
| DATE / TIME | : | 05 MAY 2011 |

### INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. Please write your answers on the answer booklet provided.
4. Answer should be written in blue or black ink except for sketching, graphic and illustration.
5. This question paper consists of FIVE (5) questions. Answer FOUR (4) questions only.
6. Answer all questions in English.

THERE ARE 5 PAGES OF QUESTIONS AND 11 PAGES OF APPENDIX, EXCLUDING THIS PAGE.

**INSTRUCTION: Answer FOUR (4) questions only.**

**Please use the answer booklet provided.**

**Question 1**

a) When selecting a refrigerant for certain application, what are the qualities that you should look for?

(5 marks)

b) State the differences between the natural refrigerants and the synthetic refrigerants?

(10 marks)

c) A thermostatic expansion valve uses R134a as the working fluid, in a refrigeration system operates at an evaporating temperature of 4 $^{o}$C. The adjustable spring is set to offer a resistance equivalent to a pressure of 60 kPa. Calculate the value of superheat.

(10 marks)

## Question 2

A food freezing system working with refrigerant R22 requires cooling capacity at 132 kW, evaporating temperature at -35°C and condenser temperature 40°C. The refrigerant liquid is subcooled to 35°C before throttling to evaporating pressure. The refrigerant vapour is superheated by 5°C before leaving the evaporator and temperature further rises by 5°C in the suction line. The pressure drop at suction valve side is 0.2 bar. Due to the heat gain from the cylinder walls, the temperature of refrigerant vapour increase by 5°C before the beginning of compression. The compression process is according to the law $PV^2$ = Constant. The pressure drop at discharge valve side is 0.3 bar. If the compressor has 3 % clearance, Calculate:

a) Clearance volumetric efficiency (2.5 marks)

b) Total volumetric efficiency (2.5 marks)

c) Mass flow rate of refrigerant in kg/s (5 marks)

d) Piston displacement in $m^3/s$ (5 marks)

e) Power needed by compressor in kW (5 marks)

f) Heat to be removed by condenser in kW (5 marks)

**Question 3**

A refrigeration system of 55 kW cooling capacity that uses a water-cooled condenser has a COP of 5.0. The overall heat transfer coefficient of the condenser is 450 $W/m^2.K$ and a heat transfer area of 18 $m^2$. If cooling water at a flow rate of 3.2 kg/s enters the condenser at a temperature of 30 $^oC$, what is the condensing temperature?
(Note: Take the specific heat of water as 4.18kJ/kg.K)

(25 marks)

## Question 4

A split air conditioner system with R22 refrigerant has a cooling capacity of 3 kW. The condensing and evaporating temperature are 40°C and 5°C respectively. Calculate the capillary tube length for the above system. (Assume ideal refrigeration cycle)

(25 marks)

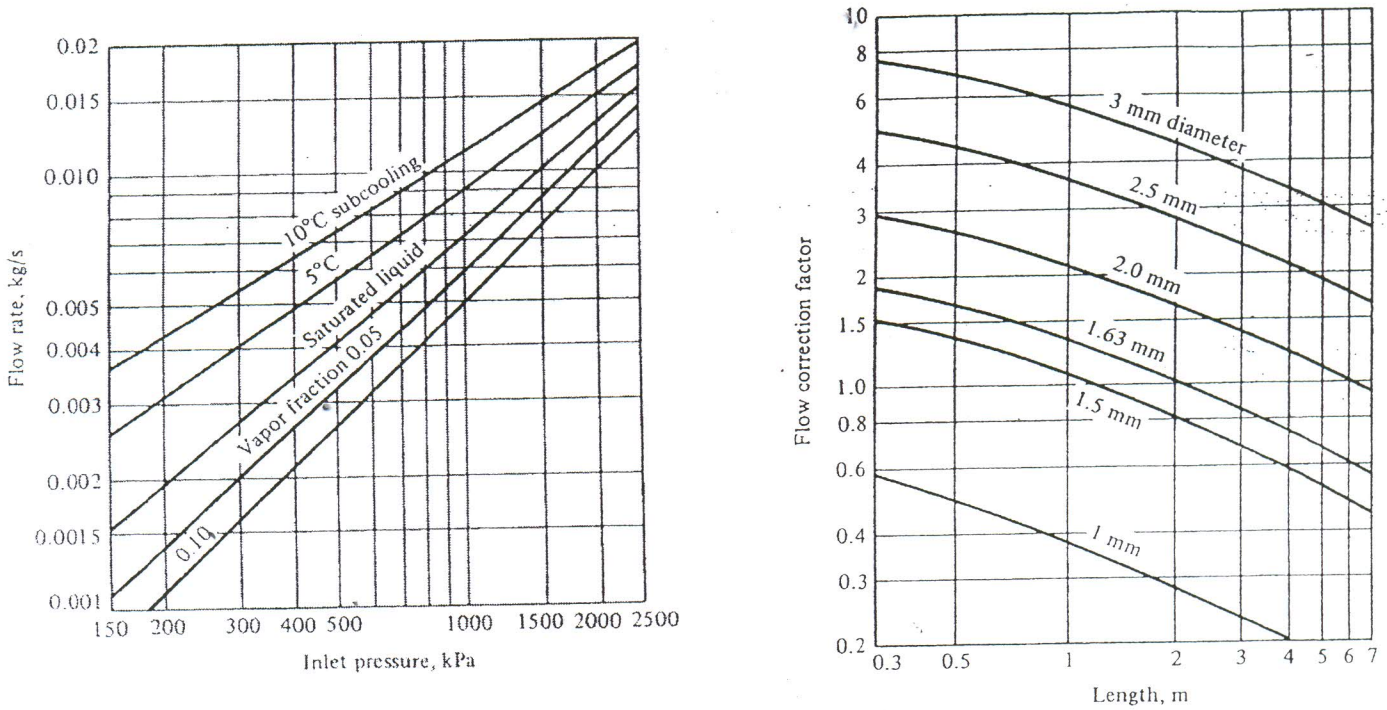



Figure Q4: Cap Tube Selection Chart

## Question 5

A DX coil cools 0.53 kg/s of air from an entering condition of 32°C DBT and 20°C WBT as shown in figure Q5. The refrigerant temperature is 9 °C. $U_r$ = heat transfer coefficient for refrigerant side is 2000 W/m$^2$K and $U_g$ heat transfer coefficient for air side is 54 W/m$^2$K. The ratio of inside and outside area is 15. Calculate the:

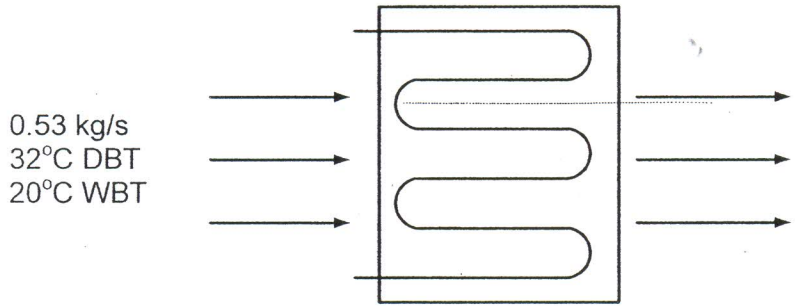



Figure Q5: DX evaporator.

a) DBT when the condensation starts.

(10 marks)

b) The surface area, in m$^2$ ,of the dry portion of the coil.

