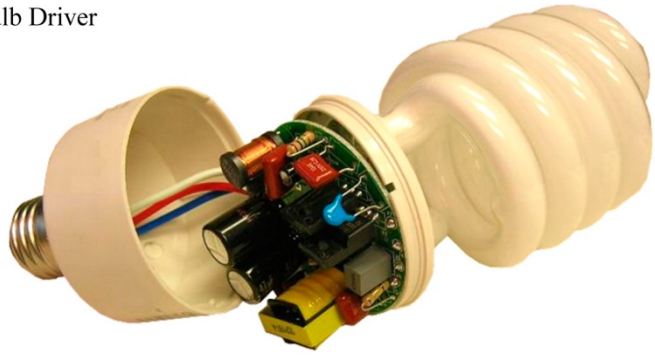
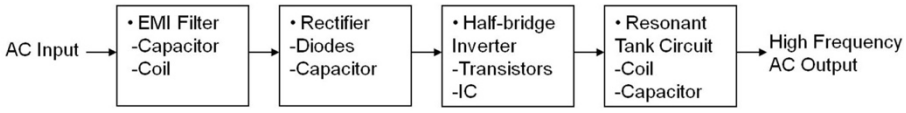
During our MTH105 class on Monday, 18th April 2016, the issue of harmful substances in CFL and LED bulbs was briefly discussed. I thought it would be fun to attempt to understand the actual levels of Mercury Vapor (HgO) contained in a CFL or LED bud and then attempt to figure out how many light bulbs it would take to effectively kill an average human.

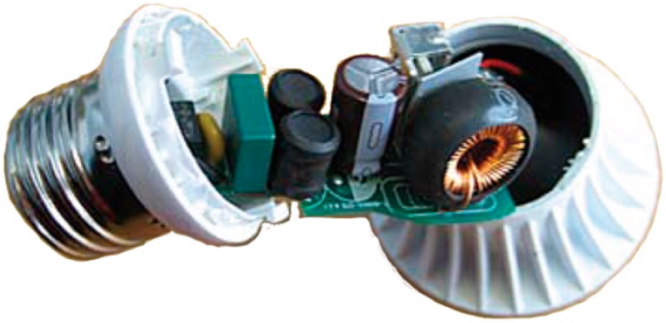
We should start with the inner workings of the bulbs.

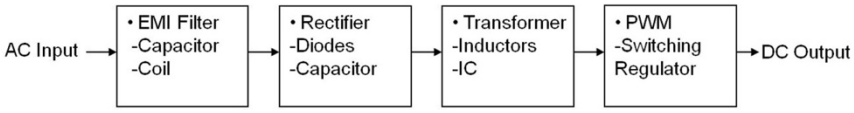
(a) CFL Bulb Driver





(b) LED Bulb Driver





[1]

I have chosen to focus on the CFL bulbs because, as you can see, the CFL is less is far less ballasted than the LED making it more of a concern for breakage and release of harmful substances. The amounts of HgO in each are comparable.

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[1] Lim, S.-R., Kang, D., Ogunseitan, O. A., & Schoenung, J. M. (2013). Potential Environmental Impacts from the Metals in Incandescent, Compact Fluorescent Lamp (CFL), and Light-Emitting Diode (LED) Bulbs. *Environmental Science & Technology*, *47*(2), 1040–1047. http://doi.org/10.1021/es302886m

Let us begin.

Based on the data collected from various sources, we find the below values:

1. Average American male: 195.5[2]
2. Average American female: 166.2[3]
3. Acute toxicity[4]
    - LD50 Oral - Rat - 18 mg/kg
    - LD50 Dermal - Rat - 315 mg/kg
4. ≈5mg per CFL based on the mercury-reduction goal set by the National Electric Manufacturers Association of 5 milligrams per CFL for lamps 25 watts or lower.[5]
    - In this particular study the average bulb contained only 2.5mg

