How Tungsten filament Light bulbs can be made to last a long time in a primitive environment. (30 Dec 06)

Efficiency of light output becomes a second priority when one is faced with the choice of light or no light for a very long period of time.

If one has only this goal in mind, the answer is relatively easy. Use LEDs or Tungsten filament light bulbs at reduced voltage. The efficiency of the LED at producing light with the same input power over a given time frame is much greater than a tungsten filament by a factor of about 3 to 8 times. If you have a choice LEDs at reduced voltage are the first choice, however in a primitive environment many times there is no choice. One has to use what is at hand. Knowledge of what can be done with Tungsten filament bulbs is vital. Tungsten filament bubs should not be underestimated.

The Guinness Book of World Records states that a fire station in Livermore, California has a light bulb that is said to have been burning continuously for over a century since 1901 (presumably apart from power outages). However, the bulb is powered by only 4 watts. A similar story can be told of a 40-watt bulb in Texas which has been illuminated since September 21, 1908. It once resided in an opera house where notable celebrities stopped to take in its glow, but is now in an area museum.

By lowering the service voltage, incandescent lamps can be made to last much longer than is normal (however, their brightness and efficiency goes down as well). Lifetime is defined as the length of time when half out of 100 of the same bulbs all running at the same voltage will still be burning. The other half will have burned out.

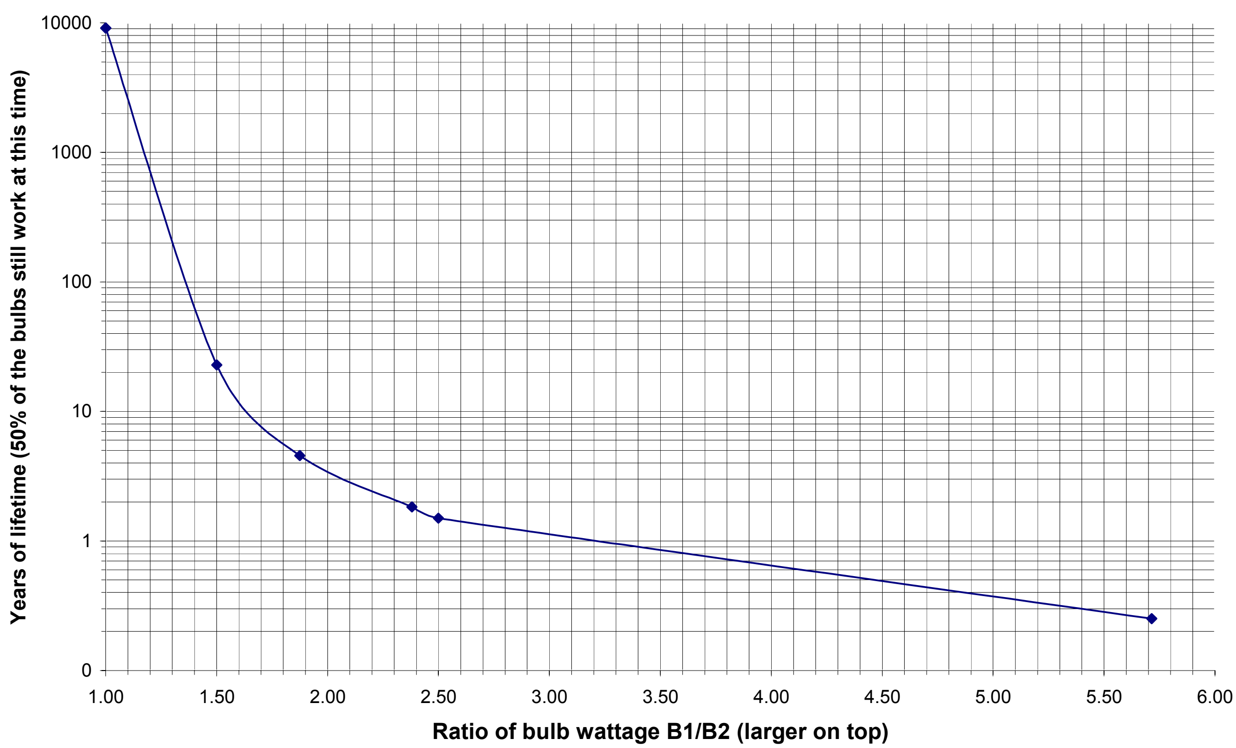
When two tungsten bulbs are wired in series, assuming the same source voltage is used, the amount of light produced is reduced and the amount of power used is less than the lowest wattage bulb (see bulb 2 column in the table). In effect the larger wattage bulb is being used as a resistor for the smaller wattage bulb that then produces the majority of the light.

