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Load Cells and Weigh Modules | Technical Note VPGFS-04

Environmental Conditions

Scope

Most of the process industries rely heavily upon strain gage based load cells for accurate and consistent weight data and expect them to perform under a wide range of adverse conditions, including mechanical and chemical attack.

The problem is that premature failure of load cells can have far reaching effects on the overall processes, and have a consequent impact on cost, safety and product reputation. Replacing a load cell in the field will involve not only the cost of the component itself, but also the expenses associated with labor, downtime and re-calibration.

There are several factors that can cause load cell failure, one of the most important is the environment. This Technical Note takes a look at the effects the environment can have on load cells and offers guidelines on how to minimize these effects through proper selection and application. In addition, existing load cell classification standards are overviewed.

Classification Standards

No area of load cell operation causes more confusion and contention than that of environmental protection and sealing standards. Although the weighing and load cell industries have in-depth standards and test procedures to define load cell and weighing system performance, no standards have been developed to cover product suitability for specific environmental conditions.

In the absence of such standards, most manufacturers have adopted the IP classification (Ingress Protection by IEC/EN60.529 or DIN 40.050) or National Electrical Manufacturers Association Standards (NEMA) Publication 250 classifications to define the level of sealing for their products. Both standards are good test procedures for environmental sealing when applied to the products for which they were intended — those being electrical enclosures, but they are not very well suited to load cells.

IP Classification

- Protection of persons against access to hazardous parts inside the enclosure.
- Protection of the equipment inside the enclosure against the ingress of solid foreign objects.
- Protection of equipment inside the enclosure against harmful effects due to the ingress of water.

The IP code consists of five categories or brackets identified by a number or letter that indicate the degree of some element to the standard. The first characteristic number relates to access to the hazardous part by persons or solid foreign objects. A number from 0 to 6 defines the physical size of the accessing object.

Numbers 1 and 2 relate to solid objects and parts of the human anatomy, while 3 to 6 relate to solid objects such as tools, wire and dust particles. As shown in the accompanying table on the next page, the higher the number, the smaller the accessing object.

Most load cell manufacturers use the number 6 for this category to signify that their products are dust tight. However the effectiveness of this classification depends on what constitutes an enclosure. Of particular significance here are load cells of a more open nature, such as single point cells, where the introduction of a tool, such as a screwdriver, could have catastrophic results even though the load cells are dust tight with regard to the critical components.

The second characteristic number relates to the entrance of water with what is described as harmful effects. Unfortunately, the standard does not define harmful. Presumably, for electrical enclosures, the main problem with water could be one of electrical shock to persons in contact with the enclosures, rather than the malfunctioning of the unit. The characteristic describes conditions ranging from vertically dripping water, through spraying and jetting, to continuous immersion.

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IP First Number Protection Against Solid Objects		IP Second Number Protection Against Liquids	
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 the vertical
3	Protected against solid objects more than 2.5 mm e.g., tools and small wires	3	Protected against direct sprays of water up to 60° from the vertical
4	Protected against solid objects more than 1 mm e.g., small wires	4	Protected against water sprayed from all directions, limited entrance allowed
5	Protected against dust-limited entrance (no harmful deposit)	5	Protected against low pressure jets of water from all directions, limited entrance allowed
6	Totally protected against dust	6	Protected against strong jets of water e.g., for use on ship decks, limited entrance allowed
		7	Protected against the effects of immersion between 15 cm and 1 m
		8	Protected against long periods of immersion under pressure

Load cell manufacturers usually adopt either the 7 or the 8 designation for their products. However the standard clearly states that "An enclosure designated with a second characteristic number 7 or 8 is considered unsuitable for exposure to water jets (designated by the second characteristic 5 or 6) and need not comply with requirements for number 5 or 6 unless it is dual coded, e.g., IP66/IP68". In other words, under certain conditions and for certain product designs, a product that passed a half-hour immersion test may not necessarily pass one that involves high pressure water jets from all angles.

As with IP66 and IP67, IP68 conditions are set by the manufacturer of the product, but must be at minimum more severe than for IP67 (i.e., longer duration or greater depth of immersion). The requirements for IP67 are that the enclosure can withstand immersion to a maximum depth of 1 meter for 30 minutes.

While the IP standard is an acceptable starting point there are shortcomings:

- The IP definition of enclosure is too loose to be meaningful for load cells.
- The IP system only relates to water entrance and ignores moisture, chemicals etc.
- The IP system can not differentiate between load cells with different constructions with the same IP rating.
- No definition is given for the term "harmful effects", so the effect on load cell performance is open to interpretation.

