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Protection from the Elements Part I: Ingress Protection

This Technical Note is Part I in a series of Notes examining the environmental durability of pico-powered lighting products. Ingress Protection (IP) ratings are covered as they apply to the Lighting Global program and the test methods in IEC 62257-9-5, Edition 2.0.

Information contained in this article builds on previous Technical Notes available on the Lighting Global website.

Introduction

Pico-powered lighting products are like other consumer electronics: they are exposed to the elements when put in use, whether indoors or out. The ability of a product to survive these exposures is a function of the design. The product housing, electronics, connectors, and materials all play a critical role in determining whether a product continues to function or whether it fails.

This technical note provides guidance on a framework for classifying levels of water and physical ingress protection and strategies for approaching the issue for product designers, regulators, and bulk purchasers. The framework is used in classifying the water resistance of products that are tested according to IEC 62257-9-5.

Parts II, III, and IV of this Technical Note series examine the effects of corrosion, heat, and solar radiation on pico-powered lighting products.

Product Lifetimes

Every product will eventually fail for one reason or another. Protection from water and physical ingress is balanced against other durability factors: lumen maintenance, accidental drops and impacts, battery degradation, and theft all lead to loss. The key to a successful strategy for water and physical ingress protection—both for manufacturers and buyers who are interested in a particular use—is to correctly anticipate environmental exposures and design the product to withstand the resulting negative effects that can lead to premature failure. There is, of course, always a balance between durability and cost.

Lighting Global suggests that products be designed to perform under normal circumstances for a minimum of ***two years***. In many cases, it is quite possible for most of the components to continue performing for much longer if the product is properly cared for by its owner. In some cases, the battery is often the first component to fail, although new battery technologies that can deliver longer lifetimes and thousands of charge / discharge cycles are increasingly common. As with many other aspects of the emerging pico-powered lighting market, lifetime performance is increasing as manufacturers develop higher performance products and compete for brand recognition by consumers. Longer lifetimes may enable longer product warranties, and these warranties (when properly applied and delivered to customers) can help build brand recognition and customer loyalty.

Ingress Protection

Ingress Protection (IP) is the term used in standards and regulations (e.g., IEC 60529 – Degrees of protection provided by enclosures) for the protection level afforded by product enclosures that keep out water and physical objects. IP classifications defined by IEC 60529 rate the ability of the housing to protect against "ingress of solid foreign objects" and "ingress of water with harmful effects." Note that there is some leeway in the definition of what constitutes "harmful effects" from water ingress, but in general the standard is understood to objectively characterize the ability of water to gain access to electronic components and conductors within an enclosure.

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The proper design of the product's external housing is essential as a first line of defense against solid foreign objects and water intrusion. Evaluating the ability of this housing to keep out foreign objects and water is the primary function of IP tests. These tests provide an IP rating for a product based on two numerals, with the first numeral indicating the physical ingress rating (for solid objects and dust) and the second numeral indicating the water ingress rating. An IP rating with one of the numerals represented by an "X" indicates that this part of the test was not performed or is not relevant (i.e., when considering water resistance, IP ratings are listed as IPX1, IPX2, etc.). The IP system for physical and water ingress is summarized in Table 1.

Table 1. IP 60529 numeric rating system

	IP	Meaning for protection of equipment against ingress of objects
1st Numeral	0	No protection
	1	≥ 50 mm
	2	≥ 12,5 mm
	3	≥ 2,5 mm
	4	≥ 1,0 mm
	5	Dust-protected
	6	Dust-tight
	IP	Meaning for protection of equipment against ingress of water
2nd Numeral	0	No protection
	1	Vertically dripping
	2	Dripping (15% angle)
	3	Spraying
	4	Splashing
	5	Jetting
	6	Powerful jetting
	7	Temporary immersion
	8	Continuous immersion

Ingress of solid objects

Pico-powered lighting products commonly use low voltages that do not present an electrocution hazard for people (i.e. >20 VDC), and so physical ingress protection is primarily relevant to the ingress of objects that could damage the product. Fingers, sticks, and other foreign objects could damage or disconnect wires or other circuit elements. A metal wire could also short out the electronics or battery resulting in a dangerous overheated battery discharge. Dust and dirt can collect on the optical parts of the enclosure and block or obscure the light source. Dust can also absorb moisture and act as a water trap on sensitive electronic parts.