(15 marks)

**END OF QUESTION**

## Formulae

$$W_p = \frac{n}{n-1}(p_s v_s)\left[\left(\frac{p_d}{p_s}\right)^{\frac{n-1}{n}}\right]$$

$$P = m \times W_p$$

$$P = \frac{n}{n-1} P_1 v_1 \left[\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right] \times 10^5 (kW)$$

$$COP = \frac{R}{W_p}$$

$$\eta_v = 1 - C\left[\left(\frac{p_d}{p_s}\right)^{\frac{1}{n}} - 1\right]$$

$$\eta_{v_T} = [1 + C]\left[\left(\frac{p_s}{p_e}\right)^{\frac{1}{n}} - C\right] - C\left(\frac{p_d}{p_e}\right)^{\frac{1}{n}} - 0.01\left(\frac{p_d}{p_s}\right)$$

$$V_p = \frac{\pi}{4} D^2 L N \eta_v$$

$$m_r = \frac{PD \times \eta_{cv_T}}{v_1}$$

$$p_1 v_1^{\,n} = p_2 v_2^{\,n}$$

$$\frac{1}{A_t U_o} = \frac{1}{h_i A_i} + \frac{1}{h_o A_t}$$

$$LMTD = \frac{\theta_i - \theta_o}{\log\left(\frac{\theta_i}{\theta_o}\right)}$$

$$m_a \times C_{pa} \times (\Delta t)_a = A_a \times V_a \times \rho_a \times (\Delta t)_a$$

Refrigerant side

$Nu_{ref} = 0.026\ (Re)^{0.8}\ (Pr)^{0.33}$

$$Re_{ref} = \frac{\rho_r \times d_i \times u_r}{\mu_r} = \frac{d_i}{\mu_r}\frac{m_r}{A_1}$$

$$\mathrm{Pr}_r = \frac{\mu_r C_{pr}}{k_r}$$

$$Nu_r = \frac{h_i \times d_i}{k_r}$$

Air side

$Nu_{air} = 0.193\ (Re)^{0.618}\ (Pr)^{0.33}$

$$\mathrm{Re}_{ref} = \frac{\rho_a \times D_e \times V_a}{\mu_a}$$

$$\mathrm{Pr}_r = 0.71$$

$$Nu_a = \frac{h_o \times D_e}{k_a}$$

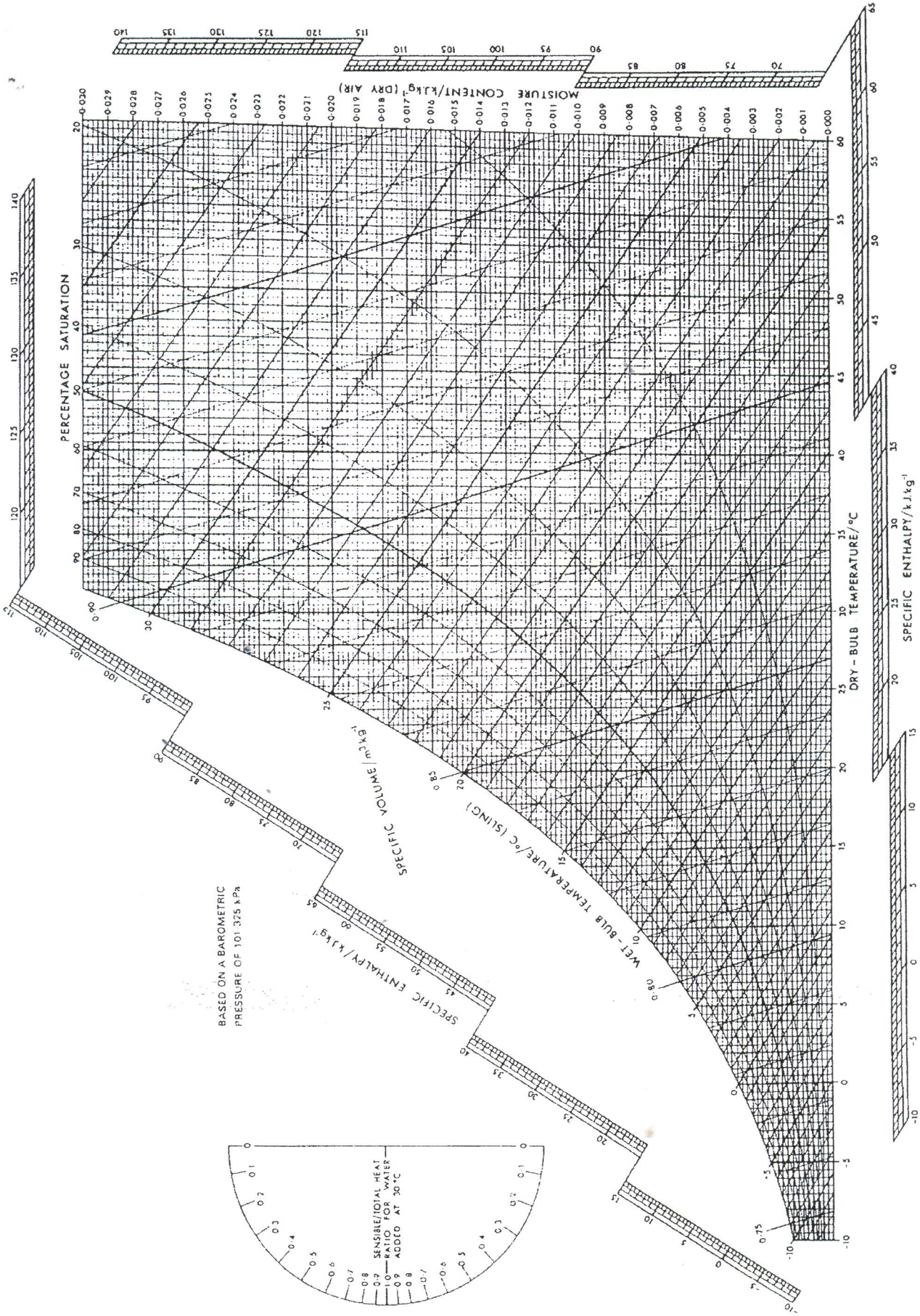
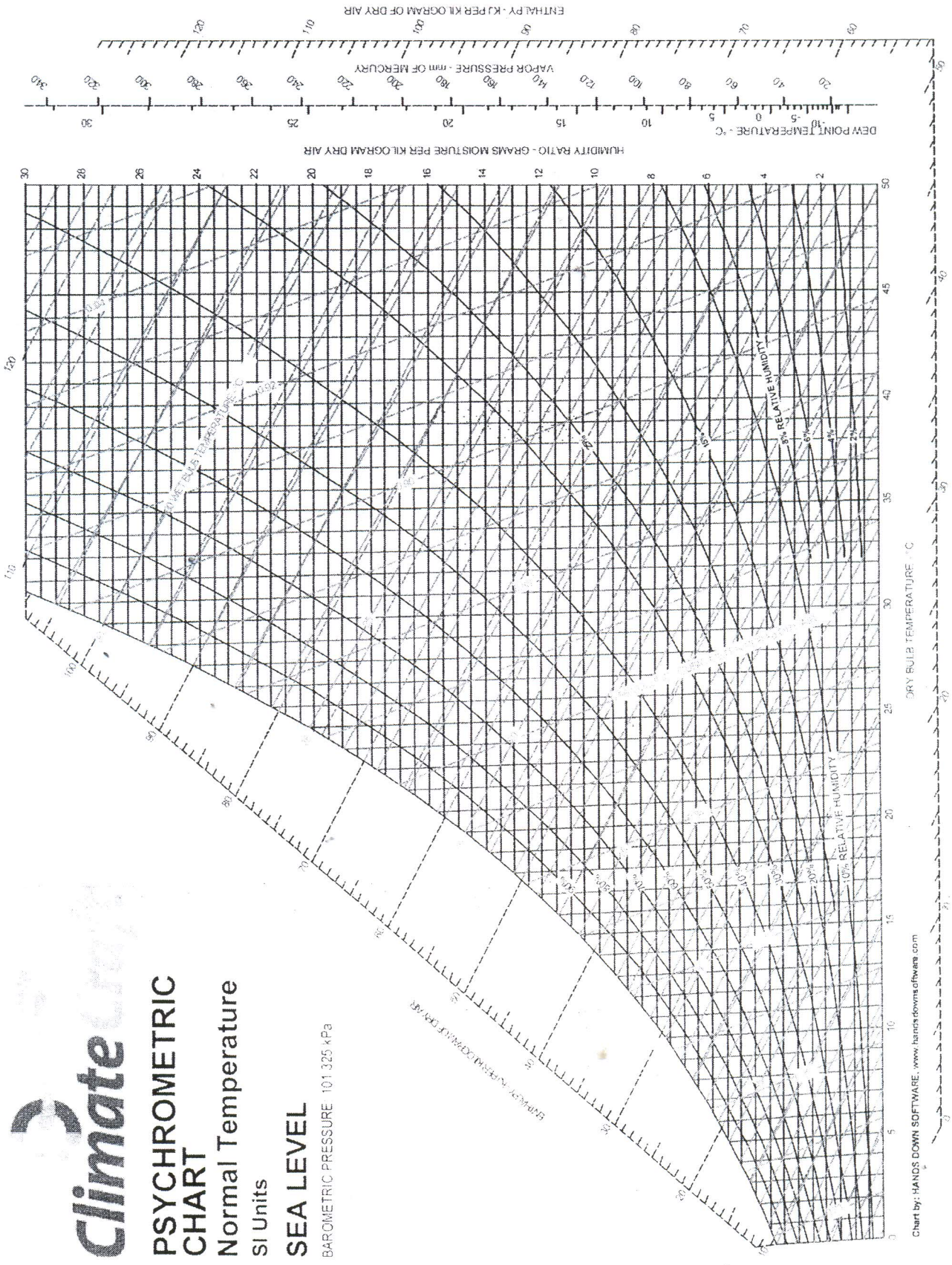



