GLOBAL ENCLOSURE STANDARDS WITHIN THE ELECTRICAL INDUSTRY

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Industry standards for electrical enclosures exist to promote safety, encourage design efficiency and define minimum levels of product performance. In the European and North American electrical industries, several standards are enforced for these reasons. Across the global marketplace, these or other standards may be followed or there may be no standards at all, which can lead to wide variations in product performance and price. In many cases, the end customer is not aware of the standards or does not clearly understand them and, therefore, does not insist that suppliers provide products that meet the standards. Focusing solely on low price without fully understanding or requiring industry standards can yield a low initial product cost, but could ultimately lead to high maintenance expenses, component failure and in the worst case, worker safety issues.

The three most globally recognized standards for enclosures are:
IEC 60529;
UL 50, 50E
NEMA 250

The purpose of this paper is to:

1. Clearly define the industry standards that exist for electrical enclosures
2. Compare the most commonly used standards so enclosure users can understand the key differences
3. Equip decision makers with the knowledge needed to select an electrical enclosure that has the appropriate rating and price to value relationship for its intended application

1.0 Standards Overview

Globally, IEC, NEMA and UL are the three most commonly recognized standards organizations.

For more information on this standard, visit IEC's Web site at: www.iec.ch

International Electrotechnical Commission (IEC) Standard 60529

The IEC is the world's leading organization that prepares and publishes International Standards for all electrical, electronic and related technologies — collectively known as electrotechnology.

IEC 60529 includes a list of codes, called Characteristic Numerals, that are used to identify ingress protection levels. Commonly referred to as the IP rating, these codes reflect an electrical enclosure's ability to protect against access to electrified parts by people, tools, moisture, dust or dirt.

For more information on this standard, visit NEMA's Web site at: www.nema.org

National Electrical Manufacturer's Association (NEMA) Standard 250

NEMA promotes the competitiveness of the US electrical product industry through the development of standards, advocacy in federal and state legislatures and executive agencies, and the collection and analysis of economic data.

Similar to IEC 60529, NEMA 250 covers enclosures for electrical equipment. Like IEC 60529, NEMA 250 addresses ingress protection, but it differs in that it also addresses specifications detailing minimum construction, performance and test criteria, corrosion resistance and more. Although its beginnings are based in the United States, NEMA is a global organization that is working to promote electrical standards worldwide.

For more information on this standard, visit UL's Web site at: www.ul.com/global/eng/pages

Underwriter Laboratories® (UL) 50, 50E

Underwriters Laboratories® is an independent product safety certification organization that has been testing products and writing safety standards for more than a century. UL evaluates more than 19,000 types of products, components, materials and systems annually, with 21 billion UL Marks appearing on 72,000 manufacturers' products each year.

UL 50, 50E is based on NEMA 250 standards. While they address many of the same points, NEMA simply indicates the design intent but does not mandate compliance via third party testing and on-site compliance visits. A product can be built to NEMA standards but actual performance compliance is at the discretion of the manufacturer. UL certification, however, is formal confirmation that required construction and performance are met after analyses and testing is completed. In summary, both NEMA and UL define standards, but only UL enforces compliance to their standards with third-party testing and inspection.

Main Points Addressed by the Standards

To standardize enclosure performance, organizations including IEC, NEMA and UL offer rating systems to identify an enclosure's capacity to withstand environmental influences—from dripping liquid to dust infiltration to complete submersion. The goal of all three organizations' ratings is to assist end-users in making an appropriate, informed enclosure selection that meets their application-specific requirements.

Electrical enclosures are rated by Type (NEMA and UL) and/or IP rating (IEC) according to the degree of protection provided. Both Type and IP ratings cover:

- The degree of human protection from hazardous components inside the enclosure
- The degree of protection for equipment inside the enclosure from ingress of solid foreign objects, including dust
- The degree of protection for equipment inside the enclosure from ingress of water

These three primary standards have similarities and differences in their performance criteria, influence on an enclosure's design elements, testing requirements and enforcement methods. The table below indicates the main points addressed by each of the standards. All three address ingress protection, however NEMA 250 and UL 50, 50E also define minimum enclosure design requirements. These requirements are detailed in section 3.0.

