Catastrophic Failure of Aging Underground Pipelines Is Inevitable in Corrosive Soils and CP Shielding Conditions
False Sense of Security!

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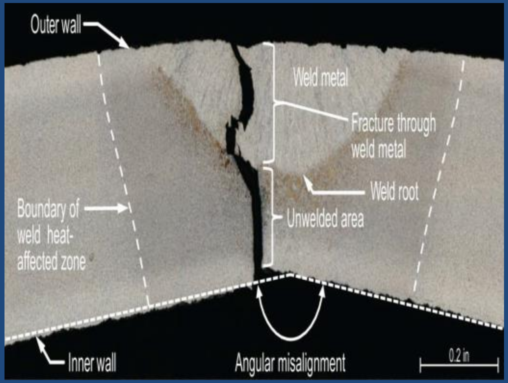
FELLOW OF NACE, FELLOW OF ASM

NACE CERTIFIED CORROSION / MATERIALS SELECTION / DESIGN / COATING / CP SPECIALIST
NACE Approved Instructor

Sept . 7, 2017

Exova

- Materials Testing and Failure Analysis
  - Pipeline Corrosion Risk Assessment
  - Cathodic Protection
  - Root Cause Failure Analysis
  - Materials Testing
  - Metallurgical Evaluation
  - Accelerated Corrosion Testing
  - Tier Testing for Coating Selection
  - Concrete Petrographic Analysis
  - QA/QC Inspection and Technical Audit
  - Corrosion Monitoring
  - Training



Dr. Zee

Certifications
- National Association of Corrosion Engineers (NACE)
- NACE Certified Materials Selection/Design Specialist
- NACE Certified Coating Specialist
- NACE Certified Cathodic Protection Specialist
- NACE Certified Corrosion Specialist

Awards:
- Colonel Cox Award, 2010
- Elected Fellow, NACE International, National Association of Corrosion Engineers, 2008
- Elected Fellow, ASM International, American Society for Metals, 2007
- Entrepreneur of the Year Award (2004), ASM
- Outstanding Service Award (1996), NACE

Achievements:
- 25 Patents on new materials and coatings
- 60+ Publications in Technical Journals
- Instructor for three annual short courses at AUCSC on Failure Analysis, Coatings and Materials Selection
- Instructor for NACE "Liberty Bell" Coating Course
- Lecturer for Technical Societies: ASM, NACE International, AFS, SAE,…
- Member of Steering Committee for Department of Defense
- Chair, ASTM Task Group on Transmission Tower Corrosion Task Group
- NACE Steering Group, Corrosion on Electric Utility Transmission & Distribution Assets
- Principal Scientist for Pentagon, Loops, Follansbee Steel, TIMET….

Pittsburgh Post-Gazette

ONE OF AMERICA'S GREAT NEWSPAPERS

As Pa. pipelines age, role of corrosion in accidents examined

July 17, 2016 12:00 AM

Darrell Sapp/Post-Gazette

Mehrooz Zamanzadeh, or "Dr. Zee," says many pipeline companies don't know what materials were laid underground decades ago. This Auger electron microscope at Exova in Robinson helps decode the mystery.


THIS MONTH: CORROSION IN THE POWER INDUSTRY
MICROBIOLOGICALLY INFLUENCED CORROSION

MP MATERIALS PERFORMANCE

CORROSION PREVENTION AND CONTROL WORLDWIDE

CATHODIC PROTECTION OF POWER TRANSMISSION TOWER FOUNDATIONS

The Effect of Chlorine Dioxide on Corrosion in Seawater

Deactivating Bacteria to Prevent Sewer Collapse

Assessing Galvanized Steel Power Transmission Towers for Corrosion

Author and Article Index to 2016 MP

NACE

FEATURE ARTICLE

Assessing Galvanized Steel Power Transmission Poles and Towers for Corrosion

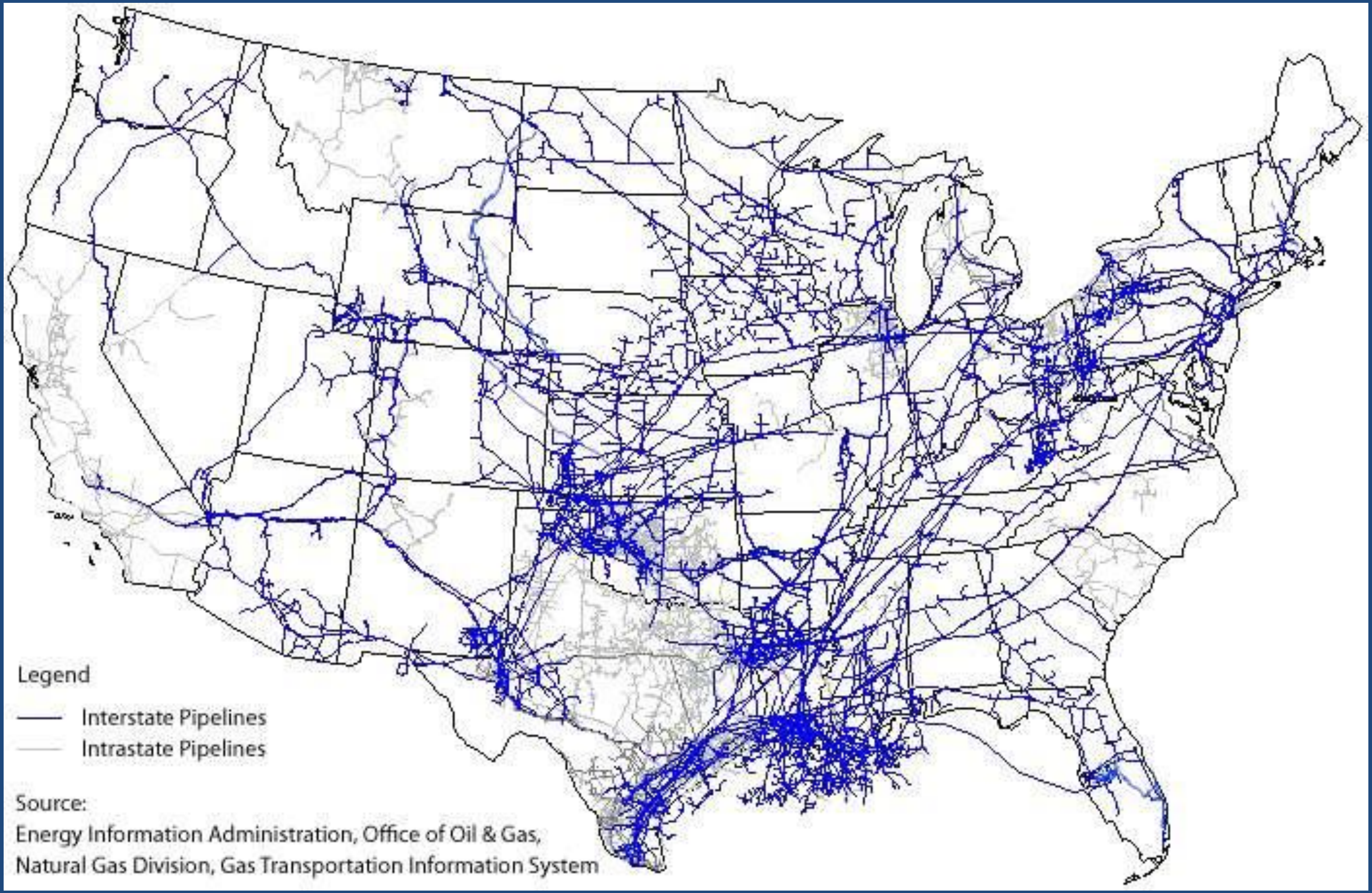
CATHODIC PROTECTION

Galvanic Cathodic Protection for Power Transmission Tower Grillage Foundations

Steel Grillage Foundations

~ Three Months in the Life of a Corrosion Expert~
Willie Nelson said it best:
On the Road Again…

