Solving Corrosion Problems On Cast Iron & Ductile Iron Water Mains

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OUTLINE

- PRESENT SCENARIO
- FACTORS INFLUENCINCING IRON CORROSION
- PROCESS
- SOLUTION
- ADVANTAGE
- CONCLUSION

As a Nation, How do We Manage our Water Assets?

- Present Condition: India earns a grade of "D-" for water and waste water infrastructure maintenance
- The Future Dilemma: India will face a serious shortfall of $11 billion per year to replace its aging water infrastructure
- At an average for water system main breaks in India is 25 to 30 breaks per 100 miles of main per year.

Main Factors Contributing to Pipe Failures

- Corrosion
  - Role of pH.
  - Alkalinity
  - Dissolved Oxygen
  - Water Velocity
  - Temperature
- External loading (Traffic and Frost)
- Installation practices
- System pressure
- Third-Party Damage

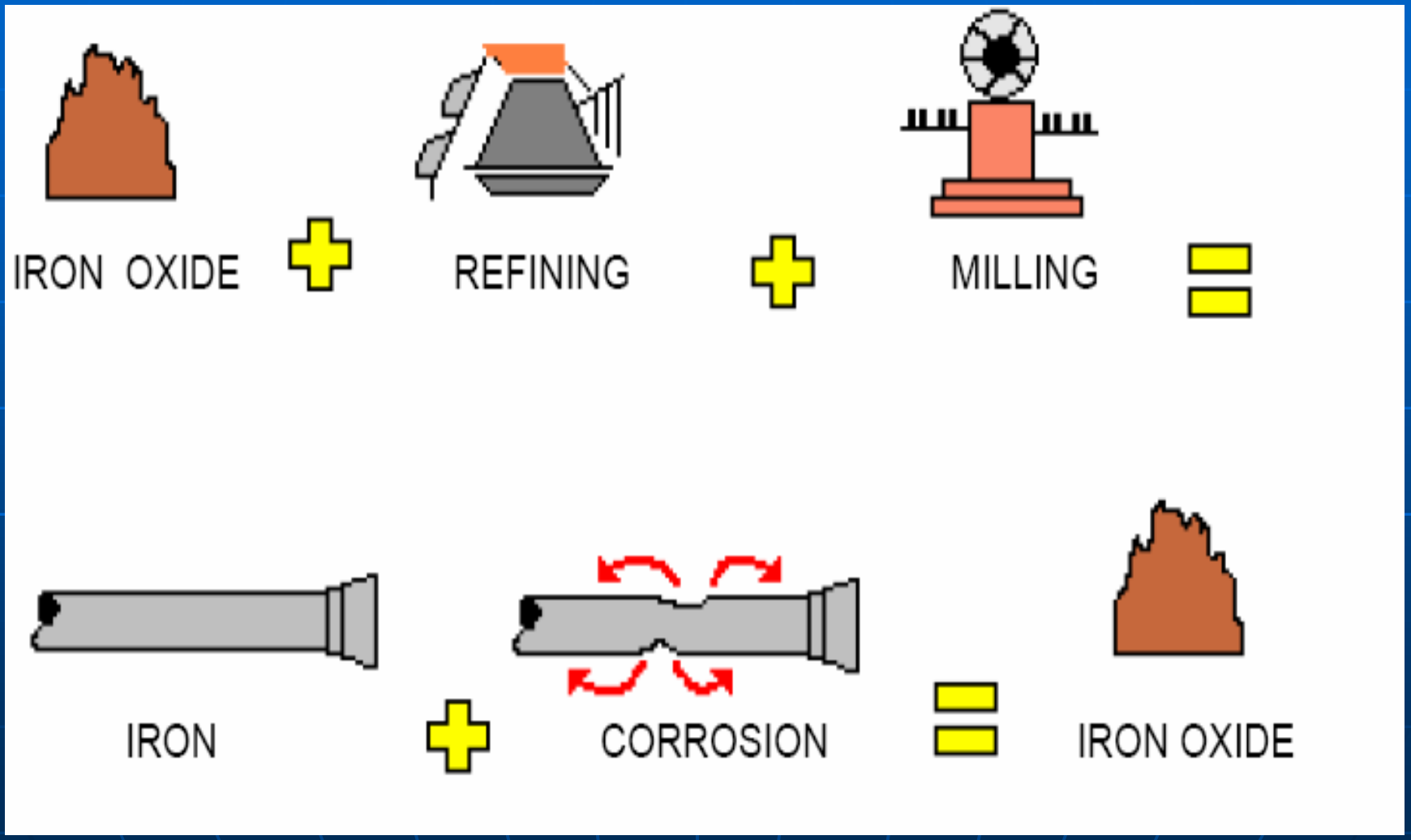
What Causes a Water Main Break?

