White Paper

Vessel Lighting Measurement

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The lighting used to illuminate the interiors of process vessels has been dominated by halogen luminaires for decades. In recent years brighter LED luminaires have emerged that are causing process experts to re-assess their vessel lighting needs. What is the ideal level of brightness? What is the relationship between brightness and the size of the vessel? How should brightness be measured? The International Society for Pharmaceutical Engineering's Bioprocessing Equipment (ISPE-BPE) subcommittee is looking at these questions in the hope that someday guidance may be offered. In the meantime, this article may shed a little light on the subject.

The traditional halogen luminaire emerged from industry suppliers based on the technology that was available. Halogen luminaires were brighter than other incandescent luminaires, and they could be used in explosion-proof enclosures. A 50W bulb was about the right size for the application. Higher wattage bulbs were available, but they required bulky enclosures to remove the heat.

Suppliers did not develop their luminaires to achieve any particular target of brightness, as no standards for light brightness or tank illumination existed. If the view was dimly lit, the only option was to increase the wattage of the bulb. This added more light, but also had the negative side effect of adding additional heat to the process.

Now that LED luminaires are available that are up to four times brighter than traditional halogen luminaires, and lumens are replacing watts as a unit of specification, process experts are wondering how many lumens are enough and how many are overkill for a given application. The answer requires an understanding of emitted light, reflected light, distance, angles, perception and light measurement methods.

The brightness of the emitted light (technically called "illuminance") of a luminaire is measured directly with a light meter. After the luminaire is installed on a process vessel, illuminance can only be measured from inside the vessel. Obviously, this would be an invasive procedure and be impractical in many process applications. Alternatively, light can be indirectly measured externally via a sight glass viewport, but that can measure only the brightness of the reflected light, technically known as "luminance," rather than "illuminance."

As the object of process inspection is not the light but rather the process media that the light illuminates, it makes sense to measure the reflected light at the sight glass port that operators use for visual inspection. In addition, using the sight port ensures that all measurements are made at the same point and angle.

It also allows for measurement during different vessel conditions, which can affect luminance. For example, light reflection from stainless steel is approximately 50%, but the process media can have varying levels of emissivity depending on color and opacity. Therefore, a half-full vessel will likely have different luminance than an empty vessel.

But is it really true that, by measuring the light levels of a stainless steel vessel from a viewport (sight glass, opening, etc.), an operator can determine that the lighting inside the vessel is appropriate for proper process observation? Let's look at the physics involved.

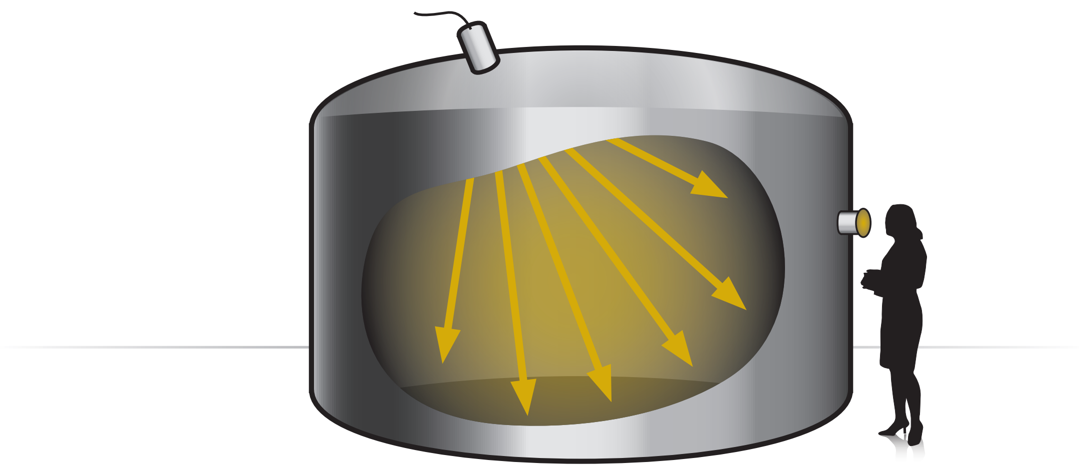

Figure 1: Measuring light levels of a stainless steel vessel through a viewport.

