

PIPE-AGEDDON

“Pipe-ageddon”

Surviving the
Corrosion Apocalypse





What is **CORROSION**?



Corrosion is a natural process of deterioration that occurs when metals react with their environment, leading to the gradual degradation of the metal.

It typically involves the formation of oxides or other compounds on the metal surface, weakening its structural integrity and aesthetic appeal.

Common forms of **corrosion** include rusting of iron and steel, tarnishing of silver, and oxidation of aluminum.

Corrosion can be accelerated by factors such as exposure to moisture, oxygen, acids, salts, and pollutants, posing challenges in infrastructure, transportation, and manufacturing.



Understanding Corrosion in Water & Wastewater Systems

Once corrosion begins in a water system, it can rapidly escalate into a significant issue, leading to costly downtime, additional resource allocation, water outages for customers, and financial losses for business customers. The costs associated with corrosion in water systems amount to billions of dollars annually. According to a study by NACE International, the global cost of corrosion across various industries, including water systems, is estimated to be around \$2.5 trillion annually.

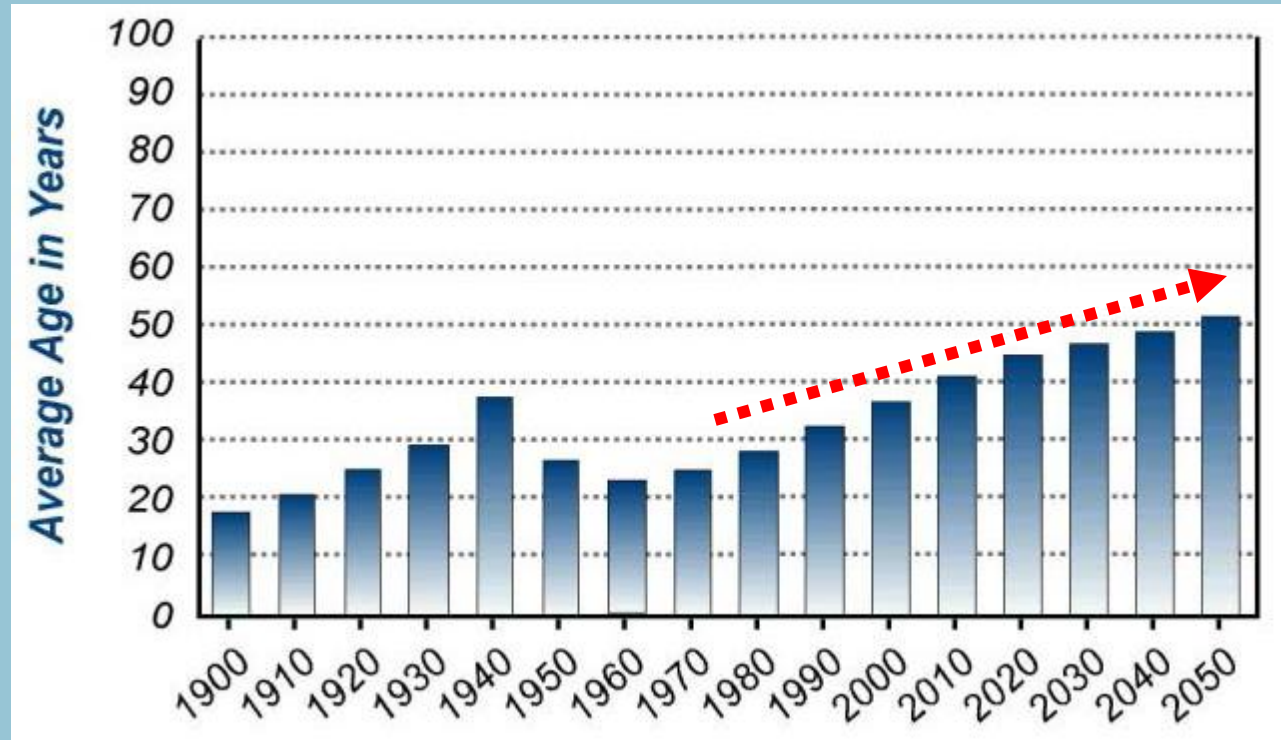
Where Do We Stand?

- 250,000 – 300,000 Water Main breaks per year
- ▶ The est. 6 billion gallons of clean drinking water per day lost to leaking pipes is around 15% of the daily drinking water usage and could support 16 million homes
- Drinking Water is delivered via 2.2 million miles of pipes across the Country. An est. 43% of installed pipes are between 20 & 50 years old, 23% greater than 50 years old, and nearly 10% of pipes were classified as “beyond their useful life” at 75-100 years.
- Utilities had been averaging a pipe replacement rate of 0.5% per year in 2015 (200 years to replace the system). By 2019, replacement rate has improved to 1.5%

Aging Infrastructure

By 2050, average age will be 50 yrs old

*Varies widely by region





NOT MY PROBLEM...

Hear That?

It's the sound of non-revenue water and your budget going down the drain.



How Much of Your Water is Non-Revenue?

Average of **24%** Per Year

Corrosion in Water Systems



Corrosion-induced metal loss can significantly impact the reliability and lifespan of water systems and their components, including distribution pipes and related equipment. This degradation leads to higher maintenance costs and premature equipment failure. Additionally, corrosion can impair heat transfer efficiency, cause deposit buildup, restrict water flow, and ultimately reduce system efficiency. Proactively understanding and addressing the various types of corrosion and their causes can prevent them from escalating uncontrollably.

TYPES OF CORROSION

- GENERALIZED (UNIFORM) CORROSION

Generalized corrosion proceeds uniformly over an exposed metal surface. With generalized corrosion, fouling is usually a more serious problem than equipment failure in treatment plants. Generalized corrosion typically never happens, aside from acidic conditions. This uniform corrosion over the entire surface of the metal is rare and leads to overall thinning, which has little effect outside of fatigue and stress conditions.

- LOCALIZED CORROSION

Localized corrosion is the most common, and most detrimental, form of corrosion. There are a number of different forms of localized corrosion include pitting, galvanic corrosion, under-deposit corrosion, and microbiologically influenced corrosion. Localized corrosion can lead to rapid metal perforation and system failure.