- Corrosion is a leading contributor to water distribution system breaks!

Corrosion Can be Defined as:

- **Practical Definition**: The Tendency of a Metal to Revert to its Native State
- **Scientific Definition**: Electrochemical Degradation of Metal as a Result of a Reaction with its Environment

Corrosion - A Natural Process



Four Basic Components of A Corrosion Cell

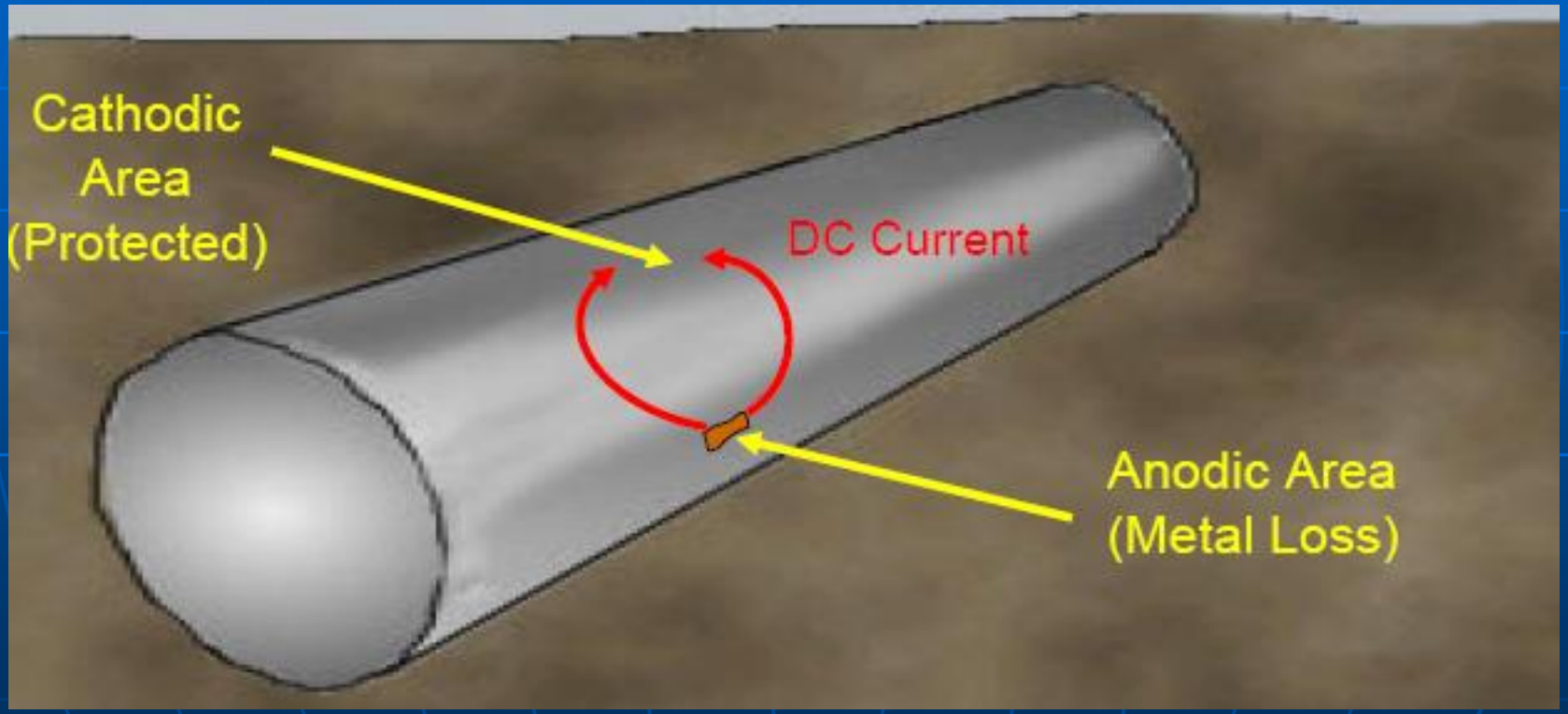
Corrosion in fresh or salt water is always the result of an electrochemical reaction.

- Anode – A metal electrode in contact with the electrolyte which corrodes .
- Cathode - A metal electrode in contact with the electrolyte which is protected against corrosion .
- Electrolyte – A solution or conducting medium such as soil, water or concrete which contains oxygen and dissolved chemicals .
- Metal Path – An external circuit that connects the anode and the cathode .

