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# Air Refrigeration Formulas

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## List of 25 Air Refrigeration Formulas

### Air Refrigeration

#### 1) C.O.P. of simple air cycle

$$\text{fx } \text{COP}_{\text{actual}} = \frac{T_6 - T_5'}{T_{t'} - T_2'}$$

[Open Calculator !\[\]\(a870788d6ed9b8fd294b7654a8c8526b\_img.jpg\)](#)

$$\text{ex } 0.207792 = \frac{281\text{K} - 265\text{K}}{350.0\text{K} - 273\text{K}}$$

#### 2) C.O.P. of simple air evaporative cycle

$$\text{fx } \text{COP}_{\text{actual}} = \frac{210 \cdot Q}{m_a \cdot C_p \cdot (T_{t'} - T_2')}$$

[Open Calculator !\[\]\(c50c8b7b2cc2cf9ff925edec0ee94c0d\_img.jpg\)](#)

$$\text{ex } 0.203528 = \frac{210 \cdot 150}{120\text{kg}/\text{min} \cdot 1.005\text{kJ}/\text{kg}^*\text{K} \cdot (350.0\text{K} - 273\text{K})}$$

#### 3) Compression or Expansion Ratio

$$\text{fx } r_p = \frac{P_2}{P_1}$$

[Open Calculator !\[\]\(f60b7a900783ac3fd531bfd9c111be6d\_img.jpg\)](#)

$$\text{ex } 25 = \frac{10\text{E}6\text{Pa}}{4\text{E}5\text{Pa}}$$

#### 4) Compression Work

$$\text{fx } W_{\text{per min}} = m_a \cdot C_p \cdot (T_{t'} - T_2')$$

[Open Calculator !\[\]\(83bbbd261710c59db0214aa27b2edc0d\_img.jpg\)](#)

$$\text{ex } 9286.2\text{kJ}/\text{min} = 120\text{kg}/\text{min} \cdot 1.005\text{kJ}/\text{kg}^*\text{K} \cdot (350.0\text{K} - 273\text{K})$$




5) COP of Air Cycle for given Input Power and Tonnage of Refrigeration 

$$\text{fx } \text{COP}_{\text{actual}} = \frac{210 \cdot Q}{P_{\text{in}} \cdot 60}$$

[Open Calculator !\[\]\(cbe80b694ebd74fcfe136a095b608235\_img.jpg\)](#)

$$\text{ex } 0.203226 = \frac{210 \cdot 150}{155\text{kJ}/\text{min} \cdot 60}$$

6) COP of Air Cycle given Input Power 

$$\text{fx } \text{COP}_{\text{actual}} = \frac{210 \cdot Q}{P_{\text{in}} \cdot 60}$$

[Open Calculator !\[\]\(3e2231b1ad3ca8da8658228c00dd08e0\_img.jpg\)](#)


$$\text{ex } 0.203226 = \frac{210 \cdot 150}{155\text{kJ}/\text{min} \cdot 60}$$

7) COP of Bell-Coleman Cycle for given Compression Ratio and Adiabatic Index 

$$\text{fx } \text{COP}_{\text{theoretical}} = \frac{1}{r_p^{\frac{\gamma-1}{\gamma}} - 1}$$

[Open Calculator !\[\]\(0d5ec72f61334709c3fc9450209b754f\_img.jpg\)](#)

$$\text{ex } 0.662917 = \frac{1}{(25)^{\frac{1.4-1}{1.4}} - 1}$$

8) COP of Bell-Coleman Cycle for given Temperatures, Polytropic Index and Adiabatic Index 

fx

[Open Calculator !\[\]\(b64b40baaee5acddc1eab8538ba84754\_img.jpg\)](#)

$$\text{COP}_{\text{theoretical}} = \frac{T_1 - T_4}{\left(\frac{n}{n-1}\right) \cdot \left(\frac{\gamma-1}{\gamma}\right) \cdot ((T_2 - T_3) - (T_1 - T_4))}$$

$$\text{ex } 0.601693 = \frac{300\text{K} - 290\text{K}}{\left(\frac{1.52}{1.52-1}\right) \cdot \left(\frac{1.4-1}{1.4}\right) \cdot ((356.5\text{K} - 326.6\text{K}) - (300\text{K} - 290\text{K}))}$$




9) Energy Performance Ratio of Heat Pump 

$$\text{fx } \text{COP}_{\text{theoretical}} = \frac{Q_{\text{delivered}}}{W_{\text{per min}}}$$

[Open Calculator !\[\]\(e78f798d4ea5c530c9db49e7d26e6b95\_img.jpg\)](#)

$$\text{ex } 0.6 = \frac{5571.72\text{kJ}/\text{min}}{9286.2\text{kJ}/\text{min}}$$