Standard	Main Points Addressed
IEC 60529	• Level of ingress protection
NEMA 250	• Level of ingress protection • Minimum enclosure design requirements
UL 50, 50E	• Level of ingress protection • Minimum enclosure design requirements

Table 1: *Main Points Addressed by IEC 60529, NEMA 250 and UL 50, 50E standards*

2.0 Ingress Protection

While all three standards address ingress protection, they do not define it in the same way. Table 2 below lists the enclosure ratings for the various Types, as defined by UL 50, 50E and NEMA 250. Table 3 lists the enclosure IP ratings, as defined by IEC 60529.

Enclosure Types

	NEMA		Enclosure	UL	
	Solids	Liquids	Rating	Solids	Liquids
INDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt)	No protection	**Type 1**	Provides a degree of protection against incidental contact and falling dirt	No protection
INDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt)	Provides a degree of protection against ingress of water (dripping and light splashing)	**Type 2**	Provides a degree of protection against incidental contact and falling dirt	Provides a degree of protection against dripping and light splashing of non-corrosive liquids
INDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt and settling airborne dust, lint, fibers and flyings)	Provides a degree of protection against ingress of water (dripping and light splashing)	**Type 5**	Provides a degree of protection against incidental contact and falling dirt, settling airborne dust, lint, fibers and flyings	Provides a degree of protection against dripping and light splashing of non-corrosive liquids
INDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers and flyings)	Provides a degree of protection against ingress of water (dripping and light splashing) and light splashing and seepage of oil and non-corrosive coolants	**Type 12**	Provides a degree of protection against incidental contact and falling dirt, circulating dust, lint, fibers and flyings	Provides a degree of protection against dripping and light splashing of non-corrosive liquids; and against light splashing and consequent seepage of oil and non-corrosive coolants
INDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers and flyings)	Provides a degree of protection against ingress of water (dripping and light splashing) and spraying, splashing, and seepage of oil and non-corrosive coolants	**Type 13**	Provides a degree of protection against incidental contact and falling dirt, circulating dust, lint, fibers and flyings	Provides a degree of protection against spraying, splashing, and seepage of water, oil, and non-corrosive coolants
INDOOR & OUTDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt and windblown dust)	Provides a degree of protection against ingress of water (windblown rain, sleet, snow)	**Type 3**	Provides a degree of protection against incidental contact, falling dirt and windblown dust	Provides a degree of protection against rain, sleet and snow
INDOOR & OUTDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt)	Provides a degree of protection against ingress of water (falling rain, sleet, snow)	**Type 3R**	Provides a degree of protection against incidental contact and falling dirt	Provides a degree of protection against rain, sleet and snow
INDOOR & OUTDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt and windblown dust)	Provides a degree of protection against ingress of water (rain, sleet, snow, splashing water and hose-directed water)	**Type 4**	Provides a degree of protection against incidental contact, falling dirt and windblown dust	Provides a degree of protection against rain, sleet, snow, splashing water and hose-directed water
INDOOR & OUTDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt and windblown dust)	Provides a degree of protection against ingress of water (rain, sleet, snow, splashing water and hose-directed water) and provides an increased level of protection against corrosion	**Type 4X**	Provides a degree of protection against incidental contact, falling dirt and windblown dust	Provides a degree of protection against rain, sleet, snow, splashing water, hose-directed water and corrosion
INDOOR & OUTDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt)	Provides a degree of protection against ingress of water (hose directed and occasional temporary submersion at a limited depth)	**Type 6**	Provides a degree of protection against incidental contact and falling dirt	Provides a degree of protection against rain, sleet, snow, hose-directed water and occasional temporary submersion at a limited depth
INDOOR & OUTDOOR	Provides a degree of protection against access to hazardous parts and ingress of solid foreign objects (falling dirt)	Provides a degree of protection against ingress of water (hose directed and prolonged submersion at a limited depth)	**Type 6P**	Provides a degree of protection against incidental contact and falling dirt	Provides a degree of protection against rain, sleet, snow, hose-directed water and prolonged submersion at a limited depth

Table 2: *Enclosure Type ratings as defined by UL 50, 50E and NEMA 250*

UL 50, 50E Listed hinged-door enclosures are suitable for use as UL 508A Industrial Control Panel Enclosures.

