When to Replace Your LED Bulbs?

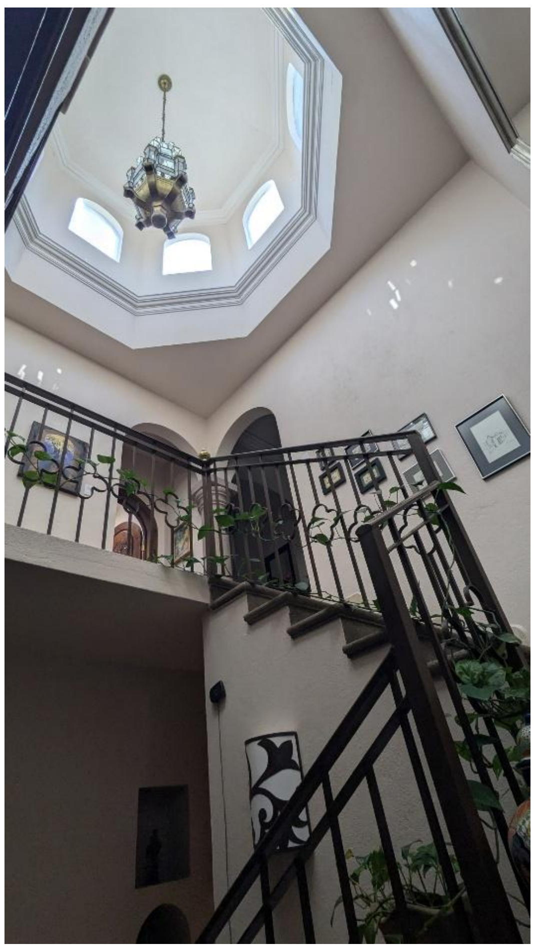
David Cunningham - December 2025

With incandescent bulbs, this was never an issue. You replaced them when they burned out.
With LEDs, they rarely burn out – they just get dimmer. The advertising claims a life of around 15 years, but the fine print tells you that the "life" of the LED is defined as when the light output has decreased to 70% of its original value and that the 15 years is based on 3 hours per day usage. So who keeps track of all that? And I defy you to look at a light bulb and tell whether its output is 230 or 330 lumens.

This all came into focus for me recently when I realized that I was having trouble seeing the steps leading down to the lower floor of our house. They are illuminated by a chandelier hanging from the top of a cupola directly above the stairwell. The chandelier is all but impossible to reach to change the LED bulbs which were installed 8½ years ago. At that time, only "40 Watt equivalent" bulbs were available in the B11 size I wanted. These output 330 lumens at a color temperature of 2700º K (normal). Today, both 500 lumen and 800 lumen bulbs are readily available, so I ordered a dozen of the 800 lumen bulbs. While on Amazon, I noticed that some very nice digital light meters were available in the $20 to $30 range, so I ordered one of these also.

Light Meter


View looking down the stairway (during the day)


View looking up the stairway with the chandelier visible at the top

I measured the light at the top of the stairs, both the landings and at the bottom step. There is a sconce light fixture on the wall near the bottom of the stairway, but it does not illuminate the upper steps or the landings. The new bulbs were installed and the measurements repeated. I also checked the illumination during the day. This data is shown below.

Location	Original LEDs 6@330 lm	New LEDs 6@800 lm	Daylight Illumination
Top Step	1.5 lux	14.3 lux	342 lux
1st Landing	1.35 lux	11.2 lux	252 lux
2nd Landing	1.7 lux	8.6 lux	195 lux
Bottom Step	4.5 lux	8.0 lux	117 lux

Changing the bulbs is not a simple matter. To reach the chandelier requires placing 3 planks across the top of the upper railings to form a platform. Then two step ladders are used – one to reach the platform and the other on top of the platform to reach the light fixture.

