



White Paper

Environmental Protection of HMI Components

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Electromechanical devices, including switches, keypads, keyboards, pointing devices and other elements such as indicators and alarms, are critical aspects of the human-machine interface (HMI) for controlling equipment and systems. Full consideration must be given to the environment in which these devices will be deployed before specifying for any advanced HMI system.

Where water, fuel, cleaning solutions, fine dust, and other materials may come in contact with control panels it is important to select components with an appropriate rating for environmental protection. Failure to do so might lead to significant danger to people and equipment.

The IP Rating System

Widely used throughout Europe, the IP Rating System describes the 'degree of protection' as defined by the International Electrotechnical Commission standard 60529 (IEC60529). IP stands for 'International Protection', frequently referred to as 'Ingress Protection'. The degree of protection as defined by the IEC is used to describe:

- protection offered to people against hazardous parts inside an enclosure;
- protection of equipment inside the enclosure against the intrusion of solids;



Switches are IP rated to prove their resistance to dirt and moisture ingress

- protection of equipment inside the enclosure against the ingress of liquids.

HMI devices need to be rated since they fall within the IEC definition of an enclosure: 'a part providing protection of equipment against certain external influences and in any direction protection against direct contact'. The rating proves the device has been tested according to international standards, providing

a more detailed measure than generic marketing terms like 'waterproof'.

Understanding the IP system is simple. The IP code designation consists of the letters IP followed by two numerals, and is sometimes followed by optional letters (see later).

An Example: IP65

The first number is a measure of how well the enclosure can prevent an invasion by solids. This encompasses all foreign bodies - anything from large objects like parts of the body (fingers, hands) or tools, down to the tiniest of dust particles. In this example, the 6 indicates the device is dust tight. The second number indicates the degree of protection against liquids of various pressures, directions and volumes (e.g. dripping, spraying, pressure washing and submersion). The 5 in this example shows it's protected against water jets coming from any angle. Where there is no rating with regard to one of the criteria (i.e. the product has not been tested against this criteria, perhaps due to unfinished or inconclusive tests), the digit is replaced by the letter 'x', e.g. IPx4, which addresses moisture only. The complete IEC classification is shown in Table 1, right, and in the chart on page 8 as it appears in the EAO catalogue.

The IEC standard defines additional letters that can be appended to classify only the level of protection against access to hazardous parts by persons:

Letter	Protected against hazardous parts with
A	Back of hand
B	Finger
C	Tool
D	Wire

Table 1 - The IP Ratings System²

First Digit		
Indicates the level of protection that the enclosure provides against access to hazardous parts (e.g., electrical conductors, moving parts) and the ingress of solid foreign objects.		
Level	Protected against objects	Effective against
0	—	No protection against contact and ingress of objects
1	>50 mm	Any large surface of the body, such as the back of a hand, but no protection against deliberate contact with a body part
2	>12.5 mm	Fingers or similar objects
3	>2.5 mm	Tools, thick wires, etc.
4	>1 mm	Most wires, screws, etc.
5	dust protected	Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact
6	dust tight	No ingress of dust; complete protection against contact
Second Digit		
Indicates protection of the equipment inside the enclosure against harmful ingress of water.		
Level	Protected against moisture	Details
0	not protected	—
1	dripping water	Dripping water (vertically falling drops) shall have no harmful effect.
2	dripping water when tilted up to 15°	Vertically dripping water shall have no harmful effect when the enclosure is tilted at an angle up to 15° from its normal position.
3	spraying water	Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect.
4	splashing water	Water splashing against the enclosure from any direction shall have no harmful effect.
5	water jets	Water projected by a nozzle against enclosure from any direction shall have no harmful effects.
6	powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effects.
7	immersion up to 1m	Ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (up to 1 m of submersion).
8	immersion beyond 1m	The equipment is suitable for continuous immersion in water under conditions which shall be specified by the manufacturer.

Further letters can be appended to provide additional information related to the protection of the device:

Letter	Meaning
H	High voltage device
M	Device moving during water test
S	Device standing still during water test
W	Weather conditions

In the same example, a switch rated IP65M indicates that it is protected against dust and water to the same IP65 level, but the device was not still during the test.