EVERYTHING CORRODES

TYPES OF CORROSION

GENERALIZED (UNIFORM) CORROSION

- *Uniformly (entire area) as a result of materials exposure to its environment.*
- *May present same symptoms as local, but over a uniformed area.*
 - * *Hot Soils*
 - * *UV Exposure*
 - * *Medium/ Chemicals in Contact*

LOCALIZED CORROSION

- *Galvanic Corrosion*
- *Pitting Corrosion*
- *Under-Deposit Corrosion*
- *Erosion Corrosion*
- *Tuberculation Corrosion*
- *Microbiologically Influenced Corrosion (MIC)*

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ATMOSPHERIC CORROSION

GALVANIC CORROSION

CLASSES OF CORROSION

ATMOSPHERIC CORROSION

THIS TYPE OF CORROSION IS CHEMICAL OR ELECTROCHEMICAL IN NATURE. HOWEVER, THERE ARE NO DISCRETE ANODE OR CATHODE AREAS. THIS FORM OF CORROSION IS UNIFORM OVER THE SURFACE EXPOSED TO ITS ENVIRONMENT.

GALVANIC CORROSION

THIS TYPE OF CORROSION IS CAUSED BY AN ELECTROCHEMICAL CORROSION CELL. THE POTENTIAL DIFFERENCE (ELECTROMOTIVE FORCE) IS CAUSED BY A DIFFERENCE IN CONCENTRATION OF SOME COMPONENT IN THE ELECTROLYTE.

ATMOSPHERIC CORROSION

Issues with hot soils?

Painting Fire Hydrants Every 3-5 Years?



ATMOSPHERIC CORROSION



ATMOSPHERIC CORROSION

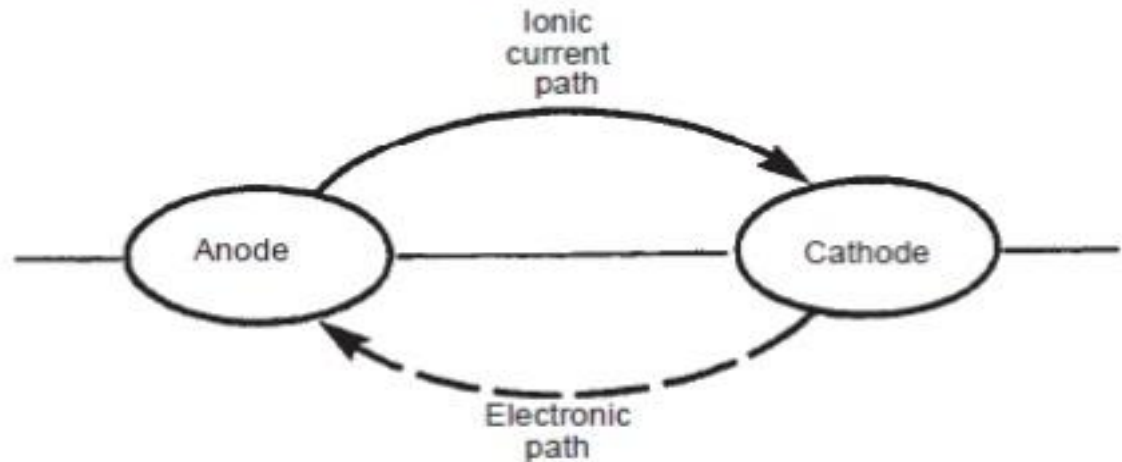


GALVANIC CORROSION

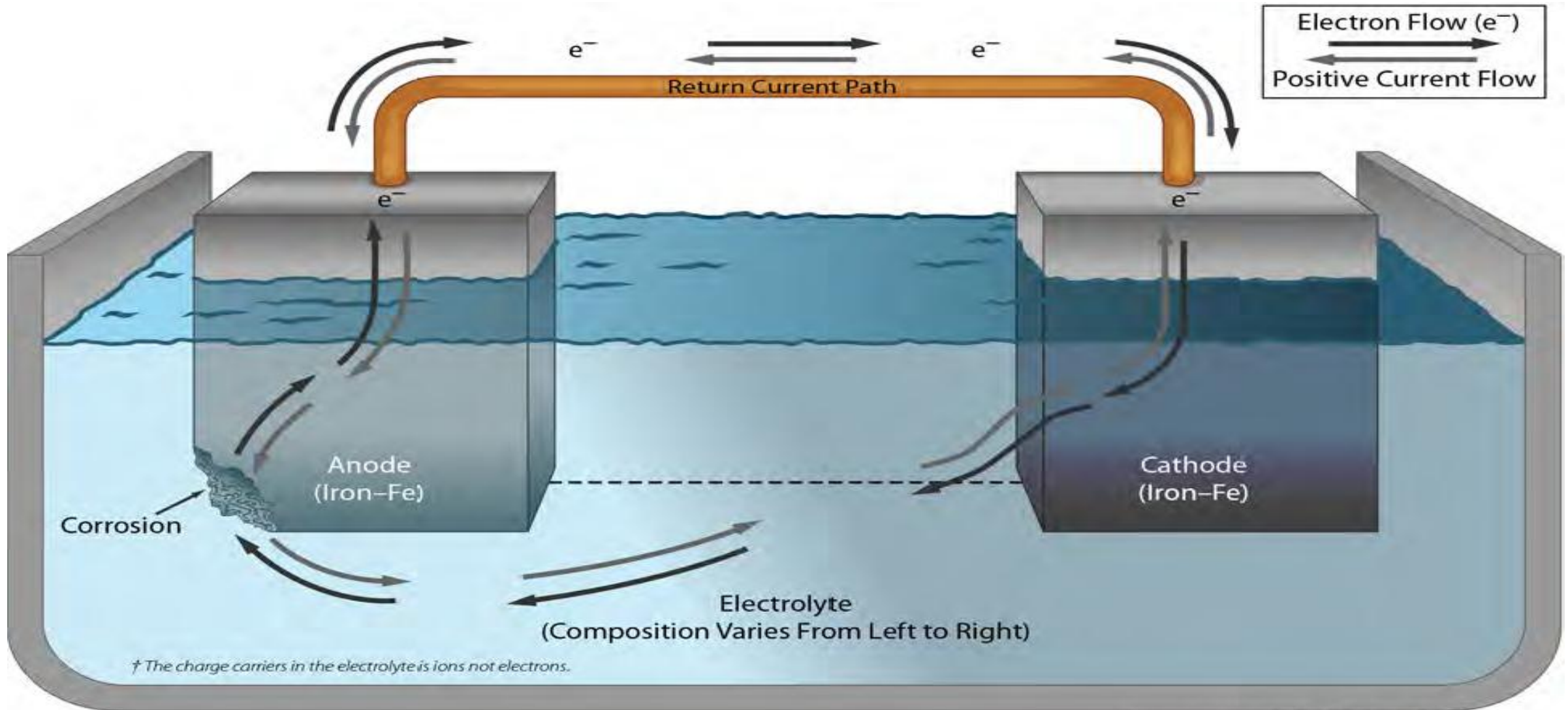
Four requirements of corrosion

- Anode
- Cathode
- Current flow
- Electronic path

} Cell



GALVANIC CORROSION



GALVANIC **CORROSION**

[illegible]

GALVANIC CORROSION



All Four
Elements of the
Cell Must be
Present for
Corrosion to
Occur!