- Corrosion Assessment of CP Protected Above Ground Tank
- AC Interference Assessment (Nebraska)
- Stress Corrosion Cracking and Rupture of a Pipeline and Explosion of a Pipelines in NE
- Corrosion failure and rupture of of a pipeline in NW
- Underground Cathodic Protection Design and Installation for Exxon Tank/Pipes
- St. Croix Federal Court House Water Line Problems and Recommending Solutions
- Cayman Island: 500,000 Gallon Storage Tank Failure Analysis
- Corrosion Mapping of City of San Diego for SGD&E
- Paint Failure on 7075 Aluminum Alloy in Major Commercial Airline
- Transformer Corrosion Assessment / Corrosion Mitigation for Distribution Poles
- Failure Analysis Of 30 inch FBE coated pipeline that exploded in service
- Pittsburgh: Jet Fuel Investigation - Plugging Filters and Biofilm
- Published "Fatigue Failure Analysis Case History" in Failure Analysis Journal
- Pipe Line Corrosion Assessment Presentations in Technical Societies, Safety Conferences
- Four NACE Courses for Engineers
- Last year frequent flyer: 195,000 miles
- No complaints except airports: **House of Pain**


Legend
Interstate Pipelines
Intrastate Pipelines
Source:
Energy Information Administration, Office of Oil & Gas,
Natural Gas Division, Gas Transportation Information System

Age and Pipelines

1. 12% of the pipeline infrastructure was installed prior to 1950,
2. 37% was installed prior to 1960,
3. 60% was installed prior to 1970,
4. 70% was installed prior to 1980,
5. 80% was installed prior to 1990, and
6. 90% was installed prior to 2000.

CATASROPHIC FAILURE OF AGING UNDERGROUD PIPE, BRIDGES, T&D STRUCTURES ARE LIKELY CONSIDERING THE CONDITIONS THEY ARE IN

- It is the intent of the law that matters, not minimum requirements that are required to be in compliance.

- Minimum requirements may not be enough for safety (compliance with regulations).

Aging Pipelines in Corrosive Soils are at Increased Risk: Leaks, Rupture, Explosions

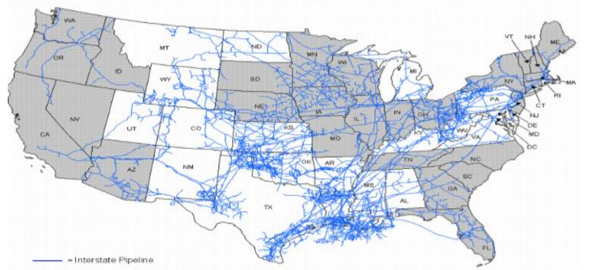


Figure 2: Interstate Natural Gas Supply Dependency, 2007
Source: Energy Information Administration, "Annual Report of Natural Gas and Supplemental Gas Supply and Disposition"

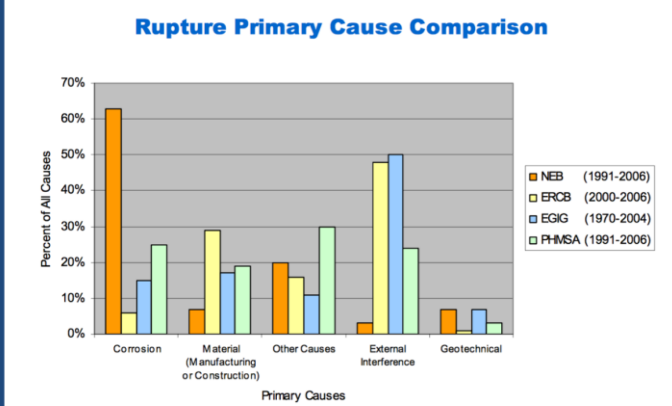


***Figure 1.8** – Comparison of pipeline failure causes for Canada (NEB and ERCB), Europe (EGIG) and the US (PHMSA)*
(Source: National Energy Board. [2008, July]. Focus on Safety and the Environment. A Comparative Analysis of Pipeline Performance, 2000 - 2006)

1. 2.907 Millions miles of pipe line in North America
2. Close to 50% were constructed during1950 and 1960's . Now over fifty years old
3. Some of these pipes are likely exposed to corrosive soils, water tables, DC corrosion and AC interference
4. Coatings are aging. Prone to stress damage, dis-bondment, blistering , and delamination
5. CP systems show variation in voltage, current , potentials. depending on the time of measurements may vary 300-400 mV ..Under protection and no protection is present
6. Initiation of localized corrosion and cracking under the delaminated coating is difficult to predict
7. Accelerated Corrosion, SCC, Pitting, Leaks, and Rupture are inventible
8. Unacceptable risks for Public Safety
9. Dis-bonded coating will prevent above ground survey detection of underlying corrosion conditions: Major Challenge for Pipeline Integrity Check

Pipe in Corrosive Soil Environment

What Can Go Wrong?

- The record shows that during the 20-year period from 1992 through 2011, there were 2,059 reportable incidents. Reportable incidents can range from incidents meeting a public nuisance level, to a significant incident with property damage, or to a serious incident involving injuries.

- From these data, one can estimate the probability of an incident at any random point if an incident were equally likely at any point in the 305,000 miles of natural gas transmission pipelines in the U.S.

- The rate for reportable incidents is approximately 0.00034 per mile per year if the likelihood of an incident occurring is the same everywhere.

Localized Corrosion?

