

# INGRESS PROTECTION RUGGEDIZATION

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Ingress protection (IP) ruggedization is used to describe products that have been modified in a few key ways for protection against the intrusion of solid particles and moisture. Several international and military guidelines have been created to consolidate and standardize the many different testing conditions. These guidelines not only provide suggestions for test methods and testing environments, but also provide a set of standardized ratings helpful for comparing the different degrees of protection for various consumer and industrial goods.

## Standards & Ratings

Several international and military standards were created to establish universal testing conditions for ingress protection and to standardize the ratings describing different degrees of protection. The most widely cited standard for ingress protection is IEC 60529. Devices tested to the ratings contained in this international standard are given two digits. The first digit describes the level of protection against solids and particles and ranges from zero to six. If a component has not been tested for protection against solid intrusion, the first digit is changed to an X (*Table 1*).

Solid Protection Digit	Description
X	Testing for protection has not explicitly been conducted.
0	No protection from solid objects.
1	Protection from objects 50mm in diameter or greater.
2	Protection from objects 12.5mm in diameter or greater.
3	Protection from objects 2.5mm or greater.
4	Protection from objects 1mm in size or greater.
5	Partial protection from dust such that intrusion does not interfere with operation.
6	Completely dust tight.

**Table 1.** The first digit of the IP rating describes the amount of protection an enclosure has from solids.

The second digit describes the protection from moisture and ranges from zero to nine (*Table 2*).

Moisture Protection Digit	Water Type	Description
X		Testing for protection has not explicitly been conducted.
0		No protection from moisture.
1	Dripping	Protection from vertically falling droplets tested for 10 minutes.
2		Protection from water droplets deflected up to 15° from vertical for 10 minutes.
3	Splashed or sprayed	Protection from water sprayed up to 60° from vertical.
4		Protected from water splashes from all directions, tested for a minimum of 10 minutes.
5	Jet spray (pressurized)	Protection from low-pressure jets 6.3mm in diameter.
6		Protection from direct pressure jets 12.5mm in diameter.
7	Continuous Immersion	Protection from full immersion for up to 30 minutes at a depth between 15cm and 1m.
8		Protection from extended immersion under higher pressure from depths greater than 1m.
9 or 9K	High-pressure and high temperature jet spray	Complete moisture protection from high-pressure, high-temperature jets, wash downs, and steam cleaning.

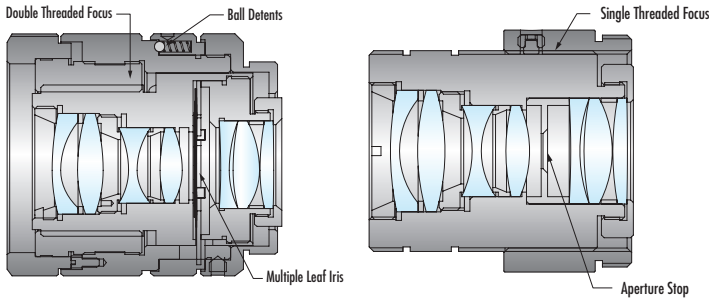
**Table 2.** The second digit of the IP rating describes the amount of protection an enclosure has from moisture.

It is important to note that these ratings are not necessarily cumulative. Compliance with IPX7 or IPX8 does not necessitate compliance with IPX5 or IPX6. Products that comply with both a jet spray rating and a continuous immersion will be specified with both ratings. For example, the waterproof [TECHSPEC® Cw Series Fixed Focal Length Lenses](#) are IPX7 and IPX9K rated. Also, because these standards were created broadly for many types of equipment and not solely for imaging lenses or imaging systems, they should only serve as guidelines for specific testing environments. It is important to consider how closely these conditions model application conditions.

## Optomechanical Design Considerations

Ingress protection for imaging lenses begins with the optomechanical design. In the same way that industrial ruggedized lenses possess simplifications that make them more durable, so too do ingress protected lenses. The complex and movable components of a standard imaging lens are typically most susceptible to liquid and debris. These components are either removed altogether or replaced with the analogous static components that typically restrict the broad performance range of a standard imaging lens to smaller ranges for settings including the size of the aperture stop and F-number (*Figure 1*).