UL 50, 50E Listed screw or clamp cover enclosures are suitable for use as UL 508A Industrial Control Panel Enclosures, if the devices inside the enclosure do not require resetting or regular maintenance.

(Ref. Table SA1.1 Section 18, UL 508A)

Enclosure IP Ratings

First Numeral			Second Numeral		
IP		Test	IP		Test
0		No protection	0		No protection
1		Protected against solid objects up to 50 mm, e.g. accidental touch by hands	1		Protected against vertically falling drops of water, e.g. condensation
2		Protected against solid objects up to 12 mm, e.g. fingers	2		Protected against direct sprays of water up to 15˚ from vertical
3		Protected against solid objects over 2.5 mm, e.g. tools and wires	3		Protected against sprays to 60˚ from vertical
4		Protected against solid objects over 1 mm	4		Protected against water sprayed from all directions (limited ingress permitted)
5		Protected against dust (limited ingress, no harmful deposit)	5		Protected against low pressure jets of water from all directions (limited ingress permitted)
6		Totally protected against dust	6		Protected against strong jets of water
			7		Protected against the effects of immersion between 15 cm and 1 m

Table 3: *Enclosure IP ratings as defined by IEC 60529*

UL/NEMA Type ratings and IEC IP ratings are quite different in their definitions, testing methods and pass/fail criteria.

While UL Type ratings are based on and, therefore, very similar to NEMA Type ratings, they are quite different from the IEC IP ratings and thus, cannot be compared or equated. The difference between the UL and IEC standards is primarily the type of testing required and the pass/fail criteria for each. For example, in some markets UL Type 12 is often equated to IP55. However, the UL and NEMA Type 12 rating is more stringent in that no dust or liquid is allowed during testing, while the IP55 rating allows some dust and liquid to enter the enclosure, as long as deposits are not harmful. Table 4 defines the testing requirements and pass/fail criteria for UL and NEMA ratings. Tables 5 and 6 define the testing requirements and pass/fail criteria for IP ratings.

UL 50, 50E & NEMA 250 Ratings				
		Protection	Test Method	Pass Criteria
INDOOR	Type 1	Incidental contact & falling dirt	Probe .250 inch max.	No penetration
	Type 2	Dripping, light splashing liquid	30 min. Drip Test	Limited water inside; Not on live parts
	Type 5	Settling dust, dripping, light splashing liquid	20 psi (170kPA) Spray Test	No water inside
	Type 12	Circulating dust, dripping, light splashing liquid & oil	30 min. Drip Test 30 psi (200kPa) Spray Test	No water inside
	Type 13	Circulating dust, spraying liquid & oil	Water & Wetting Agent 2 gal. (7.6L)/min. - 30 min.	No water inside
OUTDOOR	Type 3	Rain, sleet, snow & windblown dust	Fire Hose 45 gal. (170L)/min.	No water inside
	Type 3R	Rain, sleet & snow	(3) 5 psi Rain Nozzles - 1hr.	Limited water inside; Not on live parts
	Type 4	Hose directed water	Fire Hose 65 gal. (246L)/min. - 5 min. Minimum	No water inside
	Type 4X	Hose directed water & corrosion	Fire Hose 65 gal. (246L)/min - 5 min. Minimum, 200 hr. Salt Spray	No water inside
	Type 6	Temporary submersion at limited depth	Submerge 6 ft. (1.8 m) - 30 min.	No water inside
	Type 6P	Prolonged submersion at limited depth	Submerge 6 ft. (1.8 m) - 24 hr.	No water inside

Table 4: *Testing requirements and pass/fail criteria for UL/NEMA ratings*

IEC 60529 First Characteristic Numeral Degrees of Protection - Solids				
		Protection	Test Method	Pass Criteria
INDOOR	IP 1X	Incidental contact & solid objects	Ø 50 mm - Probe	No penetration
	IP 2X	Incidental contact & solid objects	Ø 12.5 mm - Probe	No penetration
	IP 3X	Incidental contact & solid objects	Ø 2.5 mm - Probe	No penetration
	IP 4X	Incidental contact & solid objects	Ø 1.0 mm - Probe	No penetration
	IP 5X	Dust protected	Circulating Dust	Limited dust inside; Not on live parts
OD	IP 6X	Dust tight	Circulating Dust	No dust inside