Three Digit IP Ratings

A third number was once used to specify the resistance of equipment to impact and is still shown on some products. This was dropped from the 3rd edition of IEC60529 onwards, and has been superseded by the separate IK number according to EN 62202³. While newer products are likely to be given an IK rating instead, there is not an exact correspondence of values between the old and the new standards (see Table 2 for a comparison).

Special Considerations

The IP rating system does not cover condensation, fungus and harmful vapour so assumptions should not be made that a highly rated switch will be protected. Explosion-proof switches are also not included. Switches for use in oil refineries, for instance, must be specified for that use and must be intrinsically safe. Some IP ratings may require further clarification from the manufacturer, especially for those ending IPx7 and IPx8. The number 8 specifies the device is suitable for continuous immersion in water under conditions which shall be specified by

the manufacturer. The depth of the water and the duration of continuous immersion would need to be defined. The reason is that some oceans are so deep virtually no object can withstand the pressures, and would collapse. Also, continuous might be interpreted as eternal – nobody would guarantee something forever. Where there is doubt, seek further clarification.



EAO's Series 56 pushbutton is rated IP69K

Other International Standards Relevant to Switchgear

IP69K

German standard DIN 40050-9 extends IEC 60529 with an additional rating for environmental sealing - IP69K, for high-

pressure, high-temperature wash-down applications. Devices must not only be dust tight (IP6X), but also able to withstand high-pressure and steam cleaning. The test is very strict: 80°C water is sprayed through a nozzle at pressures of

Table 2 - Comparison of 3rd Digit IP Numbers and IK Numbers⁴

Meaning of 3rd IP Digit (nb: system now obsolete)		
IP Level	Impact energy	Equivalent drop mass and height
0	—	—
1	0.225J	150g dropped from 15cm
2	0.375J	250g dropped from 15cm
3	0.5J	250g dropped from 20cm
5	2J	500g dropped from 40cm
7	6J	1.5kg dropped from 40cm
9	20.0J	5.0kg dropped from 40cm
IK Number		
IK number	Impact energy (joules)	Equivalent impact
00	unprotected	no test
01	0.150	drop of 200 gram object from 7.5 cm height
02	0.200	drop of 200 gram object from 10 cm height
03	0.350	drop of 200 gram object from 17.5 cm height
04	0.500	drop of 200 gram object from 25 cm height
05	0.700	drop of 200 gram object from 35 cm height
06	1.00	drop of 500 gram object from 20 cm height
07	2.00	drop of 500 gram object from 40 cm height
08	5.00	drop of 1.7 kg object from 29.5 cm height
09	10.0	drop of 5 kg object from 20 cm height
10	20.0	drop of 5 kg object from 40 cm height

8–10 MPa (80–100 bar) and a flow rate of 14–16 Litres/min. The nozzle must be held 10–15 cm from the tested device at angles of 0°, 30°, 60° and 90° for 30 seconds each. The test device sits on a turntable that rotates once every 12 seconds (5 rpm). The IP69K test specification was initially developed for road vehicles, especially construction vehicles and those that need regular intensive cleaning, but also finds use in other intensely hygienic applications (e.g. food industry).

NEMA

In the United States, the National Electrical Manufacturers Association sets the requirements for environmental sealing and it’s standards are widely used

throughout North, Central and South America. The NEMA Standards Publication 250 - 2008 (previously 250 - 2003; 250 - 1997) “Enclosures for Electrical Equipment (1000 Volts Maximum)” defines enclosures according to their type from 1 to 13. Detailed information on some of the types relevant to HMI components are shown in Table 3.

NEMA standards meet or exceed the IP ratings listed, but the reverse cannot be assumed. The IP code only address requirements for the protection of people, the ingress of solids and the ingress of water. The NEMA Types consider these and also numerous other requirements⁵ including:

- Construction requirements
- Door and cover securement
- Corrosion resistance
- Effects of icing
- Gasket aging and oil resistance
- Coolant effects

For this reason, it is possible to say that a NEMA Type is equivalent to an IP rating but an IP rating is not equivalent to a NEMA Type. A comparison between the two systems is shown in Table 3, but it should be noted that IP designations cannot be converted to enclosure numbers and it is the responsibility of the user to verify the enclosure rating necessary for the given application.