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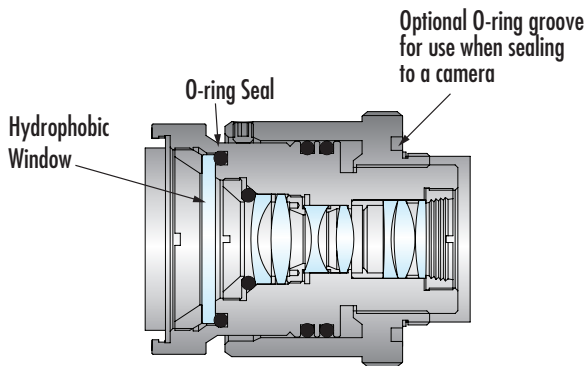


**Figure 1.** Left: A standard-model imaging lens with an adjustable iris. Right: An industrial ruggedized imaging lens with simplified mechanics.

It is important to note that ingress protected imaging lenses are not designed to stop intrusion of any kind at the end without being threaded to a camera or mount. A camera or other mounting device threaded to the end of an ingress protected lens is intended to seal away access to the optical train inside the assembly.

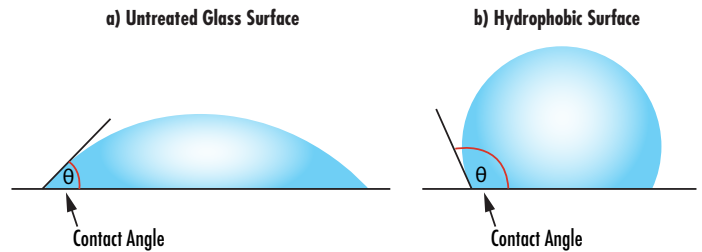
## Unique IP Considerations

Unique to ingress protected lenses are the additions of O-rings and RTV silicone, which are applied to susceptible design points, and a window added to the end of the optical train which has been coated on both sides with a hydrophobic coating (Figure 2).



**Figure 2.** An ingress protected ruggedized lens features an O-ring to seal out contaminants like dust, dirt, or moisture and a hydrophobic window at the front of the optical train.

The coating on the first window element consists of an optically active cross-linked organic polymer material deposited onto both surfaces of the window. The function of the coating is to prevent droplets from forming and then adhering to the window. “Wettability” is a measure of the surface tension (surface energy) between window and droplet which can be found using the contact angle of a droplet interacting with the surface. The surface tension and wettability are both inversely related to the contact angle (Figure 3).



**Figure 3.** Two water droplets on horizontal glass surfaces (with gravity downward). a) There is a smaller contact angle between the untreated glass surface and droplet indicating higher surface tension with the surface. b) There is a larger contact angle between the hydrophobic surface and droplet indicating lower surface tension with the surface.

This coating makes the surface hydrophobic and not hydrophilic. “Self-cleaning,” “anti-fouling,” or “self-replenishing” glass technology often used for other applications such as vehicle windshields, glass used for the construction of windows in buildings, and “anti-fogging mirrors” makes use of hydrophilic coatings that are porous and oftentimes brittle. These coatings function by increasing the surface tension of the substrate, effectively spreading out the water from the contacting droplets. While this achieves a similar result as the hydrophobic coating, a cross section from the window coated with a hydrophilic coating may be effectively thicker as a thin layer of water is spread across. This layer of water can diffract the entering light in many different ways, resulting in unpredictable changes to image quality which can diminish imaging performance.

Because the hydrophobic coating on this window is also optically active, if additional coating properties are needed, such as anti-reflection (AR), windows with custom coating stacks must be designed with all necessary properties in mind. This window can be removed or replaced if needed; it can also be cleaned by rinsing it with soapy water.

## Conclusion

Ingress protected ruggedization requires very specific testing considerations to ensure product durability after exposure to moisture and/or debris. Imaging lenses designed for use in these environments are given IP ratings to attribute the degree of protection and many lenses are given several IP ratings as the degrees of protection are not necessarily cumulative. As such, it is important to understand the protective needs of the imaging system per the application. Ingress protected imaging lenses may be used with enclosures for extra safety and redundancy, but are ideal options for protecting imaging systems from exposure to moisture alone.