Ingress of water

Water damage in the form of corrosion can be very detrimental to product lifetime and performance and can cause catastrophic failure immediately or over the course of a few days, weeks, or months. The conditions present at the surface of circuit boards and electronic connectors are often very conducive to accelerated corrosion when liquid water is present. This water can come from ingress through openings in the enclosure, seams in the plastic housing, or condensation from the warm, humid conditions often found inside pico-powered lighting products. Corrosion processes are examined in Technical Note Issue 13: "Protection from the Elements Part II: Corrosion of Electronics".

External connectors

Many pico-powered lighting products require external connectors for solar panels, batteries, cell phone chargers, and additional light points. These can often be weak points in the design and serve as water entry pathways unless properly sealed. Connector failures are common in all types of electronic products.

IEC 62257-9-5 treats external connectors separately from the requirements of the rest of the product for the purposes of ingress. Physical ingress of solid objects is allowed for the external connector itself as long as the connector does not allow penetration into the rest of the housing. The same is true for water ingress, where water is allowed on the external portions of the connector after an IP test. Water ingress into the housing, however, is still treated according to IEC 60529 regardless of the ingress path.

Types of exposure

Four types of water exposure are defined in IEC 62257-9-5:

- **No protection** — The product has no water protection and may be damaged by any water exposure.
- **Occasional rain** — The product may be exposed to occasional light rain without damage.
- **Frequent rain** — The product may be exposed to frequent rain without damage.
- **Permanent outdoor exposure** — The product may be exposed to frequent heavy rain without damage.

These exposure types are related to a product's IP rating according to Table 2.

Table 2. IP ratings for different exposure types

IP rating	Enclosure level of water protection
IPx0	No protection
IPx1	Occasional rain
IPx3	Frequent rain
IPx5	Permanent outdoor exposure

Technical and Overall Levels of Water Protection

There are several ways to protect a pico-powered lighting product from physical ingress and corrosion damage, but not every method will be appropriate for every particular product. A balance must be struck between elements of cost, complexity, and competing technical and market requirements. Whereas consumers demand quality at a low cost, they also demand auxiliary product features, such as cell phone charging, that generally require additional external connectors. The additional connectors present ingress challenges that also add cost.

IP ratings provide one useful way to characterize how well an electronic product will tolerate exposure to dirt and water. The real world protection from these hazards, however, includes several other factors: the design and layout of circuits inside the enclosure, coatings and other circuit-level protection, the ability of water to drain from the enclosure and not pool on sensitive areas, and, of course, the behavior of people using the product. The Lighting Global program recognizes these other factors and accounts for them through the creation of additional water protection categories: Technical Protection and Overall Protection.

Technical Protection

The Technical Protection category considers design and manufacturing details that fall outside of traditional IP enclosure ratings. These can include the use of conformal coatings on printed circuit boards, encapsulation of assemblies and connectors, different plating technologies that are resistant to corrosion, and the location and orientation of subassemblies within the housing that allow water to drain from the product and not collect in areas where corrosion damage will soon follow.

Given the number and variability of these additional technical protection mechanisms, Lighting Global has not proposed specific rules governing which mechanisms are considered adequate and which are not. Rather, manufacturers are encouraged to provide information that would support recognition for these design elements. In this way, manufacturers are free to experiment with new designs and innovate novel protection mechanisms for this class of products. If a product is determined to have additional technical protection, the water protection for that product is adjusted according to Table 3.