Figure 1.2 CIBSE Psychrometric chart (−10 to +60°C)


Climate
PSYCHROMETRIC CHART
Normal Temperature
SI Units
SEA LEVEL
BAROMETRIC PRESSURE 101.325 kPa
DEW POINT TEMPERATURE - °C
HUMIDITY RATIO - GRAMS MOISTURE PER KILOGRAM DRY AIR
ENTHALPY - KJ PER KILOGRAM OF DRY AIR
VAPOR PRESSURE - mm OF MERCURY
DRY BULB TEMPERATURE - °C
WET BULB TEMPERATURE - °C
RELATIVE HUMIDITY
Chart by: HANDS DOWN SOFTWARE. www.handsdownsoftware.com

## Air Properties at Atmospheric Pressure as a Function of Temperature

| Temperature (K) | Conductivity (W/mK) | Cp (kJ/kgK) | Prandtl # | Density ($kg/m^3$) | Viscosity ($Ns/m^2$) |
|---|---|---|---|---|---|
| 200 | 0.0181 | 1.007 | 0.737 | 1.7458 | 0.00001325 |
| 250 | 0.0223 | 1.006 | 0.72 | 1.3947 | 0.00001596 |
| 300 | 0.0263 | 1.007 | 0.707 | 1.1614 | 0.00001846 |
| 350 | 0.03 | 1.009 | 0.7 | 0.995 | 0.00002082 |
| 400 | 0.0338 | 1.014 | 0.69 | 0.8711 | 0.00002301 |
| 450 | 0.0373 | 1.021 | 0.686 | 0.774 | 0.00002507 |
| 500 | 0.0407 | 1.03 | 0.684 | 0.6964 | 0.00002701 |
| 550 | 0.0439 | 1.04 | 0.683 | 0.6329 | 0.00002884 |
| 600 | 0.0469 | 1.051 | 0.685 | 0.5804 | 0.00003058 |
| 650 | 0.0497 | 1.063 | 0.69 | 0.5356 | 0.00003225 |
| 700 | 0.0524 | 1.075 | 0.695 | 0.4975 | 0.00003388 |
| 750 | 0.0549 | 1.087 | 0.702 | 0.4643 | 0.00003546 |
| 800 | 0.0573 | 1.099 | 0.709 | 0.4354 | 0.00003698 |
| 850 | 0.0596 | 1.11 | 0.716 | 0.4097 | 0.00003843 |
| 900 | 0.062 | 1.121 | 0.72 | 0.3868 | 0.00003981 |
| 950 | 0.0643 | 1.131 | 0.723 | 0.3666 | 0.00004113 |
| 1000 | 0.0667 | 1.141 | 0.726 | 0.3482 | 0.00004244 |