*Remove Any One
Element and
Corrosion.....*



The Rate of, or
Acceleration Rate
of Galvanic
Corrosion is
Affected by Several
Factors:

GALVANIC CORROSION

Difference Between the Metals

Nature of the Environment

Spatial Effects such as Area,
Distance and Cell Geometry

Electrolyte Resistivity

TYPES/ SYMPTOMS OF CORROSION

ATMOSPHERIC & GALVANIC CORROSION

- *Pitting Corrosion*
- *Under-Deposit Corrosion*
- *Erosion Corrosion*
- *Cavitation Corrosion*
- *Tuberculation Corrosion*
- *Microbiologically Influenced Corrosion (MIC)*

TYPES/ SYMPTOMS OF CORROSION

PITTING CORROSION

Pitting is one of the most destructive forms of corrosion and one of the most difficult to predict. Pitting corrosion occurs when discrete areas of a metal undergo rapid localized attack while the vast majority of the surface remains virtually unaffected. Pitting is generally seen in localized corrosion, and electrochemical in nature. It is also more prevalent in low velocity or stagnant conditions and by the presence of corrosive ions (i.e. oxygen, chlorides, sulfates, etc.). Once a pit is formed, the solution inside it is isolated from the bulk environment. Over time, it becomes increasingly corrosive, and the process becomes self-sustaining.



Stainless Steel.....

TYPES/ SYMPTOMS OF CORROSION

WHAT MAKES STEEL “STAINLESS STEEL”

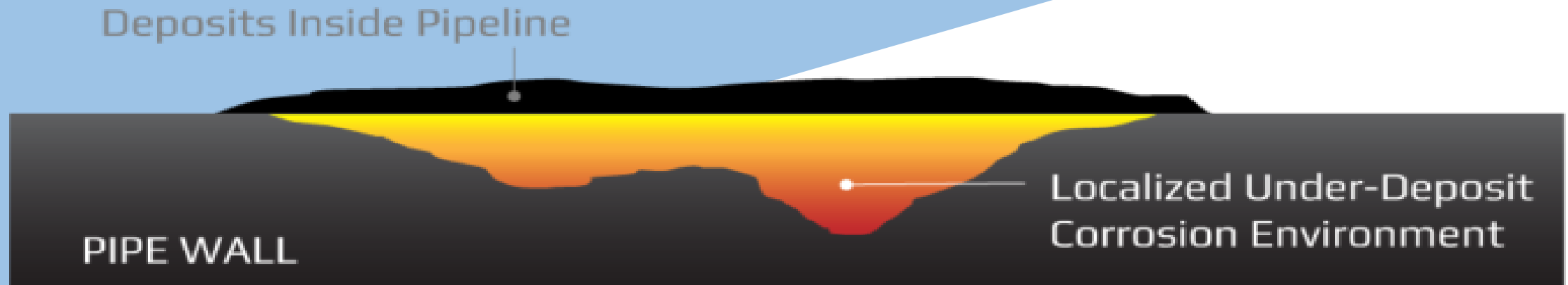
Passivation of stainless steel is a process of treating the surface to enhance its corrosion resistance. This is achieved by removing free iron from the surface and promoting the formation of a thin, protective chromium oxide layer. This layer, also known as the passive film, acts as a barrier against corrosion.

- This protective chromium oxide layer that forms on the surface of stainless steel to prevent corrosion requires oxygen to regenerate. In environments where oxygen is limited, such as in tight crevices or where stagnant water is present, this layer may not form or regenerate effectively, leading to corrosion.

TYPES/ SYMPTOMS OF CORROSION

UNDER-DEPOSIT CORROSION

Under-Deposit Corrosion, also called crevice corrosion, is localized corrosion that occurs within a crevice or any shielded area. Solutions underneath deposits become highly concentrated and corrosive just as within a pit. Alloys that depend on oxide films for protection such as stainless steel, copper, and aluminum are highly susceptible to under-deposit corrosion attack. It is more prevalent at the bottom of horizontal lines. This is why Hydrant Flushing is vital for system maintenance (laminar & turbulent flows).



TYPES/ SYMPTOMS OF CORROSION

EROSION CORROSION

Erosion-corrosion arises from a combination of corrosion and the physical abrasion resulting from fluid flow. Virtually all metals are susceptible to some type of erosion-corrosion. Soft metals or metals that rely on a passive layer for corrosion protection are especially sensitive to erosion-corrosion. Once the passive layer has been removed, the bare metal surface is exposed to the corrosive material. Fluids that contain suspended solids can directly cause or aggravate this type of corrosion. The best way to limit this is to design systems that will maintain flow velocities within the limits of the metals being used and minimize the number of changes in direction.



*Same Thing that
Caused
This.....*





EROSION CORROSION



0.00	0.00	0.00	0.10	0.10
0.40	0.40	0.40	0.65	0.65
Industrial Wastewater Treatment Collection				



TYPES/ SYMPTOMS OF CORROSION

CAVITATION CORROSION

Cavitation Corrosion is a type of erosion-corrosion where the formation and collapse of vapor bubbles in a liquid damages the metal surface. This localized corrosion occurs when the local pressure in the liquid drops below its vapor pressure, causing bubbles to form and implode, which can destroy protective layers and lead to pitting and cracking.



TYPES/ SYMPTOMS OF CORROSION

TUBERCULATION CORROSION

Tubercles are accumulations of corrosion by-products and other deposits that cap localized regions of metal loss. The structure depends on water chemistry, dissolved oxygen concentration, temperature, flow, and corrosion rates. Tubercles grow internally as metal is removed and externally as corrosion by-products build up. The corroded areas beneath tubercles are usually broad, irregular depressions. Not all red-brown iron oxide deposits in cooling water systems are tubercles. If there is no metal loss beneath the deposit, the iron in the deposit may be material transferred from elsewhere in the system.