Table 3 - NEMA ratings and IP Comparison Chart⁶ (main NEMA types used for HMI components shown here)

Type	NEMA Definition	Exceeds IP rating
4	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow, splashing water, and hose directed water); and that will be undamaged by the external formation of ice on the enclosure.	IP65: No ingress of dust; complete protection against contact; Water projected by a nozzle against enclosure from any direction shall have no harmful effects.
4X	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow, splashing water, and hose directed water); that provides an additional level of protection against corrosion; and that will be undamaged by the external formation of ice on the enclosure.	IP65 (as above)
6	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (hose directed water and the entry of water during occasional temporary submersion at a limited depth); and that will be undamaged by the external formation of ice on the enclosure.	IP67: No ingress of dust; complete protection against contact; ngress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (up to 1 m of submersion).
6P	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (hose directed water and the entry of water during prolonged submersion at a limited depth); that provides an additional level of protection against corrosion and that will be undamaged by the external formation of ice on the enclosure.	IP68: No ingress of dust; complete protection against contact; The equipment is suitable for continuous immersion in water under conditions which shall be specified by the manufacturer.
13	Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing); and to provide a degree of protection against the spraying, splashing, and seepage of oil and non-corrosive coolants.	IP54: Ingress of dust is not entirely prevented, but must not interfere with the satisfactory operation of the equipment; Water splashing from any direction shall have no harmful effect.



The choice of material and resistance to saltwater corrosion is important in marine applications. Above right: EAO Series 14 with silicone lens cover

Hermetic sealing

The NEMA Type 4x requires tests for corrosion, icing and gasket aging not included in IEC 60529 and that NO water penetrates during the rain test, whereas the IEC permits the penetration of water if there's no harmful effects and 'if it does not deposit on insulation parts or reach live parts'. This necessitates NEMA Type 4x enclosures to be hermetically sealed i.e. they must be airtight to a level which is considered reasonably or completely airtight. So, if an airtight switch is required, a NEMA rated product is preferable. This requirement is not limited to 4x - see NEMA 250 for more details.

A common question to EAO's technical department is, 'What's the difference between NEMA 4 and 4X?' Table 3 (previous page) shows that NEMA 4X has an additional test for corrosion resistance that is not required in NEMA 4.

NEMA standards are voluntary. It sets the standards but does no compliance testing. Individual manufacturers have to decide whether or not they will design and build their enclosures to meet the requirements. A manufacturer can choose to self-certify or to seek independent

third-party verification (testing). This decision is based on the requirements of the marketplace, e.g. a test agency Listing or Mark may be required. Therefore, since NEMA is not a ruling body like UL, the liabilities of results are assumed by the manufacturer.

NEMA and UL

NEMA and UL (Underwriters Laboratories Inc.) work closely to develop standards. UL 50 is harmonised with NEMA 250. The UL standard uses the same numbers but has additional requirements for construction and marking. Importantly, UL requires enclosures to be tested by qualified evaluators so NEMA is not a substitute. Both standards are widely used in North, Central and South America.

Specific Industry Requirements

Protection ratings can help to make the right decision when investing in components and systems. Internal system vulnerabilities and unnecessary costs can be avoided by choosing components which are appropriate for the specific operating environment. Some common industrial requirements are described here.

Factory and Machinery

Applications in these areas are commonly exposed to aggressively polluted environments when in use and in clean-down situations. HMI components and systems are frequently exposed to various types of oils, degreasers, sprays, and hazardous chemicals. These types of fluids and the dust particles they produce can be corrosive and have tendencies to harm both the external and internal components. Therefore, IP65 or above devices are recommended to avoid switch failure and, ultimately, costly machine down-time.

