

ENGINEERING and TECHNICAL

Electrical Fundamentals & Three Phase Calculations

Ohm's Law

The relationship between Wattage (heat) output and the applied Voltage of electric resistance heating elements is determined by a precise physical rule defined as Ohm's Law which states that the current in a resistance heating element is directly proportional to the applied Voltage. Ohm's Law is traditionally expressed as:

$$I = \frac{E}{R}$$

Where: I = Amperes (Current)
E = Voltage
R = Ohms (Resistance)

The same equation using the conventional abbreviation for voltage is:

$$I = \frac{V}{R}$$

Where: I = Amperes (Current)
V = Voltage
R = Ohms (Resistance)

An unknown electrical value can be derived by using any two known values in one of the variations of Ohm's Law shown at the right.

Voltage & Wattage Relationships

An electric resistance element only produces rated Wattage at rated Voltage. It is common for electric heating elements and assemblies to be connected to a wide range of operating Voltages. Since the Wattage output varies directly with the ratio of the square of the Voltages, the actual Wattage can be calculated for any applied Voltage. The relationship is expressed by the equation below,

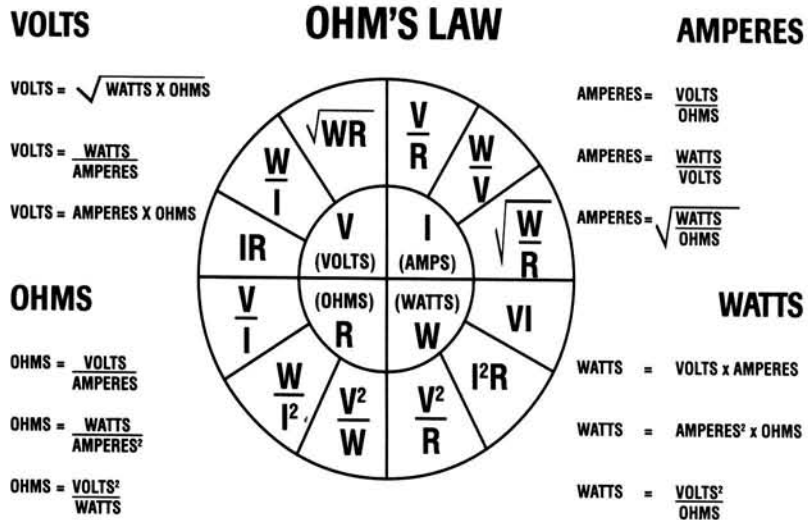
$$W_A = W_R \times \left(\frac{V_A}{V_R}\right)^2$$

Where: W_A = Actual Wattage
 W_R = Rated Wattage
 V_A = Applied Voltage
 V_R = Rated Voltage

Three Phase Equations (Balanced)

Ohm's Law, as stated above, applies to electrical resistance elements operated on single phase circuits. Ohm's Law can be modified to calculate three phase values by adding a correction factor for the phase Voltage relationships. The three phase equations shown can be applied to any balanced Delta or Wye circuit. The terms used in the equations are identified below:

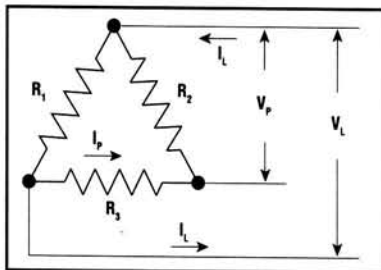
- V_L = Line Voltage
- V_P = Phase Voltage
- I_L = Line Current (Amps)
- I_P = Phase Current (Amps)
- W_T = Total Watts
- $R_1 = R_2 = R_3$ = Element Resistance
- W_C = Wattage per Circuit (Equal Circuits)
- R_C = Circuit Resistance in Ohms Measured Phase to Phase



Percent of Rated Wattage for Various Applied Voltages

| Applied Voltage | Rated Voltage | | | | | | | | | | | | | | |
|-----------------|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--|
| | 110 | 115 | 120 | 208 | 220 | 230 | 240 | 277 | 380 | 415 | 440 | 460 | 480 | 575 | |
| 110 | 100 | 91 | 84 | 28 | 25 | 23 | 21 | 16 | 8.4 | 7.0 | 6.2 | 5.7 | 5.2 | 3.7 | |
| 115 | 109 | 100 | 92 | 31 | 27 | 25 | 23 | 17 | 9.0 | 7.6 | 6.7 | 6.2 | 5.7 | 4.0 | |
| 120 | 119 | 109 | 100 | 33 | 30 | 27 | 25 | 19 | 10 | 8.4 | 7.4 | 6.8 | 6.3 | 4.3 | |
| 208 | — | — | 300 | 100 | 89 | 82 | 75 | 56 | 30 | 25 | 22 | 20 | 19 | 13 | |
| 220 | — | — | — | 112 | 100 | 91 | 84 | 63 | 34 | 28 | 25 | 23 | 21 | 15 | |
| 230 | — | — | — | 122 | 109 | 100 | 92 | 69 | 37 | 31 | 27 | 25 | 23 | 16 | |
| 240 | — | — | — | 133 | 119 | 109 | 100 | 75 | 40 | 33 | 30 | 27 | 25 | 17 | |
| 277 | — | — | — | — | — | — | 133 | 100 | 53 | 45 | 40 | 36 | 33 | 23 | |
| 380 | — | — | — | — | — | — | — | 188 | 100 | 84 | 74 | 68 | 63 | 44 | |
| 415 | — | — | — | — | — | — | — | — | 119 | 100 | 89 | 81 | 75 | 52 | |
| 440 | — | — | — | — | — | — | — | — | — | 112 | 100 | 91 | 84 | 58 | |
| 460 | — | — | — | — | — | — | — | — | — | 123 | 109 | 100 | 92 | 64 | |
| 480 | — | — | — | — | — | — | — | — | — | — | 119 | 109 | 100 | 70 | |
| 550 | — | — | — | — | — | — | — | — | — | — | 156 | 143 | 131 | 91 | |
| 575 | — | — | — | — | — | — | — | — | — | — | 171 | 156 | 144 | 100 | |
| 600 | — | — | — | — | — | — | — | — | — | — | 186 | 170 | 156 | 109 | |

3Ø Delta



$$V_P = V_L$$

$$W_T = 1.73 I_L \times V_L$$

$$I_P = I_L + 1.73$$

$$W_C = 1.73 I_L \times V_L + \# \text{ Circuits}$$

$$R_C = (2 \times V_L^2) + W_C$$

$$V_L = V_P$$

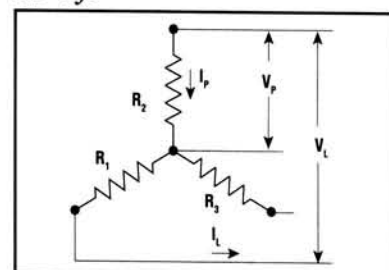
$$W_T = 3 (V_L^2 + R_1)$$

$$I_L = I_P \times 1.73$$

$$R_C = V_L^2 + 0.5W_C$$

Note — For Open Delta connections, see next page.

3Ø Wye



$$V_P = V_L + 1.73$$

$$W_T = 1.73 I_L \times V_L$$

$$I_P = I_L$$

$$W_C = 1.73 I_L \times V_L + \# \text{ Circuits}$$

$$R_C = (2 \times V_L^2) + W_C$$

$$V_L = V_P \times 1.73$$

$$W_T = V_L^2 + R_1$$

$$I_L = I_P$$

$$R_C = V_L^2 + 0.5W_C$$

Note — For Open Wye connections, see next page.