Table 3. Adjusted level of water protection for products ***with additional*** Technical water protection

IP rating	Enclosure-only level of water protection	Technical level of water protection
IPx0	No protection	Occasional rain
IPx1	Occasional rain	Frequent rain
IPx3	Frequent rain	Frequent rain
IPx5	Permanent outdoor exposure	Permanent outdoor exposure

Overall Protection

The Overall Protection category includes product labeling as part of the assessment of a product's resistance to water damage (Table 4). Products that don't get wet because their owners keep them dry are less likely to suffer corrosion damage. Lighting Global recognizes this by adjusting the level of water protection for products with labeling indicating to a customer that the product should not get wet. There are specific requirements for the labels, and only the "No protection" and "Occasional rain" levels of water protection are adjusted. Products that must meet the "Frequent rain" level or higher are not affected.

Table 4. Overall water protection with and without consumer labeling

Technical level of water protection OR Enclosure-only level of water protection	Overall water protection WITHOUT consumer labeling	Overall water protection WITH consumer labeling
No protection	No protection	Occasional rain
Occasional rain	Occasional rain	Frequent rain
Frequent rain	Frequent rain	Frequent rain
Permanent outdoor exposure	Same	Same

Product Categories

Different levels of water protection are appropriate for different types of products. Pico-powered lighting products designed to be permanently mounted outside, for example, must be built to withstand the heavy rain, wind and dust typical of an outdoor environment. Products designed for indoor use, however, do not need the same level of protection, as they are not expected to get wet under normal circumstances.

Pico-powered lighting products can be placed into one of four categories based on the arrangement of components. Different quality standards and performance targets may apply to different categories based on specific program considerations. Lighting Global has established overall protection requirements for products intended to meet the Lighting Global Minimum Quality Standards according to testing under IEC 62257-9-5 (Table 5).

Some kits that have multiple components (e.g. independent lighting points, external PV module) may fit into more than one category, with different parts of the kit in different categories.

The first word in each category name refers to the portability of the system.

- *Fixed* systems are designed for permanent or semi-permanent mounting and use in place.
- *Portable* systems are inherently portable, with the light source and energy storage components permanently or temporarily joined.

The second word refers to the arrangement of a solar module with respect to other components.

- *Separate* systems have no solar module present or the solar module is connected to other components by a cable that is sufficiently long (i.e. ≥ 3m) to place the solar module outdoors in a location with good solar access while the other components remain indoors.
- *Integrated* systems have a solar module integrated in the same casing as the other components of the product, or the product is otherwise designed so the whole product shall be left outdoors to charge via the solar module.

The four system types that can be derived from the categories listed above are:

a) **Fixed separate (fixed indoors):** These products are not inherently portable and are used indoors. The light source(s) are typically separated from the battery by cables. The solar module is also separate from the battery and connected by a cable that is long enough to place the module outdoors while the battery remains indoors (Figure 1).

Table 5. Lighting Global Minimum Quality Standards protection requirements by product category

Product Category	Required level of water protection
Fixed separate	No protection
Portable separate	Occasional rain
Portable integrated	Frequent rain
Fixed integrated	Permanent outdoor exposure

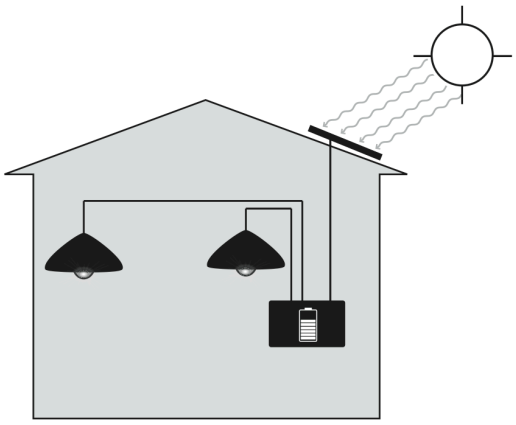

Figure 1 – Fixed Separate (fixed indoors) system—example arrangement of components

b) **Portable separate:** These products are portable, with a battery and light source permanently or temporarily joined. If the product is solar-charged, the solar module is also separate from the battery and connected by a cable that is sufficiently long to place the solar module outdoors in a location with good solar access while the battery remains indoors (Figure 2).

