Nico Frankhuizen, TQC, discusses how human perception and measurement of gloss can be misinterpreted, so using calibration systems on gauges increases accuracy and confidence

A terminology and metrology view on gloss

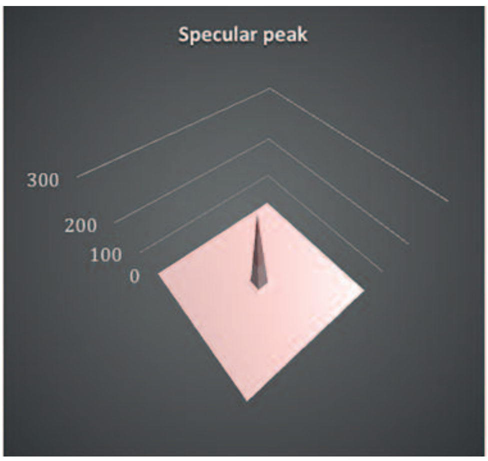
Fig 1. ***MY AIR***
Image courtesy of De Vries Yard, Feadship

On a daily basis we decide on our perception of gloss if a product meets specification or not. While for most users a product is shiny or not measurement equipment can give a definitive number on that shininess. But that number doesn't always correlates to what our eyes think they see. This difference in perception and measurement can be significant but where does it come from?

In order to answer that question we need to understand what we see and how we interpret this. Humans are best in perceiving gloss when able to see a sample from multiple angles. In a static situation we will often perceive gloss as a white spot. While moving out of the specular peak we see a loss in light intensity and a 'colour' change on the substrate. Let's call this observation of gloss 'Perceptual Gloss'. That specular peak is the light reflected directly opposite of the incoming light and is fully reflected within a parallel beam. Let's call this 'Specular Gloss'. Now we come to the equipment to measure Gloss. This not only measures specular but also measures diffuse light. To aid in differentiating let's call this 'Standard Gloss'. You would ask, what is the difference? Let me explain, the measurement based on this yacht, *MY AIR* (**figure 1**), a majestic private yacht with matte black hull and a high gloss white superstructure. You would expect a huge contrast but the two colours give an optical gloss illusion. Black surfaces will appear to be shinier and white surfaces duller. This is a trick of the mind and influences the perceptual gloss. Both specular and standard gloss are not influenced by colour.

HUMAN EYE DECEIVES

Where our human eye will tell you there is not that much difference between both surfaces specular and standard gloss will give you a different reading. On the high gloss white surfaces this specular and standard gloss will agree and give you an identical reading. However, on the matte black surface the values will be different. This is due to the sensitivity to the diffuse fraction of light that a 'standard' gloss meter will take in account. The cause for difference in these readings can be seen in **figure 2**. Both samples in this illustration would give the same gloss value when measured with a 'Standard' glossmeter, however, the height of the specular peak is completely different. This causes the different behaviour for the two samples. The difference between these two readings heavily depends on intensity of the diffuse fraction. Thus there is no correlation between the two values from both specular and diffuse reflecting surfaces and with that no correlation between specular and standard gloss measuring meters. On the black surface of the yacht I can, thus, get three different interpretations of gloss.



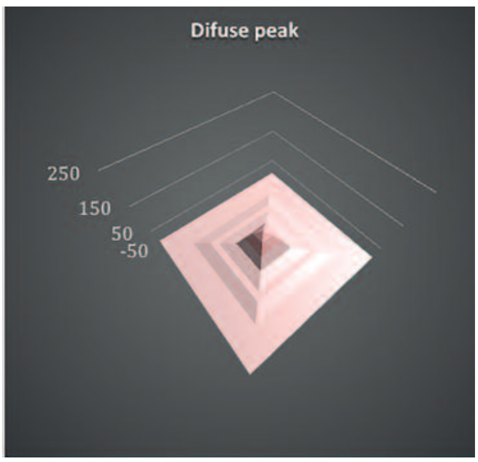


Fig 2. Representations of specular and diffuse reflection peak

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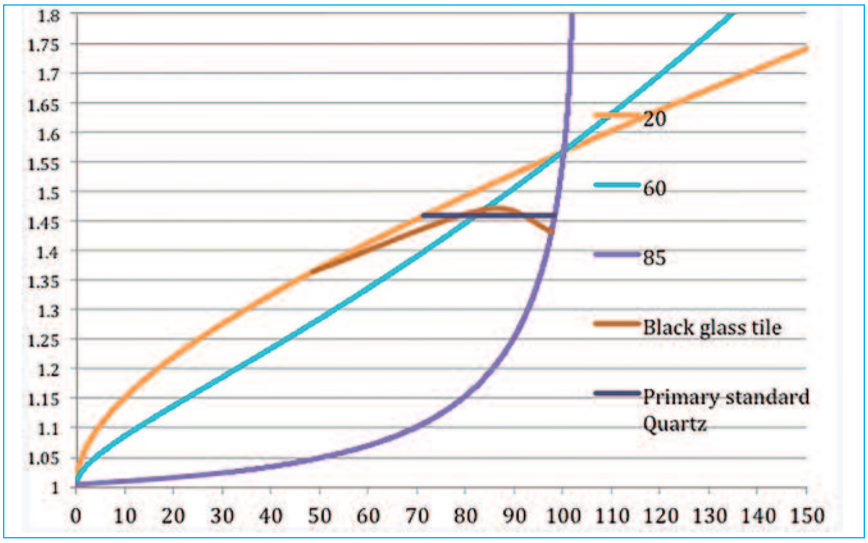
$$GU = \frac{\left(\frac{\left[\frac{n_1\cos(\theta_i) - n_2\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2}}{n_1\cos(\theta_i) + n_2\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2}}\right]^2 + \left[\frac{n_1\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2} - n_2\cos(\theta_i)}{n_1\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2} + n_2\cos(\theta_i)}\right]^2}{2}\right) * 100}{\frac{\left[\frac{n_1\cos(\theta_i) - n_r\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2}}{n_1\cos(\theta_i) + n_r\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2}}\right]^2 + \left[\frac{n_1\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2} - n_r\cos(\theta_i)}{n_1\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2} + n_r\cos(\theta_i)}\right]^2}{2}}$$