Electron Flow vs. Conventional Current

- Flow of conventional current is from positive (+) to negative (-)
- Conventional current flow from (+) to (-) will be from the cathode to the anode in the metallic circuit
- Conventional current flow from (+) to (-) will be from the anode to the cathode in the electrolyte.

Anodes & Cathodes on a Buried Metallic Pipe



Basic Electrochemistry – At the Anode

- For Metal "M": $M \rightarrow M^{n+} + n^{*}e^{-}$
- The electrons flow from the anode through the metal path to the cathode
- Positively charged iron atoms (Fe+2) combine with hydroxyl ions (OH-) to form ferrous (II) hydroxide (Fe(OH)2 and then ferric (III) hydroxide Fe2(OH)3

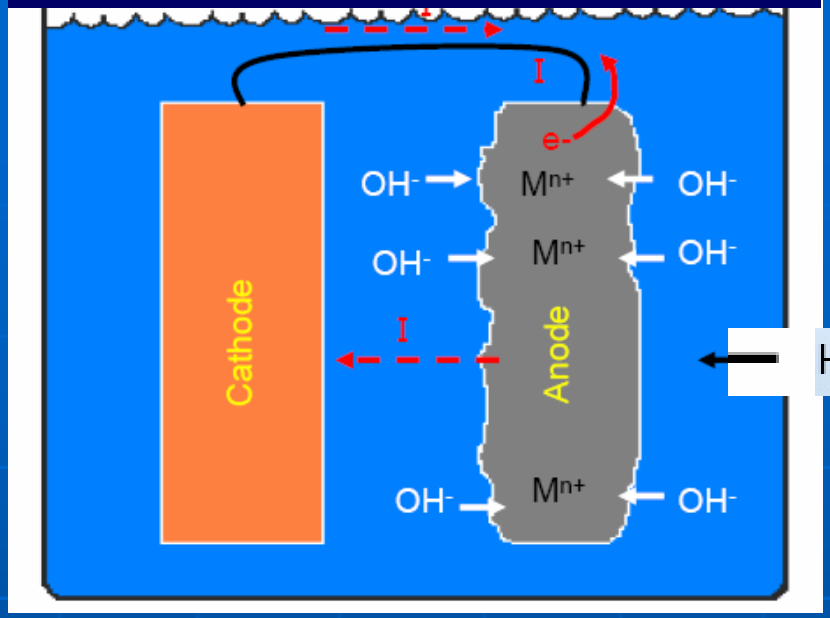
RUST: $2Fe^{+2} + 3OH^{-} \rightarrow Fe_2(OH)_3$

Basic Electrochemistry – At the Cathode

- The hydrogen ions (H+) flow from the anode *through the electrolyte* to the cathode to combine with the electrons that traveled through the metal path from the anode
- Pairs of H+ combine to form H2 gas which forms a "polarization film" on the surface of the cathode
- As the H2 gas bubbles away, a surplus of hydroxyl ions (OH-) is created at the cathode which increases the alkalinity (raises the pH) of the area around the cathode