1-Cathodic Protection Shielding

2-Electrodeposition and Conductive Soil

3-Excessive Potentials: Active and or Noble Potential

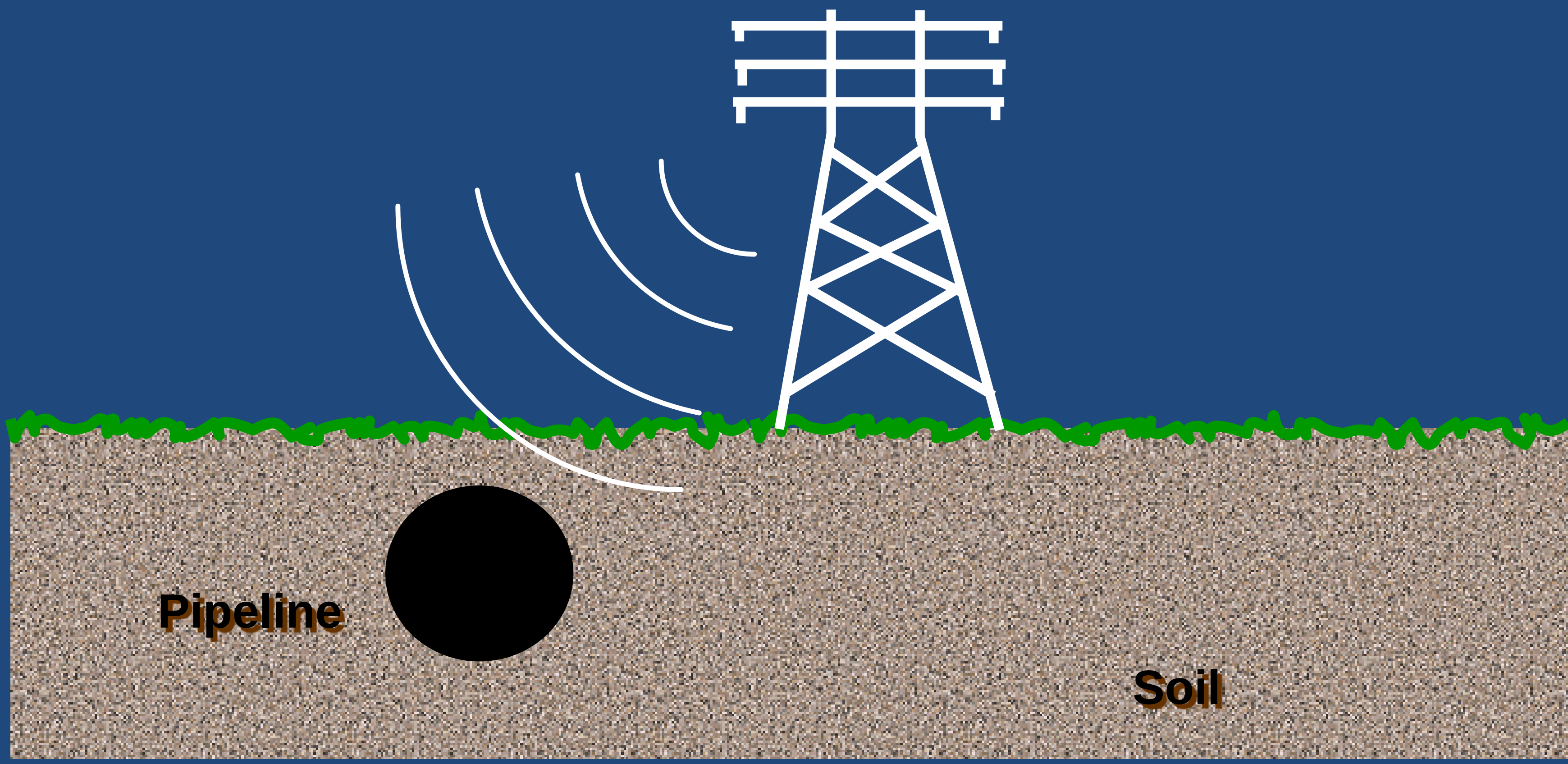
4-Stray Current and AC Interference

5-No or Less than Adequate CP

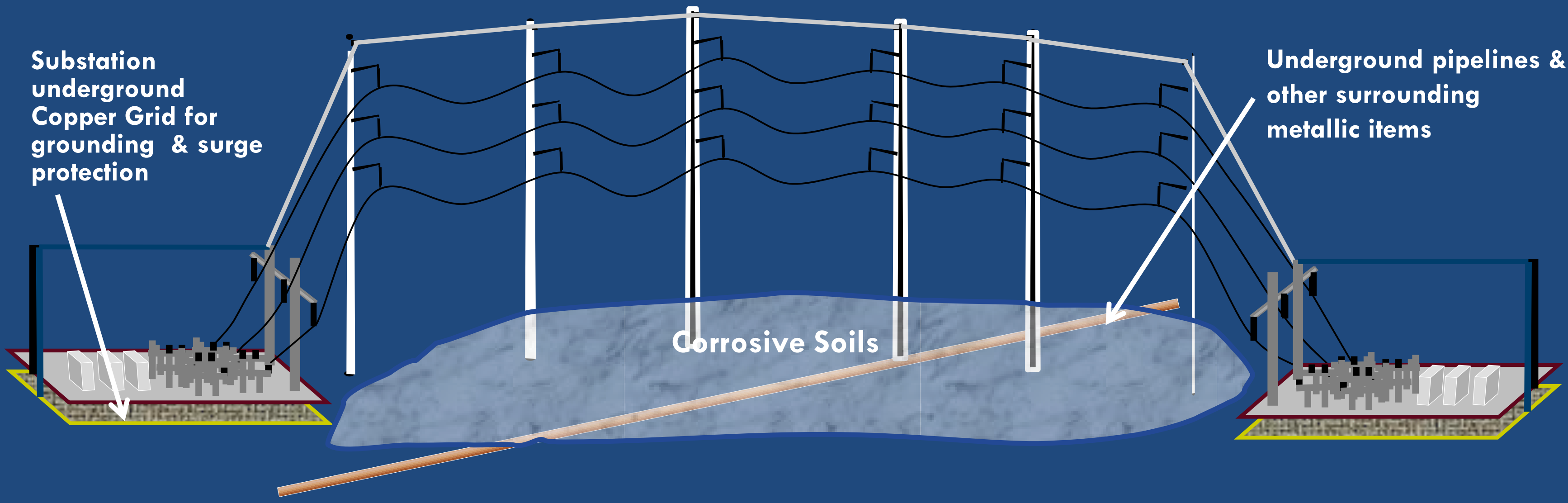
6-Copper Grounding

AC Interference

The magnetic field generated by the overhead power lines induces an AC voltage onto the pipeline. The magnitude of such currents depend on many factors such as coating condition, soil resitvity, power line voltage, distance, etc.