Watts bulb1	Watts Bulb 2	Volts Bulb 2	Estimated lifetime in years	Bulb wattage ratios	watts used for combination	% of light output/Input watt	Equivalent wattage bulb for light left
7	7	61	9132	1.00	3.0	30	1
100	100	61	9132	1.00	68.6	27	19
60	40	82	22.8	1.50	31.9	38	12
75	40	93	4.57	1.88	34.0	48	16
238	100	101	1.83	2.38	91.7	60	55
100	40	104	1.50	2.50	35.8	63	22
40	7	119	0.25	5.71	5.5	98	5

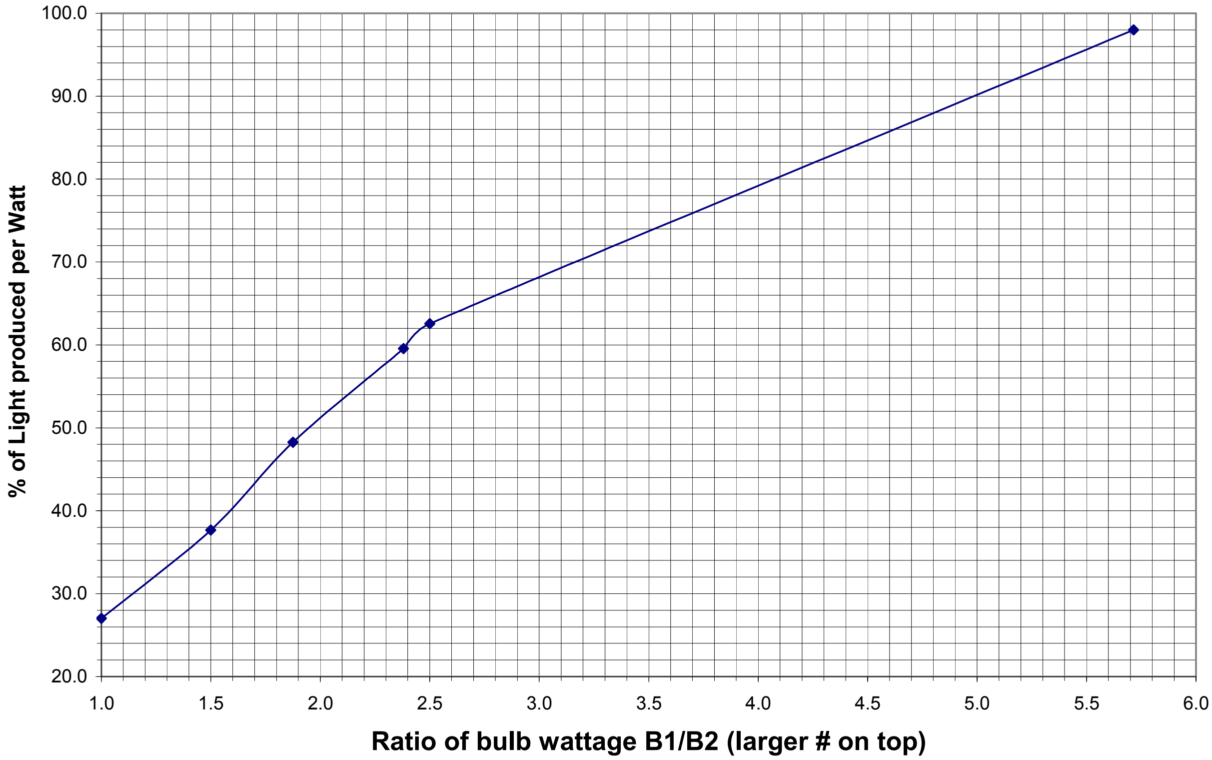
It turns out a 60 watt tungsten light bulb wired in series with a 40 watt light bulb will last twice as long as a typical mono-color LED's 11.4 year lifetime. The LED ends up half as bright at the end of this time. The 40-60 watt series connected tungsten light starts out 38% less bright (equivalent to 12 watt bulb) with a power usage of about 32 watts. After 22.8 years it is possibly a bit brighter than it started out. This is because some of the tungsten has evaporated from the filament making it thinner.