Platform for changing light bulbs

It seemed very strange to me that there had been such a change in the light output of the LEDs – nearly a factor of 10. The newer LEDs were brighter by a factor of 800/330 = 2.4, but the data shows a much greater difference. I estimate this light is turned on an average of 3 to 6 hours per day, so why had the LEDs decreased so much in 8½ years? More investigation was called for.

LED Ratings

LED light bulbs are rated for luminous output, color temperature, base and bulb type. Luminous output, measured in lumens, is the total visible light power in all directions. Since most people are not familiar with lumens, manufacturers advertise their bulbs as being equivalent to some number of watts incandescent. A rough rule of thumb is that the actual power used by an LED is 1/10th that of the incandescent equivalent bulb and the lumens produced is 10 times the incandescent equivalent power. For example, a 40 watt equivalent LED may require only 3.5 watts but might produce 330 lumens.

The human eye perceives light having a wavelength between 450 and 650 nanometers (nm) with the most sensitivity at 550 (green). An incandescent bulb produces light with a maximum spectral output (color) determined by the temperature of its filament. It can vary from a dull red with a low input power and temperature to a bright white at a high power input and temperature. LEDs radiate energy differently but are rated by correlating their apparent color to that of an incandescent bulb producing the same color. The most common color temperatures are 2700 or 3000º Kelvin (K) which are considered soft or warm white respectively. These colors are used in most household lamps. For tasks such as clothing selection or cooking, a daylight white color temperature of 5000 or 6500º K might be used. And for a relaxing light similar to that of a candle flame, a color temperature of 2400º K is common.

The base used on an LED is determined by the socket and the most common is the Edison screw-in socket E26. The 26 refers to the diameter in mm. Sometimes a bulb is marked E27. This is slightly larger, but it is compatible with an E26 socket. Smaller Edison bulbs are the E12 and E14, sometimes called candelabras. These are not interchangeable, so check the package marking carefully to be sure you get the right one. The small spotlight bulbs come with two bases – GU5.3 and GU10. GU5.3 uses two small pins, and GU10 has two heavier pins which have studs on the bottoms so they can be installed with a twist lock. In the US, GU5.3 is always used with low voltage (12 volt) lamps while GU10 is for standard 120 VAC use. However in Mexico, the 120 volt lights are sold with either of these bases. If you have a 120 VAC fixture with GU5.3 socket, consider rewiring or replacing it for one with a GU10 socket to avoid blowing out a 12 V GU5.3 bulb.

The transparent portion of the bulb comes in many shapes, but the most common sizes are Axx, Bxx, CAxx and MRxx where xx is the maximum diameter in 8ths of an inch. So the standard A19 pear shaped bulb used in fixtures having shades, ceiling fans, etc. is 19/8 = 2-3/8 inches in diameter. The torpedo shaped bulbs used in chandeliers and decorative fixtures are most commonly B10 or B11 sizes. B11 has a diameter of 11/8 = 1-3/8 inch. The most decorative bulb is the CA series which is similar to the B type but has a bent or flame tip. This bulb is designed to be visible and normally is paired with the lower 2400º K filament.

Measuring Lux to get Lumens

As mentioned above, the total visible output power of a bulb is measured in Lumens, but light meters measure the light density in units of Luxes. One Lux is One Lumen per square meter. So if the bulb radiated equally in all directions, a lux measurement could be converted to a lumen by multiplying it by the area of a sphere having a radius equal to the distance between the light bulb and the meter. Since the area of a sphere is $A = \frac{\pi r^2}{4}$ we could solve this equation for r to get an area of 1 square meter. The radius is 0.282 meters or 11.1 inches – a convenient measuring distance. At this distance, the light meter reading in lux would equal the total output in lumens *if the bulb radiated equally in all directions*. Since it doesn't, we need to determine a correction or calibration factor for the bulb.

I built a simple test fixture to power each LED separately. It consists of a socket and a support to position the light meter at a distance of 0.282 meters from the bulb.

