Selecting Pneumatic Valve Actuators in Corrosive Environments

Overview

Many process industries are challenged with corrosion problems. Whether it be from salty humid air near the coast, or from process chemicals in use at the facility, or from sanitary washdown of equipment using corrosive chemicals, it is a constant struggle to keep equipment in good condition. Corrosion is one of the leading causes of premature equipment failure and unplanned downtime. This is true for any metal equipment, but particularly for valves and actuators, because they are mechanical devices that need not only to survive the elements, but also to perform their intended function without failure.

Proper actuator selection can offer significant cost savings over the life of an automated valve package by reducing the need for premature actuator replacement. Our survey of over 100 industry experts indicated that 40% of actuator replacements or refurbishments are required due to corrosion. Also, the actuator outlasts the valve only 50% of the time, meaning that up to 20% the time it is corrosion of the actuator that is putting the valve out of service.

This paper will discuss how to specify actuators that will overcome corrosion challenges and increase the mean time between failures. We will identify the most common pain points for valve actuation in a corrosive environment, identify cost-effective solutions to prevent corrosion, and show that selecting an actuator with corrosion resistant features can reduce long-term cost of ownership by 50%.

Specifying Corrosion Resistance

The most common way of specifying corrosion resistance when selecting an actuator is to use an industry standard.

Our survey of industry experts recommended using either a salt spray test life expectancy or the corrosion categories in ISO 12944 as a guideline for selecting actuator coatings and materials. While this standard is specific to steel and zinc construction, you should consider similar salt spray test requirements when selecting aluminum actuators. Testing in a salt spray chamber in accordance with ASTM B117 gives a good indication of the actuator life expectancy in a corrosive environment. For actuators, steel or aluminum, Emerson recommends selecting an actuator that exceeds the salt spray test requirements for the 5 to 15 years life expectancy in ISO 12944.

Table 1.

Climate Exposure	Chemical Exposure	Corresponding ISO 12944 corrosion category	Salt Spray Testing (Method ASTM B117)	
			ISO 12944 Minimum for 5-15 years life expectancy	Emerson Benchmark for Actuation
Away from coast, outdoors or indoors Climate controlled buildings	Low exposure to corrosive chemicals Some humidity or city air pollution	C3	240 hours	500 hours
Outdoors 10 - 75 miles from coast Sheltered (non-climate controlled) at the coast	Chemical plants, process facilities, or other areas that have low or moderate risk of chemical attack	C4	480 hours	750 hours
Outdoors within 10 miles of the coast High relative Humidity and/or salt exposure	Areas with high contamination levels Use of caustic or acidic solutions in the process or for equipment wash-down	C5	720 hours	1000 hours

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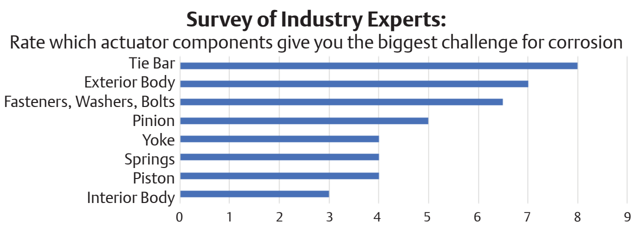
Corrosion Pain Points

In our survey, industry experts were asked to indicate which actuator components give them the biggest corrosion problems. The leading concern was corrosion around the tie bar (on scotch yoke actuators), but other leading concerns included fasteners, exterior body, and pinions (on rack and pinion actuators). The results of the survey are shown below.

Figure 1.



Minimize Corrosion on the Exterior of the Actuator (Scotch Yoke)

Problem: External tie bars on a scotch yoke actuator are surrounded by tight spaces that are difficult to coat and difficult to inspect, so the opportunities to experience corrosion are high. These tie bars are also critical in maintaining the integrity of spring-loaded actuator. A failure of the tie rods could lead to a major safety incident!

Recommended Solutions: First, where possible, eliminate the external tie bars! There are scotch yoke actuators on the market, such as the Bettis G Series, which are designed for safe operation without external tie bars. If this is not possible, then consider the materials and coatings used on the external tie bars. Xylan-coated bolts can also be used for extra corrosion protection and several manufacturers offer tie bars constructed from stainless steel. When stainless steel tie bars are not an option, then coatings and inspections become critical. Consider including a statement in your actuator specification that if external tie rods are used, the manufacturer must demonstrate that failure of any two bolts/bars shall not endanger personnel.

