BY MIKE WOOD

How bright is bright – Coda #1

The Out of the Wood column "How Bright is Bright" series, Parts 1-4, written by Mike Wood ran in the Summer 2006 through Spring 2007 issues of Protocol. *These past insertions can be viewed online at www.mikewoodconsulting.com/articles.htm.*

ALTHOUGH I THOUGHT I HAD FINISHED THE "How Bright is Bright" series of articles in the last issue I had a number of people contact me and ask follow-up questions. These showed that I really needed to revisit a couple of issues and round it out with some practical thoughts as to how to measure lighting in a logical and repeatable manner using just normal tools. A good light meter is essential, but that's about all you need to get started.

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This whole knotty problem of perception versus reality with luminaire brightness started to attract my interest many years ago when I was working for the BBC in London. One of my jobs there was to evaluate new lighting fixtures that were being offered to the BBC for use in Television Studios. It quickly became apparent that what I saw as the brightest, or flattest, or most even unit with my eyes didn't necessarily match what the unforgiving television camera saw. (This was in the early eighties with tube cameras so they were even more unforgiving than CCD based units are now!) Why was that? Why could the camera see changes in color and brightness that I couldn't?

The BBC was a benign and understanding employer in those days so we had the time to take detailed light measurements of the units and began to understand what was going on. We didn't discover anything new or revolutionary; we were just junior engineers learning about the realities of photometrics in a practical way they hadn't taught us at college.

What we had been doing, like many people, was measuring the illuminance of the light in the center of the beam and assuming that everything followed proportionally from this. Well, of course, it doesn't. As we saw in Part 2 of this series different lighting fixtures can have the same center output but appear wildly different. Some are peaky, some are flat, and others may have a hole in the center. The size and shape of the beam is as important to how bright it appears as the actual lux level in the center. You need to know the total output of the fixture as well as the illuminance profile—both are important to understanding the performance.

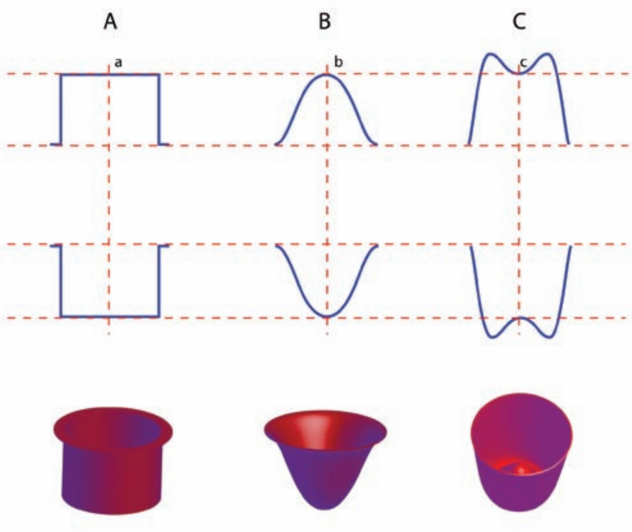

FIGURE 1

The engineering approach to this is to measure the total lumen output of the luminaire but what does *total lumens* mean? Take a look at **Figure 1**—this illustrates three possible light beam profiles; A is a hypothetical perfectly flat beam, B is a peaky distribution often seen from ellipsoidal fixtures and C has a small dip in the middle and straight(ish) sides representative of many fresnel units.

Each of the three has exactly the same center level reading as indicated by the 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.

The center illuminance (measured in lux or footcandles) doesn't tell us how much light in total is coming out of the unit. To do that, you have to add up all the illuminance readings over the whole beam. We can make 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 paint bucket while the other two give more complex shapes. In particular notice the dimple in the bottom of the container on the right that's derived from curve C. 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. A very wide, shallow bucket could hold the same amount of water as a narrow, deep one for example. 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.

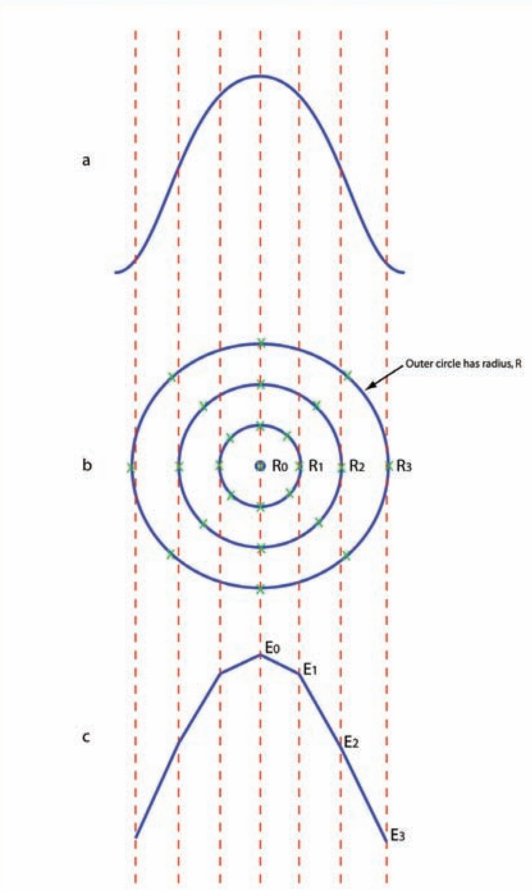

FIGURE 2

In practice of course you don't make model buckets and fill them with water (although it might be fun!) so how do you get these results? There are sophisticated systems available using digital cameras from companies like Radiant Imaging that take hundreds, even thousands, of illuminance measurements over the whole field and then sum them all to get the total. Unfortunately we don't all have access to those and even if you do it's not always convenient to set them up. Fortunately it is possible to measure total lumens for simple light fixtures with a light meter to a respectable level of accuracy; it just takes a little longer and some simple math. Doing it this way also gives you an insight into what's going on with the more complex measuring devices. Essentially you break the problem down by dividing the output beam into a number of smaller areas. You then make the assumption that each of these