Table 5: *Testing requirements and pass/fail criteria for IEC IP ratings (first numeral – protection against solids and human ingress); Dust partical type and size – talcum powder able to pass through .003 inch opening.*

IEC 60529 Second Characteristic Numeral Degrees of Protection - Water				
		Protection	Test Method	Pass Criteria
INDOOR	IP X1	Vertical falling drops	10 min. Drip Test	Limited water inside; Not on live parts
	IP X2	15° Vertical falling drops	10 min. 15° Drip Test	Limited water inside; Not on live parts
	IP X3	Spraying water	5 min. 120° Oscillating Tube or 5 min. Partial Spray	Limited water inside; Not on live parts
	IP X4	Splashing water	10 min. 360° Oscillating Tube or 5 min. Full Spray	Limited water inside; Not on live parts
	IP X5	Water jets	Fire Hose 3.3 gal. (12.5L)/min.	Limited water inside; Not on live parts
OUTDOOR	IP X6	Powerful water jets	Fire Hose 26 gal. (100L)/min.	Limited water inside; Not on live parts
	IP X7	Temporary submersion at limited depth	Submerge 3 ft. (1 m) - 30 min.	Limited water inside; Not on live parts
	IP X8	Prolonged submersion at limited depth	More Severe than X7 Customer Agreement	Limited water inside; Not on live parts

Table 6: *Testing requirements and pass/fail criteria for IEC IP ratings (second numeral – protection against liquid ingress)*

Representative UL Performance Tests

Type 4 Test

Type 12 Atomized Water Test

The tables shown to the left are meant to provide a general understanding of the protection provided by each standard, as well as the test methods utilized to verify the protection and the pass criteria for each test. For complete information, download a full copy of the standards at the following Web sites:

- **UL 50, 50E: www.ul.com/global/eng/pages/corporate/standards**
- **NEMA 250: www.nema.org/stds**
- **IEC 60529: http://std.iec.ch/**

3.0 Minimum Enclosure Design Requirements

While all three standards define ingress protection, only the NEMA 250 and UL 50, 50E standards define minimum enclosure design requirements.

NEMA and UL define requirements for:

- Strength
  - Mechanical impact on enclosure walls
  - Sheet metal thickness requirements
- Sealing
  - Gasket aging
  - Oil resistance
- Material/Finish
- Door and cover latching requirements
- Flammability
- Ventilation
- Mounting
- Thermal
- Bonding/Grounding

Only UL 50, 50E and NEMA 250 address minimum enclosure design standards. IEC 60529 does not cover enclosure design.

Enclosure Design Requirements

		Underwriters Laboratories	National Electrical Manufacturers Association	International Electrotechnical Commission
Design Requirement	Why Important	UL 50, 50E	NEMA 250	IEC 60529
Strength	Ensures consistent strength for safety and performance	x	x	—
Sealing	Ensures sealing method will perform in various environments for the life of the enclosure	x	x	—
Material/ Finish	Ensures high level of aesthetics, corrosion resistance and UV protection for end use application	x	x	—
Latching	Ensures door and/or cover is properly sealed and limits access to qualified personnel	x	x	—
Flammability	Ensures equipment and operator safety	x	x	—
Ventilation	Helps increase the life of the equipment inside the enclosure	x	x	—
Mounting	Ensures ease of installation while maintaining enclosure performance rating	x	x	—
Thermal	Ensures the enclosure will perform at a high level in extreme environments	x	x	—
Bonding/ Grounding	Ensures equipment and operator safety	x	—	—

Table 7 *illustrates the differences in the design requirements for UL, IEC and NEMA standards, in addition to describing why they are important to the end customer.*

Representative Design Requirement Tests


Gasket Tensile (Sealing) Test


Latching Cycle Test


Flammability Test


Thermal Test

Section 4.0: Testing Requirements and Enforcement of the Standard

While IEC, NEMA and UL standards define enclosure protection levels so the appropriate enclosure is used according to specific application requirements, the fact remains that these standards are not created equally. Key differences include:

