

Basics for electrohydraulics in corrosive environments

aggressive & explosive atmospheres, water-based fluids

The term "corrosive environments" for fluid power systems refers to environmental conditions in which following situations can separately or contemporary exist. They represent a potential cause of heavy corrosion for all components installed in the system.

- The surrounding atmosphere is so aggressive as to chemically attack the metal surfaces
- The operating fluid contains a high percentage of water to cause oxidation of the metal components in contact with the fluid itself

Corrosion is a natural process that converts metals into a chemically-stable forms such as oxide, hydroxide, or sulfide. It is the irreversible and progressive destruction of materials by chemical and/or electrochemical reaction with their environment.

It is the enemy of any metallic structure and component, being the very common cause of failure.

ATOS has developed a complete line of stainless steel components specifically designed to withstand aggressive atmospheres, ensuring performance and reliability of systems operating with water-based fluids like those of oil-based hydraulics.

X FULL STAINLESS STEEL with all parts made in stainless steel for complete protection to aggressive atmospheres and water-based fluids

XS EXTERNAL STAINLESS STEEL execution with only external parts made in stainless steel to provide the best surface protection to aggressive atmosphere in systems operated with standard mineral oils

XW INTERNAL STAINLESS STEEL execution with only internal parts made in stainless steel, specific for systems operated with water-based fluids

1 AGGRESSIVE ATMOSPHERES

Hydraulic systems are often located in outdoor areas, exposed to rain and atmospheric agents, or in coastal and marine environments. Such critical installations can lead to severe corrosion of the external surfaces, with the consequent risk of breakdowns or in extreme cases structural collapses, which entail higher maintenance costs.

Coastal and marine environments are the worst corrosive conditions for metals because of the quantity of sodium chloride (salt) present in the water and then in the air. The marine atmosphere also includes installations where splashing and heavy sea spray are encountered. The equipment exposed to these splash zones are indeed subjected to the worst conditions of intermittent immersion with wet and dry cycling of the corrosive agent.

However, the above environments are not the only ones prone to accelerated corrosion.

In highly industrial environments, contaminants in the air can contribute to corrosion. Emissions that come from factories, or power plants can potentially weaken the equipment. Gases like sulfur and nitrogen oxide that are emitted into the atmosphere in industrial locations, return in forms of condensation, such as acidic dew or acid rain.

Industrial dust particles can be contaminated with harmful metal oxides, chlorides, sulfates, sulfuric acid, carbon, and carbon compounds. These particles when combined with oxygen, water, or high humidity environments can be highly corrosive.

In applications with aggressive atmospheres, the use of Atos stainless steel valves **X** or **XS** is recommended

1.1 Aggressive & explosive atmospheres

In critical applications the aggressive and even potentially explosive atmospheres can coexist. For example in offshore drilling platforms and oil tankers, the saline environment is combined with the presence of highly flammable gases and vapors. For these reasons Atos solenoid operated stainless steel valves are equipped with ex-proof solenoids manufactured according to protection mode **ex-d** and certified to major international standards.

Following table summaries the main industrial sectors with relevant potential corrosive environments

	Sector	Potential cause of corrosion	Suggested Atos stainless steel execution
	Underground mines	Water-based fluids Explosive atmosphere may be present	X
	Oil refineries Power plants	Acid atmospheres Explosive atmosphere may be present	XS
	Steel industry, Die casting Light alloy casting	Water-based fluids, Pure water	X XW (1)
	Offshore & Marine	Salty atmospheres, Heavy sea water spray Explosive atmosphere may be present	XS
	Chemical industry	Acid atmospheres, Corrosive fluids Explosive atmosphere may be present	X
	Pharmaceutical industry Food processing	Pure water	X XW (1)

(1) XW can be used with water-based fluids or pure water, but only in absence of aggressive atmosphere.

1.2 Low temperature



Several hydraulic systems operate in northern areas or arctic regions with particularly cold environments. Even if the corrosion rate will be lower in a cold climate than in a temperate one, low temperatures are critical because they induce fragility in the materials and deterioration of the seals.