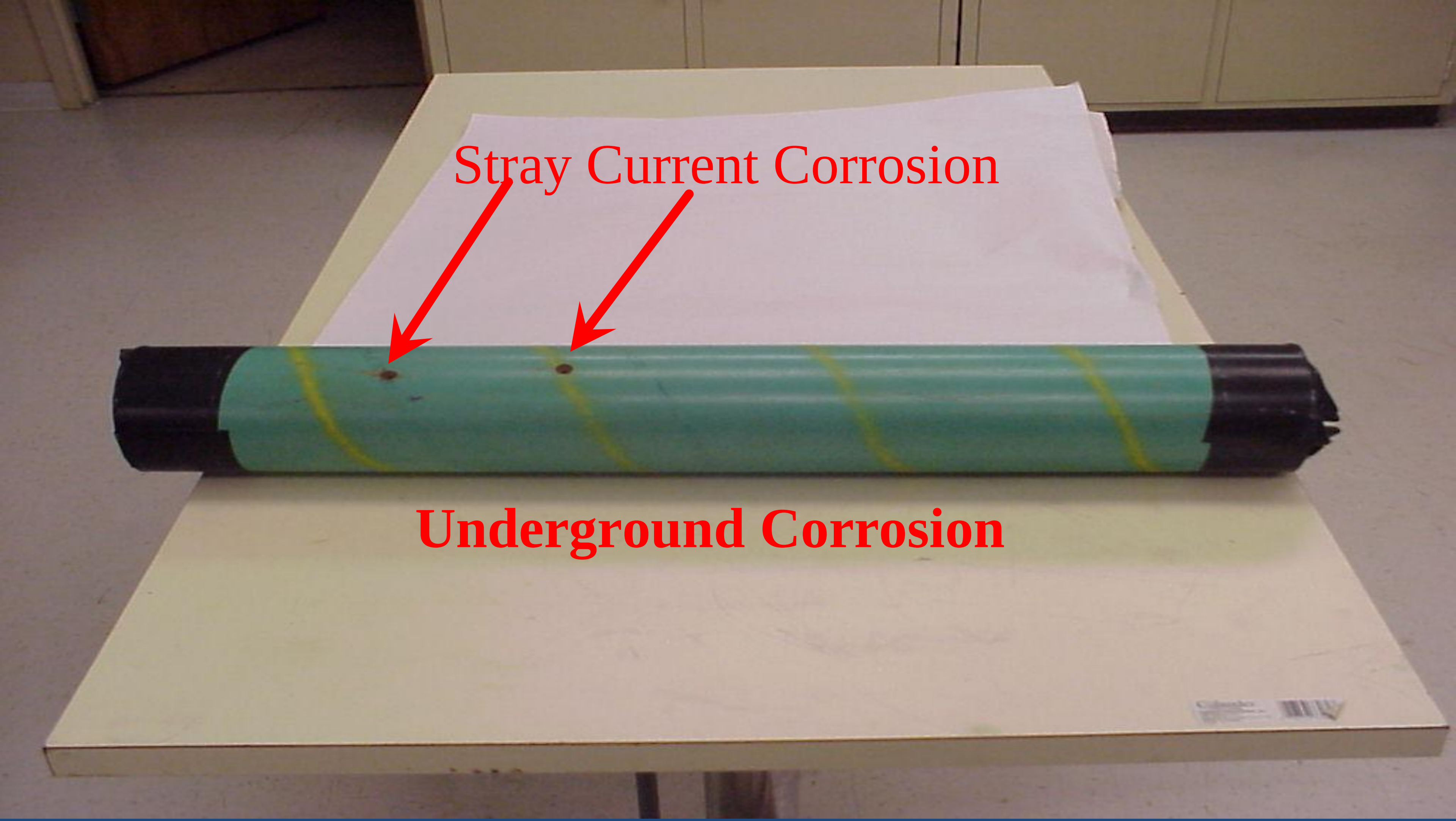
Pipe Lines and Towers



DC Corrosion

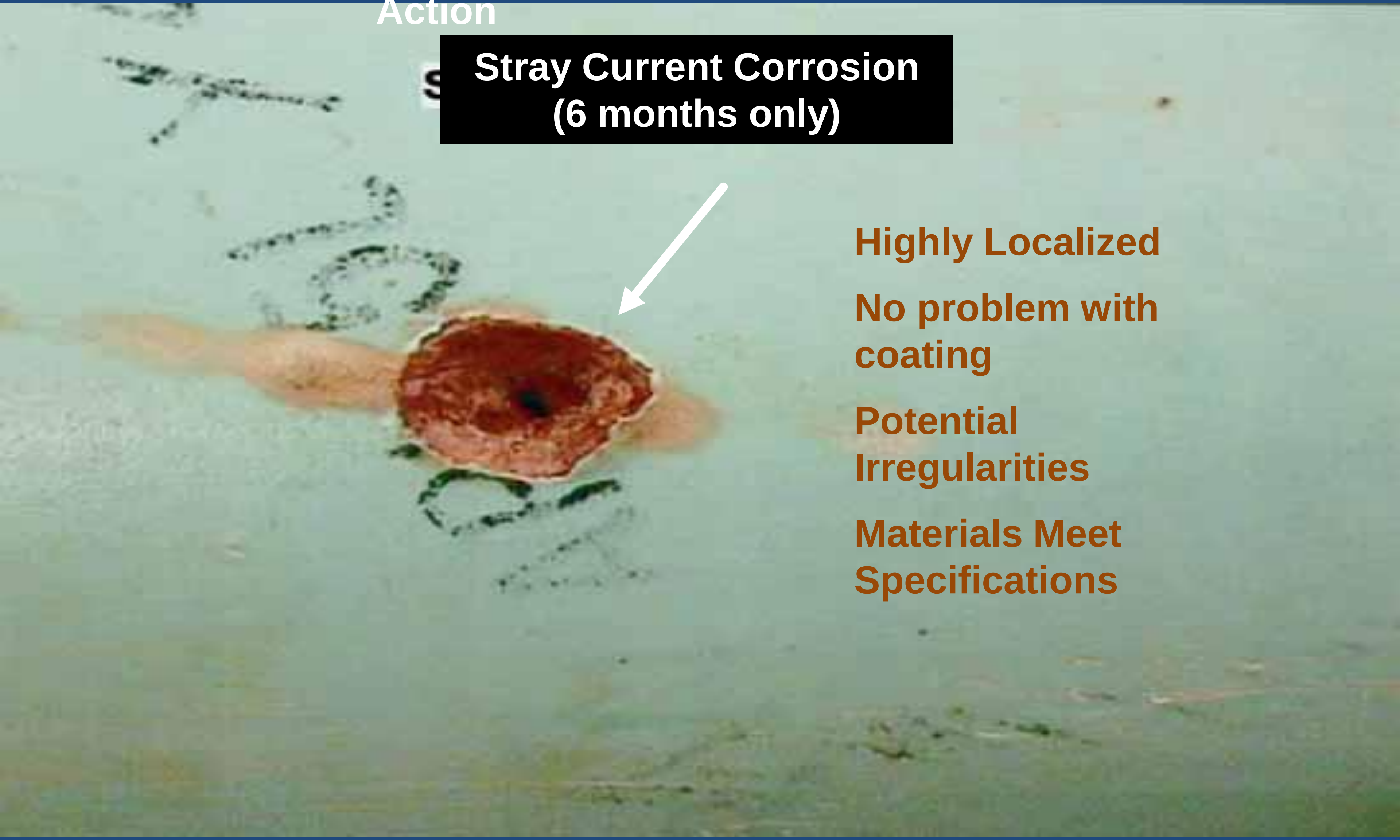
AC Interference


2



Stray Current Corrosion: Unacceptable Risk: Immediate Action

Unacceptable Risk: Immediate Action



Stray Current Corrosion (6 months only)

- Highly Localized
- No problem with coating
- Potential Irregularities
- Materials Meet Specifications

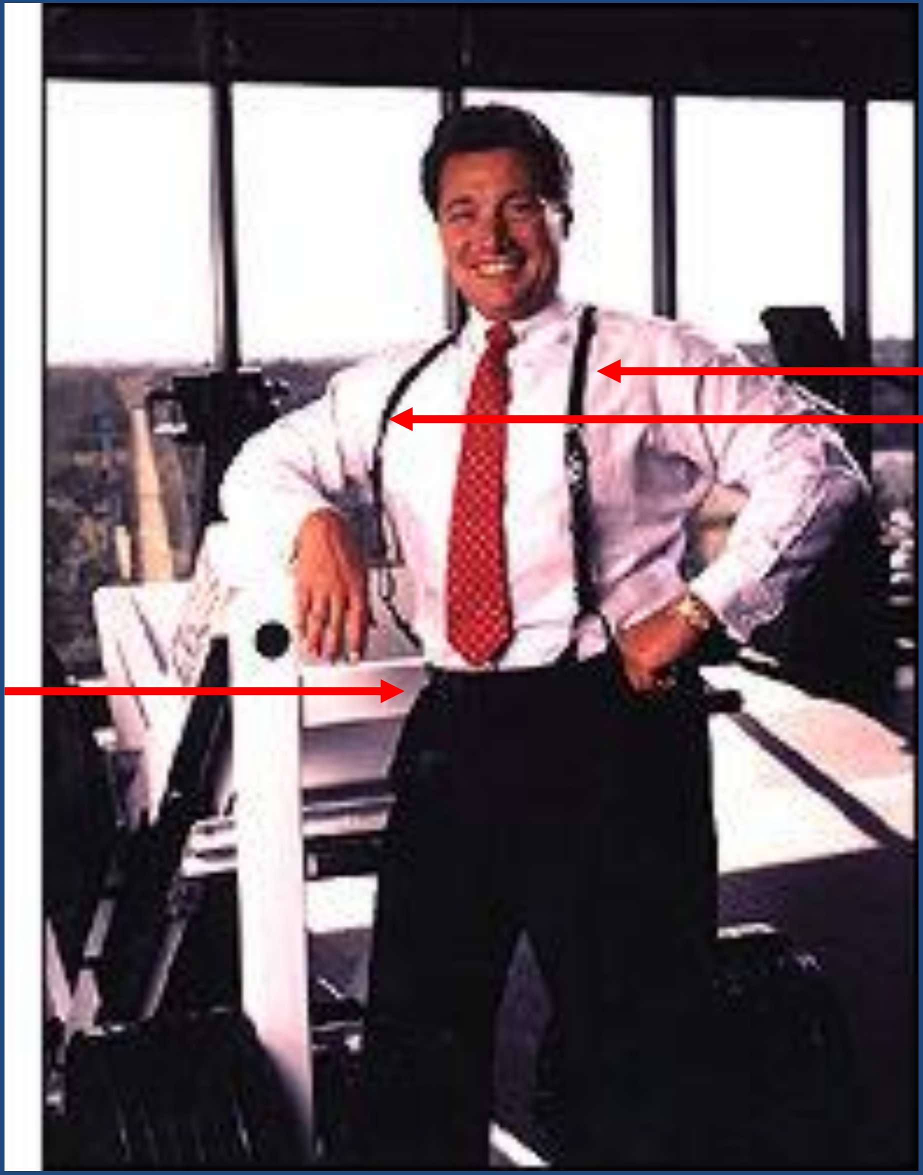
Root Cause of Failure: Stray Currents

Risk Management

- Zero Risk : Most of times not feasible or economical

- Mange risk:
  - Protective Coatings
  - Materials Selection
  - Cathodic Protection
  - Change corrosivity of environment
  - Replacement of component or structure