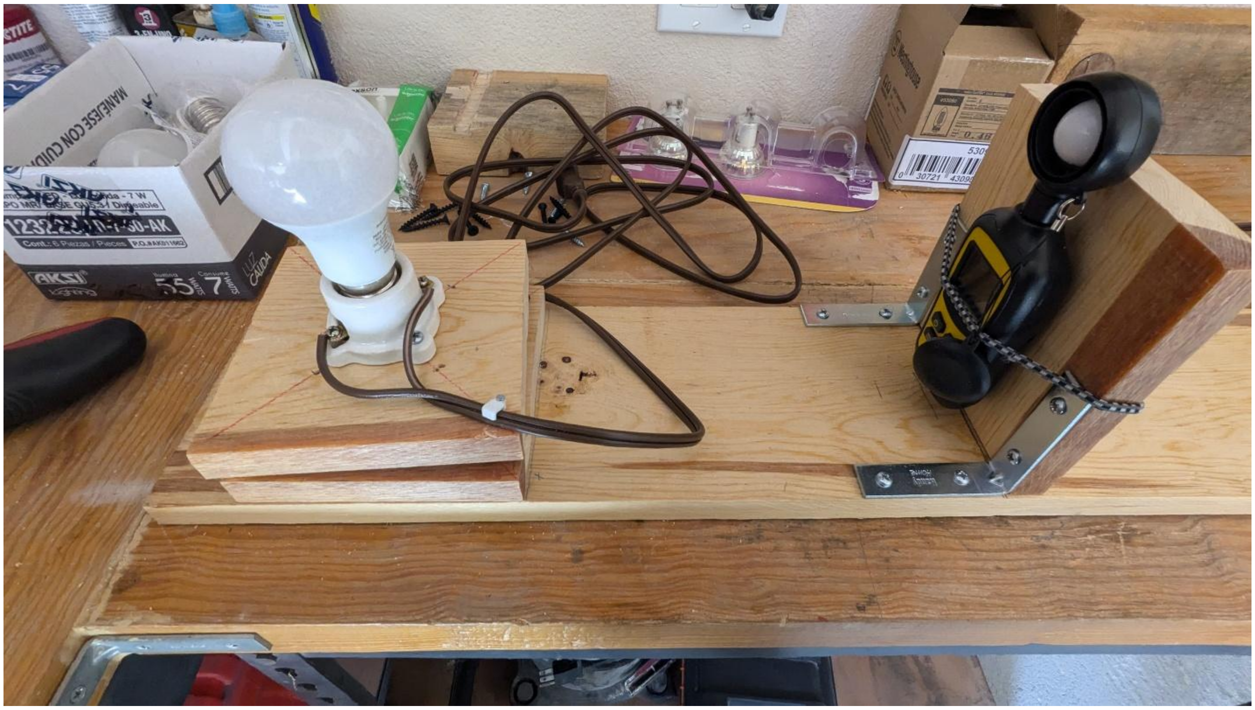
Low Cost Direct Measurement Test Fixture

The trick is to calibrate the fixture using a known source. In my case, I used the six new 800 lumen bulbs as my reference sources. I rotated the socket while keeping the distance constant and recorded the minimum and maximum intensity for each bulb. I then calculated the average intensity, then divided that into 800 lumens to get a calibration factor relating the energy in lumens to the measured intensity in lux. It turned out to be nearly a constant of 0.71 lumens per lux for all 6 bulbs. This calibration factor was then be used for all further measurements of the same geometry bulb (B11).