Atos stainless steel components **X** and **XS** are designed to operate in cold environments up to **-40°C**



For extreme conditions, option **BBT** for full stainless steel components type **X**, is available for ambient temperature up to **-60°C**

2 WATER-BASED FLUIDS

The use of water-based hydraulic fluids derives from two main requirements:

- To guarantee the safety against the risk of fire
- To reduce the degree of environment contamination in the event of accidental leaks



Safety against fire risk: hydraulic systems operate at high pressure levels, in case of accidental pipe breakages, the hydraulic fluid may ignite if coming in contact with hot surfaces.

In order to prevent risk of fire, industrial sectors like steel industry and light alloy casting, often use fire-resistant fluids instead of mineral oils.

Several types of fire-resistant fluids are existing in the market: synthetic types involve toxicological risk with consequent handling problems. For this reason, hydraulic water-based fluids are often preferred due to easy handling, the not toxic characteristics, and lower costs.

These fluids are available in different types depending on the water percentage which can reach up to 98% and they are largely used due to their fire-retardant properties.

Water-based hydraulic systems traditionally have been used in mining applications, in hot-metal areas of steel mill, die casting machines and light alloy foundries.



Eco-compatibility: the environmental impact has strongly influenced the solutions adopted in industrial plants and mobile machinery. Considering the costs associated with preventing and cleaning up environmental contamination, water-based hydraulic systems hold the potential for consistent cost savings.

Since water represents the main component in these fluids (90% or more), the hydraulic systems must be able to operate at low viscosity and must guarantee protection against oxidation by use of selected materials. In fact, despite corrosion protection additives are present in these fluids, materials made of steel, copper, zinc, aluminum, bronze, and brass alloys, as well as combinations of these materials have a higher corrosion tendency in presence of water.



Pure water: applications with severe eco-compatible requirements or production processes where the products must not be contaminated by any trace of oil or other substances, strongly require the use of pure water.

In applications with water-based fluids or pure water, the use of Atos stainless steel valves type **X** or **XW** is recommended

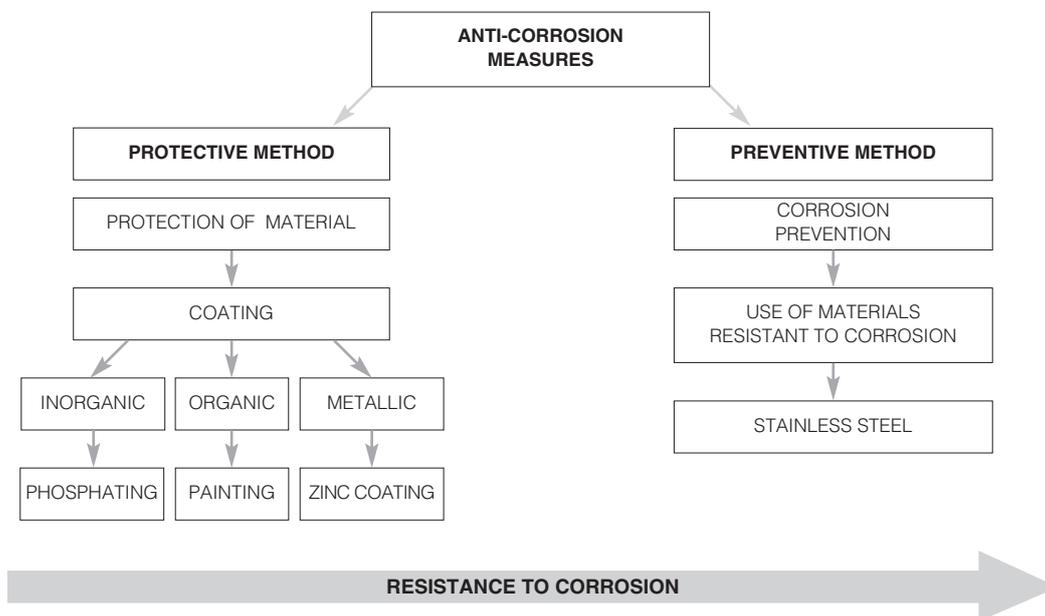
The following table summaries the classification of water-based fluids and their characteristics