Suspenders & Belt Approach: Pump Electrons!



suspenders

belt

Fusion Bonded Epoxy Coated Pipe and Blistering

>1000,000 Miles of Underground Aging Pipelines
at Risk!

Aging Pipeline Coatings

Corrosive Soils/Ions

Corrosive Water Table

DC stray corrosion

AC Interference

Shielding to CP

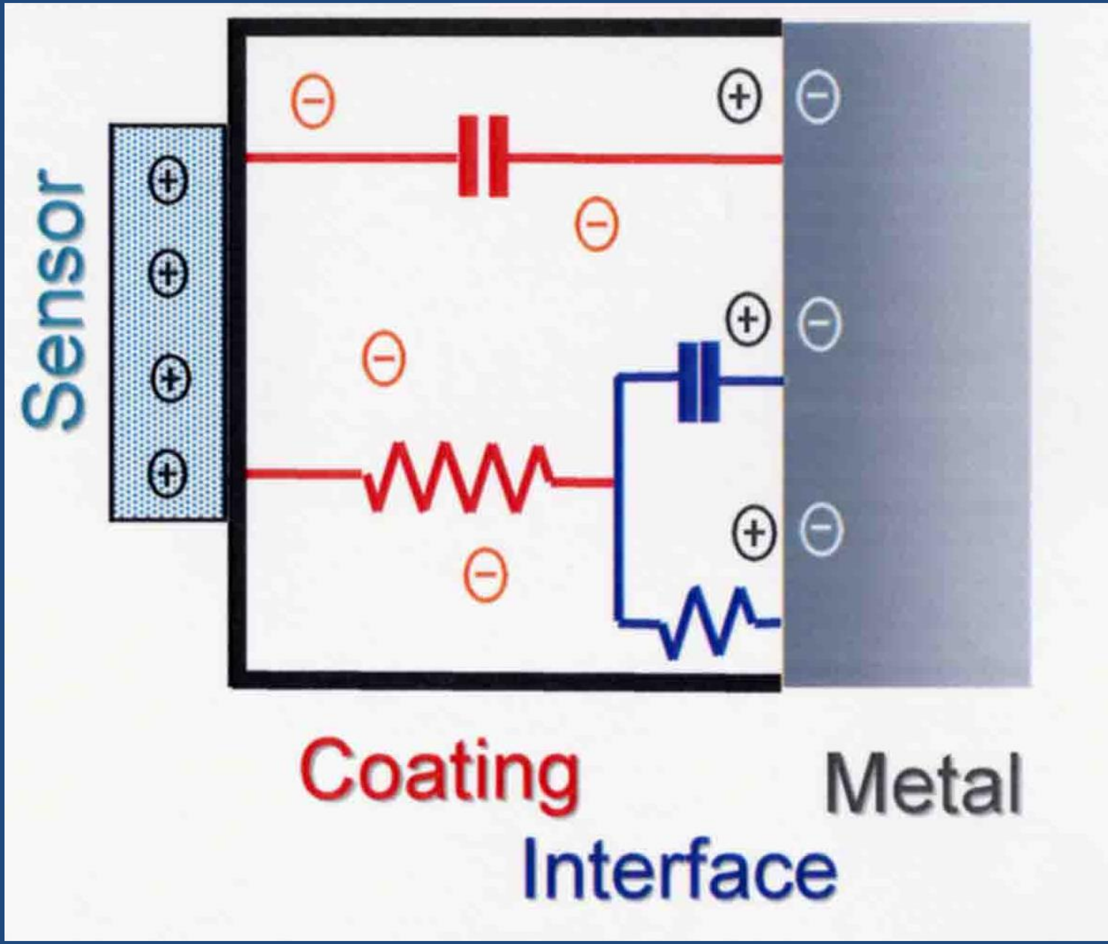
MIC

Detection of corrosion activity at blistered areas prior to deep penetration in the pipe is of great importance under corrosive conditions

Coating Failures

- Formulation Related
- Coating Selection Related
- Substrate-Related
- Stress and Temperature Related
- Surface Preparation Related
- Storage and Application Related
- Surface Contamination
- Thickness Related
- CP Related
- External Interference (DC and AC)

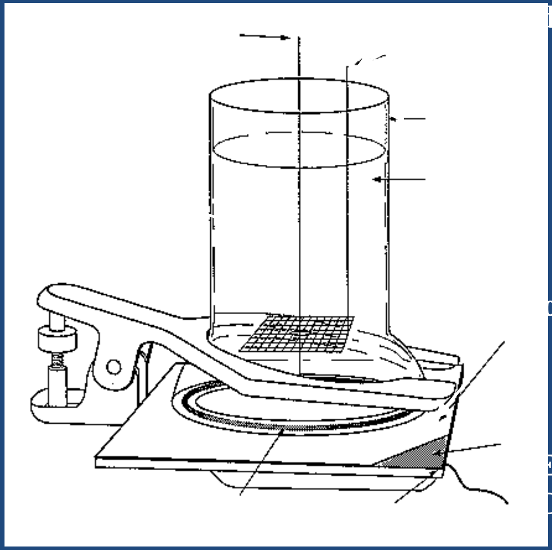
EIS



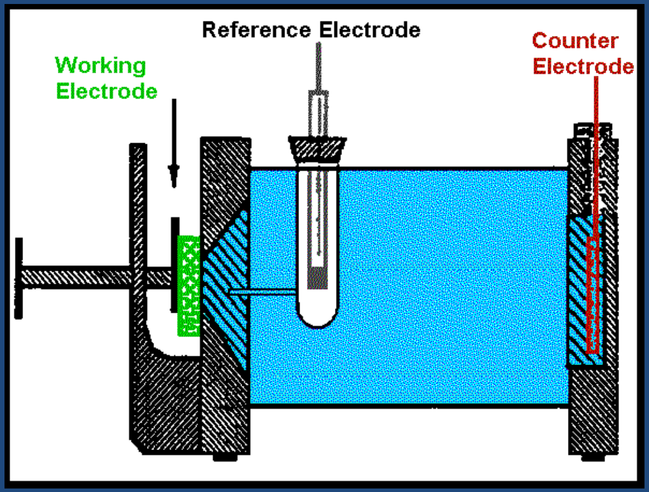
Electrochemical Test Set-Up

•These tests use a computerized electrochemical system and EIS software to collect data and help with analyses.