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smaller areas is flat to keep the math simple. **Figure 2** shows the idea, for this simple technique to work we need to assume that our original beam (shown in **Figure 2a)** is radially symmetrical (not unreasonable for many of the luminaires in our business) and take measurements around the three concentric circles (**Figure 2b**). We are essentially simplifying the curve to the shape shown in **Figure 2c** where the measurement points are joined with straight lines at the points numbered E0 – E3. We can then do some simple math and come up with a formula for the *volume of the bucket.* You can see that the more rings you choose the closer our straight line approximation comes to the original curve. In practice using 3 rings gives you an answer that is within acceptable tolerance. Entertainment luminaires and their lamps aren't scientific instruments and have an inherent manufacturing and adjustment tolerance much greater than the error introduced by this technique.

In the case illustrated, where we have broken the curve down into three concentric rings, the formula simplifies as follows:

$$\textbf{Total Field Lumens} = 0.93R^2(E_3 + 1.5E_2 + 0.75E_1 + 0.125E_0)$$

I regularly use this technique myself for product reviews. Using a chart looking something like a three foot dart-board, I measure the illuminance (lux or footcandle) levels at the center (point R_0) and at eight points around each of the three equally spaced rings ($R_1 – R_3$) as shown by the green X marks in **Figure 2.** I adjust the

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throw of the fixture such that the outermost ring is at the point where the light output is 10% of the center beam, or the field angle, thus the lumen figure returned is called the Field Lumens value—i.e. the total lumens within the field angle. The eight measurements in each ring are then averaged to give E_1 to E_3 which are plugged into the formula. Having it all in an Excel spreadsheet makes it quick and easy.

The units are important; lumens themselves are the same in both US and Metric Units but the quantities you measure to derive them have to be consistent to get the right result. If you measure the radius and distances in feet then you must measure the illuminance in footcandles. Measure in meters and you must use lux.

Note the assumptions made: This particular technique is only for smooth, radially symmetrical lights such as ellipsoidal spots and fresnel washes. It will also work for a round PAR beam—however it would be incorrect for an elliptical PAR beam or an asymmetric cyc flood. Within these limitations this technique can be very accurate.

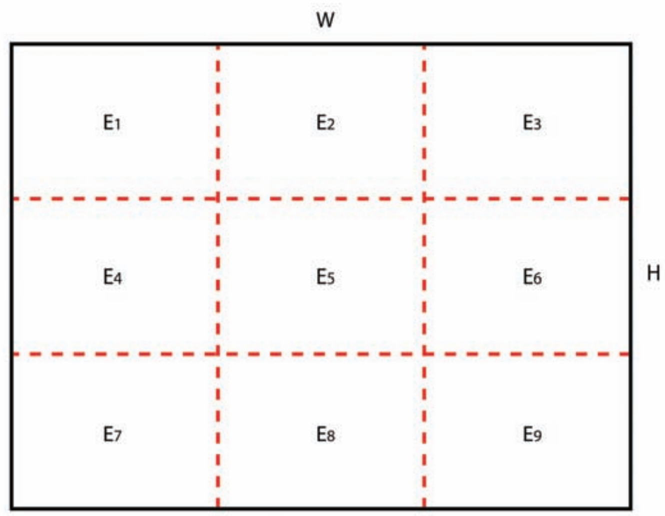

FIGURE 3

If you have a beam with a very flat profile, such as that from a video projector, the math is even easier. You've likely heard the term *ANSI lumen*. This is now a deprecated unit but is still in use. A projector may be as good as 90-95% flat so we can safely break the beam down into a small number of rectangular areas as shown in **Figure 3** without getting too big an error across each section. The measurement technique is very simple—you measure the illuminance at the nine positions shown in **Figure 3** (E1 - E9), average them, and them multiply that by the area of the screen w (W x H) to get the total ANSI Lumens. Again our units must match—W and H in meters if illuminance is in lux or W and H in feet if illuminance was measured in footcandles.

An even simpler technique you occasionally see used with projectors is *center lumens*. This makes the extreme assumption that the beam measured is so flat that you can just measure the center (E_5 in **Figure 3**) and assume that the rest of the beam is exactly the same—like beam A in **Figure 1**. This assumption is rarely true for projectors and never true for lights. Consequently this is a measurement that should never be used for lighting products; it is highly misleading and could easily give a result twice as large as the real field lumens.

However, I hear you say, this is all very well. We can measure the total lumens and look at a beam profile but what does that tell us about how bright it will look to my eye? You won't be surprised to learn that I have some thoughts about that which will be revealed next time. ■

Mike Wood is President of Mike Wood Consulting LLC which provides consulting support to companies within the entertainment industry on technology strategy, R&D, standards, and Intellectual Property. A 25-year veteran of the entertainment technology industry, Mike is the Treasurer and Immediate Past President of ESTA.