Water-based fluids			
Classification to ISO12922	Fluid characteristics and main applications	Corrosiveness	Environmental impact
HFA-E	Oil in water emulsion. Water content > 80% Underground mines, steel plants	High	Low
HFA-S	Synthetic aqueous solution. Water content = 90%-98% Underground mines, steel plants, foundries, metalforming processes	High	Low
HFB	Water in oil emulsion. Water content = 40%-60% Mobile machines As a result of a high mineral oil content up to 60%, for some applications they do not meet the limit values for fire resistant characteristics	Low	High
HFC	Water glycol solution. Water content = 35%-55% Applications: steel plants, die casting as well as other industries, representing approximately 50% of the total fire-resistant hydraulic fluids market.	Low	High
Pure water	100% de-mineralized water Food processing, pharmaceutical industry, any application with severe eco-compatibility requirements	Very high	None

3 ANTI-CORROSION MEASURES

There are several methods to protect the components from corrosion. Among these we can mention **protective** methods and **preventive** methods.

They represent two different approaches, normally selected depending on working conditions of the components and the level of aggressiveness of the environment in which they will operate.



3.1 Protective methods

They are based on protective coatings applied on the surface of steel materials. They offer a good surface protection to aggressive atmospheres but no protection of internal parts in case of water-based fluids. The protection is affected by potential scratches on the surface.

In the following we evidence the most common protective methods:

- **PHOSPHATIZING** offers a medium resistance to corrosive environments; it is not indicated for strong aggressive environments like salty atmospheres. It is a good basic treatment for subsequent painting.
- **PAINTING** is a widely adopted method to protect the surfaces from corrosion. For strong aggressive environments like marine, inorganic zinc paint and specific painting processes as per ISO 12944 are used.
- **GALVANIC ZINC COATING** is one of the best protection methods for steel materials.

Atos has developed for its standard products range an exclusive treatment process named **ECP** that guarantees an excellent surface protection to aggressive environments, see section 5



ECP is a global surface protection combining different type of treatments for the several parts of hydraulic components:

- Parts made in carbon steel or cast iron: zinc coating with black passivation
- Caps and protections made in aluminum: black opaque anodizing
- On-board drivers housing: anodizing
- Aluminum name plates: natural gloss light grey anodizing
- DC coils, external metallic parts: zinc coating (gloss silver)
- Screws: GEOMET 500A treatment
- Other parts such as DIN plugs and nuts: galvanizing + passivation

3.2 Preventive methods

They consist in the use of materials with intrinsic resistance to corrosion. Among these, stainless steel meets the mechanical properties typical of carbon steels, with intrinsic characteristics of noble materials such as the resistance to corrosive phenomena.

Stainless steel materials offer a higher protection to corrosion with respect to protective coating methods.

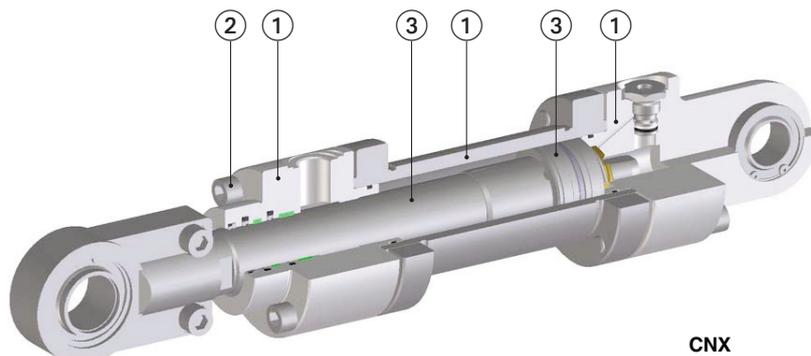
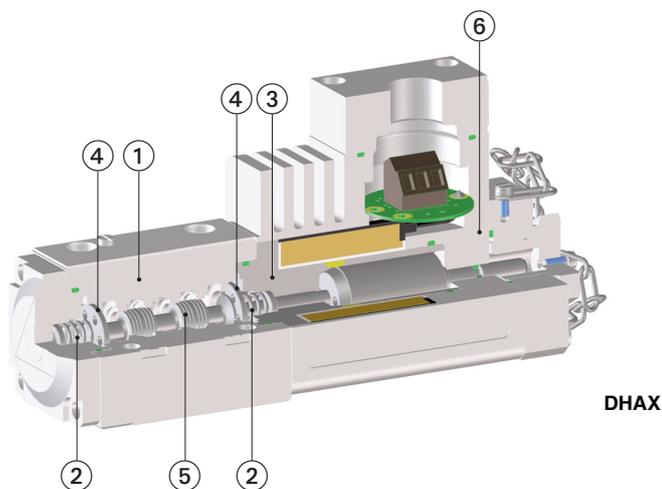
The protection is ensured both for external and internal surfaces, then this is the ideal solution in case of water-based fluids. Moreover, the corrosion protection is not affected by accidental scratches of the component surface.