Food and Drink Processing / Medical

Equipment and machinery used within these industries may be subject to intense hygiene procedures and aggressive clean-downs. IP65 is recommended as a minimum and in some case IP67 is more appropriate. Consideration should be given to whether particles could be trapped in crevices within the equipment which may later result in bacterial growth. This can be prevented by an additional rubber seal. These types of applications are ideal for flush-mounting components for ease of cleaning during wash-downs.

Public Transportation (external)

Rail vehicles are subject to very strict standards for safety and durability. Externally mounted HMI components and systems are frequently required to meet the IP69K standard (see previous sections). Transport vehicles will be typically cleaned down with high pressure water jets from all angles therefore IP67 switches are recommended at a minimum.

Lifting and Moving

Building, maintenance and agricultural machinery will be subject to aggressively polluted environments when in use and in clean-down situations. Typical applications require IP67 or even higher for external use, although IP65 might be suitable for interior applications such as cab controls. HMI components with stainless steel lenses and front bezels may be appropriate where there is high risk of damage.

Marine

Most marine applications demand a minimum IP67 for external HMI components due to the risk of immersion. Consideration of the choice of material and its resistance to saltwater corrosion is very important; an additional rubber seal might be desirable.

Oil Refineries

Due to the risk of explosion, components must be specified for that use and must be intrinsically safe. They should be tested as explosion proof, which is not classified within IP ratings.

Overcoming Problems of Sealing HMI Components

Using inappropriately rated switches poses a danger to machines and their operators. Liquids can act as a conductor of electricity, as can fine dust particles. Short-circuiting is a common problem

Fig. 1 - Typical EAO Switch Design



when ingress penetrates the seal and travels to the PCBs.

Dust and liquids in the switching element can affect how the contacts behave - see Fig. 1 - Typical Switch Design. Solids larger than dust can damage a switch when it gets into the contacts, chiefly by preventing the switch from opening and closing. Liquids can corrode both the contacts and the wiring.

Abrasion and corrosion to the contact material can lead to excessive arcing and welding. Arcing is a discharge of elec-

tricity – a spark – that can occur when contacts make or break. Welding occurs when contact material melts and fuses, causing contacts to stick. Both of these will reduce a switch's service life.

Intermittent faults may develop as these particles move around inside the enclosure. Particularly difficult and costly to diagnose, they result in increased equipment downtime or even the complete disruption of a service. For instance, a switch that fails on a passenger train can take the entire vehicle out of service until the fault is diagnosed and fixed. Good product design and the correct materials can overcome such problems.

Product Design

Today's advanced switches, keypads and other HMI components are precisely crafted from high-grade plastics, metals, and carefully calibrated springs. They are engineered like fine watches to achieve reliable, long service lives and to minimise the need for replacement. High-quality switches are expected to have a mechanical life of between 1 to 10 million operations.

Environmental protection is extremely important to maintain such a long service life. Manufacturers such as EAO guarantee this by combining precision design with the highest grade materials. A typical switch is shown here in Fig. 1 - Typical Switch Design. The lens, front ring, actuator housing, seal, pressure ring and mounting flange are critical to the actuator's IP rating. All elements must be precisely engineered so they lock together tightly around the panel and prevent ingress from the front.

Unless otherwise stated, switches are normally only tested for protection from the front; switch elements are usually un-rated. Devices that possess an integrated

switch element, for instance EAO's Series 56 range, are environmentally sealed at the front and the rear - IP67 and IP65 respectively.

Additional protection of switch elements is also possible by using accessories. For example, an EAO series 84 can achieve IP67 at the rear when fitted with rubber plugs. Where front and rear sealing is important, always check with the manufacturer.

Although switch elements are not sealed, self-cleaning contacts can help them maintain optimal performance if they are ever penetrated by dirt. Self-cleaning contacts slide against each other when making or breaking a circuit, removing contamination to keep contact resistance low. Switches for higher currents use gold-plated silver or all silver contacts that resist the effects of arcing. Minor periodic arcing with silver contacts is actually beneficial because it keeps contacts free from dirt and corrosion.

