TESTING WATERPROOF IMAGING LENSES

Written by Rebecca Charboneau & Kyle Firestone

Imaging lenses are used in machine vision applications in industries that include pharmaceuticals, food and beverage, and outdoor autonomous agriculture systems such as drones, which often require that the imaging equipment be waterproof. Standard imaging lenses typically cannot withstand environments with frequent washdowns or harsh weather conditions, as these environments create the potential for water ingress, or entry, into the imaging lens and camera which can permanently damage the equipment. In light of these requirements, waterproof lenses and cameras are currently available with a variety of waterproof ratings for different types of aqueous environments.

EO's TECHSPEC® Cw Series Fixed Focal Length Lenses are waterproof versions of the TECHSPEC® C Series Fixed Focal Length Lenses and are engineered for aqueous environments. These lenses are available in 6mm, 8.5mm, 12mm, 16mm, 25mm, and 35mm focal lengths and with a variety of fixed aperture configurations. A Cw Series Lens eliminates the need to protect the system with a lens housing tube and allows for operation at the maximum optical performance and the nominal angular field of view (AFOV) defined by the size of the sensor. This elimination also enables users to refocus in situ. The Cw Series design meets the International Electrotechnical Commission (IEC) standard of Ingress Protection (IP). The lenses have ingress protection ratings of IPX7 and IPX9K, meaning that they withstand submersion in water at a depth of up to one meter for 30 minutes and resist high-pressure, high-temperature sprays at a close range (100 - 150mm away), respectively. It is important to note that the Cw Series Lenses were tested exclusively in aqueous environments against water ingress and not against the intrusion of solids.

Optomechanical Design

The lenses consist of a window with a hydrophobic coating that has been engineered around the lens design for optimal performance and protection from water ingress (*Figure 1*). Additional O-rings are incorporated into the internal housing of the lens to provide a waterproof seal.

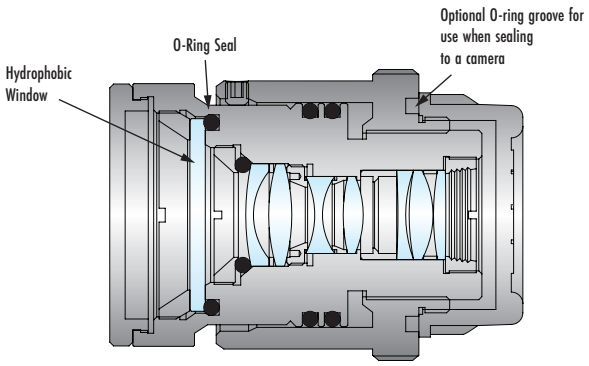

Figure 1. Internal schematic of a Cw Series Lens.

The hydrophobic coating prevents water droplets from adhering to the window surface because droplets could eventually lead to water ingress. The ability for a liquid to spread out onto a surface is known as "wettability" and is a measure of the surface tension between the window and droplet. Wettability is a characteristic ascribed to the liquid phase, not the solid surface, and it is measured as the contact angle formed between the droplet and the surface. Note that this angle is always measured starting at the boundary between the liquid and bulk fluid medium (in this case the bulk fluid medium is ambient air). The angle is measured by sweeping from this surface, through the liquid, and stopping at the interface between the liquid and solid surface. The hydrophobic coating reduces the wettability of the contacting water evidenced by a larger contact angle as compared to the angle of water in contact with an untreated glass surface. This prevents water droplets from sticking to the surface. Instead, droplets bead up and roll off.

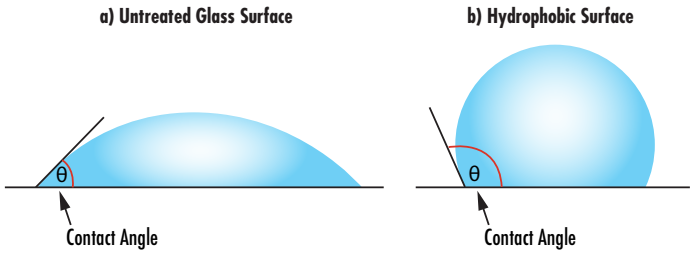

Figure 2. Two water droplets on horizontal glass surface. a) There is a smaller contact angle on the untreated surface, indicating higher surface tension. b) There is a larger contact angle on the hydrophobic surface, indicating lower surface tension.

Pairing a Cw Series Lens with an IP67-rated camera can create a waterproof machine vision system that can be utilized in environments at risk for water ingress. Utilizing a Cw Series Lens removes the need for a lens housing tube. Without such a tube, the system will have optimal optical performance in applications where wider AFOVs, refocusing, and compact system sizes are necessary. However, there are important considerations for properly sealing a Cw Series Lens to an IP67-rated camera.