When the wattage for each bulb is close to the same, the voltage drops in half for each bulb and both will produce light for about 9,000 years. For example if two 100 watt bulbs are used, the resulting power usage is about 69 Watts. The light output is equivalent to a 19 watt bulb. See the above table for various mixtures of wattage. If you have another ratio of wattage you wish to use then the approximate result for lifetime and relative light output efficiency can be obtained from the following curves.

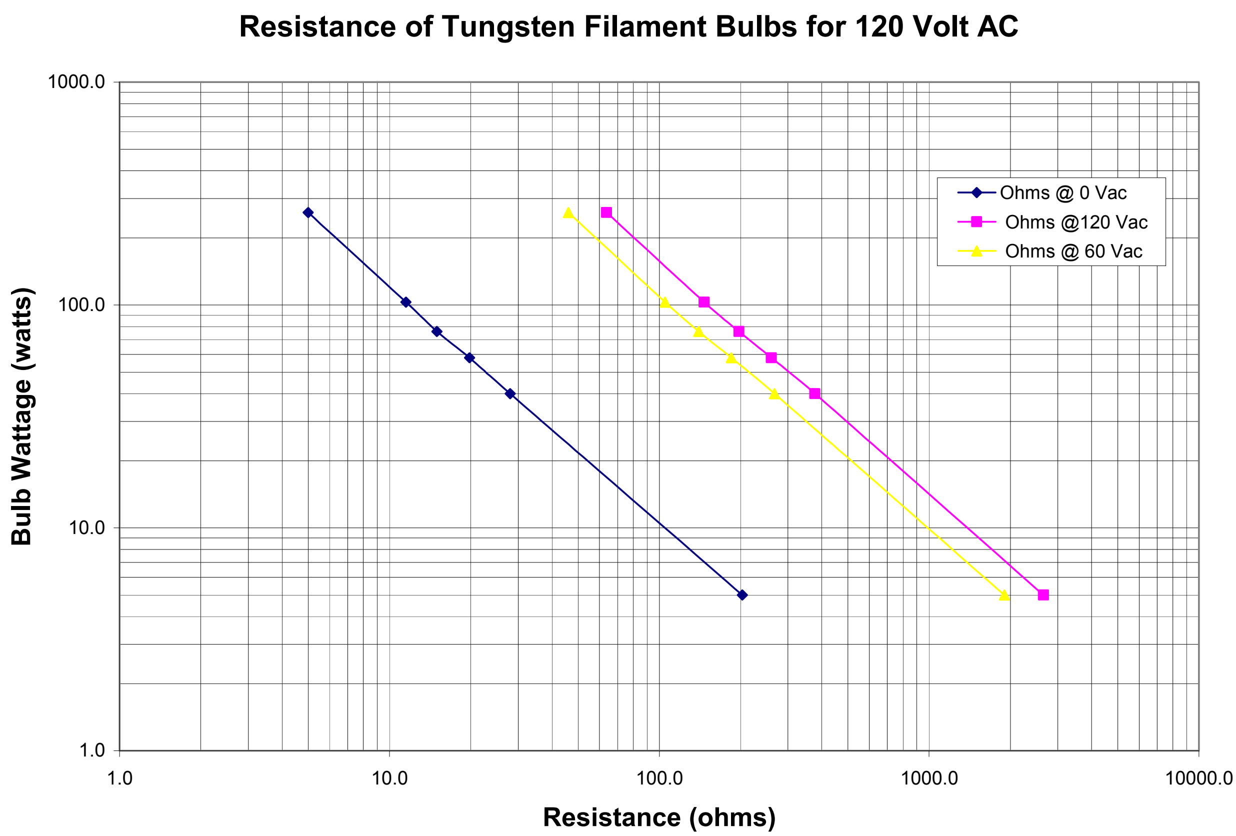
Estimated Lifetime for Two Bulbs of Different Size Wired In Series.