Formula 1. Top: Applied Fresnel formula for calculation of Gloss n_1 = refractive index air, n_2 = refractive index primary standard, n_r = refractive index standard
Graph 1. Above: Gloss (x-axis) in correlation to refractive index (y-axis). The poor stability of the black glass standard is clearly visible in comparison to the perfect line of the primary standard, in this case quartz

The differences don't limit themselves to the measured surface they are also of importance to the calibration of the glossmeters. The ISO 2813 and its ASTM counterparts all refer to gloss in relation to a primary standard material. Using the refractive index the gloss of a primary standard in relation to this primary surface is calculated as shown in **formula 1**. This formula, based on Fresnel's formula, works only for specular reflection. The resulting correlation between refractive index (n) and Gloss (GU) is shown in **graph 1**.

The formula excludes any surface topography influences. Changing the refractive index is, thus, a means of creating different gloss tiles. These tiles give very stable results. However, creating these tiles is an exact science. Many producers use a cheaper method to create their calibration tiles. These are the famous black glass that can be found supplied with virtually all glossmeters. Manufacturer tiles are, in most cases, made of the same glass but all have different values. This is achieved by introducing a surface profile to the tile, reducing the gloss by a non-defined fraction. The correlation between refractive index and gloss in all three angles is, thus, lost, as illustrated in **graph 1**.

This scattering in refractive peak resembles the illustration in **figure 2**. The introduction of the surface topography also introduces variation in the surface. Differences between surface finishing and their effect on the stability of a surface of a gloss tile are shown in **figure 3**. The variations introduced make is very hard to get a single value of modified tiles. Depending on the exact position on the tile the measurement results fluctuate significantly.

The change in the geometry of the refractive peak and the inclusion of the diffuse fraction would, in itself, not be such a big problem because we can measure that reference tile and give it a value, with a glossmeter build according to the available standards, this should be possible. Unfortunately the influence of this diffuse fraction is not always perfectly defined.

Depending on the geometry of the reflected peak the portion of light reaching the detector varies and, in combination with the size of the receiver aperture, will give different results. Within the industry variations in aperture size can be observed up to 30%. Allowing for a significant spread in actual measurement results.

FOUR PRIMARY STANDARDS

TQC is the first manufacturer to use four newly created primary standards with calculated gloss values. Where all other gloss gauges in the industry can only be traced back to a single reference tile and are all calibrated on black glass standards with all their flaws, the latest release of TQC gloss gauges don't have this problem. This new calibration system used for TQC gauges surpasses the accuracy and level of confidence of most National Metrological Institutes (NMIs). The implementation of these four primary standards for the calibration of glossmeters is an industry first. Where all glossmeters fall prey to the cumulative error of a multistep calibration process, that is based on derived standards, TQC glossmeters have overcome that problem.

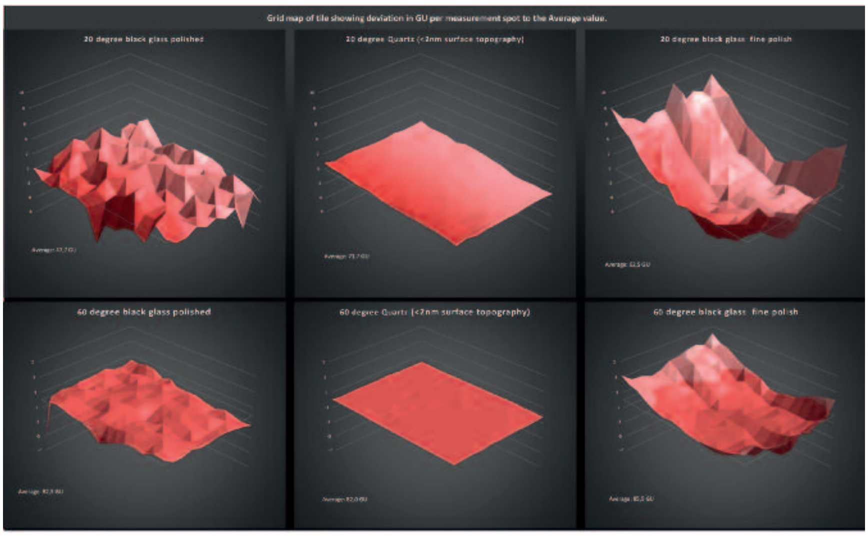


Fig 3. Grid map of tile showing deviation in GU per measurement spot to the average value