New Bulb No.	Max Lux	Min Lux	Avg Lux	A = 800/Avg Lux
1	1400	890	1145.0	0.70
2	1565	680	1122.5	0.71
3	1565	770	1167.5	0.69
4	1516	750	1133.0	0.71

5	1500	755	1127.5	0.71
6	1480	745	1112.5	0.72

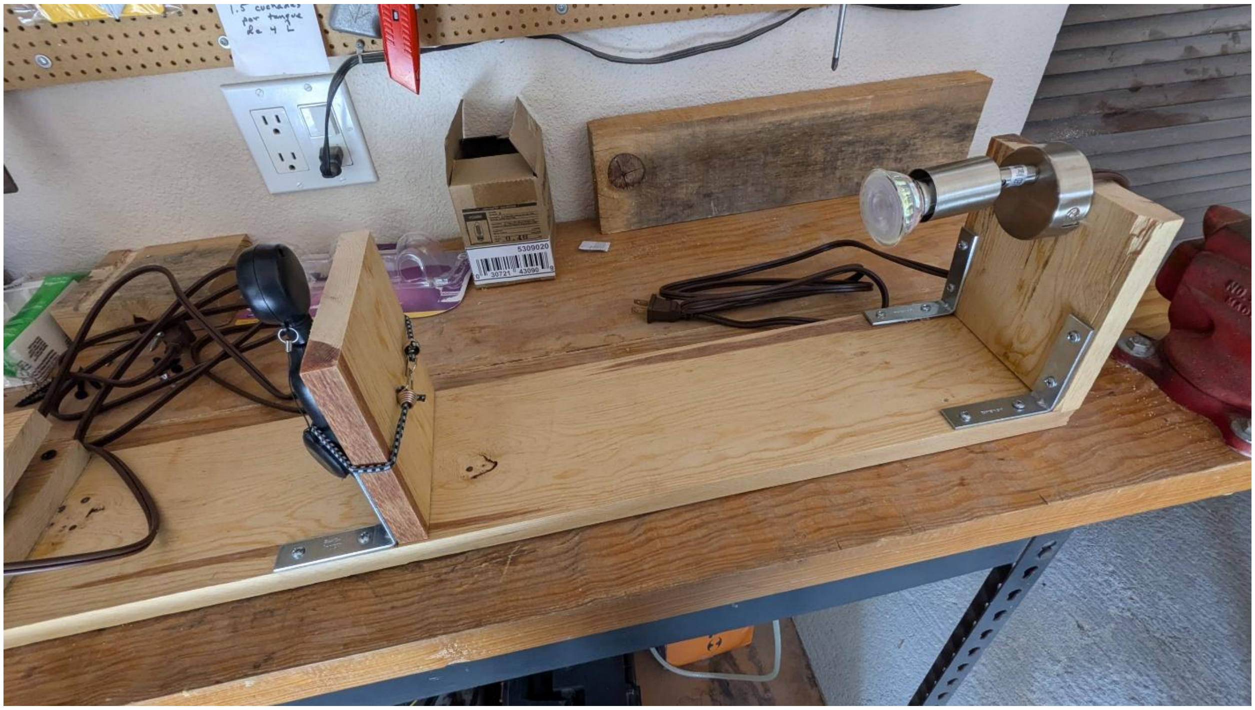
This seemed to produce fairly reasonable and consistent results, but the “fixture” was difficult to use. So I constructed another one that held the distance between the bulb and light meter constant while permitting easy rotation of the bulb on a small turnstile type bearing. The light meter is held to a vertical board with a bungee strap that allows it to be adjusted vertically.



Improved Direct Measurement Test Fixture (E26 Side)

To test the spotlight MR16 bulbs, the fixture contains a GU10 socket mounted to the right side of the meter holding piece. (The meter of course must be moved to face the bulb when used in this mode).

I retested the new 800 lumen bulbs with this fixture and found that calibration factor was fairly consistent at 0.71 square meters using the same method as described above. However, the calibration for the MR16 bulbs is entirely different as you might expect since they are designed NOT to radiate in all directions. The calibration for a new MR16 averaged 0.049 square meters.



Improved Direct Measurement Test Fixture (GU10 Side)

I then tested the 6 old bulbs removed from the staircase chandelier as well as 17 others used elsewhere in the house. All of these bulbs were of the same size, shape, color temperature, manufacturer, age, etc. However some are used much less often than the stairway lights.