Refrigerant: R22, CHClF2, Chlorodifluoromethane

| | Pressure | | Specific volume | | Enthalpy | | Specific Entropy | | Specific heat | | Viscosity | | Thermal conductivity | | Speed ??of sound | | Surface tension | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| °C | kPa | Psi | m3/kg | | kJ/kg | | kJ/kgK | | kJ/kgK | | mPa-s | | W/(mK) | | m/s | | m-N/m | |
| | | | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor |
| -40 | 105.2 | 15.26218 | 0.0007 | 0.2052 | 154.9 | 388.1 | 0.82 | 1.82 | 1.09 | 0.61 | 342 | 9.73 | 0.113 | 0.0071 | 846.9 | 160.3 | 17.9 | 17.9 |
| -38 | 115.4 | 16.74197 | 0.0007 | 0.1883 | 157.1 | 389.1 | 0.83 | 1.82 | 1.09 | 0.61 | 333.6 | 9.81 | 0.112 | 0.0072 | 837.6 | 160.6 | 17.6 | 17.6 |
| -36 | 126.3 | 18.32332 | 0.0007 | 0.173 | 159.3 | 390 | 0.84 | 1.81 | 1.1 | 0.62 | 325.5 | 9.89 | 0.1111 | 0.0073 | 828.2 | 160.9 | 17.3 | 17.3 |
| -34 | 138 | 20.02073 | 0.0007 | 0.1593 | 161.5 | 390.9 | 0.85 | 1.81 | 1.1 | 0.62 | 317.7 | 9.97 | 0.1102 | 0.0074 | 818.9 | 161.2 | 17 | 17 |
| -32 | 150.5 | 21.8342 | 0.0007 | 0.1468 | 163.7 | 391.8 | 0.86 | 1.81 | 1.1 | 0.63 | 310.2 | 10.05 | 0.1093 | 0.0075 | 809.6 | 161.5 | 16.7 | 16.7 |
| -30 | 163.9 | 23.77824 | 0.0007 | 0.1355 | 165.9 | 392.7 | 0.87 | 1.8 | 1.1 | 0.63 | 302.9 | 10.13 | 0.1084 | 0.0076 | 800.3 | 161.8 | 16.3 | 16.3 |
| -28 | 178.2 | 25.85285 | 0.0007 | 0.1253 | 168.1 | 393.6 | 0.88 | 1.8 | 1.11 | 0.64 | 295.8 | 10.21 | 0.1074 | 0.0077 | 791 | 162 | 16 | 16 |
| -26 | 193.4 | 28.05803 | 0.0007 | 0.116 | 170.3 | 394.5 | 0.89 | 1.79 | 1.11 | 0.65 | 289 | 10.3 | 0.1065 | 0.0078 | 781.6 | 162.3 | 15.7 | 15.7 |
| -24 | 209.7 | 30.4228 | 0.0007 | 0.1075 | 172.6 | 395.3 | 0.9 | 1.79 | 1.12 | 0.65 | 282.4 | 10.38 | 0.1056 | 0.0079 | 772.3 | 162.5 | 15.4 | 15.4 |
| -22 | 227 | 32.93264 | 0.0007 | 0.0997 | 174.8 | 396.2 | 0.9 | 1.79 | 1.12 | 0.66 | 275.9 | 10.46 | 0.1047 | 0.0081 | 763 | 162.7 | 15.1 | 15.1 |
| -20 | 245.3 | 35.58756 | 0.0007 | 0.0927 | 177 | 397.1 | 0.91 | 1.78 | 1.12 | 0.67 | 269.7 | 10.54 | 0.1038 | 0.0082 | 753.6 | 162.8 | 14.8 | 14.8 |
| -18 | 264.8 | 38.41658 | 0.0007 | 0.0862 | 179.3 | 397.9 | 0.92 | 1.78 | 1.13 | 0.67 | 263.7 | 10.62 | 0.1029 | 0.0083 | 744.3 | 163 | 14.4 | 14.4 |
| -16 | 285.4 | 41.40518 | 0.0007 | 0.0803 | 181.6 | 398.7 | 0.93 | 1.78 | 1.13 | 0.68 | 257.8 | 10.7 | 0.102 | 0.0084 | 734.9 | 163.1 | 14.1 | 14.1 |
| -14 | 307.3 | 44.58238 | 0.0008 | 0.0749 | 183.8 | 399.6 | 0.94 | 1.77 | 1.13 | 0.69 | 252 | 10.78 | 0.1011 | 0.0085 | 725.6 | 163.2 | 13.8 | 13.8 |
| -12 | 330.4 | 47.93368 | 0.0008 | 0.0699 | 186.1 | 400.4 | 0.95 | 1.77 | 1.14 | 0.69 | 246.5 | 10.86 | 0.1002 | 0.0086 | 716.2 | 163.3 | 13.5 | 13.5 |
| -10 | 354.8 | 51.47358 | 0.0008 | 0.0653 | 188.4 | 401.2 | 0.96 | 1.77 | 1.14 | 0.7 | 241.1 | 10.95 | 0.0992 | 0.0088 | 706.8 | 163.3 | 13.2 | 13.2 |
| -8 | 380.5 | 55.20207 | 0.0008 | 0.061 | 190.7 | 402 | 0.97 | 1.76 | 1.15 | 0.71 | 235.8 | 11.03 | 0.0983 | 0.0089 | 697.5 | 163.4 | 12.9 | 12.9 |
| -6 | 407.7 | 59.14819 | 0.0008 | 0.0571 | 193 | 402.8 | 0.97 | 1.76 | 1.15 | 0.71 | 230.6 | 11.11 | 0.0974 | 0.009 | 688.1 | 163.4 | 12.6 | 12.6 |
| -4 | 436.3 | 63.29741 | 0.0008 | 0.0535 | 195.3 | 403.5 | 0.98 | 1.76 | 1.16 | 0.72 | 225.6 | 11.19 | 0.0965 | 0.0091 | 678.7 | 163.4 | 12.3 | 12.3 |
| -2 | 466.4 | 67.66425 | 0.0008 | 0.0502 | 197.7 | 404.3 | 0.99 | 1.75 | 1.16 | 0.73 | 220.7 | 11.28 | 0.0956 | 0.0093 | 669.3 | 163.4 | 12 | 12 |
| 0 | 498 | 72.2487 | 0.0008 | 0.0471 | 200 | 405 | 1 | 1.75 | 1.17 | 0.74 | 216 | 11.36 | 0.0947 | 0.0094 | 659.9 | 163.3 | 11.7 | 11.7 |
| 2 | 531.2 | 77.06528 | 0.0008 | 0.0442 | 202.4 | 405.8 | 1.01 | 1.75 | 1.17 | 0.75 | 211.3 | 11.45 | 0.0938 | 0.0095 | 650.5 | 163.2 | 11.4 | 11.4 |
| 4 | 566.1 | 82.1285 | 0.0008 | 0.0416 | 204.7 | 406.5 | 1.02 | 1.74 | 1.18 | 0.76 | 206.8 | 11.53 | 0.0929 | 0.0097 | 641 | 163.1 | 11.1 | 11.1 |
| 6 | 602.6 | 87.42383 | 0.0008 | 0.0391 | 207.1 | 407.2 | 1.03 | 1.74 | 1.19 | 0.77 | 202.3 | 11.62 | 0.092 | 0.0098 | 631.6 | 163 | 10.8 | 10.8 |
| 8 | 640.9 | 92.98031 | 0.0008 | 0.0368 | 209.5 | 407.9 | 1.03 | 1.74 | 1.19 | 0.78 | 198 | 11.71 | 0.0911 | 0.01 | 622.1 | 162.8 | 10.5 | 10.5 |
| 10 | 680.9 | 98.78342 | 0.0008 | 0.0347 | 211.9 | 408.6 | 1.04 | 1.74 | 1.2 | 0.79 | 193.7 | 11.8 | 0.0902 | 0.0101 | 612.7 | 162.6 | 10.2 | 10.2 |
| 12 | 722.9 | 104.8767 | 0.0008 | 0.0327 | 214.3 | 409.2 | 1.05 | 1.73 | 1.21 | 0.8 | 189.5 | 11.89 | 0.0893 | 0.0103 | 603.2 | 162.4 | 9.9 | 9.9 |
| 14 | 766.7 | 111.2311 | 0.0008 | 0.0309 | 216.7 | 409.9 | 1.06 | 1.73 | 1.21 | 0.81 | 185.5 | 11.98 | 0.0884 | 0.0104 | 593.7 | 162.2 | 9.6 | 9.6 |
| 16 | 812.4 | 117.8611 | 0.0008 | 0.0291 | 219.1 | 410.5 | 1.07 | 1.73 | 1.22 | 0.82 | 181.5 | 12.07 | 0.0875 | 0.0106 | 584.2 | 161.9 | 9.4 | 9.4 |