The total amount of light emitted from a luminaire is called luminous flux. It is measured in all directions directly. As soon as the luminaire is placed into application, luminous flux cannot be measured. In application, the main concepts are illuminance and luminance. Illuminance is the amount of light that lands on a surface and luminance is the amount of light reflected by that surface. For example, if a light is shone onto an object, then that light is illuminance, while the light that reflects off the object is luminance. Luminance is what is seen by the observer (Figure 1).

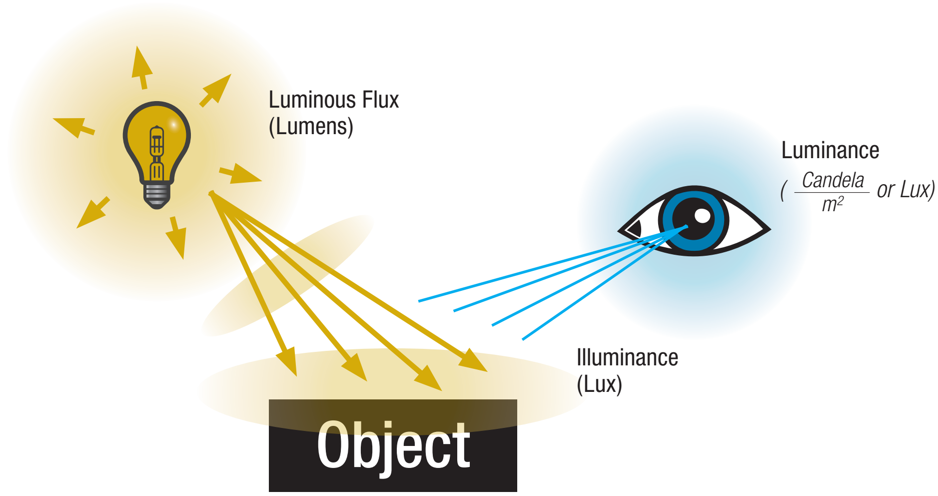

Figure 2: Light that hits an object is illuminance, but the light that reflects off and is observed by a person is luminance.

The reason this is important is because the light seen by the person observing the interior of a vessel is luminance light. This light sums up the countless variables that can affect the lighting conditions inside of the tank, figure 3.

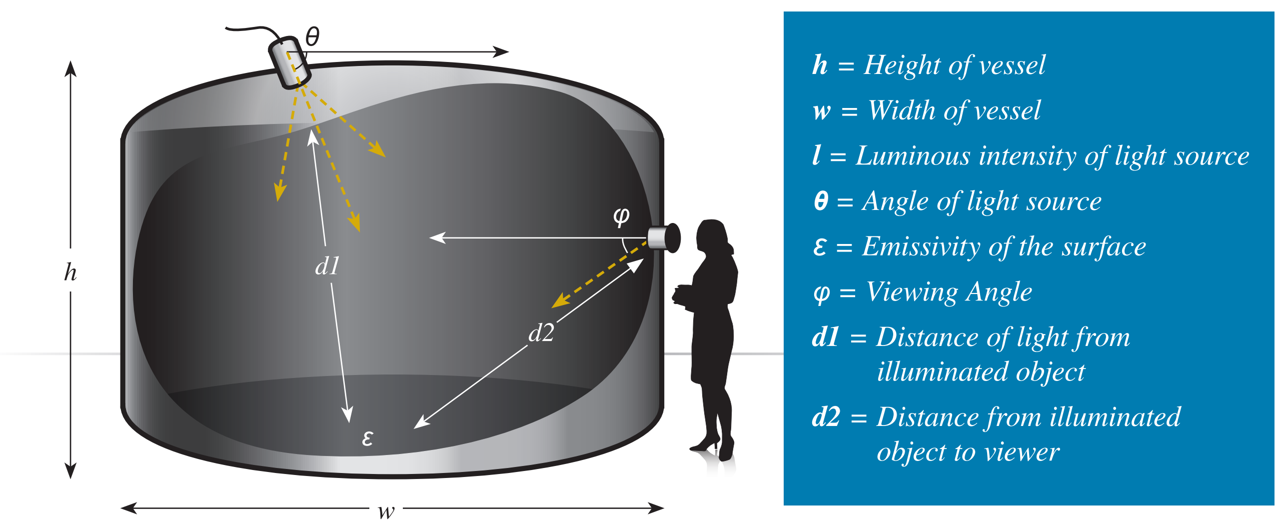

Figure 3: Some of the many factors that can affect the lighting conditions inside of a stainless steel vessel as seen by an observer.