The results for the stairway LEDs are shown below:

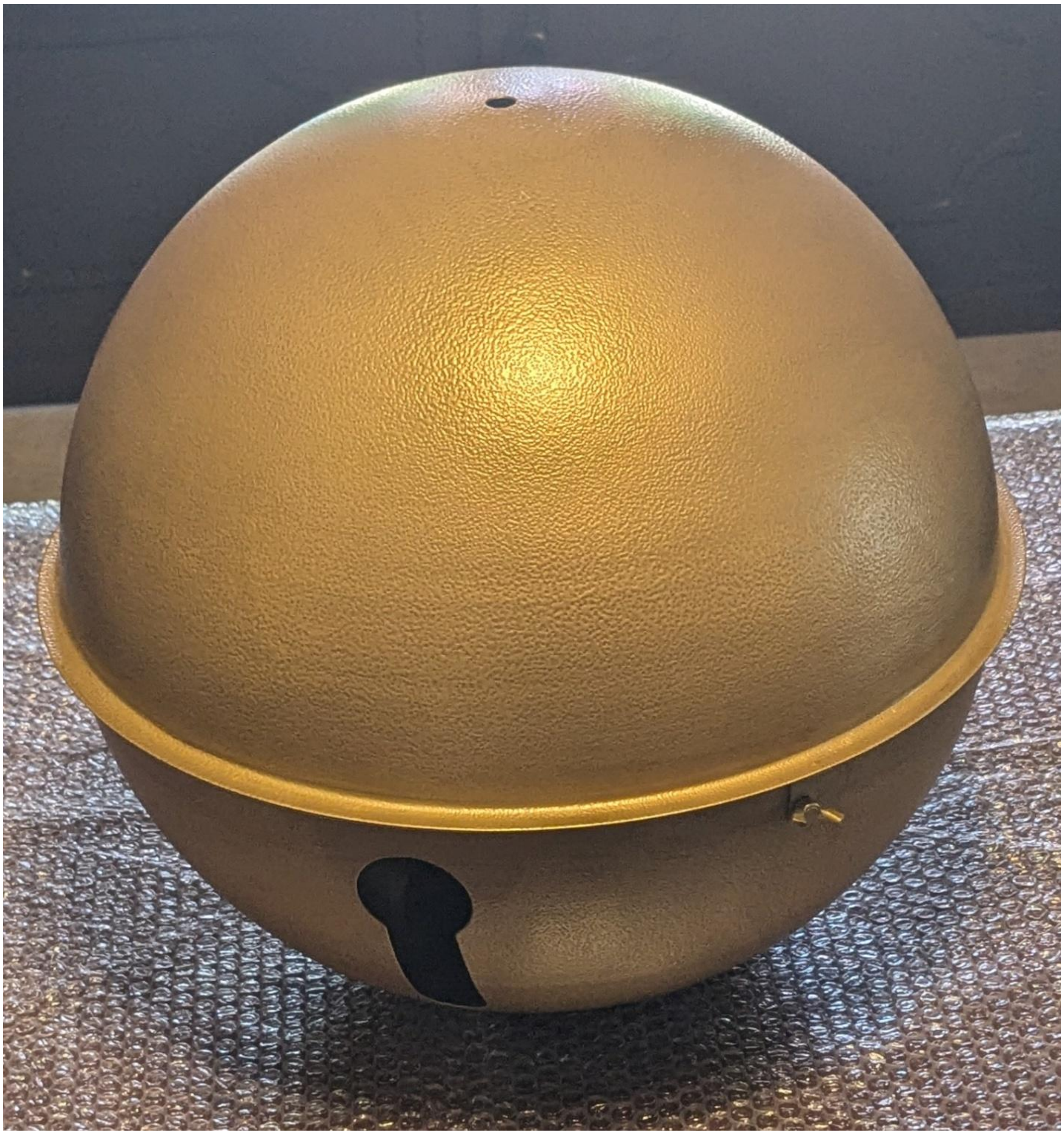
Old Bulb No.	Max lux	Min lux	Avg lux	Lumens
1	73	20	46.5	73
2	55	23	39.0	55
3	550	520	535.0	550
4	51	46	48.5	51
5	43	41	42.0	43
6	30	25	27.5	30

Bulb #3 acts like a new bulb. Apparently, it was never fully screwed into its socket and therefore never aged like the others. The degradation of the other lights is huge – their light output is about 10 to 20% of original (330 Lumens)!