Refrigerant: R22, CHClF2, Chlorodifluoromethane

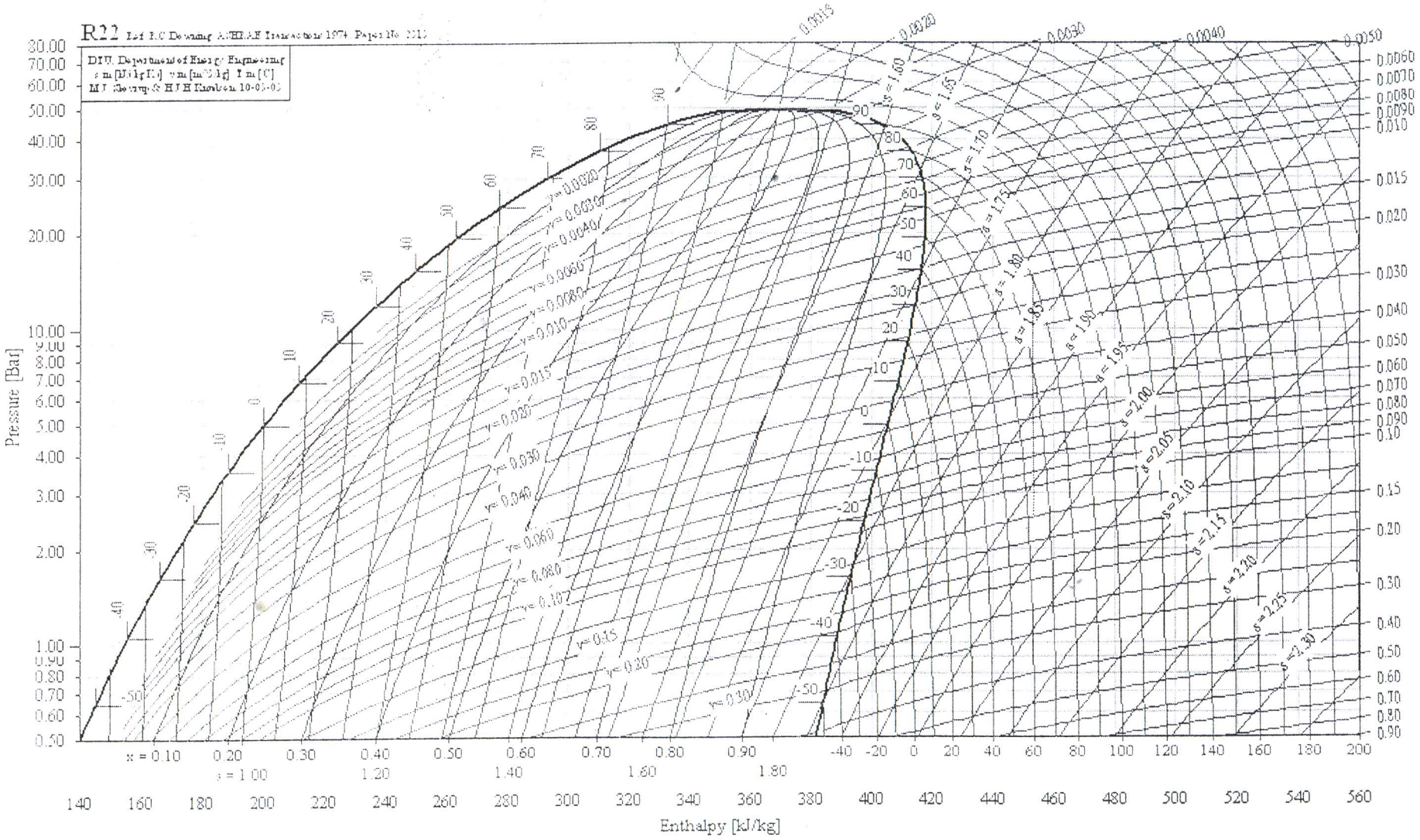
| °C | kPa | Psi | m3/kg | | kJ/kg | | kJ/kgK | | kJ/kgK | | mPa-s | | W/(mK) | | m/s | | m-N/m | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor |
| 18 | 860.2 | 124.7959 | 0.0008 | 0.022 | 221.6 | 411.1 | 1.08 | 1.73 | 1.23 | 0.83 | 177.5 | 12.17 | 0.0866 | 0.0107 | 574.6 | 161.6 | 9.1 | 9.1 |
| 20 | 910 | 132.0207 | 0.0008 | 0.0208 | 224.1 | 411.7 | 1.08 | 1.72 | 1.24 | 0.84 | 173.7 | 12.26 | 0.0857 | 0.0109 | 565.1 | 161.3 | 8.8 | 8.8 |
| 22 | 961.9 | 139.5503 | 0.0009 | 0.0197 | 226.5 | 412.2 | 1.09 | 1.72 | 1.24 | 0.85 | 169.9 | 12.36 | 0.0848 | 0.0111 | 555.5 | 161 | 8.5 | 8.5 |
| 24 | 1016 | 147.399 | 0.0009 | 0.0187 | 229 | 412.8 | 1.1 | 1.72 | 1.25 | 0.87 | 166.2 | 12.46 | 0.0839 | 0.0112 | 545.9 | 160.6 | 8.2 | 8.2 |
| 26 | 1072.4 | 155.5813 | 0.0009 | 0.0177 | 231.5 | 413.3 | 1.11 | 1.72 | 1.26 | 0.88 | 162.6 | 12.56 | 0.083 | 0.0114 | 536.2 | 160.2 | 7.9 | 7.9 |
| 28 | 1130.9 | 164.0684 | 0.0009 | 0.0168 | 234.1 | 413.8 | 1.12 | 1.71 | 1.27 | 0.89 | 159 | 12.67 | 0.0821 | 0.0116 | 526.5 | 159.7 | 7.7 | 7.7 |
| 30 | 1191.9 | 172.9181 | 0.0009 | 0.0159 | 236.6 | 414.3 | 1.13 | 1.71 | 1.28 | 0.91 | 155.5 | 12.77 | 0.0812 | 0.0118 | 516.8 | 159.2 | 7.4 | 7.4 |
| 32 | 1255.2 | 182.1016 | 0.0009 | 0.0151 | 239.2 | 414.7 | 1.13 | 1.71 | 1.29 | 0.92 | 152 | 12.85 | 0.0803 | 0.012 | 507.1 | 158.7 | 7.1 | 7.1 |
| 34 | 1321 | 191.6477 | 0.0009 | 0.0143 | 241.8 | 415.1 | 1.14 | 1.71 | 1.3 | 0.94 | 148.6 | 12.96 | 0.0794 | 0.0122 | 497.3 | 158.2 | 6.8 | 6.8 |
| 36 | 1389.2 | 201.542 | 0.0009 | 0.0136 | 244.4 | 415.5 | 1.15 | 1.7 | 1.31 | 0.96 | 145.2 | 13.07 | 0.0785 | 0.0124 | 487.4 | 157.6 | 6.6 | 6.6 |
| 38 | 1460.1 | 211.828 | 0.0009 | 0.0129 | 247 | 415.9 | 1.16 | 1.7 | 1.33 | 0.98 | 141.9 | 13.18 | 0.0775 | 0.0126 | 477.6 | 157 | 6.3 | 6.3 |
| 40 | 1533.6 | 222.4912 | 0.0009 | 0.0123 | 249.6 | 416.2 | 1.17 | 1.7 | 1.34 | 0.99 | 138.7 | 13.3 | 0.0766 | 0.0128 | 467.6 | 156.4 | 6 | 6 |
| 42 | 1609.8 | 233.5461 | 0.0009 | 0.0116 | 252.3 | 416.6 | 1.17 | 1.7 | 1.35 | 1.02 | 135.5 | 13.42 | 0.0757 | 0.0131 | 457.6 | 155.7 | 5.8 | 5.8 |
| 44 | 1688.7 | 244.9927 | 0.0009 | 0.011 | 255 | 416.8 | 1.18 | 1.69 | 1.37 | 1.04 | 132.3 | 13.54 | 0.0747 | 0.0133 | 447.6 | 155 | 5.5 | 5.5 |
| 46 | 1770.4 | 256.8456 | 0.0009 | 0.0105 | 257.7 | 417.1 | 1.19 | 1.69 | 1.38 | 1.06 | 129.1 | 13.67 | 0.0738 | 0.0136 | 437.4 | 154.2 | 5.3 | 5.3 |
| 48 | 1855.1 | 269.1337 | 0.001 | 0.01 | 260.5 | 417.3 | 1.2 | 1.69 | 1.4 | 1.09 | 126 | 13.8 | 0.0729 | 0.0139 | 427.2 | 153.4 | 5 | 5 |
| 50 | 1942.7 | 281.8425 | 0.001 | 0.0094 | 263.2 | 417.4 | 1.21 | 1.69 | 1.42 | 1.11 | 123 | 13.94 | 0.0719 | 0.0142 | 417 | 152.6 | 4.7 | 4.7 |
| 52 | 2033.3 | 294.9865 | 0.001 | 0.009 | 266 | 417.6 | 1.22 | 1.68 | 1.44 | 1.14 | 119.9 | 14.09 | 0.0709 | 0.0145 | 406.6 | 151.7 | 4.5 | 4.5 |
| 54 | 2127 | 308.5803 | 0.001 | 0.0085 | 268.9 | 417.6 | 1.22 | 1.68 | 1.46 | 1.17 | 116.9 | 14.25 | 0.07 | 0.0148 | 396.2 | 150.8 | 4.2 | 4.2 |
| 56 | 2223.9 | 322.6383 | 0.001 | 0.0081 | 271.8 | 417.7 | 1.23 | 1.68 | 1.48 | 1.21 | 113.9 | 14.41 | 0.069 | 0.0152 | 385.7 | 149.8 | 4 | 4 |
| 58 | 2324 | 337.1606 | 0.001 | 0.0076 | 274.7 | 417.6 | 1.24 | 1.67 | 1.51 | 1.25 | 110.9 | 14.58 | 0.068 | 0.0155 | 375 | 148.8 | 3.8 | 3.8 |
| 60 | 2427.5 | 352.1762 | 0.001 | 0.0072 | 277.6 | 417.5 | 1.25 | 1.67 | 1.54 | 1.29 | 108 | 14.76 | 0.067 | 0.0159 | 364.3 | 147.7 | 3.5 | 3.5 |
| 62 | 2534.3 | 367.6705 | 0.001 | 0.0068 | 280.6 | 417.4 | 1.26 | 1.67 | 1.57 | 1.33 | 105.1 | 14.96 | 0.066 | 0.0164 | 353.5 | 146.6 | 3.3 | 3.3 |
| 64 | 2644.7 | 383.687 | 0.001 | 0.0065 | 283.6 | 417.2 | 1.27 | 1.66 | 1.61 | 1.38 | 102.1 | 15.16 | 0.065 | 0.0168 | 342.5 | 145.5 | 3 | 3 |
| 66 | 2758.6 | 400.2114 | 0.0011 | 0.0061 | 286.7 | 416.9 | 1.28 | 1.66 | 1.65 | 1.44 | 99.2 | 15.38 | 0.064 | 0.0173 | 331.4 | 144.2 | 2.8 | 2.8 |
| 68 | 2876.1 | 417.258 | 0.0011 | 0.0058 | 289.9 | 416.5 | 1.29 | 1.66 | 1.69 | 1.51 | 96.3 | 15.62 | 0.063 | 0.0179 | 320.2 | 143 | 2.6 | 2.6 |
| 70 | 2997.4 | 434.856 | 0.0011 | 0.0054 | 293.1 | 416.1 | 1.29 | 1.65 | 1.74 | 1.58 | 93.3 | 15.88 | 0.0619 | 0.0185 | 308.8 | 141.7 | 2.4 | 2.4 |
| 72 | 3122.5 | 453.0052 | 0.0011 | 0.0051 | 296.4 | 415.5 | 1.3 | 1.65 | 1.8 | 1.67 | 90.4 | 16.16 | 0.0609 | 0.0192 | 297.3 | 140.3 | 2.1 | 2.1 |
| 74 | 3251.6 | 471.7347 | 0.0011 | 0.0048 | 299.7 | 414.9 | 1.31 | 1.64 | 1.87 | 1.77 | 87.4 | 16.46 | 0.0598 | 0.0199 | 285.6 | 138.9 | 1.9 | 1.9 |
| 76 | 3384.8 | 491.0591 | 0.0012 | 0.0045 | 303.2 | 414.1 | 1.32 | 1.64 | 1.96 | 1.9 | 84.4 | 16.8 | 0.0588 | 0.0208 | 273.6 | 137.4 | 1.7 | 1.7 |
| 78 | 3522.2 | 510.9927 | 0.0012 | 0.0042 | 306.8 | 413.1 | 1.33 | 1.64 | 2.06 | 2.05 | 81.4 | 17.17 | 0.0577 | 0.0217 | 261.3 | 135.8 | 1.5 | 1.5 |
| 80 | 3663.8 | 531.5358 | 0.0012 | 0.0039 | 310.4 | 412 | 1.34 | 1.63 | 2.18 | 2.23 | 78.3 | 17.59 | 0.0566 | 0.0228 | 248.8 | 134.2 | 1.3 | 1.3 |

