Important Air Refrigeration Formulas PDF

Formulas
Examples
with Units

List of 25
Important Air Refrigeration Formulas

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

Evaluate Formula

Formula

$$COP_{actual} = \frac{T_6 - T5'}{Tt' - T2'}$$

Example with Units

$$0.2078 = \frac{281\,K - 265\,K}{350.0\,K - 273\,K}$$

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

Evaluate Formula

Formula

$$COP_{actual} = \frac{210 \cdot Q}{ma \cdot C_p \cdot \left(Tt' - T2' \right)}$$

Example with Units

$$0.2035 = \frac{210 \cdot 150}{120\,kg/min \cdot 1.005\,kJ/kg*K \cdot \left(350.0\,K - 273\,K \right)}$$

3) Compression or Expansion Ratio Formula

Evaluate Formula

Formula

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

Example with Units

$$25 = \frac{10E6\,Pa}{4E5\,Pa}$$

4) Compression Work Formula

Evaluate Formula

Formula

$$W_{per\ min} = ma \cdot C_p \cdot \left(Tt' - T2' \right)$$

Example with Units

$$9286.2\,kJ/min = 120\,kg/min \cdot 1.005\,kJ/kg*K \cdot \left(350.0\,K - 273\,K \right)$$

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

Evaluate Formula

Formula

$$COP_{actual} = \frac{210 \cdot Q}{P_{in} \cdot 60}$$

Example with Units

$$0.2032 = \frac{210 \cdot 150}{155\,kJ/min \cdot 60}$$

6) COP of Air Cycle given Input Power Formula

Evaluate Formula

Formula

$$COP_{actual} = \frac{210 \cdot Q}{P_{in} \cdot 60}$$

Example with Units

$$0.2032 = \frac{210 \cdot 150}{155\,\text{kJ/min} \cdot 60}$$

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

Evaluate Formula

Formula

$$COP_{theoretical} = \frac{1}{r_p^{\frac{\gamma - 1}{\gamma}} - 1}$$

Example

$$0.6629 = \frac{1}{25^{\frac{1.4 - 1}{1.4}} - 1}$$

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

Evaluate Formula

Formula

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

Example with Units

$$0.6017 = \frac{300\,\text{K} - 290\,\text{K}}{\left(\frac{1.52}{1.52 - 1}\right) \cdot \left(\frac{1.4 - 1}{1.4}\right) \cdot \left(\left(356.5\,\text{K} - 326.6\,\text{K}\right) - \left(300\,\text{K} - 290\,\text{K}\right)\right)}$$

9) Energy Performance Ratio of Heat Pump Formula

Evaluate Formula

Formula

$$COP_{theoretical} = \frac{Q_{delivered}}{W_{per\ min}}$$

Example with Units

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

10) Expansion Work Formula

Evaluate Formula

Formula

$$W_{per\ min} = ma \cdot C_p \cdot \left(T4 - T5'\right)$$

Example with Units

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

11) Heat Absorbed during Constant Pressure Expansion Process Formula

Evaluate Formula

Formula

$$Q_{Absorbed} = C_p \cdot \left(T_1 - T_4\right)$$

Example with Units

$$10.05\,\text{kJ/kg} = 1.005\,\text{kJ/kg*K} \cdot \left(300\,\text{K} - 290\,\text{K}\right)$$

12) Heat Rejected during Constant pressure Cooling Process Formula

Evaluate Formula

Formula

$$Q_R = C_p \cdot \left(T_2 - T_3 \right)$$

Example with Units

$$30.0495\,\text{kJ/kg} = 1.005\,\text{kJ/kg*K} \cdot \left(356.5\,\text{K} - 326.6\,\text{K} \right)$$

13) Heat rejected during cooling process Formula

Evaluate Formula

Formula

$$Q_{R,\,Cooling} = ma \cdot C_p \cdot \left(Tt' - T4 \right)$$

Example with Units

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

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

Evaluate Formula

Formula

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

Example with Units

$$53.5398\,\text{kg} = \frac{550\,\text{kJ/min} \cdot 220\,\text{min}}{2260\,\text{kJ/kg}}$$

15) Local Sonic or Acoustic Velocity at Ambient Air Conditions Formula

Evaluate Formula

Formula

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

Example with Units

$$340.0649\,\text{m/s} = \left(1.4 \cdot 8.3145 \cdot \frac{305\,\text{K}}{0.0307\,\text{kg}} \right)^{0.5}$$

16) Mass of air to produce Q tonnes of refrigeration Formula

Evaluate Formula

Formula

$$M = \frac{210 \cdot Q}{C_p \cdot \left(T_6 - T5' \right)}$$

Example with Units

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

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

Evaluate Formula

Formula

$$M = \frac{210 \cdot TR}{C_p \cdot \left(T_4 - T7' \right)}$$

Example with Units

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

18) Power Required for Refrigeration System Formula

Evaluate Formula

Formula

$$P_{req} = \left(\frac{ma \cdot C_p \cdot \left(Tt' - T2' \right)}{60} \right)$$