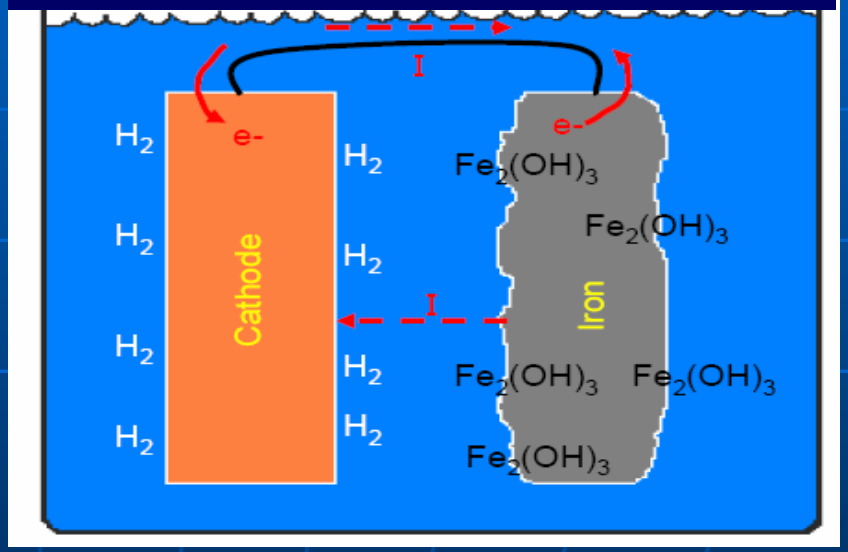
$$2H^+ + 2e^- \rightarrow H_2$$

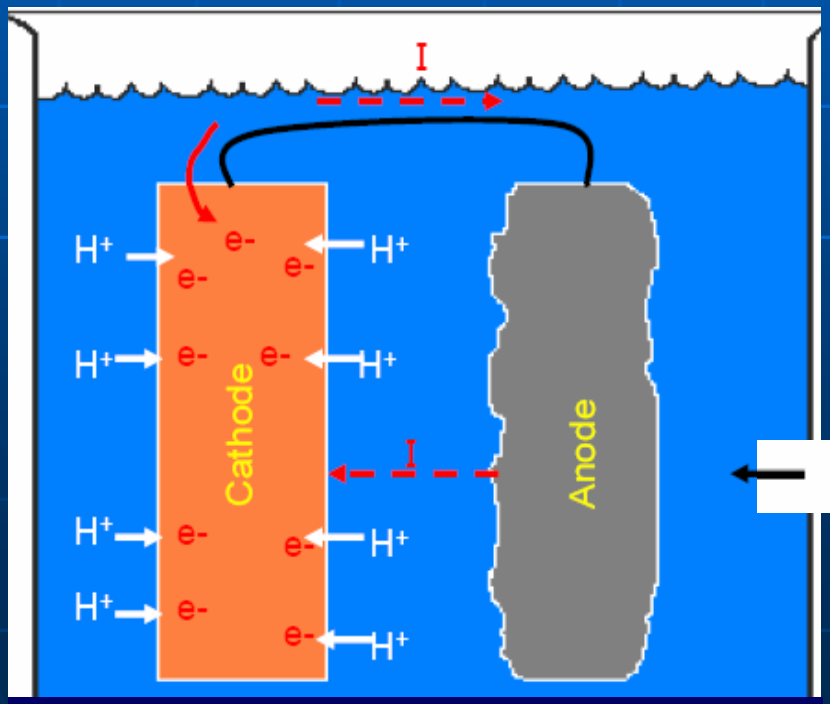
Corrosion Cell – Anodic Reactions



$H_2O \rightarrow H^+ + OH^-$

Corrosion Cell – Combined Reactions





$H_2O \rightarrow H^+ + OH^-$

Corrosion Cell – Cathodic Reactions

Corrosion of Gray Cast Iron Pipe

- Loss of the iron constituent leaves behind graphitized pipe which is brittle and lacks strength & integrity.

Over time, the pipe becomes brittle and is weakened by corrosion

- Seasonal changes in ground and water temperature, increases in water pressure, and/or ground movements, typically result in an increase of break rates

Corrosion of Ductile Cast Iron Pipe

- Subject to pitting corrosion attack in aggressive soil environments.
- These results reductions in wall thickness can allow corrosion to penetrate the pipe wall in less time than older pipe.

External Pitting of Ductile Iron Pipe in Soil

SOLUTIONS

1. REPLACEMENT
2. ISOLATION FROM ENVIRONMENT
3. CATHODIC PROTECTION (CP)
4. SACRIFICIAL ANODE INTALLATION
5. ANODE RETROFIT PROGRAM

1.RLACEMENT

Not A fisible solution because of high replacement cost and lots of wastage .

Material	Expected Life
Cast Iron	120 yrs
Carbon Steel	100 yrs
Ductile Iron	75 yrs
Plastics	60 yrs
Stainless Steel	100 yrs +

2.Isolating the Pipe from its Environment

What's Wrong Here?

Accelerated Corrosion at a Bonded Coating Defect

A Corrosion "Barrier" for Ductile Iron Pipe

3.Cathodic Protection (CP)

