Canadian Nuclear Society

Compact Fluorescent Lamps Fact Sheet – Radioactive, or Not?

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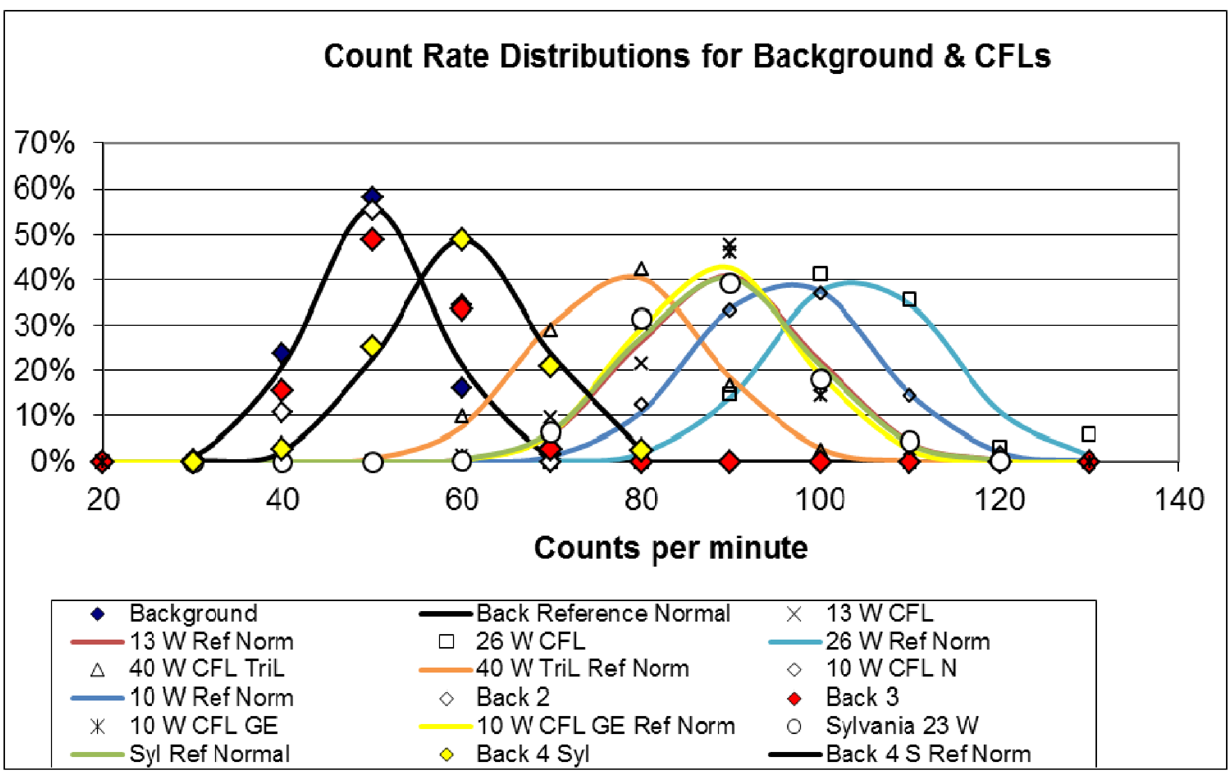
$^{85}_{36}$Kr or $^{147}_{61}$Pm?

From an academic perspective all natural and man-made materials can be considered to include some naturally occurring radioactive materials (radionuclides), and possibly other radionuclides arising from the historical atmospheric testing of nuclear weapons. In practical terms the presence of these radionuclides cannot be detected outside of specially-equipped laboratories – with a few notable exceptions. One such exception is some (but not all) Compact Fluorescent Lamps (CFLs).

