BY MIKE WOOD

More about measurement

IN THE LAST ISSUE of *Protocol* I talked about measuring total lumens, and how you might use either a flat wall method or a photogoniometer to get the data. Chatting about this with Karl Ruling later, I realized that another aspect of this is how that measurement data is presented, in particular what it means when you look at a beam profile chart.

> **"Does this mean that the total lumen figures that you see from a flat wall are wrong?"**

We are all familiar with a beam profile, I publish them myself in the reviews I write for *Lighting&Sound America*. It's a straightforward way of illustrating how a beam behaves across its width. Is it a flat distribution such as you might want for projecting gobos, or is it a blending or cosine distribution that you would use for a stage wash? In a similar way you might be interested in what the distribution of a cyc light looks like at different heights on the cyc. In every case, we are likely making an assumption about what we are looking at, and that assumption might not always be correct.

Let's start out with the charts you might see in a review or a datasheet. **Figure 1** shows the measurements I took of a luminaire, measuring across the beam in a vertical direction, top to bottom across the center of the beam. The key point here, and likely the assumption you made even though I don't say so on the chart, is that I took those measurements on a flat surface. That's typically the way we will use the product, onto a flat stage or cyc, so it makes sense to measure it that way. Or does it?

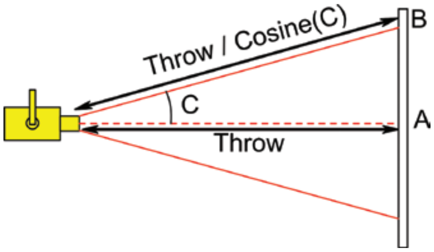

Figure 2 – Measurement set-up

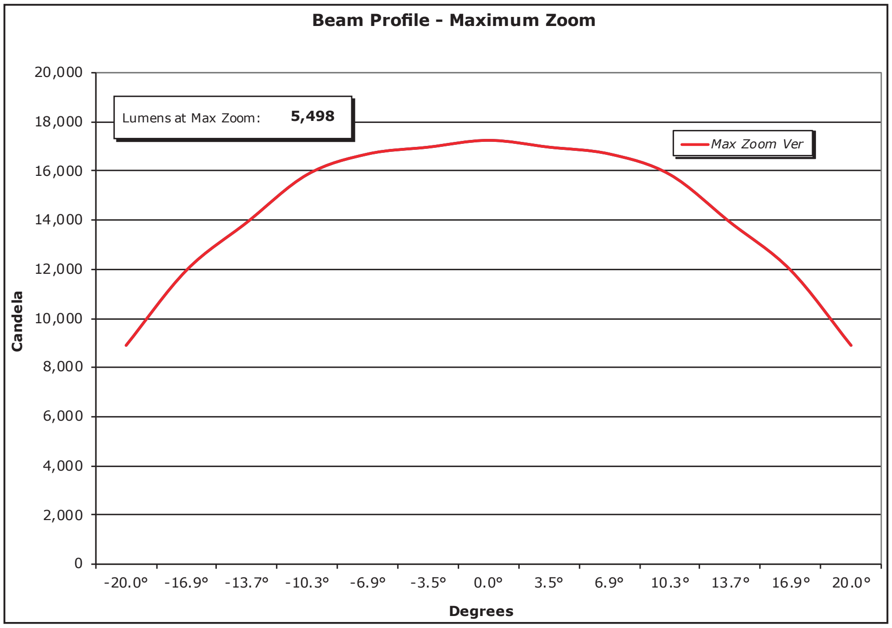

Figure 1 – Beam profile

Let's take a closer look. **Figure 2** shows a simplified side view of my test set-up. It's pretty simple, a luminaire, a wall, and a light meter. What's to think about? There's actually a lot going on here. Firstly, the throw distance to the wall is the straight-line perpendicular distance from the luminaire to point A on the wall. However, in reality, every measurement other than the one right in the center will have a throw that is longer than that. This means that the light level measured will be lower just due to the longer throw, never mind how the luminaire performs. The inverse square law comes in and, with a wide-angle luminaire, this can be quite significant when you get close to the beam edge. To get mathematical for a moment, the throw distance is going to increase with the inverse of the cosine of the angle at the point we are measuring. In **Figure 2** the throw distance at the edge of the beam, point B, which is at an angle C from the center of the beam, is Throw/Cosine(C). That means that the output will be reduced by the square of that cosine (inverse *square* law remember, it's an area that increases). If we had a luminaire with a 60° lens, then the angle each side to the edge of the beam would be 30°, and our light level would be reduced by a factor of 0.75 just by the longer throw to the edge of the beam compared to the center. If we wanted that light to look flat on a flat wall, then the edges would actually have to be about 1.33 x brighter than the center to make up for this. But we've not finished. Not only is the throw longer to the edge of the beam, but if we put our light meter flat on the wall, which we do, then it's no longer actually pointing at the light. In the case of the 60° beam we are talking about, the meter would be pointing 30° away from the light. Your light meter very likely has a cosine corrector on the sensor, usually a white dome that is there to ensure that the meter follows this cosine rule accurately as the angle varies. In our example, this gives us another cosine 30° reduction, that's another factor of 0.87, and we are now down to about 0.65 x overall.

