Sealing of Industrial Trackballs

With the enormous increase of computer usage in industrial control, medical and point of information applications the need for Trackballs to be sealed against ingress of foreign particles and liquids has never been greater.

Understanding the sealing capabilities is fundamental to the successful operation of any Trackball product in its target application. This document describes the nomenclature associated with the applicable standards and goes on to describe the principles of the seals employed in Pretorian Technologies Trackballs.

1. Applicable Standards

There are two important standards which describe a system for classifying the degree of protection of equipment. The applicable European standard is IEC 60529 (also BS 5490 in UK) and was developed by CENELEC (European Committee for Electro-technical Standardisation).

The American standard is publication number 250-1997 “Enclosures for Electrical Equipment (1000 Volts maximum)” developed by NEMA (National Electrical Manufacturers Association).

IEC 60529 salient points

This standard differentiates between particulate and liquid ingress and assigns a different rating for each. A third rating applies to the equipment’s ability to withstand loads and shocks but is rarely used.

The overall rating for a piece of equipment is quoted as follows:

IPxy

Where:

x is a numeral specifying the degree of protection against particulates.

y is a numeral specifying the degree of protection against liquids.

For example, IP45 defines a piece of equipment which is protected against solid objects greater than 1mm and water jets.

Tables 1 and 2 list the valid numerals for x and y and give details of the level of protection provided by each. Note that compliance with a particular level of protection also implies compliance with all lower degrees of protection.

Numeral	Description	Definition
0	Non-protected	No special protection
1	Protected against solid objects > 50mm	A probe of 50mm diameter shall not penetrate the equipment.
2	Protected against solid objects > 12mm	A probe of 12mm diameter shall not penetrate the equipment.
3	Protected against solid objects > 2.5mm	A probe of 2.5mm diameter shall not penetrate the equipment.
4	Protected against solid objects > 1.0mm	A probe of 1.0mm diameter shall not penetrate the equipment.
5	Dust protected	Ingress of dust is not totally prevented but does not enter in sufficient quantity to interfere with satisfactory operation.
6	Dust-tight	No ingress of dust.

Table 1: Levels of protection against particulate ingress

Numeral	Description	Definition
0	Non-protected	No special protection.
1	Protected against dripping water	Vertically falling drops of water shall have no harmful effect on equipment.
2	Protected against dripping water when tilted at an angle of 15º	Vertically falling drops of water shall have no harmful effect on equipment when equipment tilted to 15º.
3	Protected against spraying water	Water falling as a spray at angles up to 60º from the vertical shall have no effect on the equipment.
4	Protected against splashing water	Water splashed at the equipment in any direction shall have no effect.
5	Protected against water jets	Water projected from a nozzle against the enclosure from any direction shall have no effect.
6	Protected against heavy seas	Water from heavy seas or from powerful jets shall not enter the equipment in harmful quantities.
7	Protection against the effects of immersion	Ingress of water in harmful quantities shall not be possible when immersed for a limited time at limited depth.
8	Protected against immersion	The equipment is suitable for continuous submersion in water under manufacturer's specified conditions.

Table 2: Levels of protection against liquid ingress

1.1 NEMA 250-1997 salient points

The NEMA 250-1997 classifications are fundamentally different to those defined by IEC since they include aspects relating to corrosion and the effect of contaminants such as lubricants, propellants and coolants. Furthermore, the various aspects are not rated individually as with IEC, but are instead grouped into a single rating.

Table 3 gives brief descriptions of the levels of protection defined by NEMA:

It can be seen from Table 3 that it cannot be assumed that successively higher NEMA rating numbers describe higher levels of protection. Also, not all NEMA ratings have been listed in Table 3 since some are not applicable to this application.

Table 4 summarises the NEMA ratings:

Numeral	Description	Definition
NEMA 1	General Purpose	Indoor enclosures- prevents accidental contact of personnel with the enclosed equipment and provides a degree of protection against falling dirt.
NEMA 2	Drip Proof	As NEMA 1 but also provides a degree of protection against dripping or light splashing of liquids.
NEMA 3	Outdoor Use	As NEMA 2 but also provides a degree of protection against rain, sleet, snow or windblown dust. Equipment will be undamaged by the external formation of ice.
NEMA 3R	Outdoor Winter Use	As NEMA 3 but also provides full protection against accumulation of snow. Melting ice and snow will not cause damage.
NEMA 4	Water & Dust Tight	As NEMA 3R but also provides a degree of protection against splashing and hose-directed water.
NEMA 4X	Corrosion Resistant	As NEMA 4 but unaffected by severe external corrosion.
NEMA 5	Dust Proof	Prevents accidental contact of personnel with the enclosed equipment and provides a degree of protection against falling dirt, settling airborne dust, lint, fibres and insects. Also provides a degree of protection against dripping and light splashing of liquids.
NEMA 6	Limited submersion	As NEMA 4 but also provides a degree of protection against entry of water during occasional temporary immersion at a limited depth. Also undamaged by the external formation of ice
NEMA 6P	Immersible	As NEMA 6 but also provides a degree of protection against entry of water during prolonged immersion at a limited depth. Unaffected by severe external corrosion.
NEMA 12	Circulating Dust	Enclosures constructed for indoor use to prevent accidental contact of personnel with the enclosed equipment and to provide a degree of protection against falling dirt, circulating dust, lint fibres and insects and against dripping and light splashing of liquids. Also protected against oil and coolant seepage.