CFLs provide a more energy efficient alternative to incandescent lamps for some applications. When CFLs were first introduced most used a magnetic ballast and a glow-switch starter to provide a rapid turn-on characteristic as described in a National Electrical Manufacturers Association (NEMA) standard [1]. Others used electronic ballast circuits. Presently, electronic ballast circuits prevail. Electronic ballasts provide lower cost, higher efficiency and faster starting. The ballast pre-heats the electrodes, generates a high voltage transient to initiate the ionisation of the gas (mercury vapour) at turn-on, and limits the discharge current when the lamp is operating. An older CFL with a magnetic ballast (bottom-left in photograph) purchased in 2001 has a larger diameter base and is heavier.

When monitoring CFLs such as those shown with an Aware Electronics RM-80 Geiger, <u>ALL were found to be radioactive above background</u>. The highest count rates were found when the detector was placed under the glass tubes rather than under the base or ballast / electronics housing.



Histograms of the count data (count frequency distributions) are shown in the figure above with normal distributions that have the same mean and standard deviation as the count data to guide the eye. The mean count rate with the CFLs ranges from about 50% to 100% higher than that for the background obtained prior to / between monitoring the CFLs. The data series names include "W" for watt, "N" for NOMA...

The NEMA standard [1] states "The fluorescent tube does not contain any radioactive element."

Three CFLs tested were found to have <u>no apparent excess radioactivity</u> relative to background.
These three have <u>much slower turn-on characteristics</u> than the active lamps**.**

NOMA UV lamp

Blue Planet "bulb"

GE 20 W "bulb"

The bulb-type lamps are safer for installation in recessed fixtures than the exposed tube types. The manufacturers' instructions recommend <u>handling CFLs with exposed tubes only by the base housing</u>.

Glow-switch starters use a radionuclide to accelerate the ionization of the gas spark gap in a sealed enclosure. The man-made and natural radionuclides used include [1]:

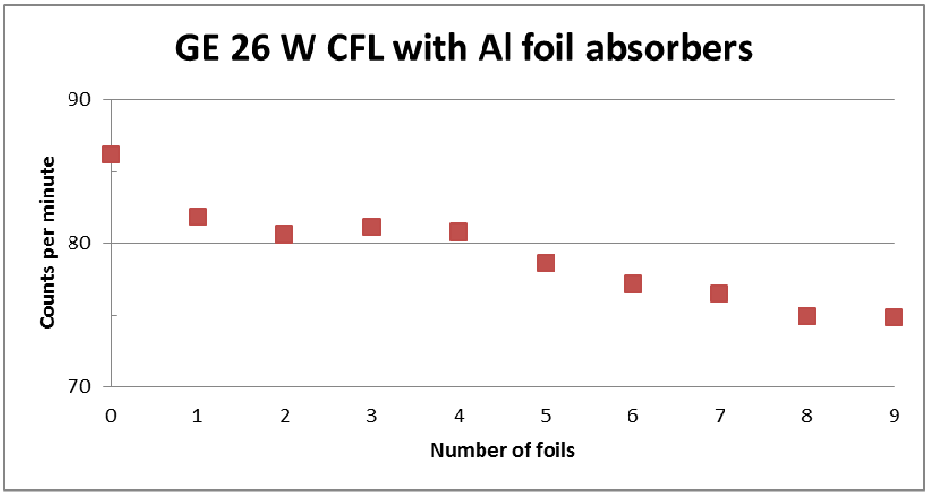
Radionuclide	$^{mass}_{no}$Symbol	**Decay mode**	**Energy**	**Half-life [y]**
Tritium	$^{3}_{1}H$	β^-	18.61 keV	12.26
Krypton-85	$^{85}_{36}Kr$	β^-	687 keV	10.756
Promethium-147	$^{147}_{61}Pm$	β^-	225 keV	2.5
Thorium (natural)	$^{232}_{90}Th$	α	4 MeV	1.41×10^{10}

Since our monitoring shows that the activity <u>appears</u> to be within the glass tube, krypton-85 (a gas) seems to be the most likely radionuclide of those listed above. If tritium had been used it would be very unlikely to have detected radiation from outside the glass as the beta energy is very low and there is no gamma radiation associated with the majority of tritium decay events.