TYPES/ SYMPTOMS OF CORROSION

MICROBIOLOGICALLY INFLUENCED CORROSION

Microbiologically Influenced Corrosion (MIC) describes corrosion processes in which bacteria play a significant role. MIC is often a contributing factor in tuberculation and other forms of corrosion. However, the bacteria do not directly attack metal. In most cases of MIC, the metabolic by-products associated with bacterial growth attack or react with the underlying metal.



EFFECTS OF CORROSION

Corrosion in water systems can lead to various negative impacts, including physical damage to plumbing, potential health risks from leaching metals, and changes in water quality like taste and appearance. It can also weaken pipes, causing leaks and failures, and increase maintenance costs.

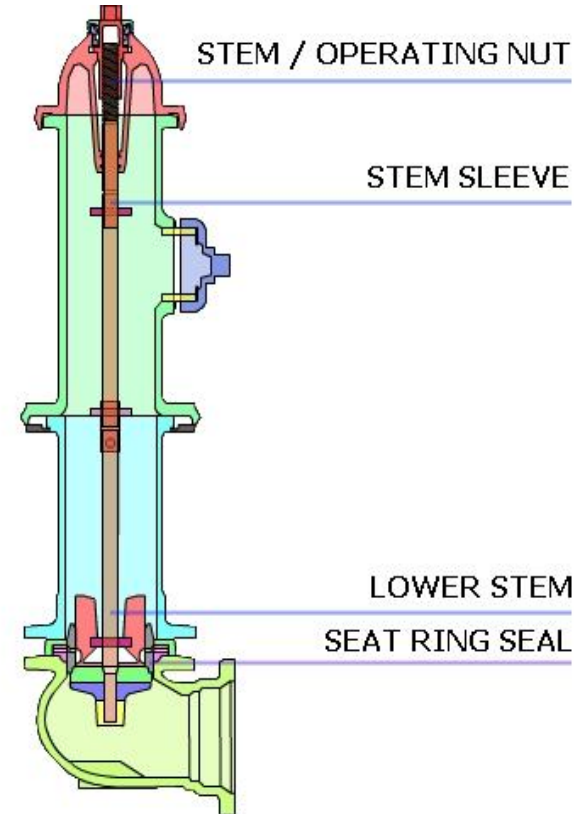






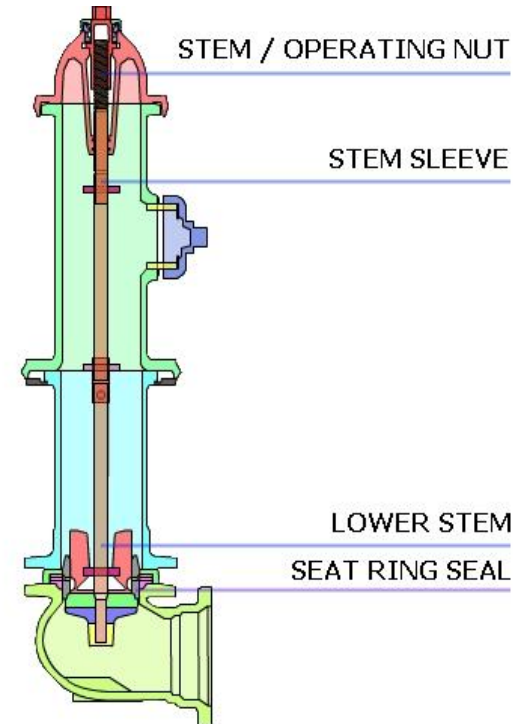
The Four Areas of Electrolysis & Hydrant Failure

1. STEM/OPERATING NUT - The stem "rusts" to the operating nut, and is the cause of "hard to operate" in many cases. Results of this condition are rounded off pentagon or square wrench nut, twisted off operating nuts, and twisted stem stress to the point of failure of the stem anti-rotation device. The hydrant can become locked and completely inoperative. Moisture is typically admitted by the stem sleeve cracking.



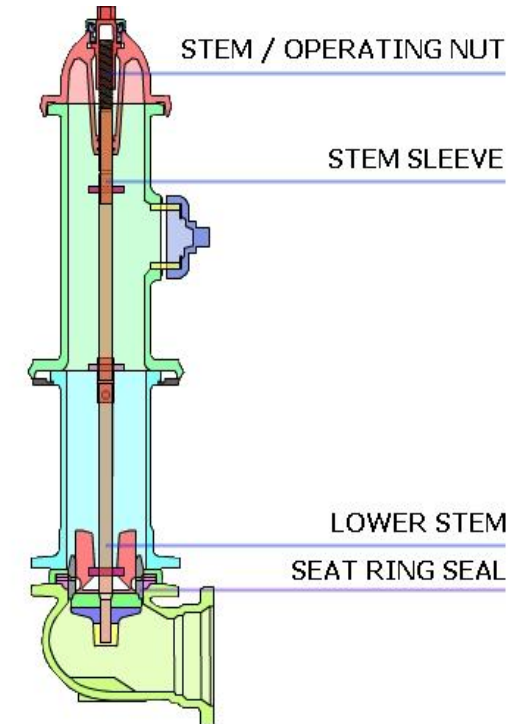
The Four Areas of Electrolysis & Hydrant Failure

2. STEM SLEEVE - The stem sleeve is a thin brass tube slid over the steel upper stem, to provide a smooth seal for the bonnet/stem juncture. Electrolysis occurs between the brass stem sleeve and the underlying steel stem. The lower 1/2" of the stem sleeve is not sealed against moisture. Water collects underneath the sleeve, rust forms and grows, and the stem sleeve cracks. Now water is able to flow through the sleeve and into the operating nut area and wash out the lubricant, resulting in the problems in 1. above. The stem sleeve can become so loose that it migrates upward and locks up the operating nut. A dry, unlubricated sleeve can also make the hydrant very difficult to operate.