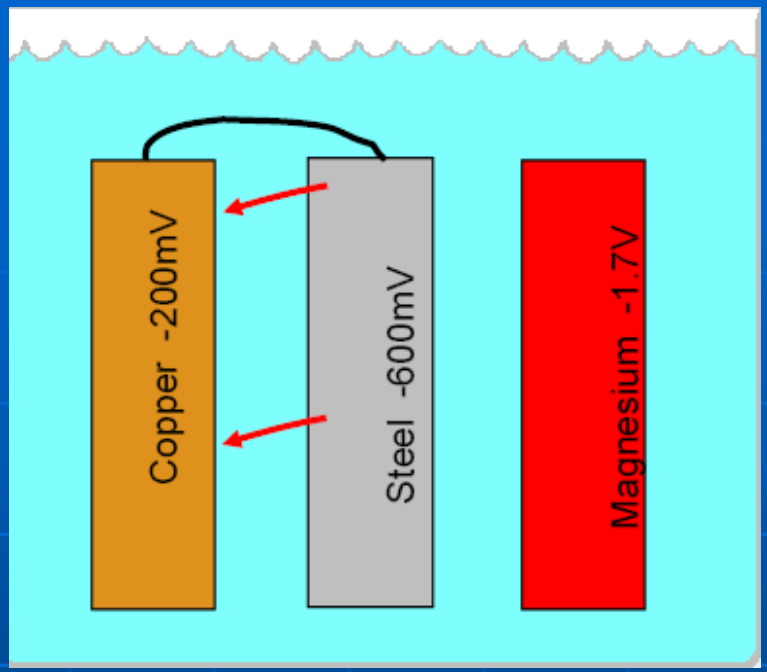
- Corrosion occurs where current discharges from metal to electrolyte.
- The objective of cathodic protection is to force the entire surface to be cathodic to the environment.
- Current is obtained from a metal of a higher energy level.

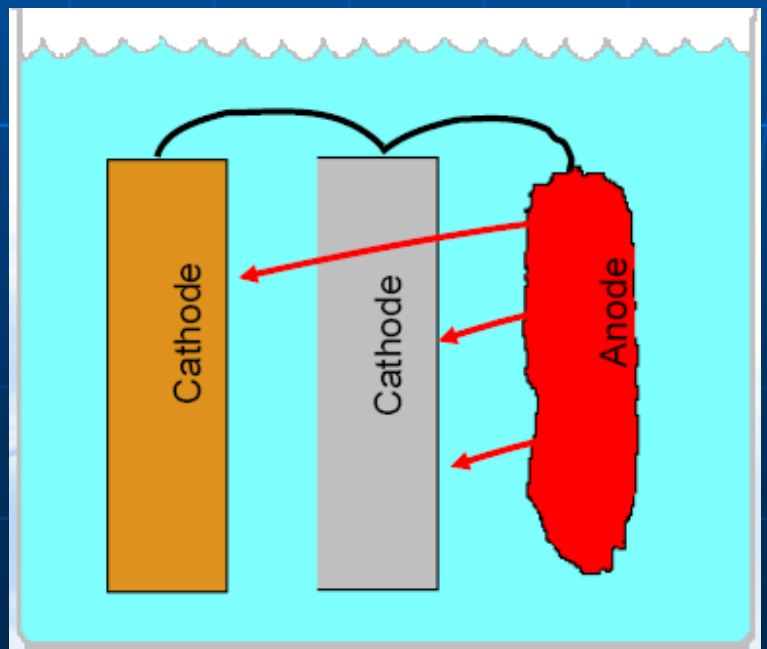
Practical Galvanic Series (contd.)

Less Active More

Material	Potential*
Pure Magnesium	-1.75
Magnesium Alloy	-1.60
Zinc	-1.10
Aluminum Alloy	-1.00
Mild Steel (New)	-0.70
Mild Steel (Old)	-0.50
Cast / Ductile Iron	-0.50
Stainless Steel	-0.50 to + 0.10
Copper, Brass, Bronze	-0.20
Gold	+0.20
Carbon, Graphite, Coke	+0.40