Below are basic set-ups used for testing coatings:



Clamp-on Cell



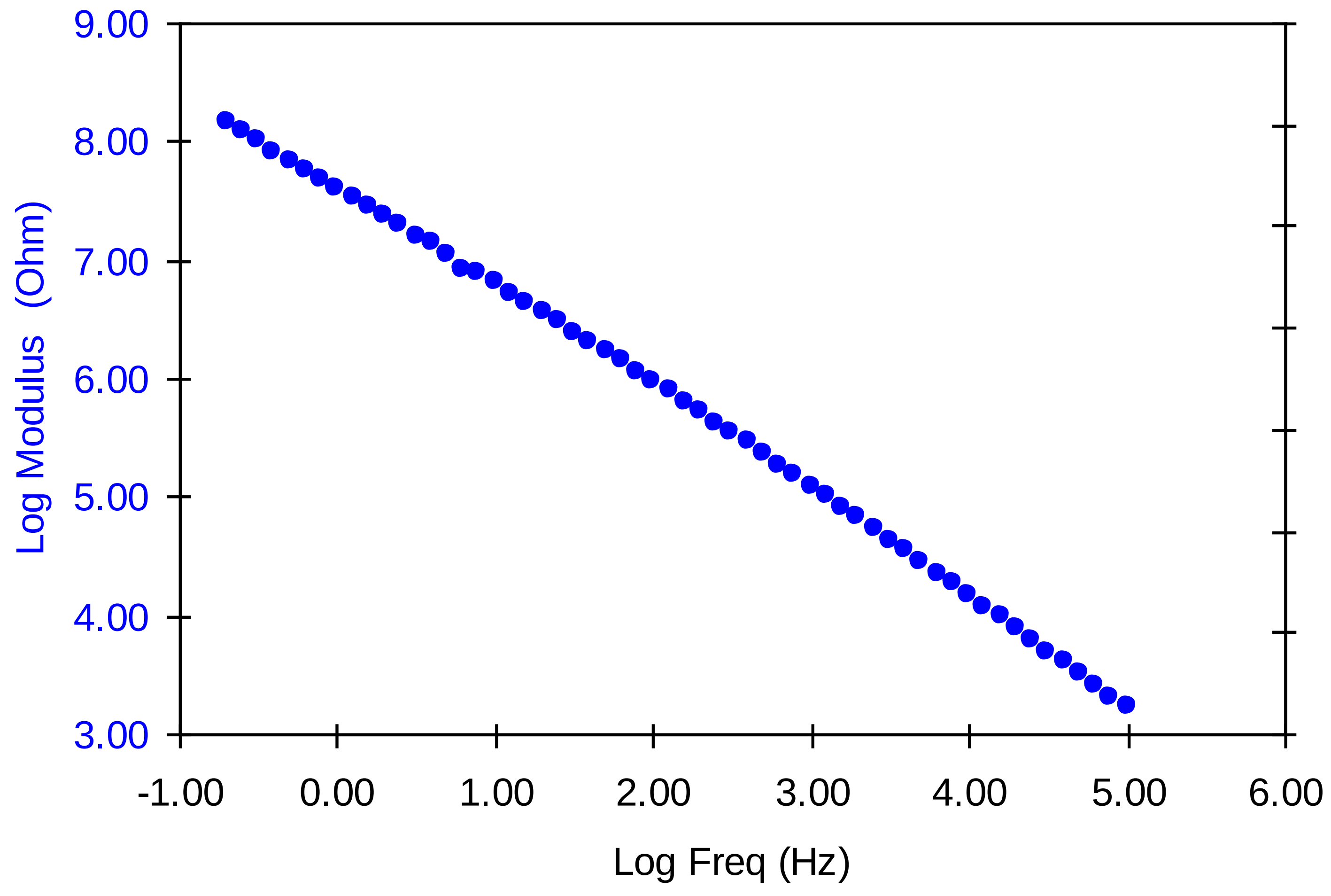
Flat Cell

Electrical Chemical Impedance Spectroscopy (EIS)

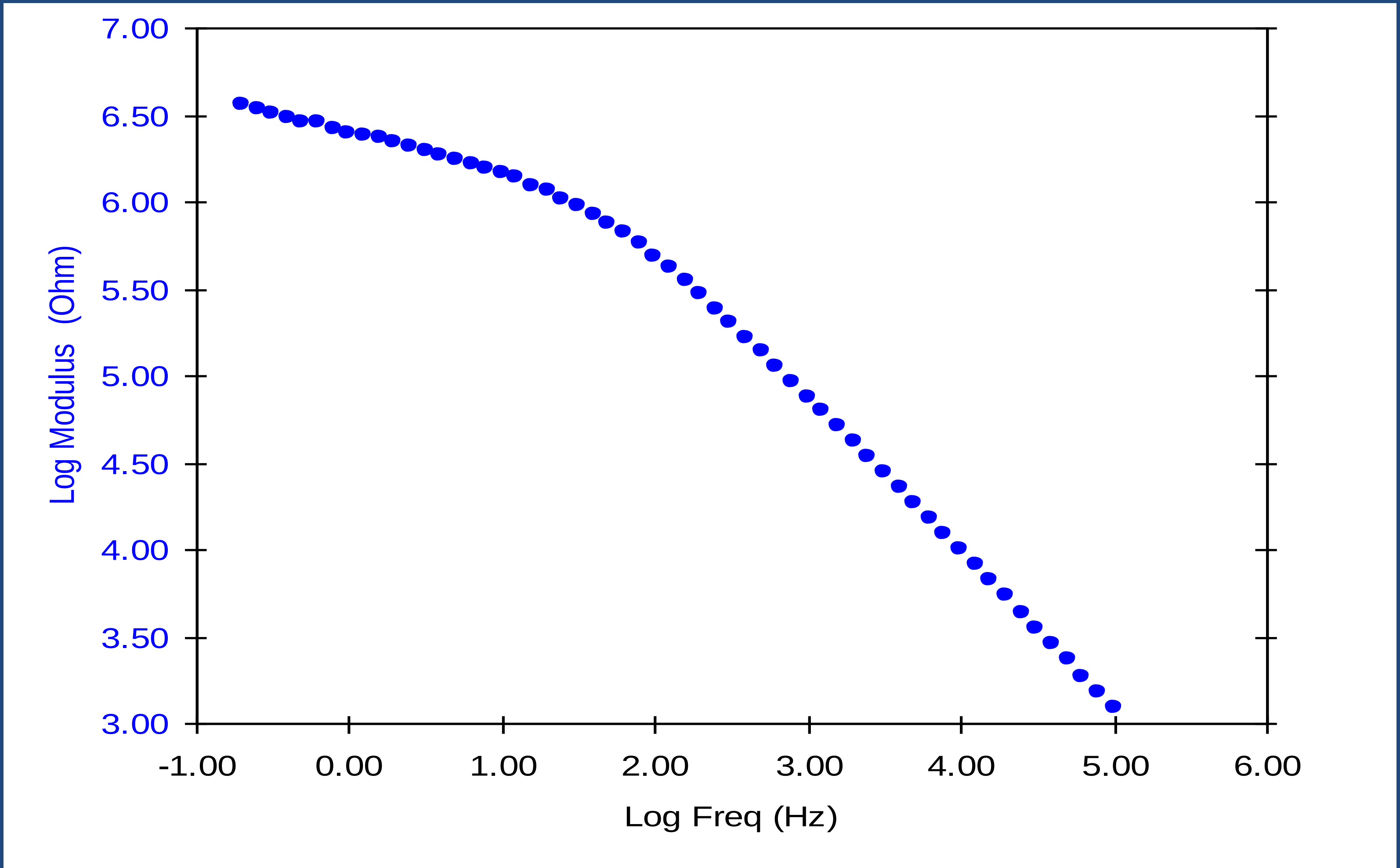
- Electrochemical measurement of coatings capacitance.