Minimize Corrosion on the Exterior of the Actuator (Rack and Pinion)

Problem: Rack and pinion actuators typically have aluminum bodies with some components made of steel. These materials will corrode over time if they are exposed to the elements without a sufficiently designed coating. Exterior corrosion of the actuator can lead to a wide variety of problems. In worst cases, severe degradation of the body can lead to catastrophic pressure failure when the material thickness of the body wall is no longer sufficient for pressure containing equipment. In other cases, corrosion near the pinion top or bottom can lead to a leaking seal, or corrosion of the end cap bolts can loosen the connection and lead to dangerous conditions under spring load.

Recommended Solution: The life of the actuator can be significantly extended by selecting appropriate materials and coatings. For example, the EL-O-Matic brand of actuators is well regarded for offering high quality powder coating over high grade chromated aluminum as a default offering. This combination yields excellent life expectancy. It is not uncommon to find EL-O-Matic actuators in service greater than 25 years after installation, while actuators with a lower corrosion resistance may typically last less than 5 years in an industrial environment. The following items will ensure long life of the actuator exterior:

- Pre-treatment – Anodization / Chromating / Degreasing:
  - Actuator bodies made of aluminum should be anodized or chromated to improve the lifespan and reduce excessive oxidation. Anodizing layer thickness should be 5 - 15 microns. These treatments also create better surface adhesion for a powder coat layer. Ensure your actuator supplier has a thorough de-greasing procedure prior to coating.

- Powder Coating:
  - After anodizing or chromating, an electrostatic powder coat of polyurethane or PTFE should be applied. The minimum paint thickness should be at least 60 microns, and the best coatings are typically 80 to 160 microns.
  - ASTM B117 defines requirements for salt spray testing. For applications where corrosion is a concern, select an actuator manufacturer that has performed testing and validated the salt spray life of the coating. For heavy duty applications, a salt test spray lifespan of >1000 hours will help ensure the actuator will survive with minimal corrosion.
- Special Coatings:
  - For advanced corrosion protection in extreme applications, some manufacturers offer special coatings. One example is the Hytork XL Series, which is available with an optional “Commando” finish. Field service has shown that the Commando actuators outperform other actuators in corrosive environments. A proprietary heat treatment with CG941 fluorpolymer impregnated in the body makes it nearly impervious to corrosion. The steel pinion is also fluorpolymer coated.
- Stainless Steel Body:
  - As an alternative to special coatings, there are actuators available with stainless steel bodies which provide excellent corrosion resistance. Examples include the Biffi Morin Series and Bettis M Series actuators. These solutions are great for offshore applications where aluminum material selection may not be acceptable.
- Bolts and Fasteners:
  - Ensure bolts and fasteners are constructed of at least grade A2 (good) or A4 (better) stainless steel.
  - Endcap bolt failures could potentially result in the ejection of a spring-loaded endcap, which is a significant safety issue. One unique solution is to not have endcap bolts at all. The Hytork XL Series utilizes a SAFEKEY system to attach the endcaps to the housing instead of bolts. If there are no bolts, they cannot corrode! The SAFEKEY system uses a flexible stainless-steel key in an internal machined keyway. Completely sealed with o-rings to prevent external contamination, the SAFEKEY system eliminates stress concentrations caused by point loading. It is stronger than conventional bolting and is impossible to remove when pressurized or with springs under tension. It is a proven means of eliminating potentially dangerous disassembly.
- Pinion Material Selection:
  - The actuator pinion is an internal component that sticks out of the top and bottom of the body. Selecting a pinion made of high-grade aluminum will go a long way toward eliminating corrosion concerns. Because an aluminum pinion is the same material as the actuator body, there is no risk of dissimilar metals corrosion.
  - It is common for pinions to be machined from carbon steel that is then plated with nickel or zinc via an electrolysis process. This plating somewhat improves the corrosion resistance of the pinion; however, the plating can wear thin or flake off at the gear teeth or at the top and bottom pinion bearing. This opens the door for rust to develop on the carbon steel pinion, which can further lead to gear tooth failure or leaking near the pinion top and bottom. Once the plating has worn, there is risk of dissimilar metals corrosion between the steel pinion and aluminum body.
  - Some manufacturers offer stainless steel pinions which are good for extremely corrosive environments, though this is often a more expensive option.

Minimize Corrosion on the Interior of the Actuator (Scotch Yoke and Rack and Pinion)

Problem: Using poor quality air as a power source can corrode the actuator from the inside. A corroded, broken spring cannot operate the valve when the fail-safe is required. This can lead to inappropriate material transfers, tank overfills, process upsets, or other critical safety incidents. A corroded pinion or gears may lock in position or break, leading to actuator failure. Additionally, if the pinion or gears push out of alignment due to corrosion, the actuator may also begin to leak across the seals.