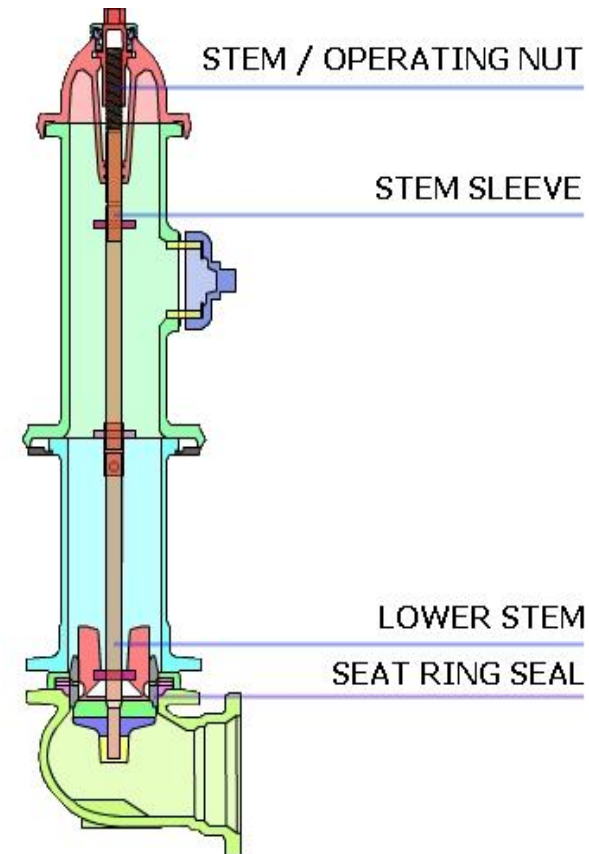
The Four Areas of Electrolysis & Hydrant Failure

3. LOWER STEM - One of the worst areas for stem rust, due to the bottom few inches contain the anti-rotation device, the drain valve, and hydrant valve. Electrolysis occurs between the brass drain valve and the steel stem. Rust here typically disables the anti-rotation device, or allows the stem to bend when opening pressure is applied from above. Stems that are designed to slide thru the drain lever can become locked to the point that they bend or break the drain lever. Rust here is further aggravated by opening the hydrant, the resulting stream of water flowing thru the elbow flushes away old stem rust, and new rust is now initiated. Coastal areas are particularly vulnerable to lower stem rust, since the lower barrel of the hydrant is typically filled with standing water from a high water table. Water allowed in through the drain holes becomes mixed with mud, bacteria, acids, etc. and is highly corrosive to the stem. It can also contaminate drinking water.



The Four Areas of Electrolysis & Hydrant Failure

4. SEAT RING SEAL COMPRESSION AREA - A nightmare area for the fire hydrant repairman. Sadly, this is a very common occurrence. Electrolysis occurs in the contact area of the brass seat ring and the cast iron hydrant elbow. A pitted surface here will not allow proper sealing of the seat o-rings or gasket, and the hydrant will leak. New seat o-rings, new seat ring, new main valve, etc. will not fix the problem. Leaks here may be undetected because water flows out the drain holes and is not visible from the groundline. Repairs are further complicated by the "locking" of the seat ring by the rust from the mating hydrant elbow., making the seat ring very difficult to remove for repairs. Most seat wrenches provided by the manufacturer are not effective in removing these locked in seat rings. Over torque of the seat wrench can result in injuries and even further damage internal parts

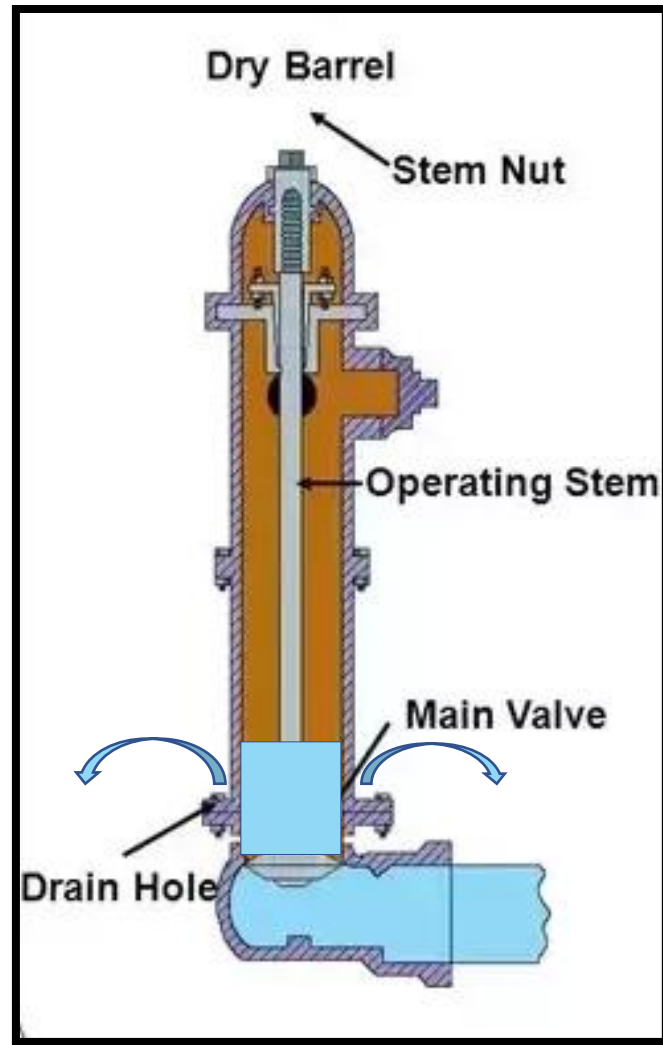


All Four
Elements of the
Cell Must be
Present for
Corrosion to
Occur!

*Remove Any One
Element and
Corrosion.....*



- When a valve seat leaks
- The water continuously leaks out of the drain holes
- Can freeze causing it to be inoperable
- Enormous amounts of waste of a valuable resource