I then tested the other 17 LEDs. The results are that all but 2 of them had outputs between 317 and 450 lumens. The other two had outputs of 37 and 18 lumens respectively. But NEITHER of these bulbs were obviously degraded when viewed in their fixtures which contained other bulbs.

This fixture was an improvement over the previous kludge, but was still inconvenient to use as it required a fairly dark room. What I really needed was an Integrating or Ulbricht Sphere.

This is the device that scientists and manufacturers use to measure light. It consists of a “large” sphere with a special coating that reflects light in all directions. Two ports (openings) are provided for the source (light bulb) and the sensor (light meter). New ones cost $10,000 and up while used ones are still expensive ($2,000+). And finding a large sphere to make my own was a problem until I happened to pass the Christmas decorations at Home Depot. There you could buy a set of two steel ornaments one of which was 13 inch in diameter and the other 18 inches in diameter. The 18 inch size was almost perfect.



Sphere Before Modification

The only problem with these spheres is that the lower hemisphere had four decorative key shaped slots cut into its sides. I covered these using 2 inch wide aluminum tape commonly used to join exhaust ducting. The tape went on both inside and outside over the slots.

Ulbricht Sphere in Operation

The source port is a hole 3 inches in diameter that allows the upper portion of an E26 porcelain light socket to fit into the sphere. To test E12 or GU10 base bulbs, adapters were used. The sensing port is a hole 1-5/8 inch diameter that exactly fits the sensing window of a slightly different light meter that has a remote sensor head.

E26 Socket with Adapters (left), Remote Readout Light Meter (right)

All machining is done in the upper hemisphere. The port holes are 90 degrees apart with the smaller one cut a few inches above the equator to allow room for one of the two eye hooks that hold the light sensor in place using a bungee cord.

It is important to install a shield or baffle that keeps the light sensor from seeing the light bulb directly. For this, I used a 3x6x1/8 inch Aluminum rectangle supported on three small angle brackets. The actual position of the shield is on the line connecting the port holes, but its position along this line was the subject of much debate between me and the GROK AI. At various times it recommended 30 deg (from the source), then 70, then 20, and finally 45 degrees. My initial installation was at 70, but when the calibration turned out to be not as expected, I moved it to 20 degrees. This made no difference, so I concluded it did not matter that much.

Painting the inside of the sphere, I used a mixture of flat white latex paint and Barium Sulfate. Mixture was 250 G Barium Sulfate powder to 100 G paint. Two coats plus primer (paint only) were applied.

Inside of Ulbricht Sphere

For calibration, I tested 43 new bulbs of all types and got a surprisingly constant value for the ratio of lumens to lux. This tells me the sphere is working correctly in uniformly distributing the light – even that of the MR16 spotlights. The Lumens to Lux ratio was 0.055 square meters