* Potentials in Volts Versus a Saturated Cu-$CuSO_4$ Electrode

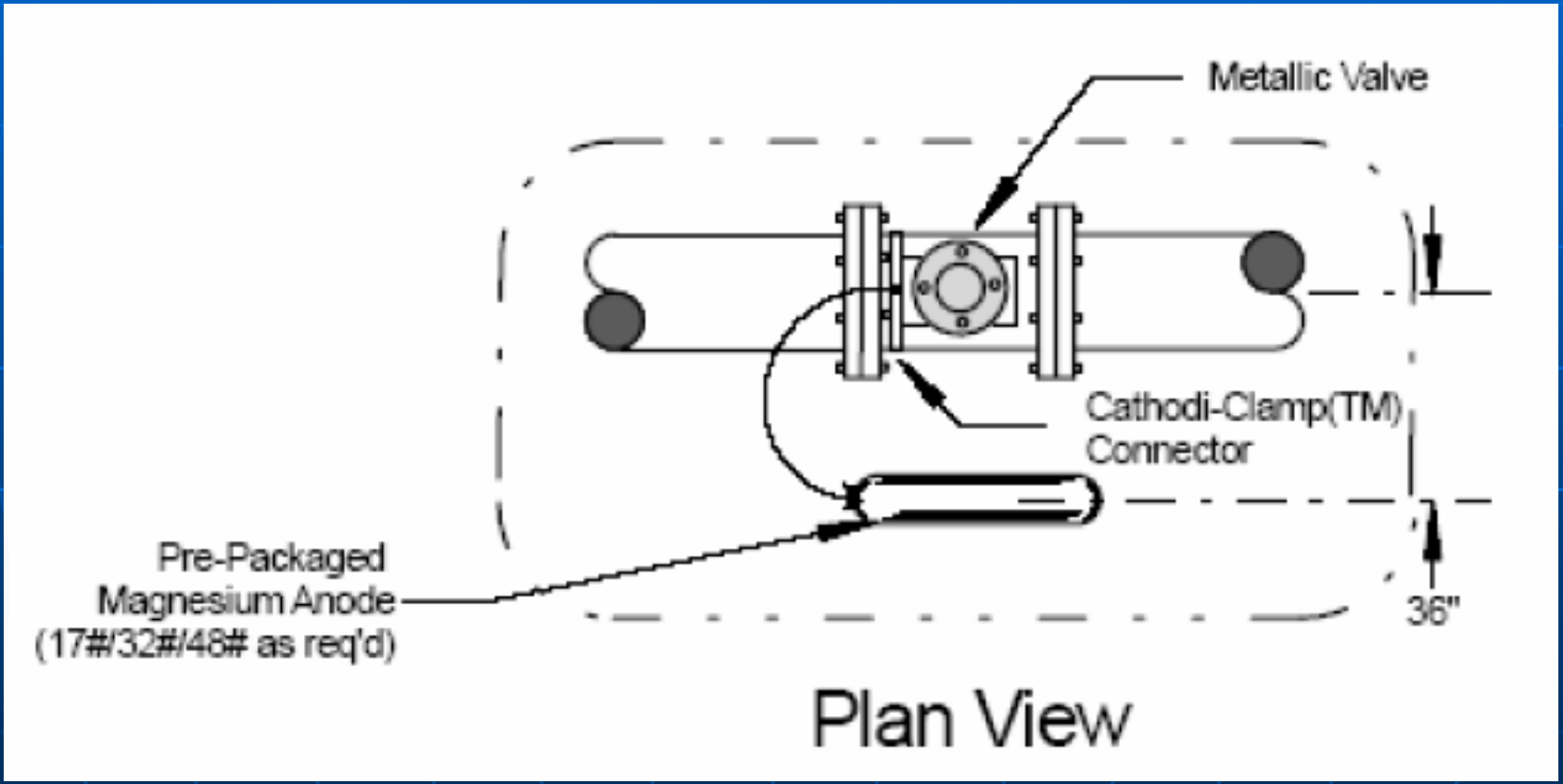




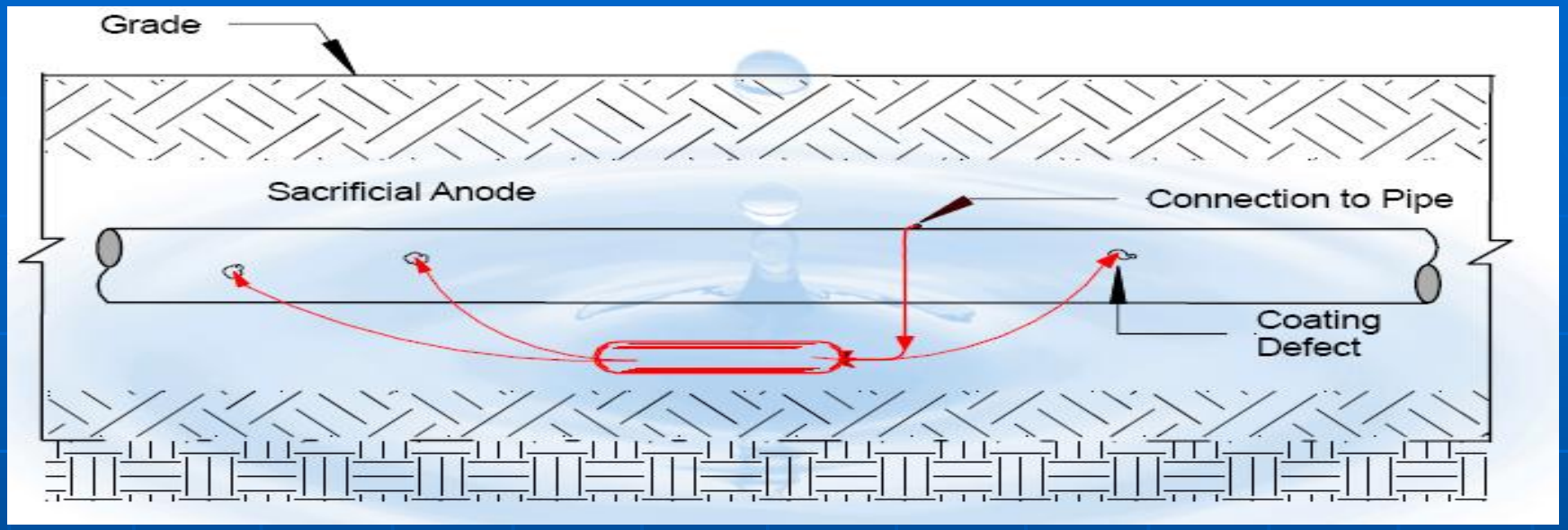
CP System Summary (contd.)