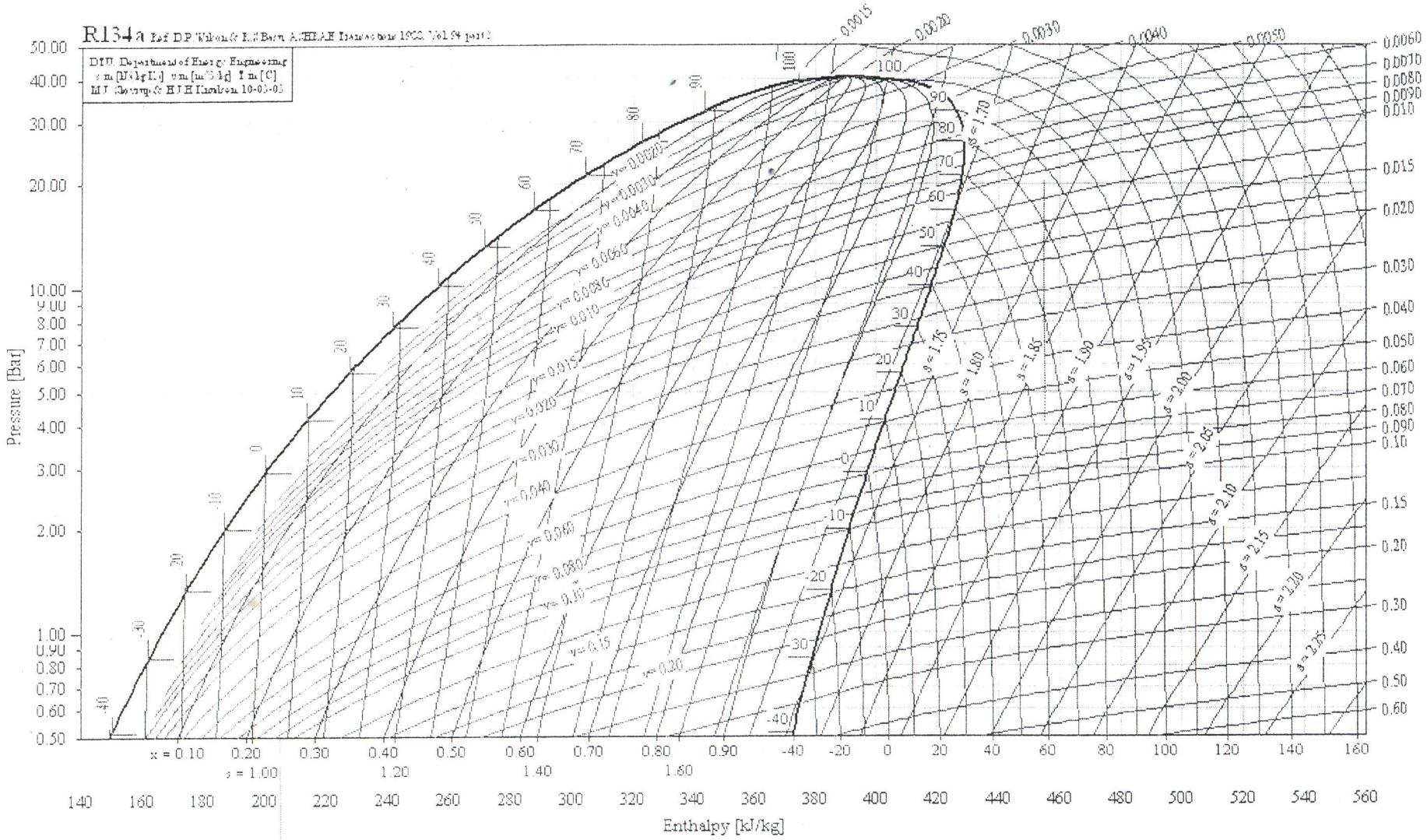
Refrigerant: R134a, CH2FCF3, 1,1,1,2-tetrafluoroethane