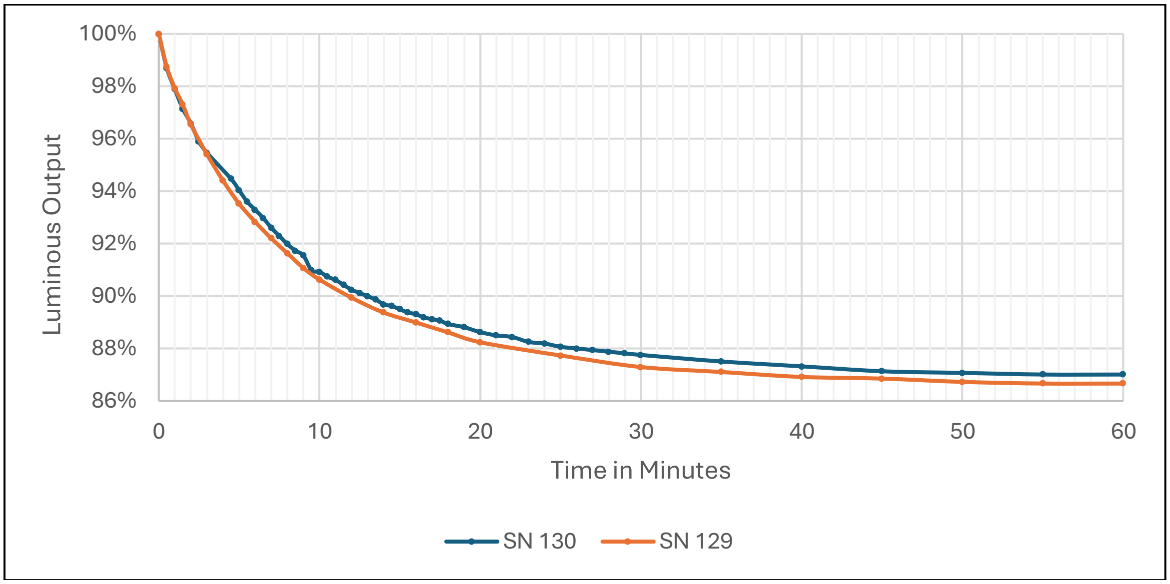
Testing Results

About 30 bulbs were tested using the direct measurement method and the sphere. A summary of the results are shown below. There is generally good agreement between the two methods, but the sphere is much easier to use and gives more consistent results.

Unit Under Test				Specified			Average Lumens Measured	
No Tested	Brand	Base	Glass	Temp	Watts	Lumens	Direct	Sphere
11	Westinghouse	E26	B11	2700	6.5	800	800	676
6	Luminaire	E26	B11	2700	4.0	330	354	360
4	Luminaire	E12	B11	2700	4.0	350	356	328
7	Philips	GU10	MR16	5000	6.0	400	505	550
6	Philips	GU10	MR16	3000	6.0	400	316	364

The sphere was then used to test all the bulbs in the house. This was actually quite easy since only a single calibration factor is required, and the tests can be done in a lighted room.

Each bulb tested (including those used for the calibration) were allowed to run for 60 seconds before the lux readings were taken. This is important for some of the bulbs as the light output generally decreases as the electronics inside the LEDs heat up. One of the worst cases was the Philips A19-6500° K bulbs. These lights continued to dim slowly for an hour! One could argue that the wait time should be 10 or 20 minutes, but that is clearly impractical.



Worst Case Temperature Dependence

Due to the sheer number of LEDs now being tested, old and new, each light was marked with a serial number using a felt pen near the bottom of the glass bulb. Bad bulbs were defined by a lumen output less than 75% of their specified value or if they were physically damaged. The latter category covered the Luminex E12-B11 bulbs which showed separation between the base and glass bulb. Fortunately, the new replacement bulbs (Philips) use a different material for joining the base and glass and are much less likely to separate mechanically.