NEMA Classification

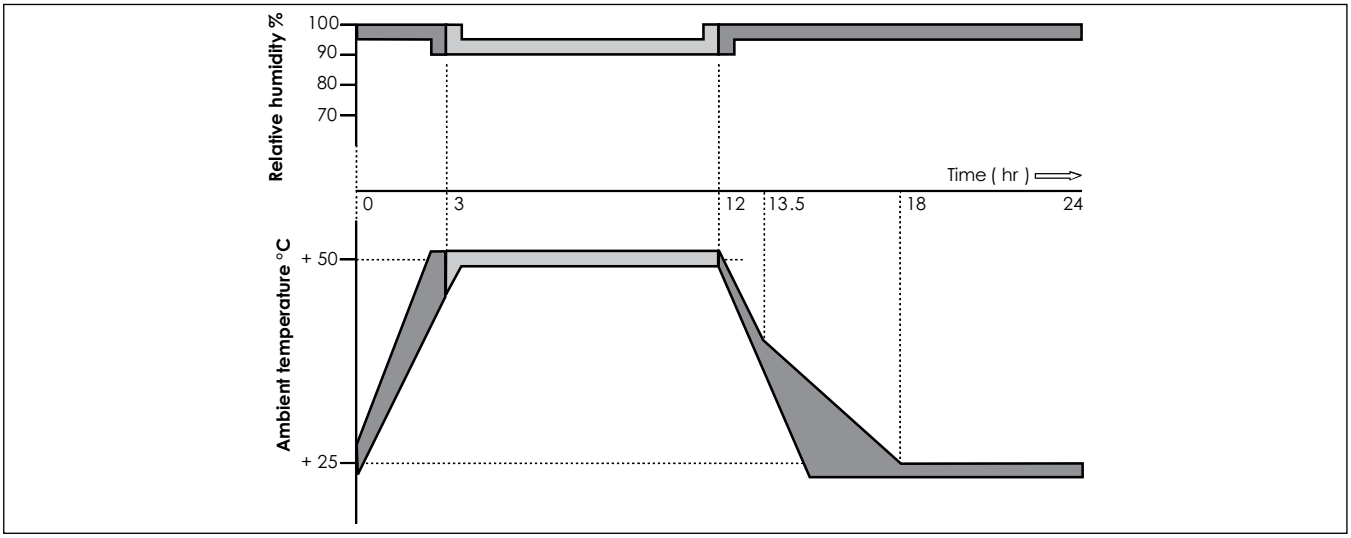
Classifications in the NEMA system run from NEMA 1 to NEMA 12, but load cell manufacturers concern themselves with NEMA 4 and NEMA 6. Unlike the IP system, NEMA does concern itself with environmental conditions such as corrosion, rust, icing, oil and coolants.

NEMA 4 enclosures are intended for indoor and outdoor use, and provide a degree of protection against windblown dust and rain, splashing water, and hose directed water. However, no consideration is given for the effects of internal condensation. NEMA 4X enclosures meet the same standards as NEMA 4 and are constructed of 304 stainless steel or other material offering equal corrosion resistance.

NEMA 6 enclosures are used where there is a chance of temporary immersion. The standard calls for the highest part of the enclosure to remain submerged in water, with its highest point 1.83 metres below the surface for 30 minutes. NEMA 6P enclosures are used where prolonged immersion may occur and resistance to corrosion is needed.

While it may seem that NEMA standards offer some advantages over the IP system for corrosion resistance, they only relate to external corrosion of enclosures. This is very limited when applied to the more complex load cell construction and the different effects of corrosion

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or water. Also, neither system concerns itself with internal condensation or the subject of cable entry into the enclosures.

Damp Heat Cycling

The IP standard clearly states that it does not deal with internal condensation or moisture within the enclosure, saying that this is the responsibility of the relevant product standard. However, moisture or condensation is of vital importance in load cell operation.

Moisture may enter the inside of the load cell over a long period and have a catastrophic effect, especially when acids or alkalis are present. One test used to determine a load cells ability to withstand moisture or condensation is the Damp Heat Cycling Test. Although there are several versions of the test, the one most universally accepted is (IEC) 68-2-30. The object of the IEC standard is "To determine the suitability of components, equipment, or other articles for use and storage under conditions of high humidity when combined with cyclical temperature changes".

It is obvious that this standard is a much more useful classification than the IP rating when it comes to defining load cell environmental suitability.

Load cells certified to OIML R-60 are tested to withstand 12 damp heat cycles of 24 hours each. Load cells which are not suited to withstand this test should be marked with "NH" (non-humidity) behind the appropriate accuracy grade.