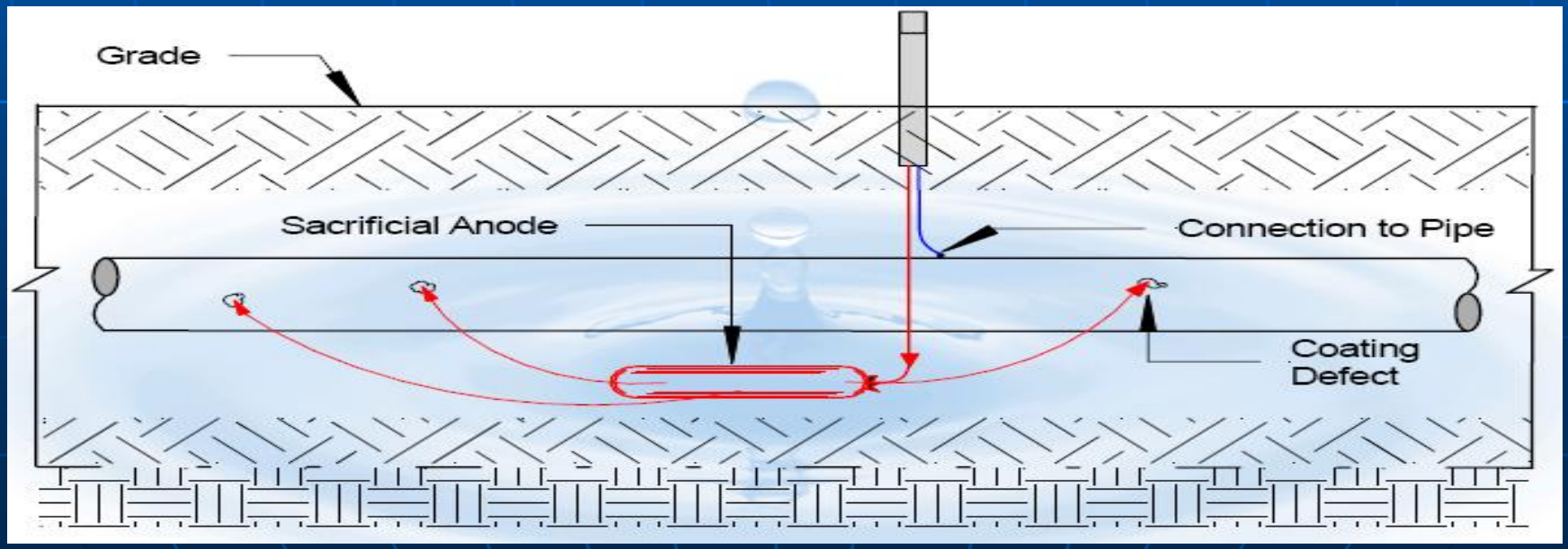
- Prepackaged anodes installed in multiple clusters along the water main.
- Each anode connected to an insulated copper cable using a mechanical splice.
- Anode header cable runs into a test station and is connected to a separate cable that connects back to the pipe.