National hydrant leak data

	No. Hydrants	Avg Loss		Gallons Lost	Gallons Lost	Gallons Lost	Gallons	Block 1		Conservative Est. of
		GPM (Est)	Gallons Lost					Denver Water	Total Est Loss	
Leak Detection Survey Referenced	Leak Detected	Per Hydrant	Per Day (Est)	Per Month (Est)	Per Year (Est)	Per 1000	Price (per 1000g)	Billable Water Revenue	Managing Lost Water	
City of Orland, CA (11-14)	80	3.5	403,200	12,264,000	147,168,000	147,168	\$2.36	\$347,316.48		\$73,584.00
Town of Ipswich, MA (8-14 - 9-14)	4	1	5,760	175,200	2,102,400	2,102	\$2.36	\$4,961.66		\$1,051.20
Town of Ashland, MA (11-14 - 12-14)	5	2.25	16,200	492,750	5,913,000	5,913	\$2.36	\$13,954.68		\$2,956.50
Town of Weston, MA (12-17)	4	4.75	27,360	832,200	9,986,400	9,986	\$2.36	\$23,567.90		\$4,993.20
Shrewsbury Water System, MA (12-15)	10	6.9	99,360	3,022,200	36,266,400	36,266	\$2.36	\$85,588.70		\$18,133.20
Colorado Survey	4	1	5,760	175,200	2,102,400	2,102	\$2.36	\$4,961.66		\$1,051.20
Example Utility #1	420	1	604,800	18,396,000	220,752,000	220,752	\$2.36	\$520,974.72		\$110,376.00
Example Utility #2	2000	1.2	3,456,000	105,120,000	1,261,440,000	1,261,440	\$2.36	\$2,976,998.40		\$630,720.00

CURRENT HYDRANT PROBLEM: RELIABILITY

Newark, NJ (2013) - 15% of City's Hydrants would cause Delays in Emergency Response

Detroit, MI (2015) - Over a two Month Period, roughly 15% of the City's Hydrants were Surveyed, of which, 279 Hydrants were flagged as "inoperable" by City Firefighters

"The way we find out a Hydrant isn't working is when we pull up to one and connect to the Hydrant"
-Dan Dugan, President D.C. Firefighters Association

CAUSE

- * INFERIOR MATERIALS/ COMPONENTS
 - WEATHERING, CORROSION, OXIDATION & RUST
- * DAMAGE FROM VANDALISM, TAMPERING & IMPACT
- * INADEQUATE PREVENTATIVE MAINTENANCE



CURRENT HYDRANT PROBLEM: WATER LOSS

Electrolysis occurs in the contact area of the brass seat ring and the cast iron hydrant elbow. A pitted surface here will not allow for proper sealing of the seat O-rings or gasket, and the hydrant will leak. New seat O-rings, new sets rings, new main valve, etc. will not fix the problem. Leaks here may be undetected because water flows out the drain holes and is not visible from the groundline. Millions of gallons of water are lost Annually due to this [alone]. *Source: Quality Hydrant Company (link below)

One Norther California City detected leaks in 80 of their existing Fire Hydrants at an average rate of 3.5gpm, which would equate to 147,168,000 gallons of clean drinking water lost each year.

CAUSE

- * CORROSION DUE TO INFERIOR MATERIALS/ COMPONENTS

Source Link: [http://www.qualityhydrant.com/default.aspx?Section=Presentation&Product=4%](http://www.qualityhydrant.com/default.aspx?Section=Presentation&Product=4%20)

CURRENT HYDRANT PROBLEM: SECURITY

"The Distribution System is the top Vulnerability of Drinking Water Systems with Hydrants Specifically Referenced"
-Dept. of Homeland Security GAO Report, 2004

In July of 2019, the unauthorized Hydrant hook-up by a Spokane, WA Hydroseeding Company resulted in a cross-contamination of the potable water system with E. Coli

Bozeman, MT (2003) - Experienced one of the worst Water thefts in US History, with almost 3 Million Gallons of Water Stolen over a three-day period

CAUSE

- * INEFFECTIVE SECURITY MEASURES
 - UNAUTHORIZED ACCESS WITH STANDARD WRENCH, BOLT CUTTERS, AND OTHER COMMON TOOLS



CURRENT HYDRANT PROBLEM: MAINTENANCE

With the cost of parts, labor and other Hydrant related incidents, the average municipality will spend between \$200 - \$700 per hydrant per year to maintain all Hydrants in their system, excluding replacement and new installations.

The majority of Hydrant Manufactures recommend that their Hydrants be serviced at least once a year to be greased, and to check for functionality.

CAUSE

- * ATMOSPHERIC CORROSION & GALVANIC CORROSION
 - INSUFFICIENT COATINGS (SUN-FADING, RUST, ETC.)
 - DAMAGING ELECTROLYSIS DUE TO DISSIMILAR METALS
- * INADEQUATE LIMITED MANUFACTURES WARRANTY



"Saving water, saving costs, saving lives"



