

Properties of Tungsten Filament Lamps

Mechanical Properties

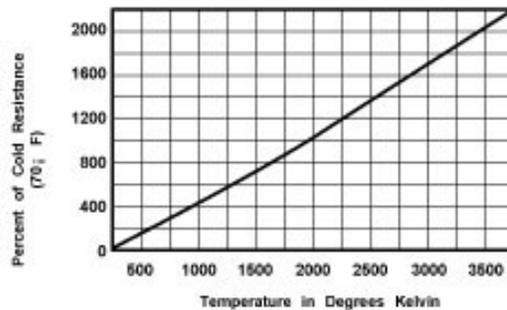
A tungsten filament is more fragile at room temperature than at elevated temperatures, particularly when there is some embrittlement due to crystallization of the aged wire. In cooling from an elevated temperature, the filament passes through the “brittle-ductile transition region” (250° to 350°C for tungsten filaments) and is much more liable to rupture below this region. Addition of small amounts of such elements as thorium, potassium, or rhenium have been found to alter ductility, tensile strength, and shock resistance, thereby directly or indirectly increasing lamp life in certain applications. A simple method to increase service life is to apply a small amount of power (usually less than 1% of operating power) to keep the filament warmed in the OFF mode. This “keep-alive” technique greatly increases the reliability of standard lamp types at small cost.

Electrical Properties

Resistance

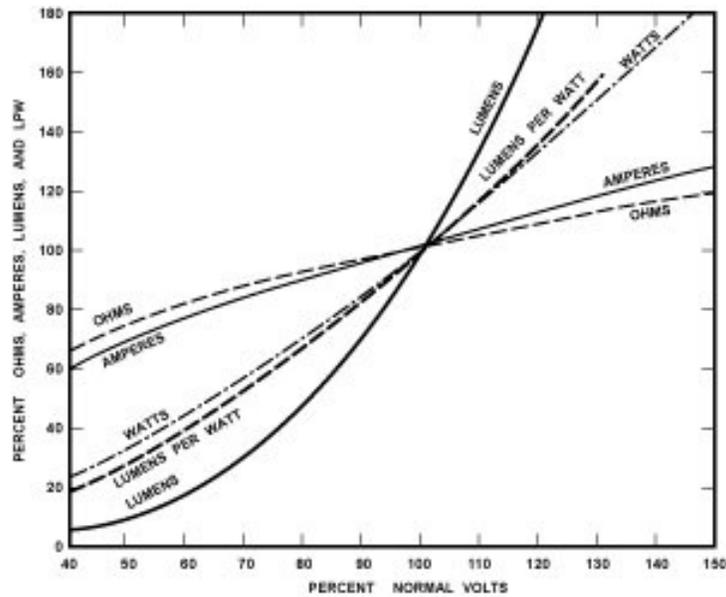
Tungsten filaments have a resistivity approximately three times that of copper at room temperature. As shown in Figure 3, the resistivity increases several thousand percent as a filament is heated to incandescence. Since the temperature coefficient of resistivity for pure tungsten is relatively constant over the range of lamp temperatures, it provides a convenient means for measuring the average temperature of a filament.

Resistance vs. Temperature of Pure Tungsten.



Effects of operating voltage variations

When incandescent lamps are operated at other than the nominal or rated voltage, the color temperature of the filament varies. The resistance, current, wattage, lumen output, and efficacy all vary as shown in Figure 4. The curves shown apply to both conventional non-halogen and halogen incandescent lamps and represent the average of many lamps. The characteristics of individual lamps may deviate increasingly from these curves for variations greater than +/- 10%. The characteristic curves may be represented near rated voltage by the equations given in Figure 5 where the values at rated voltage are in capital letters and the values at other than rated voltage are in lower case letters. The exponents given were empirically determined from many lamp types and are applicable to lamps having efficacies of about 10 to 25 lumens per watt. Actual exponents may vary from those given for specific lamp types.



$$\frac{\text{lumens}}{\text{LUMENS}} = \left(\frac{\text{volts}}{\text{VOLTS}} \right)^{3.4}$$

$$\frac{\text{lumens/watt}}{\text{LUMENS/WATT}} = \left(\frac{\text{volts}}{\text{VOLTS}} \right)^{1.9}$$

$$\frac{\text{watts}}{\text{WATTS}} = \left(\frac{\text{volts}}{\text{VOLTS}} \right)^{1.6}$$

$$\frac{\text{ohms}}{\text{OHMS}} = \left(\frac{\text{volts}}{\text{VOLTS}} \right)^{0.4}$$

$$\frac{\text{amperes}}{\text{AMPERES}} = \left(\frac{\text{volts}}{\text{VOLTS}} \right)^{0.6}$$

$$\frac{\text{life}}{\text{LIFE}} = \left(\frac{\text{volts}}{\text{VOLTS}} \right)^{13}$$

$$\frac{\text{color temperature, } \text{ }_i\text{K}}{\text{COLOR TEMPERATURE, } \text{ }_i\text{K}} = \left(\frac{\text{volts}}{\text{VOLTS}} \right)^{0.42}$$

Inrush Current

Since the cold resistance of tungsten filaments is about 1/12 to 1/16 the hot resistance, it might be expected that the initial inrush current when rated voltage is applied to a cold filament would be 12 to 16 times the rated current which flows when the filament heats up to rated temperature. The actual initial inrush current is generally limited to some smaller value by circuit reactance and is a function of the position on the ac wave at which the voltage is applied.

The time for the initial inrush current to decay to the rated current is determined almost entirely by the thermal mass of the filament, and ranges from about 0.05 seconds in 15W lamps to about 0.4 seconds in 1500W lamps.

The inrush current and decay time of incandescent lamp loads is important in the design, selection, and use of circuit breakers, switches, fuses, and other control devices

Inrush Current vs. Time for Tungsten Filaments