By using our beloved dimensional analysis, we simply convert pounds to kilograms and multiply by the LD50. We then divide by the maximum milligrams of HgO per CFL permitted by law and we see:

$$Male - oral = \frac{18mg}{1kg} \times \frac{0.4545kg}{1lb} \times \frac{195.5lbs}{} = 1599.3855 \approx 1600mg$$
$$\rightarrow \frac{\approx 1600mg}{\approx 5mg\ per\ CFL\ bulb} \approx 320\ CFL\ bulbs$$

$$Male - dermal = \frac{315mg}{1kg} \times \frac{0.4545kg}{1lb} \times \frac{195.5lbs}{} = 27989.246 \approx 28000mg$$
$$\rightarrow \frac{\approx 28000mg}{\approx 5mg\ per\ CFL} \approx 5600\ CFL\ bulbs$$

[2] FastStats. (n.d.). Retrieved April 20, 2016, from http://www.cdc.gov/nchs/fastats/body-measurements.htm

[3] FastStats. (n.d.). Retrieved April 20, 2016, from http://www.cdc.gov/nchs/fastats/body-measurements.htm

[4] MSDS - 213357. (n.d.). Retrieved April 18, 2016, from http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=US&language=en&productNumber=213357&brand=SIAL&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fproduct%2Fsial%2F213357%3Flang%3Den

[5] Li, Y., & Jin, L. (2011). Environmental Release of Mercury from Broken Compact Fluorescent Lamps. *Environmental Engineering Science*, *28*(10), 687–691. http://doi.org/10.1089/ees.2011.0027

$$Female - oral = \frac{18mg}{1kg} \times \frac{0.4545kg}{1lb} \times \frac{166.2lbs}{} = 1359.6822 \approx 1360mg$$
$$\rightarrow \frac{\approx 1360mg}{\approx 5mg\ per\ CFL} \approx 272\ CFL\ bulbs$$

$$Female - dermal = \frac{315mg}{1kg} \times \frac{0.4545kg}{1lb} \times \frac{166.2lbs}{} = 23794mg \approx 24000mg$$
$$\rightarrow \frac{\approx 24000mg}{\approx 5mg\ per\ CFL} \approx 4800\ CFL\ bulbs$$

Unfortunately, the above numbers are actually TOO high!

Based on the research conducted, most of the HgO is absorbed by the phosphorus coating on the glass of the bulb. In one study conducted in 2008, a 9W bulb containing 5mg of HgO released only 1.9% or 113μg (μg is a microgram and only 1×10^{-6} grams) of its total HgO upon shattering.[6] This is representative of most research conducted.

So, what would that look like?

$$Male - oral = \frac{18mg}{1kg} \times \frac{0.4545kg}{1lb} \times \frac{195.5lbs}{} = 1599.3855 \approx 1600mg$$
$$\rightarrow \frac{\approx 1600mg}{\approx 0.000113mg\ per\ CFL\ bulb} \approx 14{,}159{,}292\ CFL\ bulbs$$

$$Female - oral = \frac{18mg}{1kg} \times \frac{0.4545kg}{1lb} \times \frac{166.2lbs}{} = 1359.6822 \approx 1360mg$$
$$\rightarrow \frac{\approx 1360mg}{\approx 0.000113mg\ per\ CFL\ bulb} \approx 12{,}035{,}398\ CFL\ bulbs$$

Let's shift gears from light bulbs to food.

A 6oz serving of tuna exposes a person to $\approx 48\mu g$ of HgO while a typical CFL breakage results in an exposure of $\approx 0.07\mu g$ of HgO.

With an LD50 of 18mg per kg of body mass, how much tuna is required to kill an American male?

Lets suppose that the mercury in these bulbs is Dimethyl Mercury ($(CH_3)_2Hg$). The LD50 of $(CH_3)_2Hg$ is $\approx 50\mu g/kg$. How many bulbs containing 5mg of $(CH_3)_2Hg$ would one need to break to have a leathal exposure?

Enjoy!

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[6] https://www.health.govt.nz/system/files/documents/publications/screening-report-of-hg-and-cfl-may09.pdf

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