| | Pressure | | Specific volume | | Enthalpy | | Specific Entropy | | Specific heat | | Viscosity | | Thermal conductivity | | Speed ??of sound | | Surface tension | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| °C | kPa | Psi | m3/kg | | kJ/kg | | kJ/kgK | | kJ/kgK | | mPa-s | | W/(mK) | | m/s | | m-N/m | |
| | | | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor |
| -30 | 84.4 | 12.24456 | 0.0007 | 0.2259 | 160.8 | 380.3 | 0.85 | 1.75 | 1.27 | 0.78 | 401 | 9.64 | 0.1058 | 0.009 | 760.3 | 145.2 | 16 | 16 |
| -28 | 92.7 | 13.4487 | 0.0007 | 0.2068 | 163.3 | 381.6 | 0.86 | 1.75 | 1.28 | 0.79 | 389.4 | 9.71 | 0.1048 | 0.0092 | 750.9 | 145.4 | 15.7 | 15.7 |
| -26 | 101.7 | 14.7544 | 0.0007 | 0.1896 | 165.9 | 382.8 | 0.87 | 1.75 | 1.28 | 0.79 | 378.3 | 9.78 | 0.1039 | 0.0093 | 741.6 | 145.7 | 15.4 | 15.4 |
| -24 | 111.3 | 16.14715 | 0.0007 | 0.1741 | 168.5 | 384.1 | 0.88 | 1.75 | 1.28 | 0.8 | 367.7 | 9.85 | 0.1029 | 0.0095 | 732.3 | 145.9 | 15.1 | 15.1 |
| -22 | 121.6 | 17.64145 | 0.0007 | 0.1601 | 171.1 | 385.3 | 0.89 | 1.74 | 1.29 | 0.81 | 357.4 | 9.93 | 0.102 | 0.0097 | 723.1 | 146.1 | 14.8 | 14.8 |
| -20 | 132.7 | 19.25181 | 0.0007 | 0.1474 | 173.6 | 386.6 | 0.9 | 1.74 | 1.29 | 0.82 | 347.6 | 10 | 0.1011 | 0.0098 | 713.8 | 146.3 | 14.5 | 14.5 |
| -18 | 144.6 | 20.97824 | 0.0007 | 0.1359 | 176.2 | 387.8 | 0.91 | 1.74 | 1.3 | 0.82 | 338.1 | 10.07 | 0.1001 | 0.01 | 704.5 | 146.4 | 14.2 | 14.2 |
| -16 | 157.3 | 22.82073 | 0.0007 | 0.1255 | 178.8 | 389 | 0.92 | 1.74 | 1.3 | 0.83 | 329 | 10.14 | 0.0992 | 0.0102 | 695.3 | 146.6 | 13.9 | 13.9 |
| -14 | 170.8 | 24.77927 | 0.0007 | 0.1161 | 181.4 | 390.2 | 0.93 | 1.74 | 1.31 | 0.84 | 320.2 | 10.22 | 0.0983 | 0.0103 | 686.1 | 146.7 | 13.6 | 13.6 |
| -12 | 185.2 | 26.86839 | 0.0007 | 0.1074 | 184.1 | 391.5 | 0.94 | 1.73 | 1.31 | 0.85 | 311.7 | 10.29 | 0.0974 | 0.0105 | 676.8 | 146.8 | 13.3 | 13.3 |
| -10 | 200.6 | 29.10259 | 0.0008 | 0.0996 | 186.7 | 392.7 | 0.95 | 1.73 | 1.32 | 0.85 | 303.5 | 10.36 | 0.0965 | 0.0107 | 667.6 | 146.9 | 13 | 13 |
| -8 | 216.9 | 31.46736 | 0.0008 | 0.0924 | 189.3 | 393.9 | 0.96 | 1.73 | 1.32 | 0.86 | 295.6 | 10.43 | 0.0956 | 0.0108 | 658.4 | 146.9 | 12.7 | 12.7 |
| -6 | 234.3 | 33.99171 | 0.0008 | 0.0859 | 192 | 395.1 | 0.97 | 1.73 | 1.33 | 0.87 | 288 | 10.51 | 0.0947 | 0.011 | 649.2 | 147 | 12.4 | 12.4 |
| -4 | 252.7 | 36.66114 | 0.0008 | 0.0799 | 194.6 | 396.3 | 0.98 | 1.73 | 1.33 | 0.88 | 280.6 | 10.58 | 0.0938 | 0.0112 | 640 | 147 | 12.1 | 12.1 |
| -2 | 272.2 | 39.49016 | 0.0008 | 0.0744 | 197.3 | 397.4 | 0.99 | 1.73 | 1.34 | 0.89 | 273.5 | 10.65 | 0.0929 | 0.0113 | 630.8 | 147 | 11.8 | 11.8 |
| 0 | 292.8 | 42.47876 | 0.0008 | 0.0693 | 200 | 398.6 | 1 | 1.73 | 1.34 | 0.9 | 266.5 | 10.73 | 0.092 | 0.0115 | 621.6 | 146.9 | 11.6 | 11.6 |
| 2 | 314.6 | 45.64145 | 0.0008 | 0.0647 | 202.7 | 399.8 | 1.01 | 1.73 | 1.35 | 0.91 | 259.8 | 10.8 | 0.0911 | 0.0117 | 612.5 | 146.9 | 11.3 | 11.3 |
| 4 | 337.7 | 48.99275 | 0.0008 | 0.0604 | 205.4 | 400.9 | 1.02 | 1.72 | 1.35 | 0.92 | 253.3 | 10.87 | 0.0902 | 0.0119 | 603.3 | 146.8 | 11 | 11 |
| 6 | 362 | 52.51813 | 0.0008 | 0.0564 | 208.1 | 402.1 | 1.03 | 1.72 | 1.36 | 0.93 | 247 | 10.95 | 0.0894 | 0.012 | 594.1 | 146.7 | 10.7 | 10.7 |
| 8 | 387.6 | 56.23212 | 0.0008 | 0.0528 | 210.8 | 403.2 | 1.04 | 1.72 | 1.36 | 0.94 | 240.8 | 11.02 | 0.0885 | 0.0122 | 584.9 | 146.5 | 10.4 | 10.4 |
| 10 | 414.6 | 60.14922 | 0.0008 | 0.0494 | 213.6 | 404.3 | 1.05 | 1.72 | 1.37 | 0.95 | 234.9 | 11.1 | 0.0876 | 0.0124 | 575.7 | 146.4 | 10.1 | 10.1 |
| 12 | 443 | 64.26943 | 0.0008 | 0.0463 | 216.3 | 405.4 | 1.06 | 1.72 | 1.38 | 0.96 | 229.1 | 11.18 | 0.0867 | 0.0126 | 566.5 | 146.2 | 9.9 | 9.9 |
| 14 | 472.9 | 68.60725 | 0.0008 | 0.0435 | 219.1 | 406.5 | 1.07 | 1.72 | 1.38 | 0.97 | 223.4 | 11.25 | 0.0859 | 0.0128 | 557.3 | 146 | 9.6 | 9.6 |
| 16 | 504.3 | 73.16269 | 0.0008 | 0.0408 | 221.9 | 407.6 | 1.08 | 1.72 | 1.39 | 0.98 | 217.9 | 11.33 | 0.085 | 0.013 | 548.1 | 145.7 | 9.3 | 9.3 |
| 18 | 537.2 | 77.93575 | 0.0008 | 0.0383 | 224.7 | 408.7 | 1.09 | 1.72 | 1.4 | 0.99 | 212.6 | 11.41 | 0.0841 | 0.0131 | 538.8 | 145.5 | 9 | 9 |
| 20 | 571.7 | 82.94093 | 0.0008 | 0.036 | 227.5 | 409.7 | 1.1 | 1.72 | 1.4 | 1 | 207.4 | 11.49 | 0.0833 | 0.0133 | 529.6 | 145.1 | 8.8 | 8.8 |
| 22 | 607.9 | 88.19275 | 0.0008 | 0.0339 | 230.3 | 410.8 | 1.11 | 1.72 | 1.41 | 1.01 | 202.3 | 11.57 | 0.0824 | 0.0135 | 520.4 | 144.8 | 8.5 | 8.5 |
| 24 | 645.8 | 93.69119 | 0.0008 | 0.0319 | 233.1 | 411.8 | 1.12 | 1.72 | 1.42 | 1.03 | 197.3 | 11.65 | 0.0816 | 0.0137 | 511.1 | 144.5 | 8.2 | 8.2 |
| 26 | 685.4 | 99.43627 | 0.0008 | 0.03 | 236 | 412.8 | 1.12 | 1.72 | 1.43 | 1.04 | 192.5 | 11.73 | 0.0807 | 0.0139 | 501.8 | 144.1 | 7.9 | 7.9 |
| 28 | 726.9 | 105.457 | 0.0008 | 0.0283 | 238.8 | 413.8 | 1.13 | 1.72 | 1.44 | 1.05 | 187.7 | 11.82 | 0.0798 | 0.0141 | 492.5 | 143.6 | 7.7 | 7.7 |
| 30 | 770.2 | 111.7389 | 0.0008 | 0.0266 | 241.7 | 414.8 | 1.14 | 1.71 | 1.45 | 1.07 | 183.1 | 11.91 | 0.079 | 0.0143 | 483.2 | 143.2 | 7.4 | 7.4 |

