

Total lumens—revisited

With simple math you can gain some perspective on which luminaires really deliver energy savings.



BACK IN THE SUMMER 2007 ISSUE OF *Protocol*, (available on line at <http://www.mikewoodconsulting.com/articles.htm> and <http://plasa.me/summer2007>) I wrote an article about the dangers of judging lights by just looking at the centre beam illuminance, and suggested methods for how you might measure total lumens. I make no apologies for returning to the topic; I'm seeing a lot of very variable quality photometrics at the moment, particularly those published on the spec sheets for LED luminaires. When you are trying to judge if a luminaire is truly efficient or not, it is even more important to be able to separate the elixir from the snake oil. The hope is the draft PLASA standard, E1-41, *Recommendations for Measuring and Reporting Photometric Performance Data for Entertainment Luminaires Utilizing Solid State Light Sources* will help, but not all manufacturers will adopt it.

“... it is even more important to be able to separate the elixir from the snake oil.”

To some extent this article forms a companion piece to “LEDs: The State of Play,” which was published in the July 2011 issues of *Lighting&Sound America*, and *Lighting&Sound International*, sister magazines to *Protocol*. In that article I urged users to confirm that the output lumens, and thus the efficacy, of luminaires are actually what they think they are. If a luminaire claims to be green and energy

efficient, then you need methods to check that this is indeed the case. Sadly, I can assure you that many of the so-called green products on the market today are actually nothing of the kind.

Forget the rhetoric. The truth is in the numbers, but if a manufacturer doesn't give you the full data, what can you do?

There is something you can do if you have at least data about the illuminance at the center of a luminaire's beam and the diameter of the area illuminated, but let's back up and review the earlier article about what total lumens are. To start, take a look at **Figure 1**. This figure illustrates three possible light beam profiles: A is a hypothetical

perfectly flat beam, **B** is a peaky distribution often seen from ellipsoidal luminaires, and **C** has a small dip in the middle and straight(ish) sides that is a rarer distribution but is sometimes seen in fresnel units. Each of the three beam shapes has exactly the same center level reading, as indicated by the red dotted line. This means that a light meter would read the same for each fixture when placed in the center of the beams at points a, b, and c respectively.

That center illuminance (measured in footcandles or lux) doesn't tell us how much light in total is coming out of the unit. To do that, you have to add up the illuminance readings over the whole beam. We can make

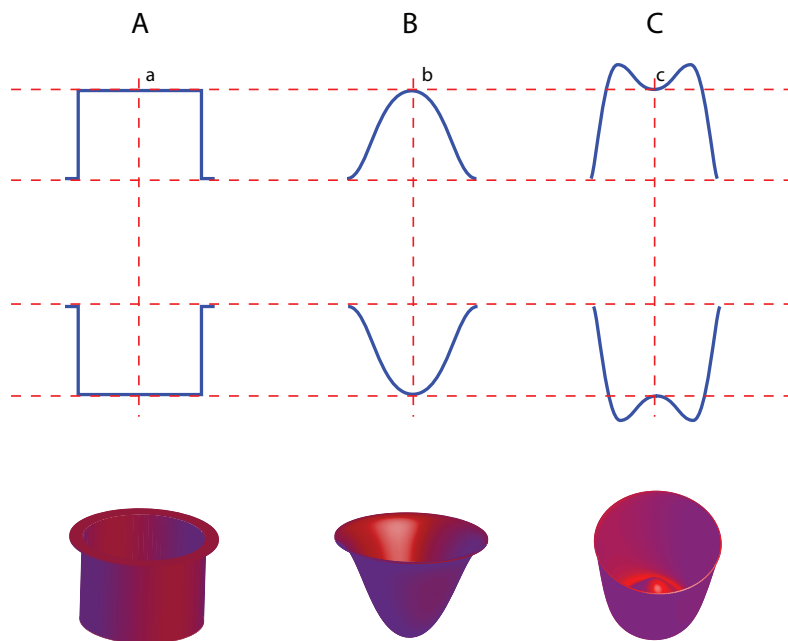


Figure 1 – three possible light beam profiles

a good analogy with buckets and water. The second row of **Figure 1** is the same as the first but with the light profile curves turned upside down to make U shapes. The final row takes that U and rotates it to make a bucket. The flat beam, **A**, gives you a cylindrical, straight sided bucket while the other two give more complex shapes. If we were to fill these imaginary buckets with water then the amount of water each one holds is analogous with the total lumen output of that fixture. It's clear that bucket **A** would hold more water than bucket **B**, for example. Remember lumens are a measure of the total amount of light, not its intensity, so a very wide, shallow bucket might hold the same amount of water as a narrow, deep one. Similarly a very wide dim luminaire might actually output just as many lumens as a narrow bright one—it's just that those lumens are spread out over a wider area.