10) Expansion Work 

$$\text{fx } W_{\text{per min}} = ma \cdot C_p \cdot (T_4 - T_5')$$

[Open Calculator !\[\]\(05be7c7a8995decd503647c99211f7c2\_img.jpg\)](#)

$$\text{ex } 9286.2\text{kJ}/\text{min} = 120\text{kg}/\text{min} \cdot 1.005\text{kJ}/\text{kg} \cdot \text{K} \cdot (342\text{K} - 265\text{K})$$

11) Heat Absorbed during Constant Pressure Expansion Process 

$$\text{fx } Q_{\text{Absorbed}} = C_p \cdot (T_1 - T_4)$$

[Open Calculator !\[\]\(fe3aebe81acea8d45108cd2768939da7\_img.jpg\)](#)


$$\text{ex } 10.05\text{kJ}/\text{kg} = 1.005\text{kJ}/\text{kg} \cdot \text{K} \cdot (300\text{K} - 290\text{K})$$

12) Heat Rejected during Constant pressure Cooling Process 

$$\text{fx } Q_R = C_p \cdot (T_2 - T_3)$$

[Open Calculator !\[\]\(899d8b7697d64725bf017d3296cfcf1b\_img.jpg\)](#)

$$\text{ex } 30.0495\text{kJ}/\text{kg} = 1.005\text{kJ}/\text{kg} \cdot \text{K} \cdot (356.5\text{K} - 326.6\text{K})$$

13) Heat rejected during cooling process 

$$\text{fx } Q_{R, \text{Cooling}} = ma \cdot C_p \cdot (T_t' - T_4)$$

[Open Calculator !\[\]\(40770d9ed6ed4f1222ebf89a1396e8b2\_img.jpg\)](#)

$$\text{ex } 16.08\text{kJ}/\text{kg} = 120\text{kg}/\text{min} \cdot 1.005\text{kJ}/\text{kg} \cdot \text{K} \cdot (350.0\text{K} - 342\text{K})$$




14) Initial Mass of Evaporant Required to be Carried for given Flight Time 

$$\text{fx } M_{\text{ini}} = \frac{Q_r \cdot t}{h_{\text{fg}}}$$

[Open Calculator !\[\]\(e2376d476d06eb31946dc01a69a4403a\_img.jpg\)](#)

$$\text{ex } 53.53982\text{kg} = \frac{550\text{kJ}/\text{min} \cdot 220\text{min}}{2260\text{kJ}/\text{kg}}$$

15) Local Sonic or Acoustic Velocity at Ambient Air Conditions 

$$\text{fx } a = \left( \gamma \cdot [R] \cdot \frac{T_i}{MW} \right)^{0.5}$$

[Open Calculator !\[\]\(0b5e7e25e8775f7e7e80906ada4f0021\_img.jpg\)](#)


$$\text{ex } 340.0649\text{m/s} = \left( 1.4 \cdot [R] \cdot \frac{305\text{K}}{0.0307\text{kg}} \right)^{0.5}$$

16) Mass of air to produce Q tonnes of refrigeration 

$$\text{fx } M = \frac{210 \cdot Q}{C_p \cdot (T_6 - T_5')}$$

[Open Calculator !\[\]\(bd3b31712ad9bab5a241210fa6925cdd\_img.jpg\)](#)

$$\text{ex } 117.5373\text{kg}/\text{min} = \frac{210 \cdot 150}{1.005\text{kJ}/\text{kg} \cdot \text{K} \cdot (281\text{K} - 265\text{K})}$$

17) Mass of air to produce Q tonnes of refrigeration given exit temperature of cooling turbine 

$$\text{fx } M = \frac{210 \cdot TR}{C_p \cdot (T_4 - T_7')}$$

[Open Calculator !\[\]\(7bc43b319a082987e20f7bf78f4bab80\_img.jpg\)](#)


$$\text{ex } 117.8507\text{kg}/\text{min} = \frac{210 \cdot 47}{1.005\text{kJ}/\text{kg} \cdot \text{K} \cdot (290\text{K} - 285\text{K})}$$



18) Power Required for Refrigeration System [Open Calculator !\[\]\(eafc244b53721dd1ec133f0772f70fc7\_img.jpg\)](#)


$$\text{fx } P_{\text{req}} = \left( \frac{m_a \cdot C_p \cdot (T_t' - T_2')}{60} \right)$$

$$\text{ex } 9286.2 \text{ kJ/min} = \left( \frac{120 \text{ kg/min} \cdot 1.005 \text{ kJ/kg} \cdot \text{K} \cdot (350.0 \text{ K} - 273 \text{ K})}{60} \right)$$