CP Installation



4.Sacrificial Anode Installation





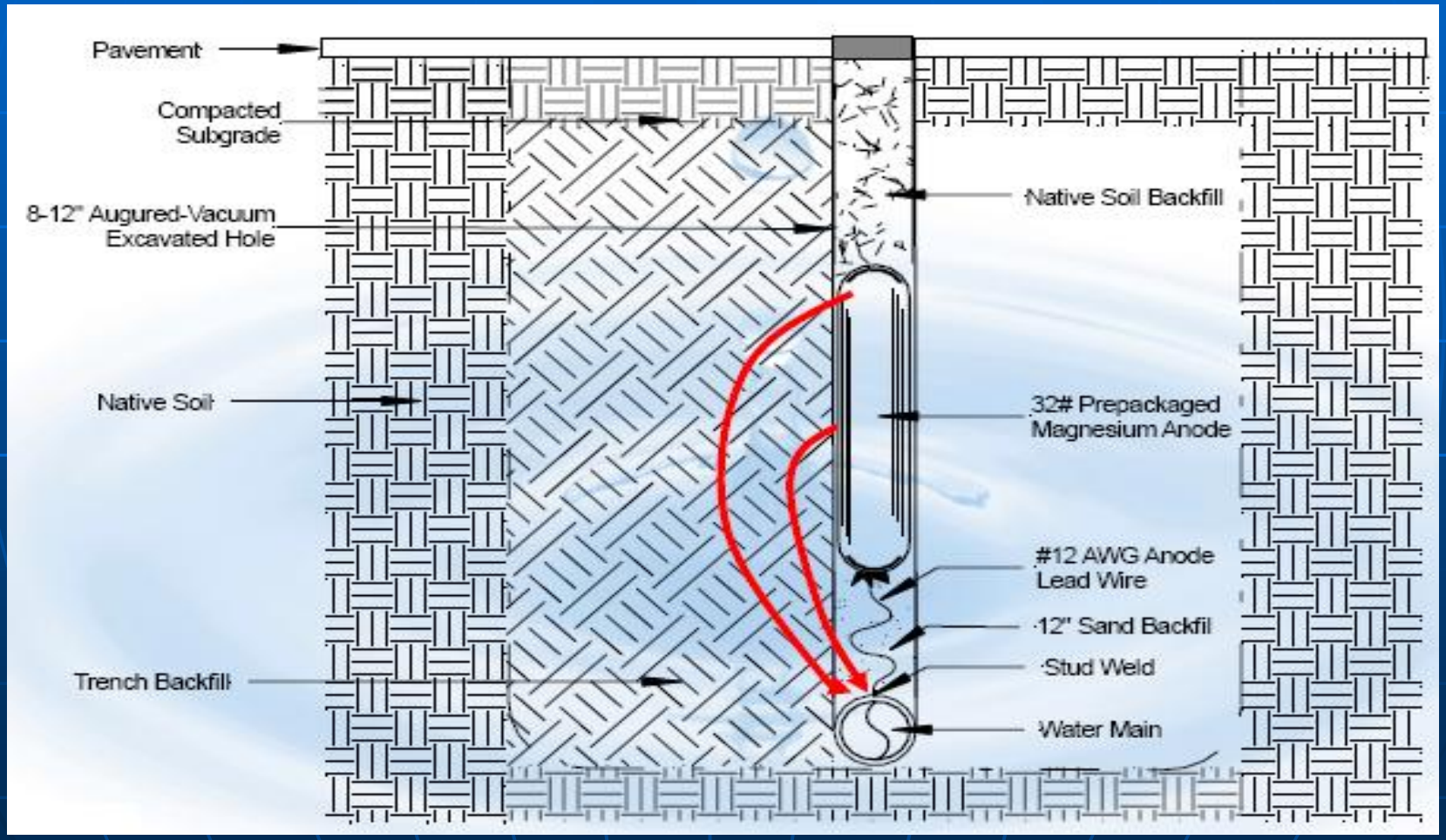
5.Implement Anode Retrofit Program (ARP)

- Addresses the corrosion problem
- Reduces breaks and extends main life
- Little disruption to the environment
- Economical relative to replacements
- Improves customer satisfaction

Factors to Consider in an Anode Retrofit Program (contd.)

- Number of main breaks
- Severity of breaks
- Critical customers in outages
- Does current main meet current & future customer needs?
- Will existing main need to be relocated or replaced as result of other construction in area?
- Ease of access to water main to install anodes (location, depth, etc.)
- Pipe material.

Typical Anode Retrofit Installation Method



ADVANTAGES

- The CP system will extend the life of the new water transmission main by at least 25 years at a cost that is much less than…
  - Pipe repairs or,
  - Main replacement or,
  - The potentially more significant (but incalculable) indirect costs that could occur as a result of a service disruption to a power plant that this main serves.
- Retrofitting cathodic protection to existing cast iron water mains is currently being achieved at a cost of approximately 8-10% of the cost to replace the piping

CONCLUSION

- Iron pipe corrosion is extremely complicated and is affected by practically every physical, chemical, and biological parameter in water distribution systems. This work provides a summary of key factors that utilities must evaluate in order to mitigate iron corrosion problems. Utilities should also consider potential secondary impacts on corrosion due to compliance efforts for new regulations.

THANK YOU