Table 3: NEMA ratings

Protection Aspect	1	2	3	3R	4	4X	5	6	6P	12
Incidental contact with enclosed equipment	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Falling dirt	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Falling liquids and light splashing		✓	✓	✓	✓	✓	✓	✓	✓	✓
Circulating dust, lint, fibres and insects			✓	✓	✓	✓		✓	✓	✓
Settling airborne dust, lint, fibres and insects			✓	✓	✓	✓	✓	✓	✓	✓
Hosedown and splashing water					✓	✓		✓	✓	
Oil and coolant seepage										✓
Corrosive agents						✓			✓	
Occasional temporary submersion								✓	✓	
Occasional prolonged submersion									✓	

Table 4: NEMA rating summary

1.2 Comparison between IEC and NEMA ratings

Because of the differences between the ratings it is difficult to determine exact equivalences. However, Table 5 lists broad equivalents:

NEMA rating	IEC rating
1	IP10
2	IP11
3	IP54
3R	IP14
4	IP56
5	IP52
6	IP67
6P	IP68
12	IP52

Table 5: NEMA/ IEC equivalents

2. Features incorporated into Pretorian Technologies Trackballs

Pretorian Technologies industrial Trackballs have been carefully designed to minimise the ingress of both particulate and liquid contamination. Units are available with both IP40 (NEMA 1) and IP65 (NEMA 4) ratings.

The IP40 versions are described as 'unsealed' and provide limited protection against particulate objects but no protection against liquid ingress. Units with this rating should be used in benign environments such as offices, homes and clean industrial environments.

The IP65 versions are sealed against ingress of both small particulates (i.e. dust) and water. Units with this rating may be used in harsh environments where contamination by foreign objects and liquids is expected. Typically such units are used in industrial, medical, high usage and public access applications.

The remainder of this section details some of the measures which have been taken to achieve the IP65 level of protection:

2.1 Self-adjusting Floating Seal

The most obvious area of ingress of both liquid and particles is via the gap between the ball and the body mouldings of the Trackball. Of course it is impossible to completely seal this interface and still allow free movement of the ball. Therefore any seal is a working compromise between ease of use and the degree of protection.

The Pretorian Technologies Trackballs use a self-adjusting seal which is manufactured to very high levels of roundness and concentricity, using special low-friction materials. This ensures that the lip of the seal is in contact with the ball surface around the entire circumference of the ball, whilst minimising the drag on the ball itself. This type of seal benefits from the thin deposit of grease on the ball surface which results from finger contact since this acts as a lubricant.

If the ball and seal were to become slightly eccentric the force exerted on the seal allows it to move relative to the ball until it is again concentric. This process continually adjusts the seal as the ball rotates and also compensates for any change in dimensions due to mechanical wear or temperature.

This type of seal is capable both of holding water and of scraping talcum powder off the surface of the ball. This allows us to give the unit an IP65 rating. However, it should be noted that

when the ball if rotated, any liquids which are present on the ball surface will tend to be carried into the mechanism, reducing the rating to IP54.

2.2 Ball skirt
On the underside of the unit a skirt arrangement ensures that if any foreign matter or liquid does breech the seal, it cannot contaminate the printed circuit board. Typically this might be a problem with water ingress trickling down the ball cavity and then leeching, by capillary action, under the circuit board and causing corrosion.

With the ball skirt in place, however, the water trickles down the inner face of the skirt and then drips off the unit, well away from the sensitive electronics.

2.3 Shaft housings
It is normal practice in Trackball assemblies to have a cylindrical area in the mouldings directly beneath the shaft assemblies and between the support bearings. This can form a lagoon, damming the water and causing seepage through the bearing saddles and into the area containing the opto-electronic devices. Again, this may lead to failure of the device due to electrical short circuit or corrosion.

Pretorian Technologies includes a drainage feature which allows any water trapped in these areas to leak away down the sides of the ball cavity and to drip off the ball skirt. Figure 3 shows the detail of this feature.

2.4 Sealing gasket
All IP65 rated units are provided with a gasket to allow the unit to be sealed against the panel to which it is mounted. The gasket is manufactured from a closed-cell material which prevents seepage due to capillary action. This ensures that any water which spills between the ball surround and the seal cannot enter the enclosure.

3. Common Contaminants
Because of the typical applications in which Trackballs are used, there are a number of contaminants which are commonplace. Some of these are listed in this section:

3.1 Ultrasound gel
This aqueous based gel is used by the medical profession to create a suitable path between the ultrasonic probe and the human body. It is very common for some of this gel to be transferred to the ball and in turn onto the shaft assemblies.

Initially this causes a problem of slippage between the ball and shafts since the gel is a lubricant. Longer term the water content evaporates off and leaves a flaky residue which detaches from the shaft and ball surfaces.

Because the gel clings to the ball surface, an IP65 seal is of limited use in preventing ingress into the mechanism. Whilst most of the gel is removed by the seal, some remains on the ball and in time may cause problems.

3.2 Fibrous material
This type of contamination is typical of high-usage and public access applications and is usually caused by

fibres from clothing falling onto the unit, although debris is often found to include hairs.

An IP65 seal is effective in preventing this type of contamination and it is therefore not recommended to install IP40 units in such applications.

3.3 Beverages
Again, this type of contamination is commonplace in high-usage and public access applications and may be inadvertent or malicious. The worst types of beverage include coffee and cola due to their corrosive effects and sticky deposits.

In all cases the IP65 seal in conjunction with the ball skirt is sufficient to prevent any damage. However, the ball surface may become sticky, degrading the overall performance of the Trackball.