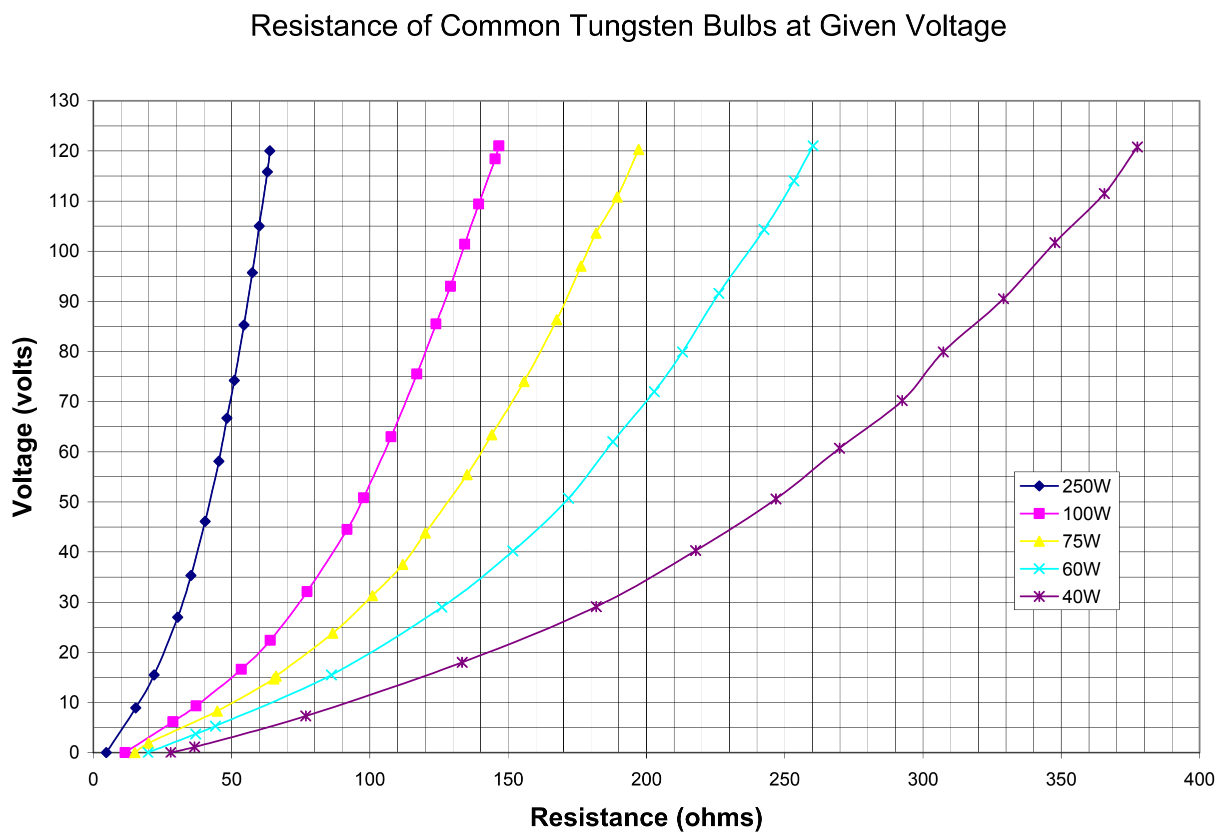
Resulting Light for Two Bulbs of Different Size (wattage) Wired In Series.