How can we estimate total lumens if all we have is a spec sheet that tells us the centre illuminance and the field width? This kind of V-diagram spec data is very common; you will often see a diagram looking something like that shown in **Figure 2**. (Note: This technique only works for luminaires with round, symmetrical beams. Not for asymmetric beams such as those from cyc lights.)

The table and diagram show us the field diameter and centre illuminance at a range of throw distances. Note that I have deliberately left the units off this

Throw	1	2	3	4	5
Diameter	3	6	9	12	15
Centre Power	1000	250	111	62	40

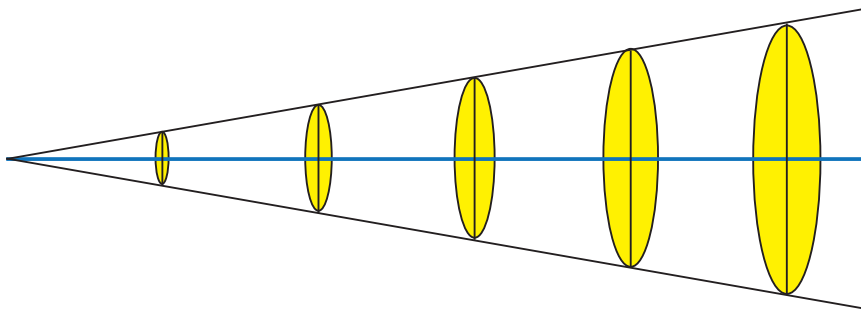


Figure 2 – sample spec sheet of centre illuminance and field diameter

diagram. As long as they are self-consistent, either units of metres and lux, or feet and footcandles, the units will work for the rest of my explanation. That is, if the throw and diameter are in metres, then the illuminance should be in lux, and similarly for feet and footcandles.

We know nothing about the profile of the beam, whether it is peaky or flat, but we can still make some assumptions and get an idea of how many lumens we have. Let's first of all assume that we don't have a distribution like that shown in **Figure 1C**, with a dip in the middle. That's an unusual distribution not often seen with current luminaires, so it's not unreasonable to dismiss it. Now we know that the distribution is either completely flat as shown in **Figure 1A**, or, more likely, has some kind of centre peak and then falls off to the edges, as shown in **Figure 1B**.

Of the two, the completely flat beam has the most lumens thus, if we work out the total lumens for that, we will have an upper limit for the maximum possible total lumens this light could produce.

Figure 3 shows this case in more detail.

Remember that we need the volume of the rotated shape (the water in the bucket) to get the total lumens. With a round cylinder like this the math is simple: the area of the circle is π times the diameter squared, divided by four: $A = \pi \times D^2 / 4$. The total lumens is the centre illuminance times this area or $C \times A$.

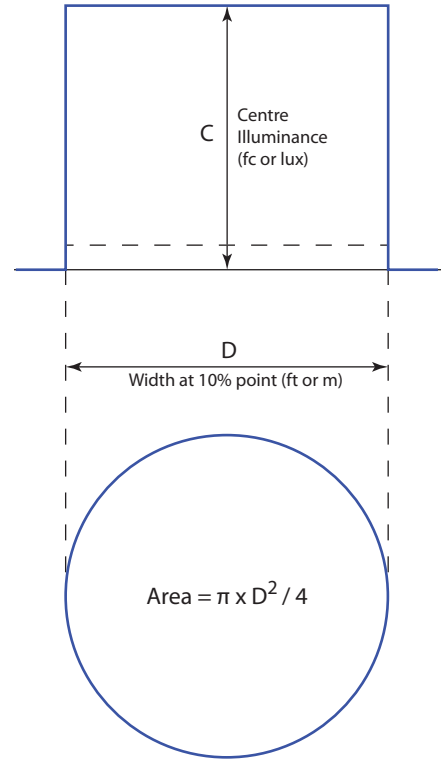


Figure 3 – calculating the rotated shape's volume

If we substitute in some of the values from the table in **Figure 2** we can check this out. Let's use the values for a throw of 1; we have a diameter of 3 and a centre illuminance of 1000.

$$\text{Total lumens} = \pi \times 3^2 \times 1000 / 4 = 7068 \text{ lm}$$

(Note again that it doesn't matter if we are using m and lux, or ft and fc. As long as we don't mix units the answer in lumens will be the same!)

What if we try another throw distance, perhaps the data at 5 feet? Then we substitute 15 for the diameter and 40 for the centre illuminance:

$$\text{Total lumens} = \pi \times 15^2 \times 40 / 4 = 7068 \text{ lm}$$

Total lumens are unaffected by throw distance. If the original V-diagram data is good, it should give the same answer, or close to it, for any throw.