19) Power required to maintain pressure inside cabin excluding ram work [Open Calculator !\[\]\(10f8862fc183b400327470ea85afe9ae\_img.jpg\)](#)

$$\text{fx } P_{\text{in}} = \left( \frac{m_a \cdot C_p \cdot T_2'}{\text{CE}} \right) \cdot \left( \left( \frac{P_c}{P_2'} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right)$$

$$\text{ex } 155.0701 \text{ kJ/min} = \left( \frac{120 \text{ kg/min} \cdot 1.005 \text{ kJ/kg} \cdot \text{K} \cdot 273 \text{ K}}{46.5} \right) \cdot \left( \left( \frac{400000 \text{ Pa}}{200000 \text{ Pa}} \right)^{\frac{1.4-1}{1.4}} - 1 \right)$$

20) Power Required to Maintain Pressure inside Cabin including Ram Work [Open Calculator !\[\]\(35dc653d59570f8f891c312eeece91a2\_img.jpg\)](#)

$$\text{fx } P_{\text{in}} = \left( \frac{m_a \cdot C_p \cdot T_a}{\text{CE}} \right) \cdot \left( \left( \frac{P_c}{P_{\text{atm}}} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right)$$


$$\text{ex } 155.7478 \text{ kJ/min} = \left( \frac{120 \text{ kg/min} \cdot 1.005 \text{ kJ/kg} \cdot \text{K} \cdot 125 \text{ K}}{46.5} \right) \cdot \left( \left( \frac{400000 \text{ Pa}}{101325 \text{ Pa}} \right)^{\frac{1.4-1}{1.4}} - 1 \right)$$

21) Ram Efficiency [Open Calculator !\[\]\(b538fe54c1f3a7343e37e85cc2d00497\_img.jpg\)](#)

$$\text{fx } \eta = \frac{(P_2') - P_i}{P_f - P_i}$$

$$\text{ex } 0.866667 = \frac{150000 \text{ Pa} - 85000 \text{ Pa}}{160000 \text{ Pa} - 85000 \text{ Pa}}$$




22) Refrigeration Effect Produced 

$$\text{fx } R_E = m_a \cdot C_p \cdot (T_6 - T_5')$$

[Open Calculator !\[\]\(9dfdaff1d86ba3c1f8353b4d1b61b8c5\_img.jpg\)](#)


$$\text{ex } 1929.6\text{kJ/min} = 120\text{kg/min} \cdot 1.005\text{kJ/kg}\cdot\text{K} \cdot (281\text{K} - 265\text{K})$$

23) Relative Coefficient of Performance 

$$\text{fx } \text{COP}_{\text{relative}} = \frac{\text{COP}_{\text{actual}}}{\text{COP}_{\text{theoretical}}}$$

[Open Calculator !\[\]\(2b376d1a92330ab09dad2665d2f89bf5\_img.jpg\)](#)

$$\text{ex } 0.333333 = \frac{0.2}{0.6}$$

24) Temperature Ratio at Start and End of Ramming Process 

$$\text{fx } T_{\text{ratio}} = 1 + \frac{v_{\text{process}}^2 \cdot (\gamma - 1)}{2 \cdot \gamma \cdot [R] \cdot T_i}$$

[Open Calculator !\[\]\(c444627dab9fee9a1550c053ffaaaae2\_img.jpg\)](#)

$$\text{ex } 1.202801 = 1 + \frac{(60\text{m/s})^2 \cdot (1.4 - 1)}{2 \cdot 1.4 \cdot [R] \cdot 305\text{K}}$$

25) Theoretical Coefficient of Performance of Refrigerator 

$$\text{fx } \text{COP}_{\text{theoretical}} = \frac{Q_{\text{ref}}}{W}$$

[Open Calculator !\[\]\(06a315363e7801bba8c7489a6694af19\_img.jpg\)](#)