Load Cell Construction

Besides a given IP-rating or NEMA-classification load cells should also be classified according to their design in terms of cable entry, material of construction and gages sealing method. Load cells can be divided into six main groups in terms of sealing:

1	Open	IP64	The gages have a minimum basic coating, but no formal potting
2	Potted	IP65	Critical areas are covered with potting compound, but no mechanical protection
3	Enclosed	IP67	Critical areas are fully potted and mechanically protected with rubber bellows or side plates; have standard cable entry
4	Enclosed	IP66/IP67	Critical areas (are potted) and protected with welded covers (bellows, cups, etc.); have standard cable entry
5	Enclosed	IP66/IP68	Critical areas (are potted) and protected with welded covers and have water block cable entry
6	Hermetically Sealed	IP66/IP68	Critical areas (are potted) and protected with welded covers and have glass to metal sealed cable entry

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Whether or not the products 4 to 5 in the above listing meet the IP66 classification may depend upon how the load cells are used and whether additional mechanical protection is provided. In parallel with these six classifications, different load cells are constructed from different materials. The main ones are aluminium; copper beryllium; tool steel-painted; tool steel-nickel plated or stainless steel. Certain products may be a combination of these e.g., tool steel-nickel plated body with stainless steel bellows or cups.

The Cable Entry

While it is relatively common to weld-seal critical areas on a load cell body, one potential problem area is the cable entry. A variety of methods are used to make sure cells are properly sealed at this point.

1) In some load cells the main cable enters through a conventional cable gland directly into the gage area. Regardless of how well the gage area is sealed, however moisture and solvents can penetrate either around the gland or through the centre of the cable itself. Often, temperature changes cause a pumping action to occur, pushing moisture down the inside of the cable. Entry also can be via a leaking junction box or through a damaged part of the cable. This can take some time to reach critical areas, but once there it will become sealed in place to do its damage.
2) An improvement on the cable gland is a water block at the point of cable entry. Here, the main cable terminates at for example a small circuit board with on-going wires leading to the gage area. The block is fully potted to prevent moisture or other contaminants from reaching the critical areas.
3) The best solution is the use of a glass-to-metal cable entrance. This prevents any contamination from reaching the gage or other critical areas. In addition, the manufacturing process used must keep the load cell free from residue contaminations. The problem of residuals is usually solved by purging the internal cavity with helium. VPG Transducers model RLC is first filled with helium, which allows leaks to be found with conventional leak detection equipment and just before closing the load cell the helium will be replace by argon.

Corrosion Resistance

The corrosion resistance of load cells is a very complex subject, one that is further complicated by the variety of available configurations. As a result it is only possible to use standard corrosion charts as guidance for load cells. In addition, the following factors must be considered:

- Surface finish
- Weld areas around seals, bellows and cups
- Thickness of seals
- Varying construction materials
- High stress levels at loading points

The environment itself plays a large part in how a particular load cell type behaves in practice. Salt water, for example, has different corrosion effects depending on the local circumstances. Stainless steel in stagnant salt water is subject to crevice corrosion and a regular wash down is necessary to avoid degradation.

Unfortunately the term stainless steel has become synonymous with "no corrosion, no problem and no maintenance". While stainless steel load cells usually offer optimum protection in most environments, other factors should be taken into account. In certain applications, painted or plated load cells may offer better long-term protection.

Additional Coatings

Protective coatings are the oldest and most widely used method of corrosion control. Special paints are often used after installation to protect load cells and mounting hardware. However, the effectiveness of these is dependant upon initial surface preparation as well as the specific environment (care should be exercised when preparing the surface to prevent any damage to the load cell itself; if in doubt, please contact our manufacturing operation):

- One that provides an inert barrier against attack (paint)
- One that provides reactive (galvanic) protection, such as cadmium plating

An alternative is wrap-around protective covers. These can provide good environmental protection, but can be self-destructive if corrosive material is trapped inside the cover. Paint or plating can not always protect the load application point on certain load cell designs.

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The suitability of any paint-like protective coating should be checked with the end-user of the load cell as well as the supplier of the coating. The influence on accuracy after coating is usually negligible small, but the coating must be "flexible" enough to withstand the deflection of the load cell. Very suitable flexible coatings with an excellent resistance to most harsh environments can often be found at a car-shop.