There are times when you may wish to know the resistance of a given wattage to use as a resistor. As long as one stays below the rated design voltage of typically 120 volts, light bulbs make a good resistor when high power is needed. The following two charts may help.

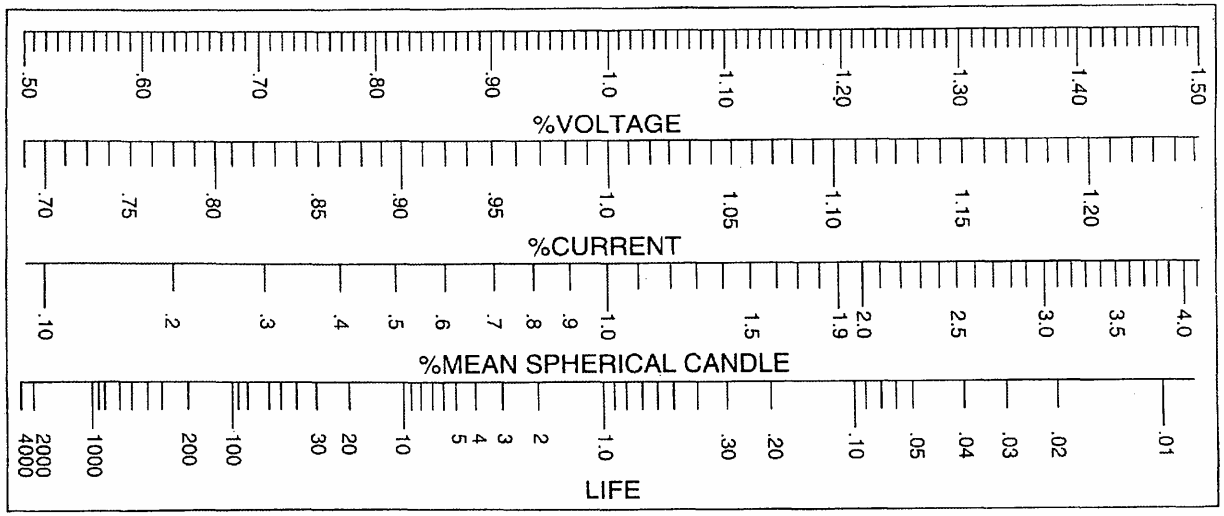


The next chart shows commonly available bulbs and there resistance with different AC voltages. They also have a useful positive temperature coefficient in that they increase in resistance as the current-temperature goes up.



As a side note: It is a good idea if you measure your planned primitive survival electrical system and how much it surges or changes in voltage. Estimate the change in voltages over and above 120 Volts, then drop this amount of voltage or more as a minimum for what is planned to be delivered to tungsten bulbs for a planned normal 2000 Hr lifetime.

The following nomograph is usefully when calculating how much additional drop in voltage is needed to get the intended longer lifetime. Adding the amount of surge above 120 V for the generator system to the delta needed for the long lifetime and subtracting this from 120 volts gives the average voltage one should run your tungsten bubs at to get longer lifetime.