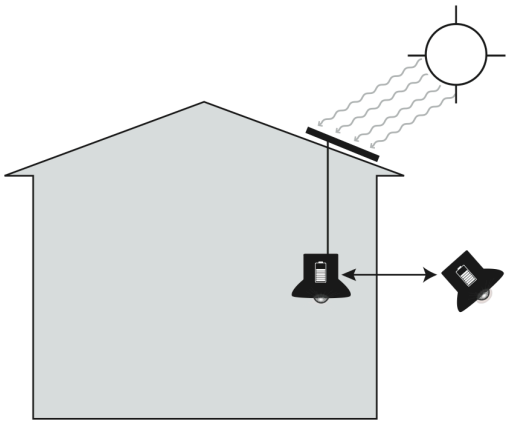

Figure 2 – Portable Separate system—example arrangement of components

c) **Portable integrated**: These products are portable and charged with a solar module integrated in the casing or otherwise designed so the whole product shall be left outdoors to charge via the solar module (Figure 3).

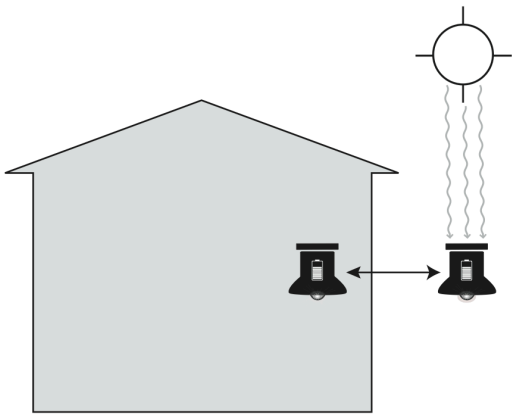

Figure 3 – Portable integrated system—example arrangement of components

d) **Fixed integrated (fixed outdoors)**: These products are not inherently portable and are charged with a solar module that is integrated in the casing or is otherwise designed so the whole product shall be left outdoors to charge via the solar module. These may also include lighting points that can be placed indoors (see Figure 4).

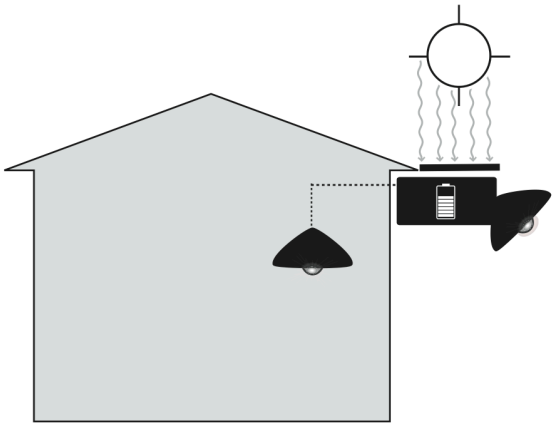

Figure 4 – Fixed integrated (fixed outdoors) system—example arrangement of components

Conclusions

As the pico-powered lighting market continues to mature and new products take on an increasingly important role in the lives and livelihoods of customers who rely on them, the issue of lifetime will remain a key element. Longer lifetimes will provide increased value to end users and open up new opportunities. A product's ability to withstand exposure to the natural elements of foreign objects, rain, and sunlight is a critical factor in determining how long the product will remain in service. Longer lifetimes reduce the waste associated with end-of-life disposal and provide the customer with a durable product. Proper design of the product enclosure, internal electronics, and packaging materials can make a big difference in how long these products will last.

Some material included in this Technical Note was originally developed by the Lighting Global quality assurance team for the Lighting Global Quality Test Method (LG-QTM) document. A portion of this material also appears in IEC 62257-9-5, Edition 2.0.