Trane® Engineering Toolbox

An in-depth look...

Power Factor Correction

This handy tool calculates the trigonometric relationships between power factor, kW, kVs and amps for electric motors. It also helps you quickly find the nominal size capacitor needed to correct your AC motor's power to a desired power factor, and generates the corrected power factor for up nine part-load data points.

Timothy Zurick's 1977 *Air Conditioning, Heating & Refrigeration Dictionary* defines power factor as "the ratio of the power consumed (watts) in a circuit to the power drawn (volt-amperes). This ratio describes the difference between the amount of power actually used and the amount of apparently used."

The distinction between actual and apparent power use is a crucial one. A low power factor (a ratio less than 1.0) doesn't increase a motor's power consumption, but it does require more current. The utility company must generate and distribute surplus current. Larger-than-necessary distribution components, such as wires and switching gears, are sized to provide the apparent current rather than the actual. Utility companies often impose an economic penalty on customers with low power factors or high apparent power consumption (kVA).

If enough information is known about a primarily inductive circuit, it's possible to calculate the required amount of capacitance for power factor correction. The characteristics of inductive and capacitive elements offset each other when applied in the same circuit. This interaction means that adding capacitive elements, or capacitors, to a primarily inductive circuit will increase its power factor and reduce the resulting current draw.

The entries for Power Factor Correction are very versatile. Based on the information you have about the motor, you can choose one of five sets of values:

Uncorrected Power Factor

Prior to adding a capacitor, it's the ratio of real power (kW) to apparent power (kVA) at any given point in time in an electrical circuit. This value is generally available from the motor manufacturer.

Rated Load Amps

Rated Load Amps (RLA) are the amount of current that a rotation machine draws when operating at a rated voltage, speed (RPM), and torque.

kW Input

A kilowatt is a measure of power defined as 1,000 joules per second of energy flow. kW should be entered for the full load (rated) condition.

Brake Horsepower

Brake Horsepower is the actual power delivered to or by a shaft.

Motor Efficiency

Motor efficiency is entered as a percent.

You must also enter either capacitance or Corrected Power Factor. Then, the Engineering Toolbox will solve for the remaining aspects.

Corrected Power Factor
Corrected power factor is the power factor with installed capacitors. If you are using the tool to calculate the amount capacitance required to attain a desired power factor, then the corrected power factor is the desired power factor.

Installed Capacitance
The amount of capacitance that must be added to the motor to attain the corrected power factor and line current.

Engineering Toolbox returns the Line Current and Required Capacitance, as well as Corrected Power Factor.

Required Capacitance is the amount of capacitance (in Kvar) that must be added to the motor to attain the Corrected Power Factor and Line Current.

Capacitors used for Power Factor Correction are generally offered in predetermined sizes that seldom match the Required Capacitance. Typically, designers pick the closest-size capacitor that is smaller than the Required Capacitance to avoid overcorrecting.

Standard capacitors are also cataloged at a specific voltage and frequency. If they are used at a different voltage or frequency, they must be re-rated to the new condition using the following equation:

$$Kvar\ actual = Kvar\ rated \times (V\ actual / V\ rated)^2 \times (f\ actual / f\ rated)$$

Properties of Air
Properties of air is an electronic version of the Trane psychrometric chart. You enter any two properties of a known quantity of air and the program calculates the five other properties.

Using one start point, this applet calculates all properties of moist or dry air at normal HVAC conditions. It’s an electronic version of the Trane psychrometric chart, and it uses the same calculating routines as TRACE 600 and TRACE Load 700. It’s so easy to read, too—no more incorrect interpretations!

Enter any two values and the program will instantly calculate the other five properties (if pychrometrically possible). Engineer's Toolbox takes any combination of:

- Altitude
- Dry bulb
- Wet bulb
- Specific humidity
- Enthalpy
- Dew point
- Relative humidity
- Specific volume

and returns the remaining properties:

- Altitude
- Barometric pressure
- Air pressure
- Dry bulb
- Wet bulb
- Specific humidity
- Enthalpy
- Dew point
- Relative humidity
- Specific volume
- Humidity ratio

Try the web enabled Properties of Air calculator.

Mixed Air Properties
Enter psychrometric information about two known quantities of air and the program returns properties for the mixture of the two quantities. The Mixed Properties of Air applet is very similar to the Properties of Air applet.

Engineering Toolbox requires values for both air quantities, including:

- Quantity
- Dry Bulb
- Wet Bulb
- Altitude

With these values entered, Engineering Toolbox calculates values for each air quantity, as well as a combination of the two. Values calculated include:

- Altitude
- Barometric pressure
- Air quantity
- Air pressure
- Dry bulb
- Wet bulb
- Humidity ratio
- Humidity
- Specific humidity
- Enthalpy
- Specific volume
- Dew Point
- Relative humidity

Try the web-enabled version of the Mixed Air Properties calculater for yourself!

Fluid Properties
Calculates physical properties of the five different fluids used in HVAC applications including water, ethylene glycol, propylene glycol, calcium chloride, and methanol brine.

Engineering toolbox requires values for fluid type, temperature, and concentration, to calculate:

- Temperature concentration
- Viscosity
- Freezing point
- Specific gravity
- Thermal conductivity
- Specific heat

Refrigerant Properties
Calculates several properties of ten commonly used refrigerants.