$$\text{ex } 0.6 = \frac{600\text{kJ/kg}}{1000\text{kJ/kg}}$$



## Variables Used

- **a** Sonic Velocity (Meter per Second)
- **C<sub>p</sub>** Specific Heat Capacity at Constant Pressure (Kilojoule per Kilogram per K)
- **CE** Compressor Efficiency
- **COP<sub>actual</sub>** Actual Coefficient of Performance
- **COP<sub>relative</sub>** Relative Coefficient of Performance
- **COP<sub>theoretical</sub>** Theoretical Coefficient of Performance
- **h<sub>fg</sub>** Latent Heat of Vaporization (Kilojoule per Kilogram)
- **M** Mass (Kilogram per Minute)
- **M<sub>ini</sub>** Initial Mass (Kilogram)
- **ma** Mass of Air (Kilogram per Minute)
- **MW** Molecular Weight (Kilogram)
- **n** Polytropic Index
- **P<sub>1</sub>** Pressure at Start of Isentropic Compression (Pascal)
- **p<sub>2</sub>'** Stagnation Pressure of System (Pascal)
- **P<sub>2</sub>** Pressure at End of Isentropic Compression (Pascal)
- **P<sub>atm</sub>** Atmospheric Pressure (Pascal)
- **p<sub>c</sub>** Cabin Pressure (Pascal)
- **P<sub>f</sub>** Final Pressure of System (Pascal)
- **P<sub>i</sub>** Initial Pressure of System (Pascal)
- **P<sub>in</sub>** Input Power (Kilojoule per Minute)
- **P<sub>req</sub>** Power Required (Kilojoule per Minute)
- **p<sub>2</sub>'** Pressure of Rammed Air (Pascal)
- **Q** Tonnage of Refrigeration in TR
- **Q<sub>Absorbed</sub>** Heat Absorbed (Kilojoule per Kilogram)
- **Q<sub>delivered</sub>** Heat Delivered to Hot Body (Kilojoule per Minute)
- **Q<sub>r</sub>** Rate of Heat Removal (Kilojoule per Minute)





- $Q_R$  Heat Rejected (Kilojoule per Kilogram)
- $Q_{R, \text{Cooling}}$  Heat Rejected during Cooling Process (Kilojoule per Kilogram)
- $Q_{\text{ref}}$  Heat Extracted from Refrigerator (Kilojoule per Kilogram)
- $R_E$  Refrigeration Effect Produced (Kilojoule per Minute)
- $r_p$  Compression or Expansion Ratio
- $t$  Time in Minutes (Minute)
- $T_1$  Temperature at Start of Isentropic Compression (Kelvin)
- $T_2$  Ideal Temp at End of Isentropic Compression (Kelvin)
- $T_3$  Ideal Temp at End of Isobaric Cooling (Kelvin)
- $T_4$  Temperature at End of Isentropic Expansion (Kelvin)
- $T_6$  Inside Temperature of Cabin (Kelvin)
- $T_a$  Ambient Air Temperature (Kelvin)
- $T_i$  Initial Temperature (Kelvin)
- $T_{\text{ratio}}$  Temperature Ratio
- $T_2'$  Actual Temperature of Rammed Air (Kelvin)
- $T_4$  Temperature at the end of Cooling Process (Kelvin)
- $T_5'$  Actual Temperature at end of Isentropic Expansion (Kelvin)
- $T_7'$  Actual Exit Temperature of Cooling Turbine (Kelvin)
- $TR$  Ton of Refrigeration
- $T_t'$  Actual End Temp of Isentropic Compression (Kelvin)
- $V_{\text{process}}$  Velocity (Meter per Second)
- $w$  Work Done (Kilojoule per Kilogram)
- $W_{\text{per min}}$  Work Done per min (Kilojoule per Minute)
- $\gamma$  Heat Capacity Ratio
- $\eta$  Ram Efficiency



## Constants, Functions, Measurements used

- **Constant:** [R], 8.31446261815324  
*Universal gas constant*
- **Measurement: Weight** in Kilogram (kg)  
*Weight Unit Conversion* ↗
- **Measurement: Time** in Minute (min)  
*Time Unit Conversion* ↗
- **Measurement: Temperature** in Kelvin (K)  
*Temperature Unit Conversion* ↗
- **Measurement: Pressure** in Pascal (Pa)  
*Pressure Unit Conversion* ↗
- **Measurement: Speed** in Meter per Second (m/s)  
*Speed Unit Conversion* ↗
- **Measurement: Power** in Kilojoule per Minute (kJ/min)  
*Power Unit Conversion* ↗
- **Measurement: Specific Heat Capacity** in Kilojoule per Kilogram per K (kJ/kg\*K)  
*Specific Heat Capacity Unit Conversion* ↗
- **Measurement: Mass Flow Rate** in Kilogram per Minute (kg/min)  
*Mass Flow Rate Unit Conversion* ↗
- **Measurement: Latent Heat** in Kilojoule per Kilogram (kJ/kg)  
*Latent Heat Unit Conversion* ↗
- **Measurement: Rate of Heat Transfer** in Kilojoule per Minute (kJ/min)  
*Rate of Heat Transfer Unit Conversion* ↗
- **Measurement: Specific Energy** in Kilojoule per Kilogram (kJ/kg)  
*Specific Energy Unit Conversion* ↗



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