4 STAINLESS STEEL MATERIALS

There are several types of stainless steel materials having different mechanical, physical and corrosion resistance characteristics. The most common designation methods in the stainless steel sector is the AISI (American Iron and Steel Institute).

In the following table are reported the stainless steel classification and the specific types used in Atos stainless steel valves

Classification	AISI Series	Characteristics and main applications	Materials used in Atos stainless steel valves
Austenitic	200 300	Best corrosion resistance of all stainless steels because they contain at least 16% chromium. Added nickel and manganese hold the metal in an austenitic microstructure. AISI 316L offers the best resistance to salt and acids AISI 302 steel has excellent mechanical properties and good corrosion resistance.	AISI 316L - Valve Body ① Cylinders housing and heads ① AISI 316 A4 - Cylinders tie rods ② AISI 302 - Spring ②
Ferritic	400	Ferritic stainless steels contain only chromium in the range of 11% to 30% but they have a lower carbon content than the martensitic ones. AISI430F has moderate resistance to corrosion, which increases with the percentage of chromium. It is ideal for parts to be machined in high speed machine tools. AISI 431 steel is particularly suitable for induction hardening. Among the martensitic steels it reaches the highest corrosion resistance values	AISI 430F - Solenoid tube ③ AISI 431 - Cylinders rod and piston ③
Martensitic	400 500	They contain 12 to 14% chromium, 0.2 to 1% molybdenum, and no significant amount of nickel. It is considered strong and hardenable by heat treatment. AISI420B provides the maximum corrosion resistance in the hardened state and after polishing. AISI440C high hardness steel has good corrosion resistance and excellent wear resistance.	AISI 420B - Washer ④ AISI 440C - Valve spools ⑤
Precipitation Hardening	17-4PH	PH stainless steels contain around 17% chromium and 4% nickel. AISI 630 steel has excellent resistance to corrosion. Similarly to martensitic stainless steels. The 17-4 PH reaches the optimal resistance to corrosion after heat treatment.	AISI 630 - Solenoid housing ⑥



5 SPECIFICATIONS TO VERIFY THE CORROSION RESISTANCE

ISO 9227 - the method recognized at European regulatory level, is the accelerated corrosion tests in a salt spray chamber according to UNI EN ISO 9227:2006 Corrosion tests in artificial atmospheres - Salt spray tests

This standard defines the requirements of the equipment and the procedure that must be used to perform the tests in neutral salt spray (NSS), salt-acetic fog (AASS) and cupro acetic salt spray (CASS), to evaluate the resistance to corrosion of metallic materials, with or without permanent or temporary anticorrosive protection.

The salt spray test it is not directly representative of the corrosion protection in real atmospheres, due to the high concentration of chloride and the absence of dry periods. However, this is a practical test, mainly used for the qualification of protection processes. It is a comparative method useful to verify the corrosion resistance of a certain material in comparison with others.