Rapid Lamp Calculator Diagram

This diagram allows the user to determine the dependence of Current, Mean Spherical Candela and Life on the value of voltage applied to the lamp as a percentage of the design voltage for that lamp. Draw a horizontal line through the percent of design voltage to be used and read the value of the calculated parameters on the right side of the diagram

The following is notes or background of how all this was arrived at: (for the technically inclined)

Typically the experts say: The average lifetime of incandescent light bulbs is about 750–2000 hours. It would take at least 6-11 incandescent bulbs to last as long as one compact fluorescent light, which have an average lifetime between 11,250 and 15,000 hours." The harsh reality is for the most part we the users don't see on the market these long lasting fluorescents. Most users would currently say they both last about the same time.

One reason for this is each "start" of a fluorescent lamp reduces its lifetime a little (as it blasts some cathode material off the filaments of the lamp). So if the on-off cycle of a fluorescent lamp is very short, then its life won't approach that average 10K hour number cited above. On-off cycling also has an effect on incandescent lamps, but it's much less significant, especially for lower-voltage lamps.

Fluorescent lamps will not light at reduced voltage thus it becomes difficult to extend there lifetime. Near the end of it's life the intensity is much less than when new. Bottom line, for really long life we must rule out fluorescents.

In North America, a typical "long life" incandescent lamp is actually a 125V or 130V lamp; when operated on 120V, it can live a very long life. The lifetime of an incandescent lamp is approximately inversely proportional to the sixteenth power of the voltage. See the article and the last page for a very usefully nomograph of lifetime versus voltage, current and output light."

http://www.intl-lighttech.com/applications/appl-tungsten.pdf

Approximately 95% of the power consumed by an incandescent light bulb is emitted as heat, rather than as visible light. An incandescent light bulb, with this ~5% efficiency, is about one quarter as efficient as a fluorescent lamp (about 20% efficiency), and produces about six times as much heat for the same amount of light from both sources.

Since it is impossible (and in fact against electrical codes) to get 130 volts from any normal mains, these typically run at a more realistic 115 volts in North America. By dropping the voltage by 12%, the current also drops (non-linearly) by approximately 7%, reducing the actual wattage by about 18%. This in turn reduces the light output by 34%, but also increases the bulb's service life by a factor of 7. This is the concept of the "long-life bulb".

A 5% reduction in operating voltage will double the life of the bulb, at the expense of reducing its light output by 20%.

Efficiency: A typical 100 W bulb for 120 V systems, with a rated light output of 1750 lumens, has an overall efficacy of 17.5 lumens per watt, compared to an "ideal" of 242.5 lumens per watt for one type of white light. Unfortunately, tungsten filaments radiate mostly infrared radiation at temperatures where they remain un-melted or solid (below 3683 Kelvin's). An ideal thermal radiator produces visible light most efficiently at temperatures around 6300 °C (6600 K or 11,500

°F). Even at this high temperature, a lot of the radiation is either infrared or ultraviolet, and the theoretical luminous efficiency is 95 lumens per watt." No known material can be used as a filament at this ideal temperature, which is hotter than the sun's surface.

Type	Overall luminous efficiency	Overall luminous efficacy (lm/W)
40 W tungsten incandescent	1.9%	12.6
60 W tungsten incandescent	2.1%	14.5
100 W tungsten incandescent	2.6%	17.5
glass halogen	2.3%	16
quartz halogen	3.5%	24
high-temperature incandescent	5.1%	35
ideal black-body radiator at 4000 K	7.0%	47.5
ideal black-body radiator at 7000 K	14%	95
ideal white light source	35.5%	242.5
ideal monochromatic 555 nm source	100%	683

See the following for more info:
http://en.wikipedia.org/wiki/Light_bulb

In September 2003 a new type of blue LED was demonstrated by the company Cree, Inc.. This produced a commercially packaged white light having 65 lumens per watt (26% efficiency) at 20 mA, becoming the brightest white LED commercially available at the time. In 2006 they have demonstrated a prototype with a record white LED efficiency of 131 lumens per watt (54% efficiency) at 20 mA.
Compared to 100 watt tungsten light at 17.5 lumens per watt the LED is between 3.7 and 7.5 times more energy efficient at producing white light.