Recommended Solutions:

- Ensuring input air quality:
  - Inlet air for the actuator should be filtered and regulated. The input air filter, 40 microns, should be installed in the air header to prevent water or dust from entering the actuator from the plant air system. Determine maximum flow and maximum allowable pressure drop at the maximum flow rate. Ensure that the pressure loss in the control system due to the filter does not exceed 5 psi.
  - Where corrosion is a concern, consider installing a re-breather. A re-breather directs the air exhausted during the spring stroke from one side of the piston to the other. This ensures that the air on both sides of the piston are fed with clean instrument air, rather than allowing the spring chamber to suck in humid, salty, dusty, or chemical-containing atmospheric air. The FieldQ brand of actuators is available with QC control modules that have this re-breather function as standard.
- Spring Material Selection:
  - Spring steel should have an electrophoretic finish to prevent corrosion. Corrosion of the spring will quickly end the life of an actuator. The springs must be phosphated and de-embrittled to ensure longevity of fatigue life.
- Treatment of internals of body and piston:
  - For good performance over a long period of time, internal exposed aluminum surfaces of the actuator should be chromated or anodized, at a minimum.
- Grease selection and application:
  - The grease lubricates the moving parts, ensures soft parts remain supple to seal properly, and prevents air and moisture from attacking the internal surfaces. Select a grease that is suitable for the temperatures to which the actuator will be exposed. This will ensure the grease performs its intended function efficiently. The actuator manufacturer should be able to provide a list of approved greases for chemical compatibility with soft parts like o-rings and gaskets. Grease should be applied liberally during actuator assembly and reconfiguration.

Conclusions

Pneumatic actuator life can be extended by selecting the best materials and coatings for the application. In corrosive environments (C5 Category), an actuator with high corrosion resistance (aluminum pinion, anodized and powder coated, and proven over 1000 hours in a salt spray test) can be expected to last over 15 years in the plant. Under the same conditions, a cheap actuator with low corrosion resistance (carbon steel pinion, anodized only, and proven to 250 hours in a salt spray test) may only last three years.

See examples on next page.

While the low-cost actuator saves money on the initial installation, you can reduce long-term cost-of-ownership by over 50% by investing in actuators with higher corrosion resistance. This becomes especially true with larger, more expensive size actuators.

Table 2.

	Rack and Pinion Actuator Double Acting, 5.5 barg (80 psig)	Cost of Initial Installation	Cost of Maintenance (every 5 years)	Cost of Replacement (every 3 years)	30-Year Cost of Ownership, per Actuator
Actuator with AL Pinion and 1000 hr salt spray life	Small Actuator <100 Nm (<885 in-lb)	$377	$127	N/A	$1,262
	Medium Actuator 100-750 Nm (885-6640 in-lb)	$802	$193		$2,378
	Large Actuator >750 Nm (>6640 in-lb)	$3,111	$487		$8,170
Actuator with CS Pinion and 250 hr salt spray life	Small Actuator <100 Nm (<885 in-lb)	$290	N/A	$290	$3,286
	Medium Actuator 100-750 Nm (885-6640 in-lb)	$597		$597	$6,571
	Large Actuator >750 Nm (>6640 in-lb)	$2,246		$2,246	$24,703

In an example of a typical industrial plant with 100 actuators, investing in the corrosion resistant actuator features will have an annual savings of almost $34K. That's about half a million dollars over 30-year life of the plant!

Table 3.

	Rack and Pinion Actuator Double Acting, 5.5 barg (80 psig)	30-Year Cost of Ownership, per Actuator	Quantities in a Typical Process Plant with 100 Actuators	30-Year Cost of Ownership, per Actuator	Total Savings Over 30 Plant Life
Actuator with AL Pinion and 1000 hr salt spray life	Small Actuator <100 Nm (<885 in-lb)	$1,262	32	$40,384	$61,567
	Medium Actuator 100-750 Nm (885-6640 in-lb)	$2,378	55	$130,768	$230,647
	Large Actuator >750 Nm (>6640 in-lb)	$8,170	13	$106,210	$214,925
Actuator with CS Pinion and 250 hr salt spray life	Small Actuator <100 Nm (<885 in-lb)	$3,186	32	$101,951	N/A
	Medium Actuator 100-750 Nm (885-6640 in-lb)	$6,571	55	$361,415	
	Large Actuator >750 Nm (>6640 in-lb)	$24,703	13	$321,135	

Selecting actuation that can survive challenging high corrosion environments will save money and prevent plant downtime over the long run. As a leading supplier of pneumatic actuation, Emerson and our network of solution providers can help you select the right actuator to ensure the lowest long-term cost of ownership.

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