Unit Under Test				Specified			Measured		Calculated			
S/N	Brand	Base	Glass	Temp	Watts	Lumens	Watts	Lux	Lumens	% of Spec	Lumens/Watt	Location
201	Philips	E26	A19	3000	8.0	800	7.3	14200	788	99%	108	Desk fan
202	Philips	E26	A19	3000	8.0	800	7.3	14060	780	98%	107	Desk fan
203	Philips	E26	A19	3000	8.0	800	7.4	14120	784	98%	106	Desk fan
204	Philips	GU10	MR16	3000	6.0	400	5.2	7580	421	105%	81	Desk wall W
205	Technolite	E26	A15	3000	4.5	420	3.7	7080	393	94%	106	Desk BR Wall
206	Technolite	E26	A15	3000	4.5	420	3.8	6500	361	86%	95	Desk BR Wall
207	Philips	GU10	MR16	3000	6.0	400	5.1	7560	420	105%	82	BR2 Annex
208	Smartlite	E26	A17	3000	7.0	690	6.4	9860	547	79%	86	BR2 Fan
209	Smartlite	E26	A17	3000	7.0	690	6.4	9820	545	79%	85	BR2 Fan
210	Smartlite	E26	A17	3000	7.0	690	6.3	9720	539	78%	86	BR2 Fan
108	IPSA	GU10	MR16	3000	5.0	300	4.4	7980	443	148%	101	BR2 Clo Wall
212	Smartlite	E26	A17	3000	7.0	690	6.5	9550	530	77%	82	BR2 BR Wall
213	Smartlite	E26	A17	3000	7.0	690	6.4	9330	518	75%	81	BR2 BR Wall
214	Smartlite	E26	A17	3000	7.0	690	6.4	9530	529	77%	83	BR2 BR Wall
215	Smartlite	E26	A17	3000	7.0	690	6.3	9560	531	77%	84	BR2 BR Wall
216	Feit	E26	A19	3000	7.5	740	7.4	9580	532	72%	72	Lower Patio Ceil/Fan
217	Feit	E26	A19	3000	7.5	740	7.5	9850	547	74%	73	Lower Patio Ceil/Fan
218	Feit	E26	A19	3000	7.5	740	7.5	10430	579	78%	77	Lower Patio Ceil/Fan
219	Feit	E26	A19	3000	7.5	740	7.4	9700	538	73%	73	Lower Patio Ceil/Fan
120	Philips	GU10	MR16	3000	6.0	400	3.0	6550	364	91%	121	Desk Wall
121	Philips	GU10	MR16	3000	6.0	400	3.0	6740	374	94%	125	Desk Wall
122	Philips	GU10	MR16	3000	6.0	400	3.0	6620	367	92%	122	Desk Wall

Typical results are shown in the above table. The Smartlite and Feit bulbs were subsequently replaced with Philips 3000K 8 watt 800 lumen lights.

Conclusions

An Ulbricht sphere is an accurate and convenient method for measuring the lumen light output of an LED bulb. It can be made in about a day's time using the 18 inch sphere sold at Home Depot as a Christmas decoration at a cost of about $125. The light meter and other electrical fittings add another $50.

There is probably a business opportunity to sell Ulbricht spheres for home use or for use by people offering light bulb replacement services.

The degradation in LED output is so gradual that it is not obvious. Testing all the bulbs in a house is tedious, but necessary if you want to be sure they are producing the lumen output they are rated for. In my case, it took about 12 hours (spread over a couple of weeks) to test about 200 bulbs which included new and replaced bulbs. About 10% of the bulbs tested were below 75% of their rated output, and some of these were below 20% of their rated output.

It would be useful if LED bulbs incorporated a sensor that would signal that it had degraded and should be replaced. For example it could do this by blinking just after turning on. This would be far more useful than some of the other frivolous features provided in current "smart" bulbs.

The simple fact is that there is presently no good way to know when to replace your LED lights if by "good" we mean a simple way to determine when an LED is no longer producing 70% or more of its specified lumen output. Most of the time this is not be a big problem, but losing lighting on a stairway is a safety issue. If nothing else, you should be alert to dimly lit situations and replace the suspect bulbs with new ones of the same or larger lumen output before a dangerous situation can arise. In critical locations, like a stairway, check the illumination of the steps with a light meter annually. (See the table on page 3).

An alternative is to keep track of the replacement date for such lights by recording their replacement date on your digital calendar. For example, if a light is used 3 hours per day, its recommended replacement time is 13 years. But most people move within this time period. However, if a light is used 6 or 12 hours per day, the replacement period is only 7 or 3½ years respectively. That is too long to remember but worth adding to your calendar.