All Atos components are approved with salt spray tests in order to guarantee the best resistance to environmental corrosion



5.1 Resistance in salt neutral spray test (NSS)

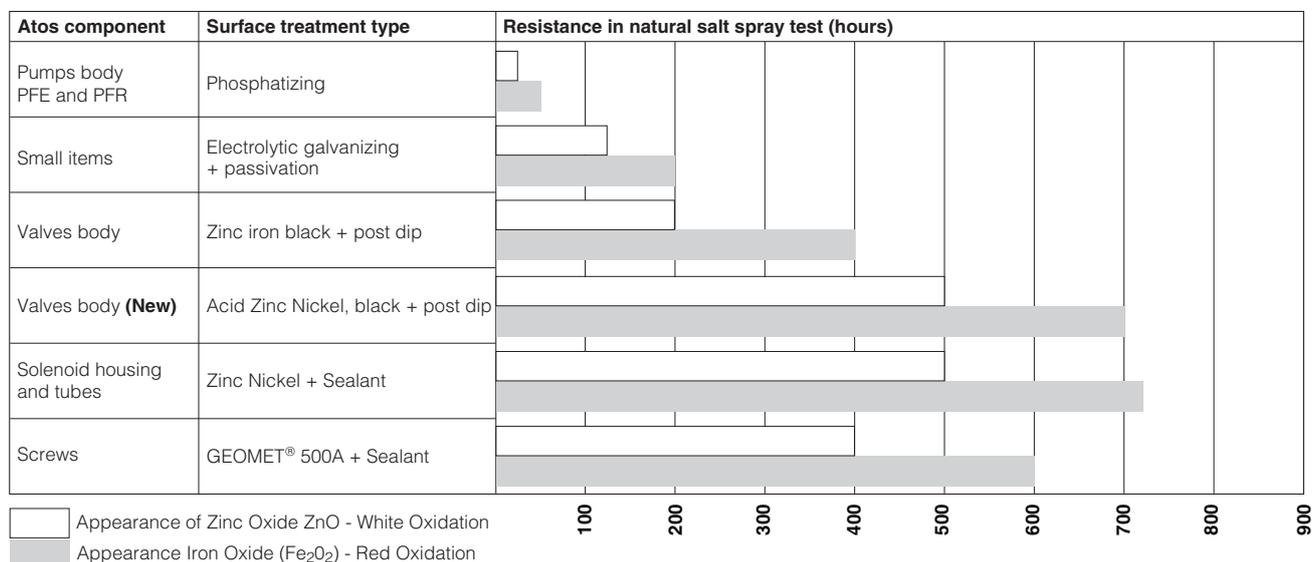
Carbon steel with zinc surface treatment

The resistance to corrosion is expressed in hours of performance in neutral salt spray (NSS according to UNI ISO 9227), before white and red oxidization appears on 5% of the total surface of the sample under test.

The white oxidization is the first step of corrosion. It evidences that the protective effect of the zinc passivation is ended, and the salt is going to attack the zinc layer. In this situation the steel material remains integer because it is still protected by the zinc layer.

Once the zinc layer is finished, the corrosion attacks the steel material and then there will be the appearance of red oxidization (red rust), which is the second type of corrosion that must be verified in the salt spray test.

The salt spray resistance of the main Atos components is shown in the following table.



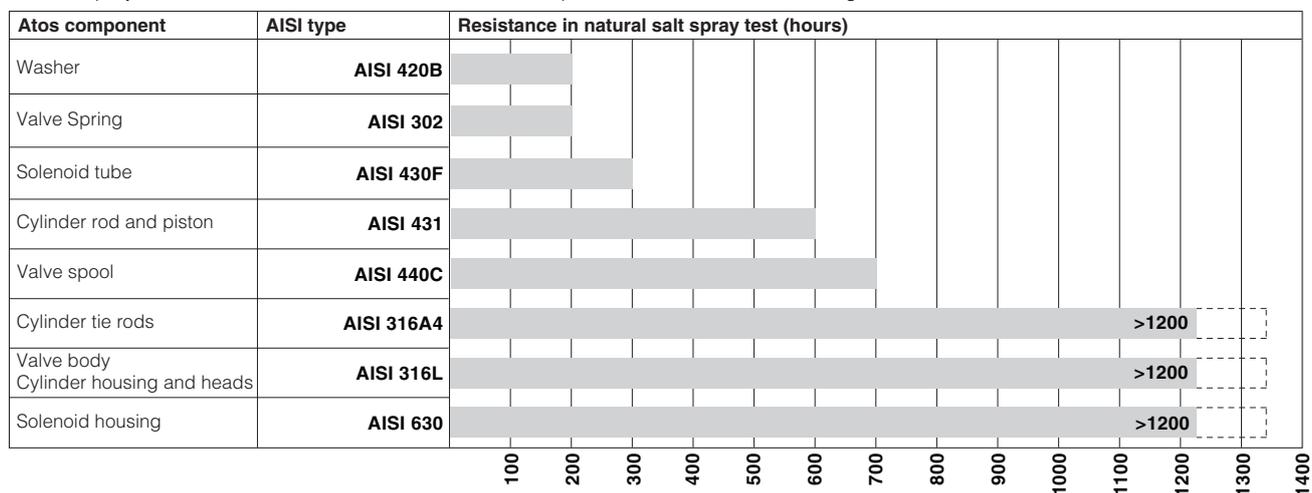
Stainless steel - resistance in salt neutral spray test (NSS)