It is generally accepted that to observe an object in fine detail, one should have an illuminance somewhere in excess of 1000 lux. As stated previously, measuring the inside of a tank is difficult and can't be done during production. Also, calculating this lighting is a complicated affair that requires many known variables.

$$E = \frac{\text{Lumens} \bullet \text{CU} \bullet \text{LLF}}{\text{Workplace Area}}$$

Cu *= Coefficient of Utilization*
LLF *= Light loss factor*
Workplace Area *= Primary area of interest*

Figure 4: Estimated Illumination using the Lumen method

Measuring light at the viewport is simpler, and the light that reaches the viewport is—in a way—the final output of the lighting system. All the variables that affect the light inside of the stainless steel vessel have come into play (as long as the light is not directly shining on the viewport). If the luminaire at the viewport is at some minimum lighting threshold, operators can assume that the inside of the tank is achieving proper illuminance, without completing a complicated equation.

A minimum luminance level is acceptable because human perception of bright light is surprisingly flat, meaning it takes large quantitative changes in light to produce a noticeable qualitative change in light. Just because a light is brighter by a large margin, it does not mean the change will be noticed easily by a person. Also when human performance is measured at various lighting levels, performance remains fairly constant as long as a minimum brightness is surpassed. If the interior of a tank is over-lighted, then ability of an observer may not be significantly improved, but if the interior is insufficiently lit, then observation will be negatively affected.

The goal, therefore, is to select a luminaire bright enough to meet the minimum threshold of luminance for reliable observation in a particular application without paying for more lumens than one really needs. The surest answer is to try a luminaire and see how well it works. If the view is too dim, then replace it with a brighter luminaire. A better approach is to measure the luminance of the vessel at the sight port. As these approaches may be impractical, L.J. Star www.ljstar.com, a manufacturer of process vessel luminaires, offers a table of rough guidelines (Table 1).

Vessel Type (stainless)	Vessel Volume	Half Full or Empty	Process Media	Desired Luminance (light measured at sight port)	Suggested Luminaire Lumens Rating (cool LED)
Reactor	50 Liters	Half full	Clear or semi clear liquid	50Lx	1000 Lm
		Half full	Transparent yellow liquid	50Lx	1500 Lm
		Empty	Empty	50Lx	1000 Lm
Reactor	5,000 Liters	Half full	Clear or semi clear liquid	50Lx	2500 Lm
		Half full	Transparent yellow liquid	50Lx	3000 Lm
		Empty	Empty	50Lx	2000 Lm
Storage Vessel	20,000 Liters	Half full	Clear or semi clear liquid	50Lx	4000 Lm
		Half full	Transparent yellow liquid	50Lx	5000 Lm
		Empty	Empty	50Lx	3000 Lm
Bioreactor	12 Liters	Half full	Clear or semi clear liquid	50Lx	500 Lm
		Half full	Transparent yellow liquid	50Lx	500 Lm
		Empty	Empty	50Lx	500 Lm

Note that Table 1 does not include all factors. For example, a process engineer with a large tank application had been satisfied with his view of valves at the bottom of his vessel until he saw the difference made by a brighter light. Another process engineer found that his brighter light was too bright for his video camera image. It is always wise to consult with an experienced supplier before specifying an LED luminaire for a particular application.

Glossary

Luminous Flux – Total amount of light emitted by a light source. Unit lumens.

Luminous Intensity – Intensity of light directionally emitted by a light source. Unit Candela.

Illuminance – Amount of light landing on a surface. Unit Lux.

Luminance – Amount of light reflected by a surface. Unit $\frac{Candela}{m^2}$ or Lux.

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L.J. Star Incorporated provides an extensive line of process observation equipment – sight glasses, lights, sanitary fittings, and level gage instrumentation. Product lines include Metaglas® Safety Sight Windows, Lumiglas® Explosion Proof Lights and Cameras, Visual Flow Indicators, Sight Ports, Sanitary Clamps, Magnetic Level Gages and Gage Glass. Metaglas is the #1 selling fused sight glass, proven in thousands of installations around the world. Unlike some other sight glasses, it meets stringent DIN 7079 and DIN 7080 quality standards, and it is approved for USP Type I use. For additional information, or to request third-party documentation of standards compliance and product performance claims, contact L.J. Star Incorporated, P.O. Box 1116, Twinsburg, OH 44087. Phone: 330-405-3040. Fax: 330-405-3070. Email: view@ljstar.com. Website: www.ljstar.com.