- Comparison of initial coating capacitance to final coating capacitance to find the percent ideal of the coating.

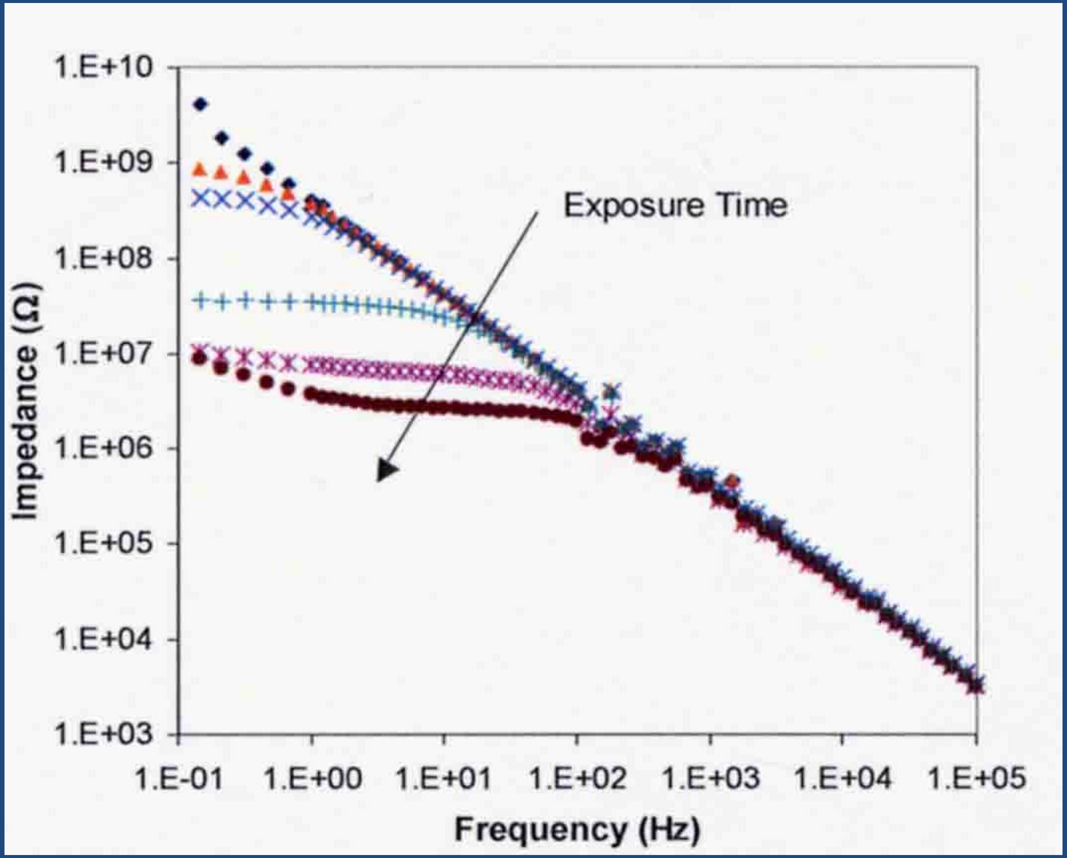
Electrochemical Behavior of a Purely Capacitive Coating (Ideal)



Electrochemical Degradation (from Ideal) of an Organic Coating

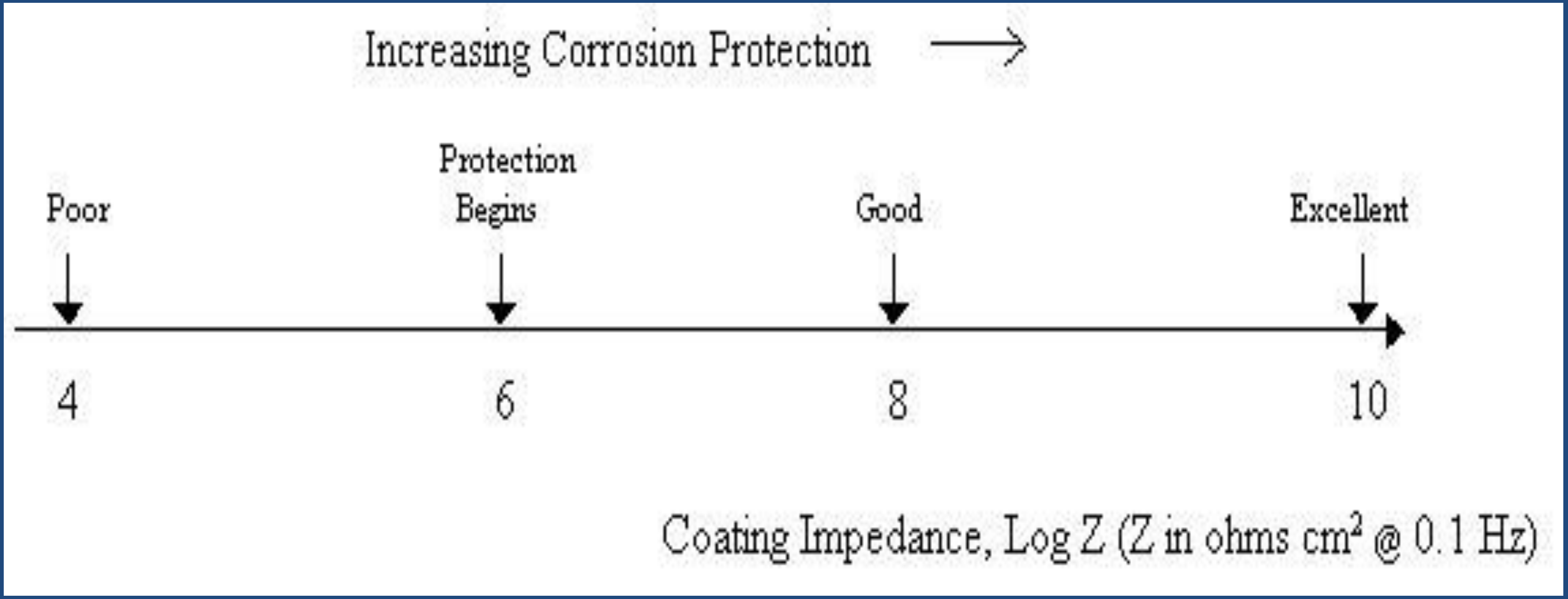


EIS Testing



1.E+10
1.E+09
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
Impedance (Ω)
Exposure Time
1.E-01
1.E+00
1.E+01
1.E+02
1.E+03
1.E+04
1.E+05
Frequency (Hz)

Corrosion Protection of Organic Coating In Moderately Corrosive Immersed Conditions



Coatings

1. Dis-bondment
2. CP Shielding

Dis-bondment of Coatings

- Dis-bondment of the tape coating from the outer pipe wall can result in moisture ingress between the tape and the steel, promoting corrosion. In this instance, the polyethylene tape no longer separates the pipe wall from a corrosive environment and the high electrical resistance of the tape shields the surface from receiving the adequate protective current of the cathodic protection system.

New US DOT Title 49 Section 192.112

- The US Pipeline and Hazardous Material Safety Administration (PHMSA) has adopted a new ruling for those pipelines that want to increase maximum allowable operating pressure (MAOP) to80%.