Discrepancies in C-Mount designs among IP67-rated cameras require an additional sealant component to ensure the system does not flood. Details in this paper include the recommended methods for sealing a Cw Series Lens with an IP67-rated camera and provide supporting evidence for the viability of this method.

Recommended Sealing Methods

The optimal method recommended for sealing a waterproof system consists of applying a Viton® Fluoroelastomer O-ring between a Cw Series Lens and IP67-rated camera.

The O-ring should be lubricated with silicone grease and fitted around the lens C-Mount (*Figure 3*). Properly fitting the O-ring ensures that a seal is maintained between the camera and imaging lens to prevent water ingress. When attaching a Cw Series Lens with an O-ring, it is important to apply at least 30 in.-lb. of torque (e.g. torque screwdriver) to fasten the lens to the camera.

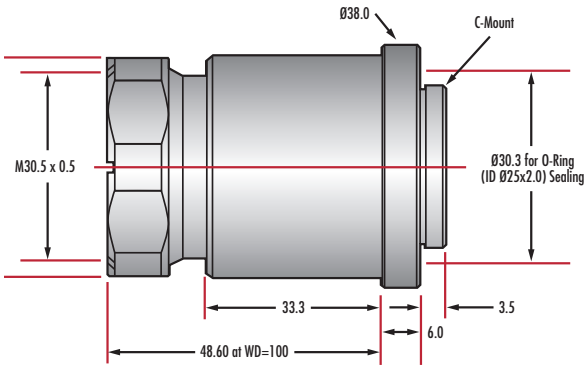

Figure 3. External schematic of a Cw Series Lens.

The recommended sealing methods were validated through in-house testing using IPX7 standard procedures in accordance with the IEC 60529 standards. Several IP67-rated cameras were tested with the Cw Series Lens to determine if other sealant methods could be used for different cameras. The selected IP67-rated cameras were the IDS Imaging FA, and the Lucid Vision Labs Triton and Atlas cameras. A lens tube attachment is required for the Lucid Vision Labs cameras when using a Cw Series Lens to provide the O-ring with additional surface area to create a leakproof seal. The cameras were submerged in one meter of water for 30 minutes within the testbed (*Figure 4*). A lubricated O-ring was fastened inside of a Cw Series Lens and then tightened to 30 in.-lb. for each IDS Imaging FA and Lucid Vision Labs Triton and Atlas camera. Moisture-sensitive stickers were placed on the internal surfaces of the camera and lens to confirm that there was no water ingress for both cameras after submersion for 30 minutes. Compared to the other sealant methods below, the O-ring was the only method that prevented water ingress for all camera tests.

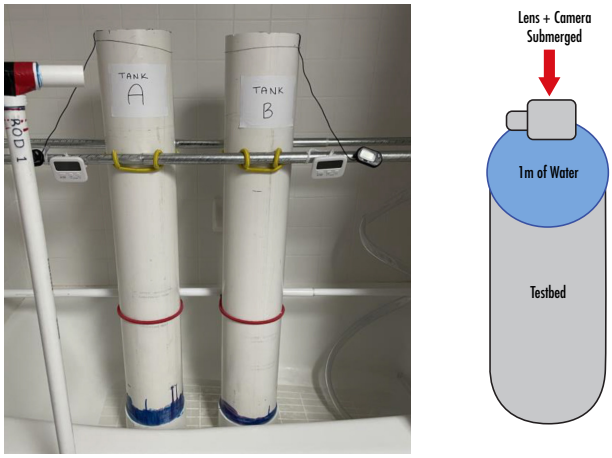

Figure 4. Schematic of testbed.

Sealing Methods to Avoid

It is not recommended that PTFE (polytetrafluoroethylene) tape be used to secure a Cw Series Lens to an IP67-rated camera. On our test, PTFE tape alone was fitted around the threading of the C-Mount on the IDS FA, Lucid Vision Labs Triton, and Atlas test cameras, and after submersion for 30 minutes there was water ingress in all the tested IDS FA cameras. This demonstrates the importance of using an Oring as opposed to other sealant methods. A lens housing tube could be added for additional protection but is unnecessary as the Cw Series Lenses have been confirmed to be IPX7 and IPX9K rated.

Conclusion

There are many considerations when adapting a system to operate in an environment susceptible to water ingress. A Cw Series Lens with a fitted O-ring can be paired with an IP67-rated camera to create an ideal waterproof system. Additional precautions may be used for further protection such as using pipe thread sealant, though this is not necessary. It is recommended that the Oring always be the sealant method used. Following these recommendations, when using a Cw Series Lens, the user can expect improved optical performance in environments susceptible to water ingress compared to a setup with a lens housing tube that may limit the field of view and the ability to refocus the lens.