Preventative Maintenance

Preventative maintenance is often overlooked or ignored by both load cell users and service companies. However, the regular service and maintenance of load cells in a weighing system will greatly improve their long-term reliability and performance as well as greatly reduce their sensitivity to corrosion. Maintenance inspections can be divided into two categories:

- Routine: Performed at periodic intervals, it includes the removal of any material or debris build-up from around the load cells and mounting fixtures. Serious damage can occur to the load cells if mounting systems do not function correctly. Any damage or degradation of surface coatings should be remedied and all cables and junction-boxes should be checked. To minimize the effects of flooding, any drainage systems in the pit should be free from debris. Where required, regular wash down of the load cell should be carried out to prevent chemical attack.
- Ad hoc: Made immediately after any adverse or unexpected events such as flash floods, gales, seismic activity or electrical storms.

In general, careful consideration must be given to any reason for failure. If this has occurred as a result of ingress of water or chemicals, then continued deterioration of any other load cell(s) in the system can be expected, resulting in mechanical failure. This failure can have serious safety and cost consequences.

The chart on the right should only be used as guidance. Acids, bases and salts in a solution of water. More information about specific substances is available on request. Resistance designation:

0 Not affected
1 Slightly affected, additional protection recommended
2 Severely affected, additional protection necessary
3 Not applicable

Corrosion Chart

	con (%)	T (°C)	1.4542 1.4301	1.4403 1.4568
H_2O_4 (sulfuric acid)	0.0	60	0	0
	1	20	1	0
	2	60	1	0
	5	35	2	1
	10	20	1	0
	20	20	1	0
	20	35	2	2
	25	25	1	2
	40	20	2	1
	>40	>20	3	3
HCl (hydrogen chloride)	0.2	20	1	0
	0.2	50	2	0
	1	20	2	0
	2	20	1	1
	>2	>20	3	3
HNO_3 (nitric acid)	50	65	0	0
	60	20	0	0
	60	Boil	1	1
	65	Boil	2	2
	>90	Boil	3	3
H_3PO_4 (phosphoric acid)	30	102	0	0
	50	108	1	0
	50	Boil	2	1
	60	20	0	0
	60	Boil	3	3
	80	20	1	0
	80	Boil	3	3
CH_3-COOH	10	20	0	0
	10	Boil	1	0
	80	20	0	0
	80	Boil	2	1
HCOOH (formic acid)	10	20	1	0
	10	Boil	2	1
	40	65	2	0
H_2CO_3	<100	<Boil	0	0

Chart continues next page

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Corrosion Chart (cont.)

	con (%)	T (°C)	1.4542 1.4301	1.4403 1.4568
NaOH (sodium hydroxide)	25	Boil	0	0
	30	Boil	2	0
	34	20	0	0
	34	Boil	2	2
	50	20	1	1
	60	Boil	3	3
$Ca(OH)_2$	<100	<Boil	0	0
NH_4OH	<100	<Boil	0	0
$NaNO_3$	<100	<Boil	0	0
NA_2CO_3	<100	20	0	0
	100	820	3	3
NaCl (sodium chloride)	<100	30	0	0
	100	>30	2	0
NH_4Cl	10	20	0	0
	10	Boil	1	0
	25	20	1	0
	25	Boil	2	1
$(NH_4)_2SO_4$ (ammonium sulfate)	5	20	0	0
	10	20	1	0
	10	Boil	2	0
$FeCl_2$	10	25	0	0
$FeCl_3$	1	20	2	1
	5	20	3	3
K_2CO_3	30	65	0	0
HBr/HF			3	3
Acetone	100	<Boil	0	0
Ether	100	<Boil	0	0

Conclusion

Selecting the wrong load cell for a particular application in terms of environmental compatibility can have far reaching consequences in terms of costs, safety and product reputation. Current classifications fall well short of defining adequate environmental standards for load cells. As a result, this subject needs careful review by both load cell users and manufacturers to ensure that clear guidelines are available.

Users should be able to compare like-for-like features when selecting products from different manufacturers. If in doubt, they should ask pertinent questions relating to:

- Construction of the load cell
- Cable entry method
- Past experiences (long-term environmental success stories)

For applications in harsh environments, additional protection for the load cells may be needed to assure their reasonable working life. This can be achieved with enhanced scale designs and the use of additional coatings on the load cell, such as paints, greases and plating. The scale or system design should minimize the possibility of material build-up around the cells. If appropriate, the design should also provide mechanical protection from the effects of direct water and solvents whilst cleaning. Sealing compounds and rubbers used on some load cells can deteriorate when exposed to chemicals or direct sunlight. Because they embrittle rubber, chlorine-based compounds are a particular problem.

Load cells correctly selected and regularly maintained should be capable of a working life in excess of ten years. There are always exceptions, but the engineer needs to be able to obtain the optimum performance out of his or her selected load cells.