Stainless steels materials offer a corrosion resistance characteristic typically higher than carbon steels with surface treatments.

The corrosion resistance of stainless steels depend to their type and class and to the aggressive environment to which they are exposed. Corrosion phenomena in many cases are limited to surface oxidation phenomena due to "free iron" and they manly concern to aesthetic factors rather than effective corrosion.

However, in some circumstances, they may present local corrosion attack such as the alveolar corrosion which is the predominant form of stainless steel corrosion.

The salt spray resistance of the main Atos stainless steel components is shown in the following table.



ISO 9223 - this standard establishes a classification system for the corrosiveness of atmospheric environments.

It defines the corrosivity classes of atmospheric environments, based on the corrosion rate detected on standardized metallic samples in one year of exposure.

The corrosion rates are classified in 6 different categories C1, C2, C3, C4, C5, CX calculated on the annual corrosion loss of metals like zinc, copper and carbon steel [$\mu\text{m}/\text{year}$] and it makes possible a rough identification of the corrosivity class based on the knowledge of the local environment.

The standard specifies the key factors in atmospheric corrosion of metals and alloys. These are made up of the combined effect of temperature and humidity and sulfur dioxide pollution and salinity carried by the air.

Classification based on measurement of corrosion rate for Zinc - data are provided for the first year of exposure to the specific environment

Corrosion Category ISO9223	Corrosiveness	Corrosion rate for Zinc layer ($\mu\text{m}/\text{year}$)	Duration of protection (1)	Salt spray test ISO9227	Typical outdoor environment
C1	Very low	<0,1	-	-	Dry or cold zone, atmospheric environment with low pollution
C2	Low	0,1÷0,7	-	-	Temperate zone, atmospheric environment with low pollution ($\text{SO}_2 < 12 \mu\text{g}/\text{m}^3$) Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, sub-arctic areas.
C3	Medium	0,7÷2,1	Short Medium Long	120 h 240 h 480 h	Temperate zone, atmospheric environment with medium pollution ($\text{SO}_2: 12\div40 \mu\text{g}/\text{m}^3$) or certain effect of chlorides, coastal areas with low deposit of chlorides
C4	High	2,1÷4,2	Short Medium Long	240 h 480 h 720 h	Temperate zone, atmospheric environment with high pollution ($\text{SO}_2: 40\div80 \mu\text{g}/\text{m}^3$) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without spray of salt water. Tropical zone, atmosphere with medium pollution
C5	Very high	4,2÷8,4	Short Medium Long	480 h 720 h 1440 h	Temperate zone, atmospheric environment with very high pollution ($\text{SO}_2: 80\div250 \mu\text{g}/\text{m}^3$) and/or strong effect of chlorides, e.g. industrial areas, coastal and offshore areas with salt spray. Tropical zone, atmosphere with high pollution and/or strong effect of chlorides
CX	Extremely high	>8,4	-	-	Subtropical and tropical zone, very humid period, atmospheric environment with very intense pollution (SO_2 above $250 \mu\text{g}/\text{m}^3$) Strong effect of chlorides i.e. coastal and offshore areas, occasional contact with salt spray.

- (1) Short = 2-5 years
Medium = 5-15 years
Long = >15 years