An attempt to acquire a gamma spectrum from one of the CFLs shown to be radioactive was unsuccessful. This suggests <u>that primarily beta radiation</u> is being detected by the Geiger and that any gamma radiation present was not detectable relative to background.

A set of four measurements taken at incremental 90° angles with rotation about the longitudinal axis for one CFL shows that the ionising radiation appears to be uniform.

A set of measurements taken at one angle with incremental numbers of aluminum foil shields between the lamp and the Geiger detector indicate that there is some low energy beta radiation stopped by a single aluminum foil, but beta having penetrated the glass will penetrate up to nine foils. Moreover, the data indicate that some of the beta radiation has sufficient energy to scatter additional electrons from the first few foils.



Websites indicate that the glow-switch is a sealed device at one of the electrodes within the tube. This arrangement does not <u>seem</u> to be consistent with the spatial uniformity of the observations.

The Sylvania website FAQ0009-0800 describes Sylvania DULUX compact fluorescent lamps with 2-pin bases as containing starter switches with 0.01 µCi (370 Bq) of krypton-85 [2]. This lamp was not tested.

The Philips Material Safety Data Sheet for the PLC 22W 15mm and PLC 28W 15 mm compact fluorescent lamps identify that they contain "less than 330 nCi (12.2 kBq) of Pm-147 (within a sealed glow switch)." [3] The Health Physics Society Fact Sheet on Consumer Products Containing Radioactive Materials describes CFLs as having "less than 1 µCi (37 kBq) of Pm-147 in a sealed starter (or glow) switch." [4]

An informal reference on the internet suggests that the phosphors are radioactive. A US regulatory document [5] observes in a discussion of ophthalmic glass lenses that some rare earth compounds may include small amounts of radium or thorium. This may be applicable to those used in phosphors as well. The failure to obtain a gamma spectrum suggests that neither these nor potassium (^{40}K) are contributing significantly to the radiation observed.

A typical glow starter contains < 1 kBq of ^{85}Kr, much less than the 37 GBq [6] or 100 GBq [7] maximum allowed as an exempt quantity for licensing requirements. It is not possible to confirm that the CFLs tested have a similar quantity of ^{85}Kr, or a larger or smaller amount, without additional information or more sophisticated measurements.

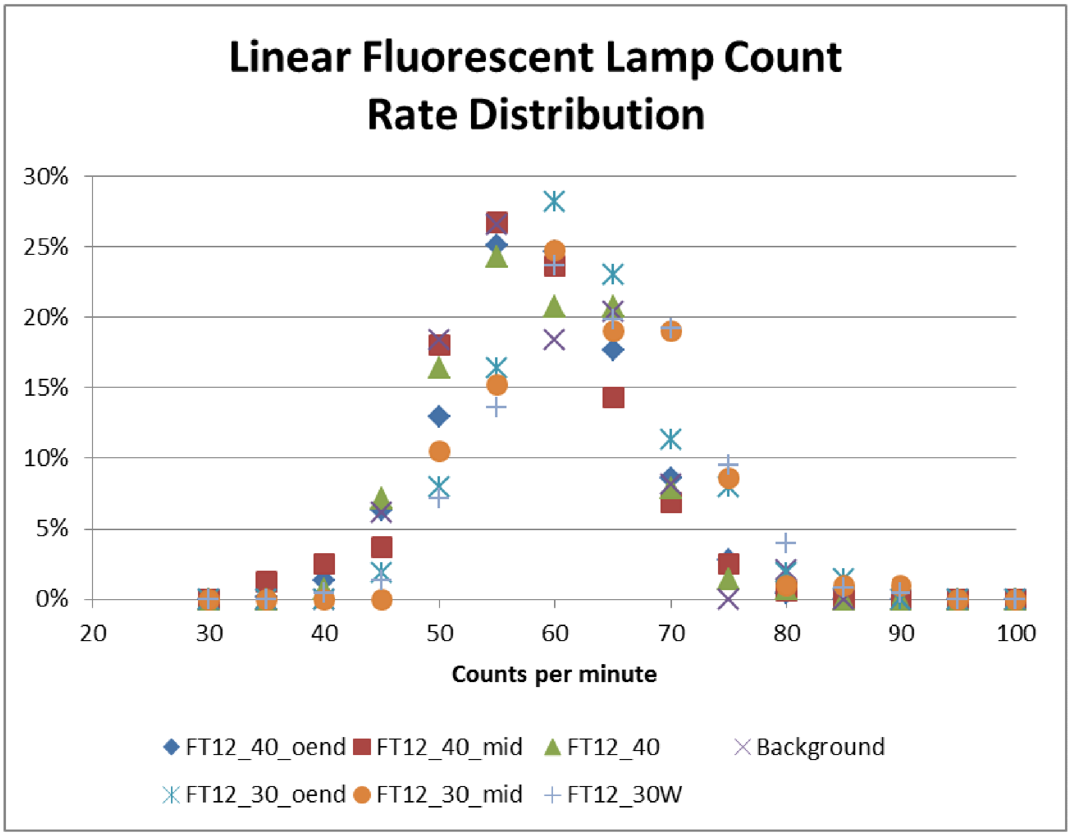
^{85}Kr is produced by fission of ^{235}U in reactor fuel. The Interactive Chart of the Nuclides [8] data shows that ^{85}Kr decays to ^{85}Rb (rubidium), which is stable. The beta decay energies are listed below and the mean beta energy is 250.7 keV. Similarly ^{147}Pm decays to ^{147}Sm (samarium) which is also stable.