Now we have the absolute maximum value possible for the total lumens of this light: 7,068 lm. In reality, the output beam won't be completely flat, so this figure will be reduced. But by how much? **Figure 4** shows a possible situation.

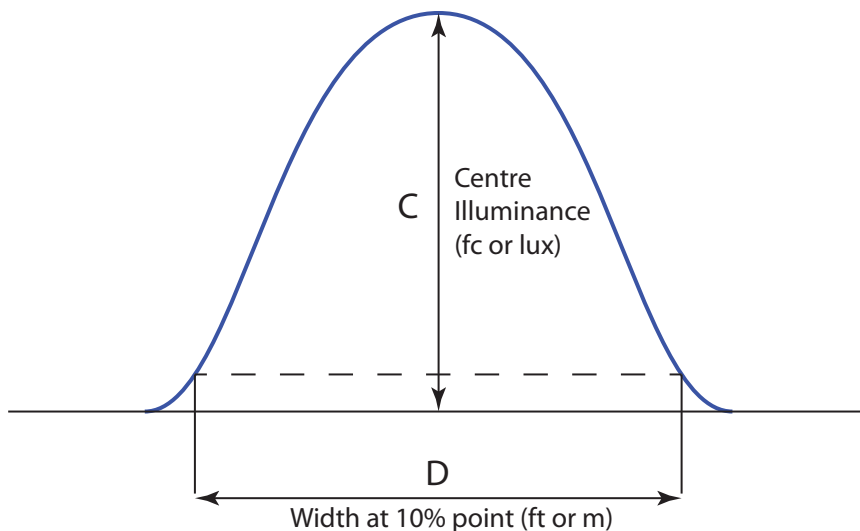


Figure 4 – estimating the centre to edge ratio

We can still get values for C and D, but the total volume in our sloping sided bucket will be less than that of the perfectly straight sided, cylindrical, one.

We can work out some theoretical reductions in the output if we assume the distribution is a true cosine curve. For example, a cosine curve from a profile spot where the edge brightness is one third of the centre brightness (a centre to edge ratio of 3:1) would have a total lumen output of 65% of that of the flat beam. **Table 1** shows a range of values for other centre to edge ratios:

now make an estimate of our total output. We may not know the center to edge ratio, but a good rule of thumb is to use 10:1 for wash lights (10:1 is 10% which is our definition of field lumens), and 3:1 for spots. Depending on how flat the beam is, some will be higher than this, but some may be much lower. In our example case, we might assume that our sample light was a spot, use the 65% scaling, and get a final result of: 7068 x 65% = 4,500 lm.

This may all still look complex, but as we are only looking for a rough answer, we can ruthlessly simplify the math, round

Centre to edge ratio	Output Reduction	Final Multiplier, F
1:1	100%	0.7
2:1	74%	0.6
3:1	65%	0.5
5:1	57%	0.4
10:1	51%	0.3

Table 1

Just to complicate things further, most fixtures are not true cosine curves. Wash lights, in particular, can be peakier, which reduces the output even more from the flat field, perhaps by a further 20%.

However, with all that in mind, we can

our numbers, and end up with the total multipliers shown as the last column in **Table 1**. This gives the following rule-of-thumb equation:

$$\text{Total lumens} = F \times (\text{Field Diameter})^2 \times \text{Centre Illuminance}$$

Where F is the value from **Table 1** based on our estimate of center to edge ratio. If you don't know that, then use F=0.4 as an average. No, it's not precise. Yes, it could be widely out if the luminaire has a really unusual distribution. Yes, the manufacturer may disagree, but they should also give you the full information so you don't need to do this! However, if you don't have the full data, this approximation is going to give you at least a ballpark answer. It's also simple enough that you can often work it out quickly in your head.

Forget the rhetoric. The truth is in the numbers...

Once we have an estimate for total lumens we can get to our true goal of trying to evaluate if a luminaire is energy efficient, and use it to work out the efficacy of our luminaire. If our example luminaire shown in **Figure 2** consumed 300 W from the supply, then we can now estimate that it has an efficacy of 4500/300 = 15 lm/W.

The result isn't an exact answer and by no means is a replacement for full data that includes true measurement of total lumens. However, if nothing else, doing this simple math might give you a feel for how total lumens are affected by the beam profile, and which luminaire really delivers energy savings. ■

Mike Wood runs Mike Wood Consulting LLC which provides consulting support to companies within the entertainment industry on product design, technology strategy, R&D, standards, and Intellectual Property. A 30-year veteran of the entertainment technology industry, Mike is the current chair of the PLASA Governing Body and Treasurer of PLASA North American Regional Board. Mike can be reached at mike@mikewoodconsulting.com.