Example with Units

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

19) Power required to maintain pressure inside cabin excluding ram work Formula

Evaluate Formula

Formula

$$P_{in} = \left(\frac{ma \cdot C_p \cdot T2'}{CE} \right) \cdot \left(\left(\frac{p_c}{p2'} \right)^{\frac{\gamma - 1}{\gamma}} - 1 \right)$$

Example with Units

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

20) Power Required to Maintain Pressure inside Cabin including Ram Work Formula

Evaluate Formula

Formula

$$P_{in} = \left(\frac{ma \cdot C_p \cdot T_a}{CE} \right) \cdot \left(\left(\frac{p_c}{P_{atm}} \right)^{\frac{\gamma - 1}{\gamma}} - 1 \right)$$

Example with Units

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

21) Ram Efficiency Formula

Evaluate Formula

Formula

$$\eta = \frac{p_2' - P_i}{P_f - P_i}$$

Example with Units

$$0.8667 = \frac{150000\,\text{Pa} - 85000\,\text{Pa}}{160000\,\text{Pa} - 85000\,\text{Pa}}$$

22) Refrigeration Effect Produced Formula

Evaluate Formula

Formula

$$R_E = ma \cdot C_p \cdot \left(T_6 - T5' \right)$$

Example with Units

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

23) Relative Coefficient of Performance Formula

Evaluate Formula

Formula

$$COP_{relative} = \frac{COP_{actual}}{COP_{theoretical}}$$

Example

$$0.3333 = \frac{0.2}{0.6}$$

24) Temperature Ratio at Start and End of Ramming Process Formula

Evaluate Formula

Formula

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

Example with Units

$$1.2028 = 1 + \frac{60\,\text{m/s}^{2} \cdot \left(1.4 - 1 \right)}{2 \cdot 1.4 \cdot 8.3145 \cdot 305\,\text{K}}$$

25) Theoretical Coefficient of Performance of Refrigerator Formula

Evaluate Formula

Formula

$$COP_{theoretical} = \frac{Q_{ref}}{w}$$

Example with Units

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

Variables used in list of Air Refrigeration Formulas above

- **a** Sonic Velocity *(Meter per Second)*
- **C_p** Specific Heat Capacity at Constant Pressure *(Kilojoule per Kilogram per K)*
- **CE** Compressor Efficiency
- **COP_{actual}** Actual Coefficient of Performance
- **$COP_{relative}$** Relative Coefficient of Performance
- **$COP_{theoretical}$** Theoretical Coefficient of Performance
- **h_{fg}** Latent Heat of Vaporization *(Kilojoule per Kilogram)*
- **M** Mass *(Kilogram per Minute)*
- **M_{ini}** Initial Mass *(Kilogram)*
- **ma** Mass of Air *(Kilogram per Minute)*
- **MW** Molecular Weight *(Kilogram)*
- **n** Polytropic Index
- **P_1** Pressure at Start of Isentropic Compression *(Pascal)*
- **p_2'** Stagnation Pressure of System *(Pascal)*
- **P_2** Pressure at End of Isentropic Compression *(Pascal)*
- **P_{atm}** Atmospheric Pressure *(Pascal)*
- **p_c** Cabin Pressure *(Pascal)*
- **P_f** Final Pressure of System *(Pascal)*
- **P_i** Initial Pressure of System *(Pascal)*
- **P_{in}** Input Power *(Kilojoule per Minute)*
- **P_{req}** Power Required *(Kilojoule per Minute)*
- **$p2'$** Pressure of Rammed Air *(Pascal)*
- **Q** Tonnage of Refrigeration in TR
- **$Q_{Absorbed}$** Heat Absorbed *(Kilojoule per Kilogram)*
- **$Q_{delivered}$** Heat Delivered to Hot Body *(Kilojoule per Minute)*
- **Q_r** Rate of Heat Removal *(Kilojoule per Minute)*
- **Q_R** Heat Rejected *(Kilojoule per Kilogram)*

Constants, Functions, Measurements used in list of Air Refrigeration Formulas above

- constant(s): **[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

- $Q_{R,\ Cooling}$ Heat Rejected during Cooling Process *(Kilojoule per Kilogram)*
- Q_{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_{ratio} Temperature Ratio
- $T2'$ Actual Temperature of Rammed Air *(Kelvin)*
- **T4** Temperature at the end of Cooling Process *(Kelvin)*
- $T5'$ Actual Temperature at end of Isentropic Expansion *(Kelvin)*
- $T7'$ Actual Exit Temperature of Cooling Turbine *(Kelvin)*
- **TR** Ton of Refrigeration
- Tt' Actual End Temp of Isentropic Compression *(Kelvin)*
- $v_{process}$ Velocity *(Meter per Second)*
- **w** Work Done *(Kilojoule per Kilogram)*
- $W_{per\ min}$ Work Done per min *(Kilojoule per Minute)*
- γ Heat Capacity Ratio
- η Ram Efficiency

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