$$^{85}_{36}\mathrm{Kr} \xrightarrow[100\%]{} {}^{85}_{37}\mathrm{Rb} + \beta^- + \gamma \qquad \Delta E = 0.687\ \mathrm{MeV}$$

Probability	β^- energy	γ energy & probability
99.563%	251.6 keV	
0.434%	47.7 keV	514 keV 0.434%
		362.8 keV 2.2 x10^{-6}%
		151.2 keV 2.2 x 10^{-6}%
2.4 x 10^{-7}%	124.03 keV	129.8 keV 2.2 x 10-7%
		151.2 keV (included above)

$$^{147}_{61}\mathrm{Pm} \xrightarrow[100\%]{} {}^{147}_{62}\mathrm{Sm} + \beta^- + \gamma \qquad \Delta E = 0.224.6\ \mathrm{MeV}$$

Probability	β^- energy	γ energy & probability
99.99%	61.93 keV	
0.006%	27.07 keV	121.2 keV 0.006%
4.7 x 10^{-7}%	7.08 keV	76.1 keV 2.2 x 10^{-7}%
		197.3 keV 4.7 x 10^{-7}%



Tests were conducted with conventional "straight" fluorescent tubes, a FT12-30W and a FT12-40W tube at both ends and the near the middle of the tube. The data are indistinguishable from background.

The CFLs tested present no radiological hazard to the consumer. The count rates with the Geiger close to the lamp tubes are similar to those obtained when monitoring the low energy gamma emitted by an ionisation smoke detector (see CNS Smoke Detector ^{241}Am Fact Sheet). The beta radiation has limited range in air and is not highly penetrating. At any reasonable distance the ionising radiation is not detectable above background.

Given that radionuclides are introduced into CFLs to provide a performance attribute of value to consumers, it is curious that they do not bear a "best before date". The decay of the radionuclides is both predictable and independent of the usage pattern for the lamp. Consumers may experience changes in CFL performance characteristics over periods in excess of the manufacturer's estimated lifetime even for lamps that are used infrequently. An "old-stock" CFL that includes ^{147}Pm may not offer good value, for example.

References:

1. Radioactive Substances in Compact Fluorescent Lamps, National Electrical Manufacturers Association LSD 15-1993 (R-2001), http://www.nema.org/stds/lsd15.cfm
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8. Interactive Chart of the Nuclides, http://www.nndc.bnl.gov/chart/