- The elements addressed by each standard
- Whether the standard requires third-party testing and manufacturing site inspection
- The actual testing requirements
- How test results are interpreted

Standard	Main Points Addressed	Testing Requirements	Lab Inspection Required for Product Certification	Manufacturing Site Inspection Required
IEC 60529	• Level of ingress protection	Self testing allowed	No: IEC allows self-compliance. Some manufacturers choose to have their products certified by an independent test facility	No
NEMA 250	• Level of ingress protection • Minimum enclosure design requirements	Self testing allowed	No: NEMA allows self-compliance	No
UL 50, 50E	• Level of ingress protection • Minimum enclosure design requirements	Testing by UL lab or a UL-certified lab is required	Yes: UL requires verification of the testing and annual audits of UL-certified labs to validate compliance with the standards	Yes: UL inspects each manufacturing site monthly to ensure compliance with the UL product design certification

Table 8 *compares the amount of oversight required to display the certification mark for each of the standards.*

Only UL Requires Third-Party Testing Certification

The NEMA and UL standard organizations are commonly recognized in North America, and their ratings are based on like application descriptions and anticipated performance. While NEMA provides specific guidelines but leaves compliance up to the manufacturer, UL requires testing by qualified, third-party evaluators in certified labs. Additionally, site inspectors visit manufacturing facilities to ensure compliance of prescribed manufacturing methods and material specifications.

IEC and NEMA are similar in that they don't require independent testing and leave compliance up to the manufacturer. Due to this lack of testing, enclosure performance and the rating assigned can vary by manufacturer. At the end-user level, code compliance and enforcement of electrical enclosure and component installations are typically completed by local inspectors, referred to as "Authority Having Jurisdiction" (AHJ), who are commissioned by a local agency. Installing products and assemblies that are third-party certified or Listed to a standard for a specific use reduces the range of interpretations that inspectors may have to make.

IEC 60529 and NEMA both allow self testing by the enclosure manufacturer. Only UL 50, 50E requires testing and inspection by a UL-certified lab and inspector.

Oversight	Why Important	UL50, 50E	NEMA 250	IEC 60529
Certified Test Lab	Ensures equipment calibration, compliance to ISO 9001 & ISO 17025 and compliance to Agency Standards	x		
Testing Reviewed	Provides assurance that the testing was done properly	x		
Manufacturing Inspected	Ensures that enclosures are being built and certified correctly and consistently	x		
Field Inspected	Ensures that enclosures have been properly built and certified for the end use application	x		
Penalties	Provides a deterrent to building and certifying enclosures that do not meet the requirements	x		
Self Declaration	Does not provide the oversight necessary to ensure enclosures were tested, built or certified correctly		x	x

Table 9 *describes why oversights are important and whether or not they are included in each standard.*

Conclusion

As the global economy continues to expand at accelerated rates, industries and markets will experience significant growth opportunities. The need for energy, infrastructure, food, clean water, construction materials and consumer goods drives tremendous capital investment by corporations, private investors and governments. This investment in equipment, machinery and automation improves output and efficiency and must provide a financial return or, at the very least, optimal price versus performance value to the investor.

To help keep this equipment, machinery and automation running smoothly, electrical enclosures protect sensitive electrical and electronic components from damage caused by elements such as water, wind, dust, dirt, heat, cold, humidity and chemicals in the environment in which they're located. Enclosures don't protect against all of these elements equally however, so it's important to understand enclosure ratings and the protection levels they provide.

The IEC, NEMA and UL organizations provide standards to identify the degree of protection enclosures provide against specific elements, but only UL certifies that enclosures pass specified tests to achieve each rating. While some lower-cost enclosures can provide a low initial price tag, if they aren't certified according to the specific application's needs, the maintenance and damage costs to the components can be significant. Even worse, improper use of enclosures can result in damage to equipment outside the enclosure and even potential safety issues for workers and those in close proximity to the enclosures.

For additional information on enclosure ratings, visit the following Web sites: IEC: iec.ch, UL: ul.com or NEMA: nema.org

Primary Global Locations

Brazil
Pentair Technical Products Brazil
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