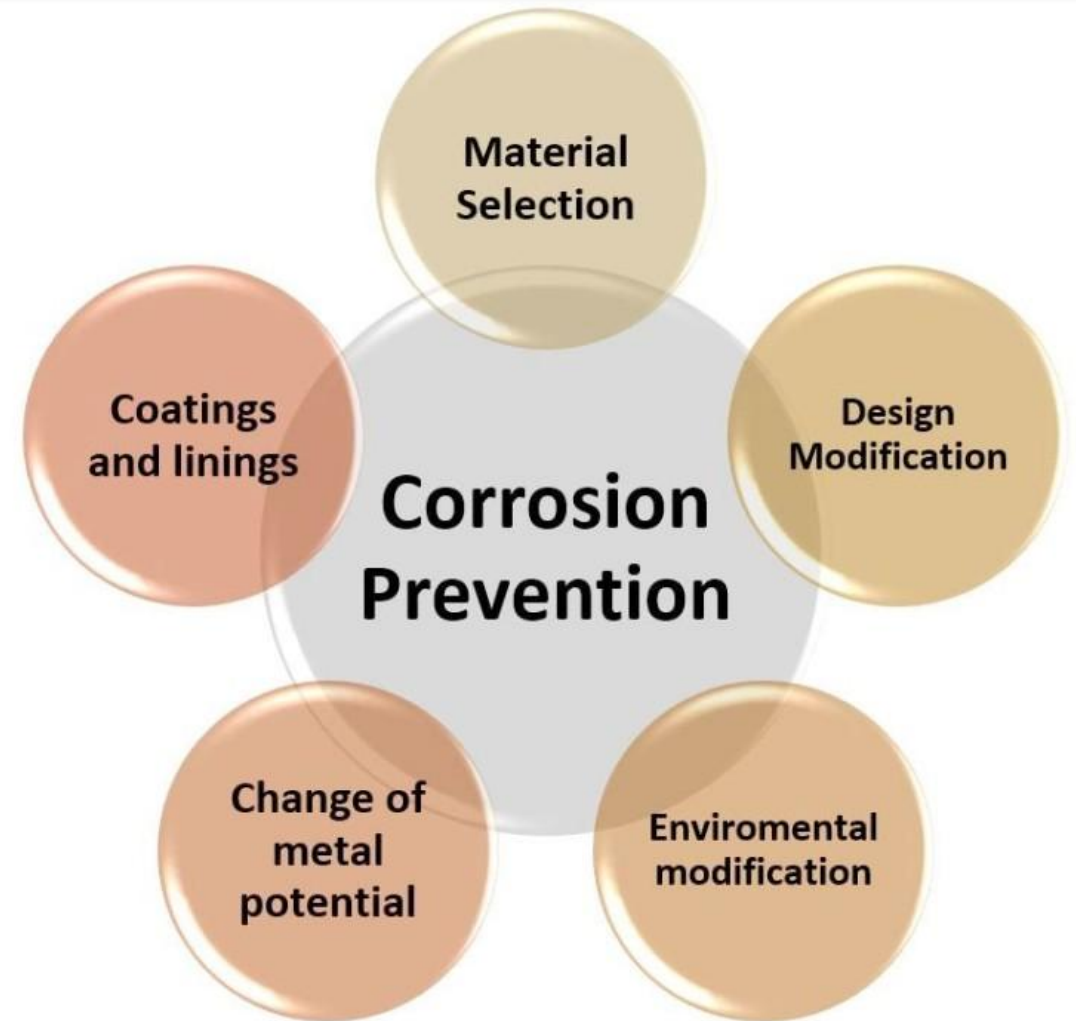
EFFECTS OF CORROSION



MANAGING CORROSION

FACTORS IN MITIGATING CORROSION

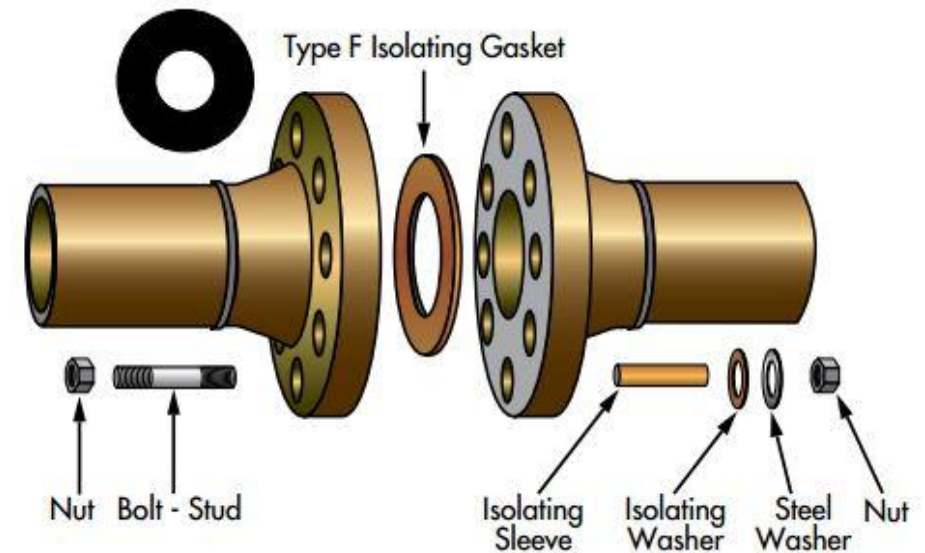
There are several factors influencing the rate of corrosion including diffusion/ Insulation or Isolation, temperature, conductivity, and type of ions. The rate of corrosion can be controlled or reduced by applying anti-corrosion coatings or corrosion protection techniques.



MANAGING CORROSION

INSULATION OR ISOLATION

In the majority of cases, the corrosion rates of metals are controlled by the diffusion of reactants to and from the metal surface. Freshly exposed bare steel surfaces will corrode at a greater rate than those that are insulated and isolated. **Dielectric Insulation/ Isolation**