> "Ears are good."

Hang on, you might say, does that angle matter? Well, it might. It depends on the surface of the wall or stage the light is hitting. If it were a perfectly diffuse reflector then it might not matter, but if it's a surface that is at all specular or reflective, as many paint finishes are, then it matters a lot. The light at the edge of the beam will be reflected away from the viewer, thus making the edges of the beam look dimmer than they really are. **Figure 3** shows the problem. Light hitting the surface at point B will be scattered in all directions, however the more reflective (specular) the surface, the more will be directed towards point D, likely away from the viewer (unless you are that unlucky audience member sitting at point D in direct line of fire), and the light level in all the other directions will be reduced.

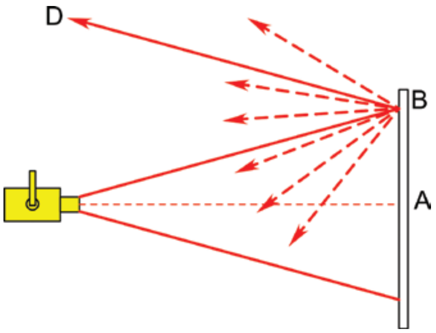

Figure 3 – Specular reflection

Now we have three cosines, cosine^3 or cosine cubed, reducing the light when we get away from the center of the beam. There's actually one more, which is to do with the light emitting area of the lens. If it were a perfect point source, which we often assume in simple photometrics, then the off-axis angle wouldn't matter. However, real luminaires have real lenses that have a real size. As we get off-axis, we can see less and less of that lens, the round shape becomes an ellipse with a correspondingly smaller area. You won't be surprised to hear that this is one more cosine loss, making cosine to the fourth power, cosine^4. However, this is one that is often ignored as in a real theatre the luminaires are usually far enough away that they behave reasonably close to a point source. *Note: all of this applies to a camera as well as a luminaire, although in reverse, and you're likely familiar with wide angle camera lenses causing vignetting or darkening around the edge of the image, particularly in the corners.* ***Figure 4*** *shows an example. This isn't a fault in the lens or camera, its simple physics when imaging onto a flat sensor. These days we can fix this with post-processing or Photoshop if we want to, not so easy when real film stock was used. Camera manufacturers call this "natural vignetting."*

Does this mean that the total lumen figures that you see from a flat wall are wrong, and too low because of this? No, because the math you use to calculate lumens from the raw data allows for these cosine reductions and factors them in. The total lumens figures from a flat wall measurement can be believed. However, what usually doesn't get corrected are the beam profile figures that get published. I know, in my own case, that I correct for the cosine losses when I calculate and report total lumens, but I don't make any corrections to the beam profiles such as that shown in **Figure 1**. What you see is exactly what I measured, no corrections. I do this because I think it's what people expect, and it shows the reality of projecting onto a flat surface.

Most, but not all, of these cosine corrections go away if you use a photogoniometer instead of a flat wall. With a goniometer you rotate the light so the distance to the light meter always stays the same no matter the angle, no inverse square losses. The meter is also always facing

Figure 4 – Natural vignetting

directly at the light, so that loss goes away as well. The only one that remains is the loss that comes from seeing a smaller area of the output lens as it turns. What this means, and what I've been leading up to for the last 1,200 words, is that a beam profile from a photogoniometer will look very different than one from a flat wall measurement.