Refrigerant: R134a, CH2FCF3, 1,1,1,2-tetrafluoroethane

| °C | Pressure kPa | Pressure Psi | Specific volume m3/kg Liquid | Specific volume m3/kg Vapor | Enthalpy kJ/kg Liquid | Enthalpy kJ/kg Vapor | Specific Entropy kJ/kgK Liquid | Specific Entropy kJ/kgK Vapor | Specific heat kJ/kgK Liquid | Specific heat kJ/kgK Vapor | Viscosity mPa-s Liquid | Viscosity mPa-s Vapor | Thermal conductivity W/(mK) Liquid | Thermal conductivity W/(mK) Vapor | Speed ??of sound m/s Liquid | Speed ??of sound m/s Vapor | Surface tension m-N/m Liquid | Surface tension m-N/m Vapor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 815.4 | 118.2964 | 0.0008 | 0.0251 | 244.6 | 415.8 | 1.15 | 1.71 | 1.46 | 1.08 | 178.6 | 12 | 0.0781 | 0.0145 | 473.9 | 142.7 | 7.2 | 7.2 |
| 34 | 862.6 | 125.144 | 0.0009 | 0.0237 | 247.5 | 416.7 | 1.16 | 1.71 | 1.47 | 1.1 | 174.2 | 12.09 | 0.0773 | 0.0148 | 464.6 | 142.1 | 6.9 | 6.9 |
| 36 | 911.8 | 132.2819 | 0.0009 | 0.0224 | 250.5 | 417.6 | 1.17 | 1.71 | 1.48 | 1.11 | 169.9 | 12.18 | 0.0764 | 0.015 | 455.2 | 141.6 | 6.6 | 6.6 |
| 38 | 963.2 | 139.7389 | 0.0009 | 0.0211 | 253.4 | 418.5 | 1.18 | 1.71 | 1.49 | 1.13 | 165.6 | 12.27 | 0.0756 | 0.0152 | 445.8 | 141 | 6.4 | 6.4 |
| 40 | 1016.6 | 147.486 | 0.0009 | 0.02 | 256.4 | 419.4 | 1.19 | 1.71 | 1.5 | 1.14 | 161.4 | 12.37 | 0.0747 | 0.0154 | 436.4 | 140.3 | 6.1 | 6.1 |
| 42 | 1072.2 | 155.5523 | 0.0009 | 0.0189 | 259.4 | 420.3 | 1.2 | 1.71 | 1.51 | 1.16 | 157.4 | 12.47 | 0.0739 | 0.0157 | 427 | 139.7 | 5.9 | 5.9 |
| 44 | 1130.1 | 163.9523 | 0.0009 | 0.0178 | 262.4 | 421.1 | 1.21 | 1.71 | 1.52 | 1.18 | 153.4 | 12.58 | 0.073 | 0.0159 | 417.5 | 138.9 | 5.6 | 5.6 |
| 46 | 1190.3 | 172.686 | 0.0009 | 0.0169 | 265.5 | 421.9 | 1.22 | 1.71 | 1.54 | 1.2 | 149.4 | 12.69 | 0.0721 | 0.0162 | 408 | 138.2 | 5.4 | 5.4 |
| 48 | 1252.9 | 181.7679 | 0.0009 | 0.016 | 268.5 | 422.7 | 1.23 | 1.71 | 1.55 | 1.22 | 145.6 | 12.8 | 0.0713 | 0.0165 | 398.5 | 137.4 | 5.1 | 5.1 |
| 50 | 1317.9 | 191.1979 | 0.0009 | 0.0151 | 271.6 | 423.4 | 1.24 | 1.71 | 1.57 | 1.25 | 141.8 | 12.92 | 0.0704 | 0.0167 | 389 | 136.6 | 4.9 | 4.9 |
| 52 | 1385.4 | 200.9907 | 0.0009 | 0.0143 | 274.7 | 424.1 | 1.25 | 1.71 | 1.58 | 1.27 | 138 | 13.04 | 0.0696 | 0.017 | 379.4 | 135.7 | 4.7 | 4.7 |
| 54 | 1455.5 | 211.1606 | 0.0009 | 0.0135 | 277.9 | 424.8 | 1.26 | 1.71 | 1.6 | 1.3 | 134.4 | 13.17 | 0.0687 | 0.0173 | 369.7 | 134.7 | 4.4 | 4.4 |
| 56 | 1528.2 | 221.7078 | 0.0009 | 0.0128 | 281.1 | 425.5 | 1.27 | 1.7 | 1.62 | 1.32 | 130.7 | 13.3 | 0.0678 | 0.0176 | 360 | 133.8 | 4.2 | 4.2 |
| 58 | 1603.6 | 232.6466 | 0.0009 | 0.0121 | 284.3 | 426.1 | 1.28 | 1.7 | 1.64 | 1.35 | 127.1 | 13.44 | 0.067 | 0.018 | 350.3 | 132.7 | 3.9 | 3.9 |
| 60 | 1681.8 | 243.9917 | 0.0009 | 0.0114 | 287.5 | 426.6 | 1.28 | 1.7 | 1.66 | 1.39 | 123.6 | 13.59 | 0.0661 | 0.0183 | 340.5 | 131.7 | 3.7 | 3.7 |
| 62 | 1762.8 | 255.743 | 0.001 | 0.0108 | 290.8 | 427.1 | 1.29 | 1.7 | 1.68 | 1.42 | 120.1 | 13.74 | 0.0652 | 0.0187 | 330.6 | 130.5 | 3.5 | 3.5 |
| 64 | 1846.7 | 267.915 | 0.001 | 0.0102 | 294.1 | 427.6 | 1.3 | 1.7 | 1.71 | 1.46 | 116.7 | 13.91 | 0.0643 | 0.0191 | 320.7 | 129.4 | 3.3 | 3.3 |
| 66 | 1933.7 | 280.5368 | 0.001 | 0.0097 | 297.4 | 428 | 1.31 | 1.7 | 1.74 | 1.5 | 113.3 | 14.09 | 0.0635 | 0.0195 | 310.7 | 128.1 | 3 | 3 |
| 68 | 2023.7 | 293.5938 | 0.001 | 0.0092 | 300.8 | 428.4 | 1.32 | 1.7 | 1.77 | 1.55 | 109.9 | 14.27 | 0.0626 | 0.02 | 300.5 | 126.8 | 2.8 | 2.8 |
| 70 | 2116.8 | 307.1005 | 0.001 | 0.0087 | 304.3 | 428.6 | 1.33 | 1.7 | 1.8 | 1.61 | 106.5 | 14.48 | 0.0617 | 0.0205 | 290.3 | 125.5 | 2.6 | 2.6 |
| 72 | 2213.2 | 321.086 | 0.001 | 0.0082 | 307.8 | 428.9 | 1.34 | 1.69 | 1.84 | 1.67 | 103.2 | 14.69 | 0.0608 | 0.021 | 279.9 | 124 | 2.4 | 2.4 |
| 74 | 2313 | 335.5648 | 0.001 | 0.0077 | 311.3 | 429 | 1.35 | 1.69 | 1.89 | 1.73 | 99.8 | 14.93 | 0.0599 | 0.0216 | 269.4 | 122.6 | 2.2 | 2.2 |
| 76 | 2416.1 | 350.5223 | 0.001 | 0.0073 | 314.9 | 429 | 1.36 | 1.69 | 1.94 | 1.81 | 96.5 | 15.18 | 0.059 | 0.0222 | 258.7 | 121 | 2 | 2 |
| 78 | 2522.8 | 366.0021 | 0.0011 | 0.0069 | 318.6 | 429 | 1.37 | 1.69 | 2 | 1.9 | 93.2 | 15.46 | 0.0581 | 0.0229 | 247.8 | 119.4 | 1.8 | 1.8 |
| 80 | 2633.2 | 382.0187 | 0.0011 | 0.0064 | 322.4 | 428.8 | 1.38 | 1.68 | 2.06 | 2.01 | 89.8 | 15.77 | 0.0571 | 0.0237 | 236.6 | 117.7 | 1.6 | 1.6 |


R22
Pressure [Bar]
Enthalpy [kJ/kg]


R134a
Pressure [Bar]
Enthalpy [kJ/kg]