- CFC-11 (R-11)
- CFC-12 (R-12)
- HCFC-22 (R-22)
- HFC-32 (R-32)
- CFC-113 (R-113)
- CFC-114 (R-114)
- HCFC-123 (R-123)
- HFC-134a (R-134a)
- CFC-500 (R-500)
- CFC-502 (R-502)

Engineering Toolbox requires entries for Refrigerant type, Temperature and Concentration. In return Engineering Toolbox calculates:

- Temperature concentration
- Liquid enthalpy
- Liquid viscosity
- Liquid thermal conductivity
- Specific heat
- Density
- Vapor enthalpy
- Vapor viscosity
- Vapor thermal conductivity
- Vapor entropy
- Sonic velocity
- Specific heat
- Specific volume

Refrigerant Line Sizing
This calculator combines refrigerant properties and piping design fundamentals to compute line sizes for suction, discharge, and liquid lines of split systems using R-12 or R-22.

System values required are:

- Refrigerant type
- Saturated suction temperature
- Condensing temperature
- Evaporator tonnage
- Superheat
- Subcooling
- Compressor superheat

The discharge line connects the outlet of the compressor to the condenser. In a "condensing unit," the discharge line is an integral part of the packaged piece of equipment and need not be sized.

Engineering Toolbox selects a discharge line to maintain the velocity of the refrigerant vapor below 3,500 fpm and the total pressure drop in the discharge line below 6 psi.

When selecting a line size, be sure that the minimum tons reported for the line are lower than the minimum capacity of the refrigeration circuit. If it is not, reduce the line size of vertical risers only. If the minimum tons for a 30-ton circuit are reported as 11.6 tons for a 1-5/8" discharge line, this means that the refrigerant can carry oil in this size line down to 11.6 tons. As long as the minimum capacity of the circuit is greater than 11.6 tons, the line size is acceptable. If it is not, the vertical riser sections of the line should be reduced one size to 1-3/8".

It is good practice to maintain refrigerant velocity above 500 fpm.

Discharge line values required include:

- Line length
- Ball valve count
- Angle valve count
- Short elbow count
- Long elbow count
- Tee "thru" count
- Tee "branch" count

The liquid line connects the condenser to the expansion device, which is at the inlet of the evaporator.

Engineering Toolbox selects a liquid line to maintain the velocity of the liquid refrigerant below 600 fpm and to maintain subcooling greater than 5° F at the inlet to the expansion device. The system needs to have enough subcooling so that the refrigerant will not flash to vapor before it reaches the expansion valve. It ensures this by selecting a line size that will have at least 5° F of subcooling remaining at the inlet of the expansion valve.

For R-22 ... When vertical upward flow exists in the liquid line (i.e., when the condenser is located below the evaporator), loss of head pressure due to the column effect of the liquid must be taken into consideration. The loss of head pressure is most likely to occur when the liquid is very dense (liquid temperature is low). To avoid loss of head pressure in vertical upward lines, an adjustment factor is applied to the subcooling before the expansion valve so, that the program does not choose a line that will not perform when the outdoor conditions are not at design. The adjustment factor applied is based on the properties of refrigerant R-22 at 50° F. For every 10 feet of upward flow 3.2° F is subtracted from the subcooling before the expansion valve; 5 °F before the expansion must still be maintained even with the adjustment factor.

Liquid line values required include:

- Line length
- Ball valve quantity
- Angle valve quantity
- Short elbow quantity
- Long elbow quantity
- Tee "thru" quantity
- Tee "branch" quantity
- Filter drier
- Solenoid valve
- Elevation change

The suction line connects the evaporator to the compressor inlet.

Engineering Toolbox selects a suction line to maintain the velocity of the refrigerant vapor below 4,000 fpm and the total pressure drop in the suction line below 6 psi.

When selecting a line size, be sure that the minimum tons reported for the line is lower than the minimum capacity of the refrigeration circuit. If not, reduce the line size of vertical risers only. For example, if the minimum tons for a 30-ton circuit is reported as 11.7 tons for a 2-1/8" suction line, this means that the refrigerant can carry oil in this size line down to 11.7 tons. As long as the minimum capacity of the circuit is greater that 11.7 tons, the line size is acceptable. If it is not, the vertical riser sections of the line should be reduced one size to 1-5/8".

It is a good practice to maintain refrigerant velocity above 500 fpm. Suction line values required include:

- Line length
- Ball valve quantity
- Angle valve quantity
- Short elbow quantity
- Long elbow quantity
- Tee "thru" quantity
- Tee "branch" quantity
- Suction filter quantity

Electronic Ductulator®

The electronic version of the Trane Ductulator, simplifies the manual process of sizing ductwork based on equal-friction methodology. It computes the friction rate or pressure drop in a particular duct so that you can specify an appropriate nominal size.

The equal-friction-duct sizing methodology attempts to keep the pressure drop, per unit length of duct, relatively constant throughout the system. It is widely used to size relatively low-velocity constant-volume systems and to size the flexible ductwork between each VAV box and diffuser.

Use the entries in the Ductulator window to describe the physical characteristics of the duct and specify two performance parameters (typically airflow and velocity). The program will calculate the friction rate and dimensions. With that information, enter a nominal duct size that approximates the calculated value(s) and let the program determine the new friction rate and velocity.

Ductulator requires the following information to solve the equal-friction-related equations:

- Duct shape
- Material type
- Roughness
- Duct ID
- Length

Plus any two of these variables: Airflow, Friction Rate and Velocity Dimensions.

For round duct, enter the Diameter plus Airflow or Friction Rate or Velocity.

For rectangular or oval duct, either:

- Enter the Height and Width PLUS Airflow or Friction Rate or Velocity. These entries can be made in any order.
- Enter one dimension (either Height or Width) plus two other variables from among Airflow, Friction Rate and Velocity. This method fixes the duct height or width if you enter the value before completing the other entries.

Remember that you can represent fittings and terminations by defining equivalent lengths of straight duct.

On completing these calculations, the program automatically displays the Ductulator Report in spreadsheet format. Use the click-and-drag borders between the headings to adjust the column widths and the horizontal scroll bar to aid onscreen viewing.