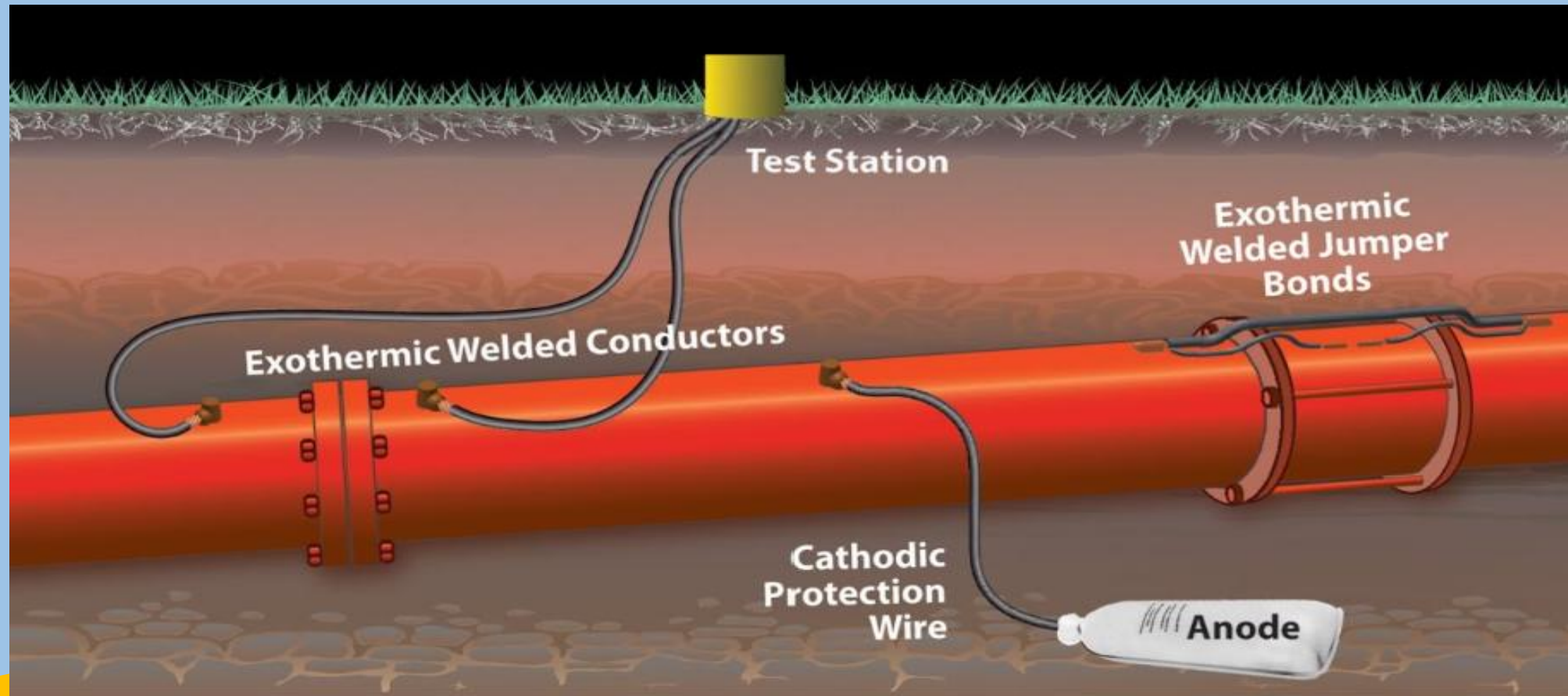
MANAGING CORROSION

TEMPERATURE

As corrosion rates are determined by diffusion, diffusion rates are also controlled by temperature. Steel and other metals corrode at faster rates at higher temperatures than at lower temperatures. As a result, there is less corrosion during winter than summer. Soft waters (with alkalinity less than 50 mg/L) are very corrosive during summer.

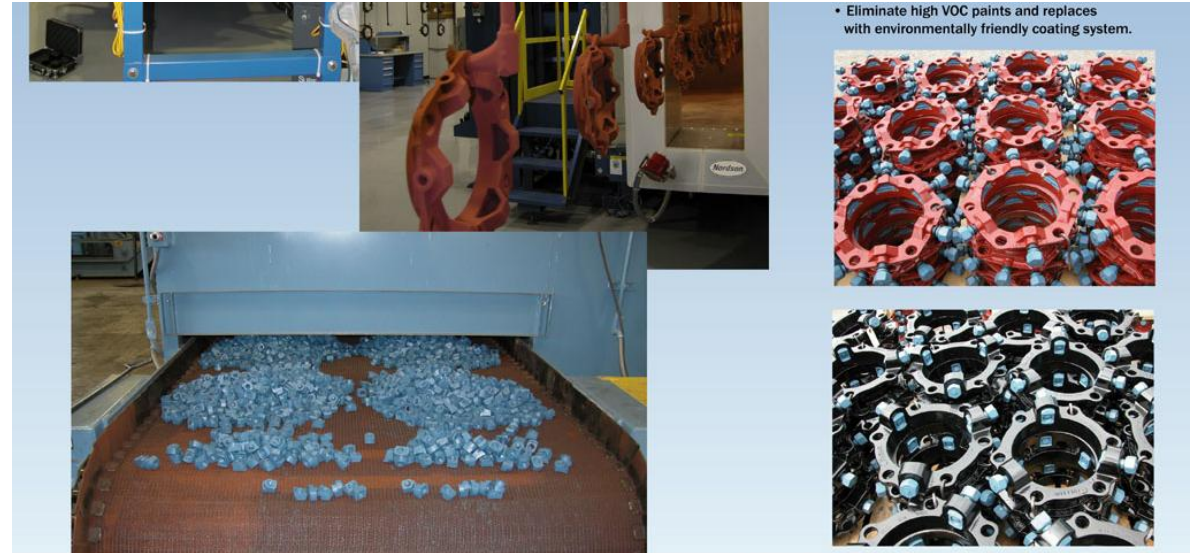
MANAGING CORROSION

CORROSION PROTECTION SYSTEMS – CATHODIC PROTECTION



MANAGING CORROSION

Selection of Materials & Coatings



• Eliminate high VOC paints and replaces with environmentally friendly coating system.

MEGA-BOND™ Restraint Coating System



Stop Replacing Corroded Valves.

MIC-Resistant Valves
Armed with



ArmorTek®, a 3-part coating system designed to inhibit Microbially Induced Corrosion (MIC).

- 1 Durable Primer
- 2 Patented Microbial Inhibitor
- 3 Robust Topcoat



The **ONLY** Valve/
Strainer Combo
with an **8-Year**
MIC Warranty*

*Terms and conditions apply.



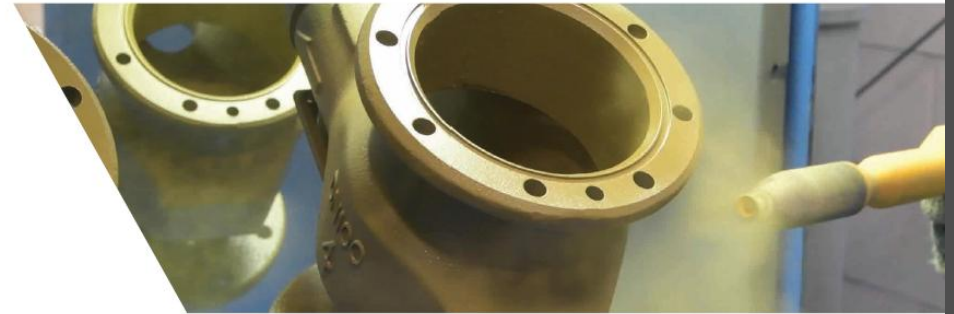
Stop Replacing
Corroded Valves

WATTS



Microbiologically Induced Corrosion (MIC), a damaging process where microorganisms like bacteria and fungi produce corrosive byproducts, is enemy #1 of ACVs (automatic control valves)/PRVs (pressure-reducing valves) and Plate Strainers.

These microorganisms create biofilms on your valve's surfaces, trapping corrosive substances and promoting localized corrosion. Over time, this weakens your valve, leading to leaks, poor performance, and potential failure. MIC poses a significant threat to ACVs/PRVs and Strainers, and can compromise their reliability and functionality.



How it Works:

- ArmorTek coating is applied to select ACVs/PRVs and Plate Strainers at our U.S.-based factory
- Install as usual.
- Enjoy reliable corrosion protection that extends your system's lifespan.



Stop Replacing
Corroded Valves

WATTS

KEY “TAKEAWAYS”

- * *WHAT ARE THE TWO TYPES & CLASSES OF CORROSION?*
- * *NAME THE 4 COMPONENTS OF A CORROSION CELL?*
- * *WHAT IS A GALVANIC CHART?*
- * *WHAT IS THE GOAL OF CORROSION CONTROL?*
- * *NAME 3 SYMPTOM TYPES OF CORROSION?*
- * *NAME 3 METHODS OF CORROSION CONTROL?*

PIPE-AGEDDON

QUESTIONS?

“Pipe-ageddon”

Surviving the
Corrosion Apocalypse