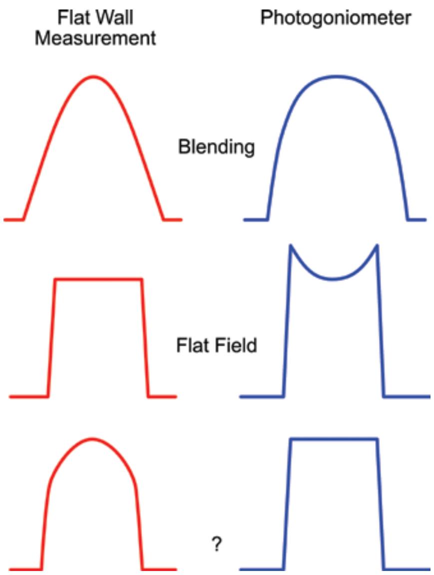

Figure 5 – Beam profiles

Figure 5 shows three pairs of profiles, the ones on the left, in red, are what you would see on a flat wall, while the blue profiles on the right show the same luminaire, but this time as measured with a photogoniometer. The top pair are a normal blending distribution. The photogoniometer version doesn't look a lot different, apart from being somewhat fatter around the waist. The next pair however look very different. This is what you get from a fixture with a flat field, like a gobo projector or a TV fresnel wash. The left, red, image looks as we expect, flat top on the wall, but the blue photogoniometer profile looks very different, it has two large ears at the edge of the beam! If you think about it, this must be the case. For a light to appear flat on a wall or screen it must actually be brighter at the edges to make up for the longer throw and off-axis beam. *The image with ears actually looks very familiar to me as this was how we used to characterize and qualify fresnel luminaires for use in the BBC (this was many, many years ago in the high and far off times, oh Best Beloved...) We wanted as flat a field as possible for the camera, and our specs were written assuming that a photogoniometer would be used to measure the lights.*

The bottom pair in **Figure 5** shows something theoretical that I don't know that I've seen before. In this case I took what would be a flat field from a photogoniometer (right in blue) and reversed the math to see what that would look like on a flat wall. The result is shown in red. This, arguably, is a true flat field, but unless you are projecting on the inside of a large sphere, or perhaps a curved IMAX screen, then probably of little practical value.

There's no hidden meaning or revelation here. The only message I'm trying to get across is one I've covered many times before, data can lie. You knew that already, and the need to make sure you understand what you are looking at before making a judgement.

Presented with the profile with ears above, you might instantly reject the product as having an odd output. However, if you knew that this was from a photogoniometer then you might recognize it as a flat field.

Just in case you think you've never seen a photogoniometer profile, you probably have without necessarily realizing it. These are exactly what are shown in the candela charts often shown in photometric data for architectural luminaires. **Figure 6** shows an example.

This is a light designed to produce a flat field on a road, and it has ears, just like the diagrams shown above. Ears are good. ■

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 40-year veteran of the entertainment technology industry, Mike is a past President of ESTA and Co-Chair of the Technical Standards Council. Mike can be reached at mike@mikewoodconsulting.com.

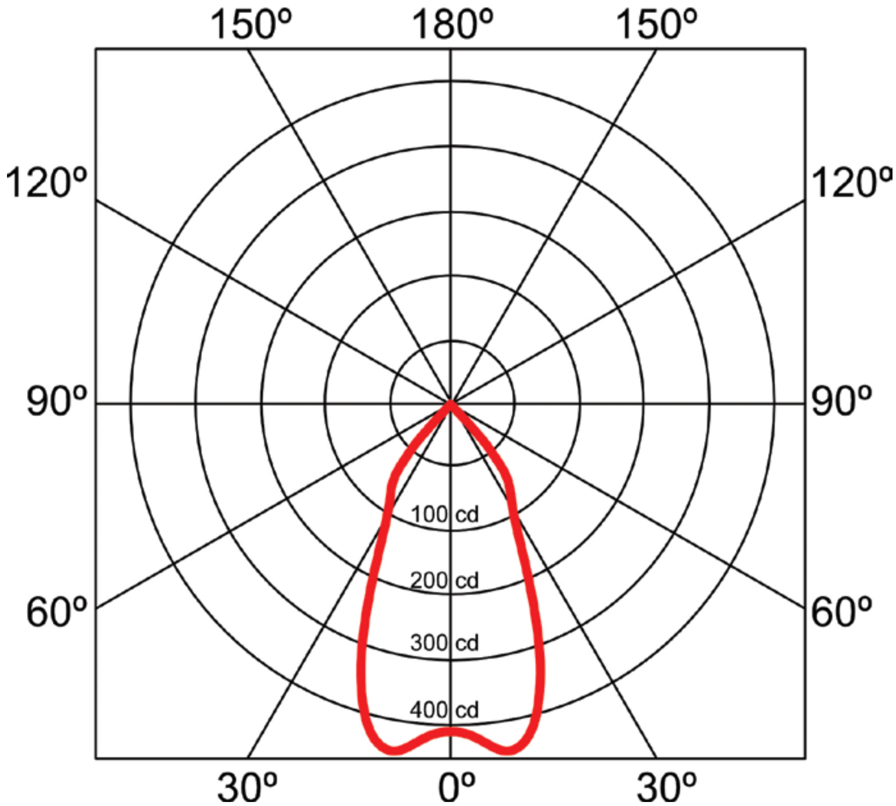

Figure 6 – Polar photometric chart