Most Appropriate Materials

To address the ergonomic risks associated with environmentally harsh applications it is wise to consider stainless steel

and durable polymer-based products that operate reliably under demanding conditions. Where required, control products fabricated from these materials offer protection up to IP67 as well as resistance to heat, shock, vibration, and vandalism.

Correct Technical Data

The IP ratings system is detailed, but on closer examination there are some subjective values, like low pressure and high pressure, that might require further clarification from the manufacturer. For example, EAO publishes the rate of water flow for IPx5 as 12.5 litres per minute and IPx6 as 100 litres per minute without any harmful ingress.

Published data should be a minimum standard based on thorough testing in environmental test chambers. Further information should be freely available where required, as is the case for IP68 where the duration and depth of immersion might be critical to the application's use.

Unless otherwise stated, the ratings should be published for the standard product without any modification or use of additional seals and covers.

Conclusion

Understanding how the NEMA and IP Ratings system work is critical to avoiding danger to people and internal system vulnerabilities. A system is only as strong as its weakest link. Selection of the correct component for the application is crucial to avoid failure and costly downtime.

Protection ratings are very helpful for making cost-effective decisions when investing in components - why specify for an HMI device that will resist high-pressure jet washing if it will never be used in dirty environments?

It should be noted that neither system is intended to be a product standard. Product standards may encompass other environmental tests for heat, vibration, etc. Individual HMI devices will be subject to the end product standard.

Chart 1 - IP Ratings Chart?

Protection against touching live parts or ingress of solid objects		Protection against ingress of liquids		Protection against mechanical impacts	
IP	First Figure	Second Figure	IP	Third Figure	IK
No Protection.	0 	0	No Protection.	0 	No Protection.
Touching by hand or 50mm dia objects.	1 	1	Vertical water droplets. No harmful ingress.	1 	Impact 0.225 joule.
Touching by finger or 12mm dia objects.	2 	2	Showering at 15° from the vertical. No harmful ingress.	2 	Impact 0.375 joule.
Touching by tools or wire 2.5mm dia or 2.5mm dia objects.	3 	3	Showering at 60° from the vertical. No harmful ingress.	3 	Impact 0.50 joule.
Touching by tools or wire 1mm dia or 1mm dia objects.	4 	4	Splashing from any direction. No harmful ingress.	4 	Impact 2.00 joule.
Total touch protection or no harmful ingress of dust.	5 	5	Water jets from any direction 12.5 l/min. No harmful ingress.	5 	Impact 6.00 joule.
Total touch protection or no ingress of dust.	6 	6	Large volumes of water 100 l/min. No ingress.	6 	Impact 20.00 joule.
		7	Immersion up to 1 metre deep. No ingress.		
		8	Submersion at specified depths exceeding 1 metre. No ingress.		

Standards Organisations

IEC – International Electrotechnical Commission, publishes international standards for all electrical, electronic, and related technologies.

<http://www.iec.ch>

NEMA – National Electrical Manufacturers Association, a U.S. trade association sets ratings for environmental sealing.

<http://www.nema.org>

An informative FAQs document

has been produced by NEMA

and is available here: <http://www.nema.org/search/results-search.cfm?query=IP+ratings&submit=GO>

UL – Underwriters Laboratories. Chiefly dealing with product safety, UL develops standards and test procedures for components, materials, assemblies, tools.

<http://www.ul.com>

References

1. IEC 60259(ed2.1, 2001), clause 4.1.
2. IEC 60259(ed2.1, 2001), clause 5,6.
3. British European Standard BS EN 62262 was first defined in by BS EN 50102:1995. Following its adoption as an international standard by IEC 62262 in 2002, the standard was renumbered EN 622624.
4. http://en.wikipedia.org/wiki/ip_code
5. Details of all the tests are published in NEMA 250 and can be purchased from the NEMA website (<http://www.nema.org/stds/250.cfm>).
6. www.nema.org/stds/whitepapers/upload/briefcomparison-250-60529.pdf
7. IP Chart as it appears in the EAO main product catalogue 2007, page 39.

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