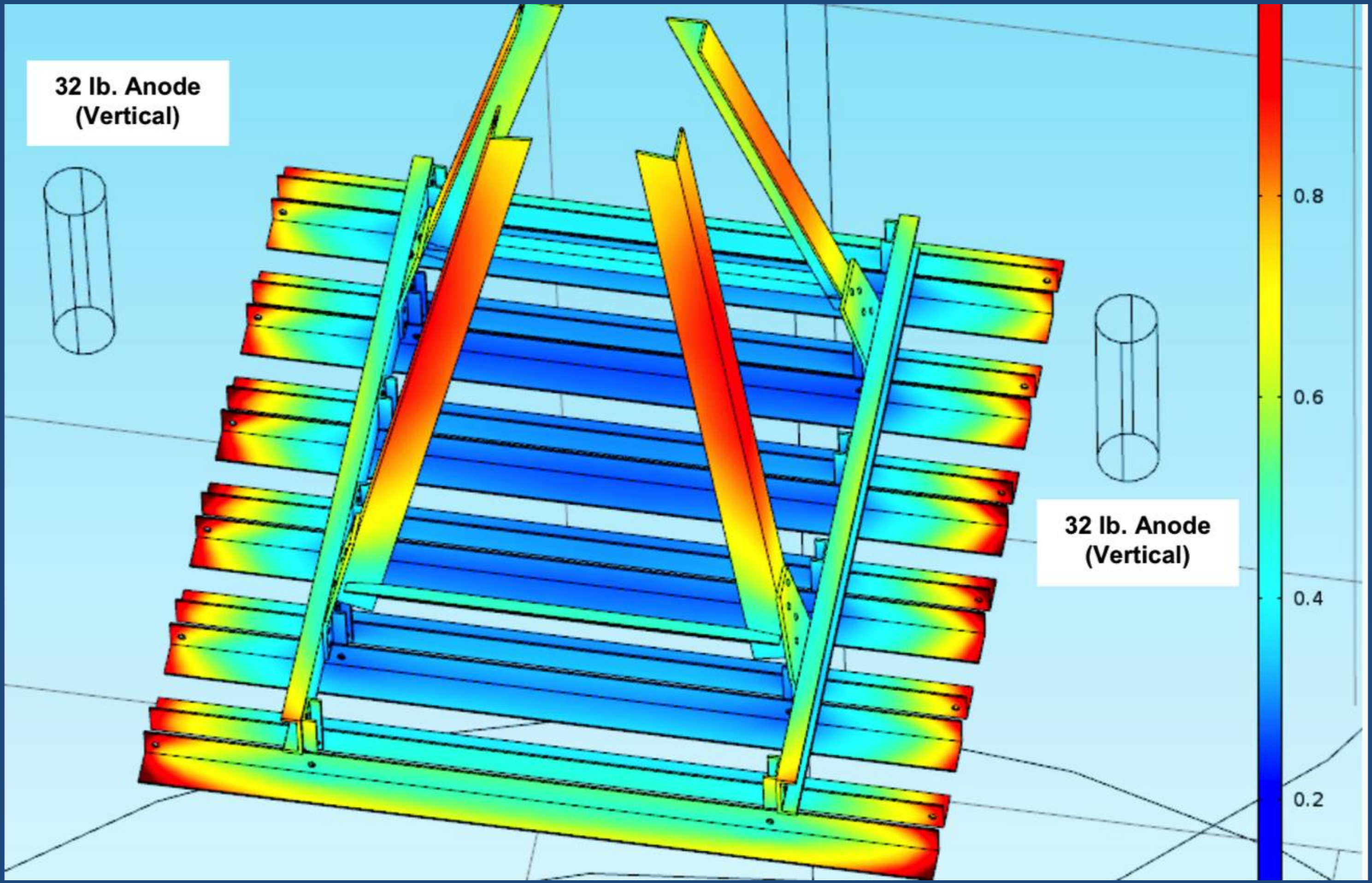
- The pipe must be protected against external corrosion by a non-shielding coating system.

What is Cathodic Protection?

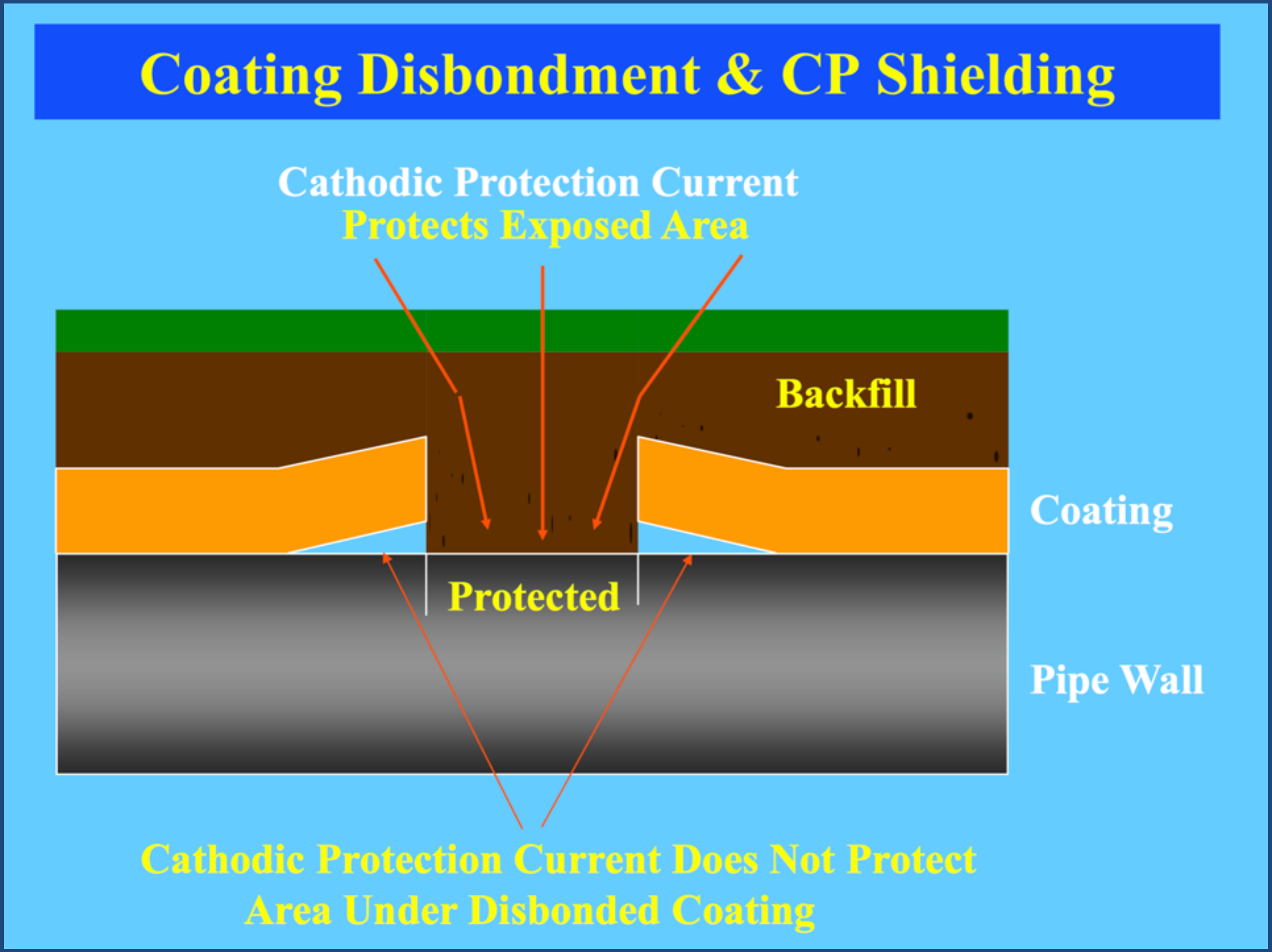
Cathodic Protection is a technique to reduce the corrosion rate of a metal surface by making it the cathode of an electrochemical cell. Pumping Electrons

Caution - Cathodic protection is not effective in presence of shielding.

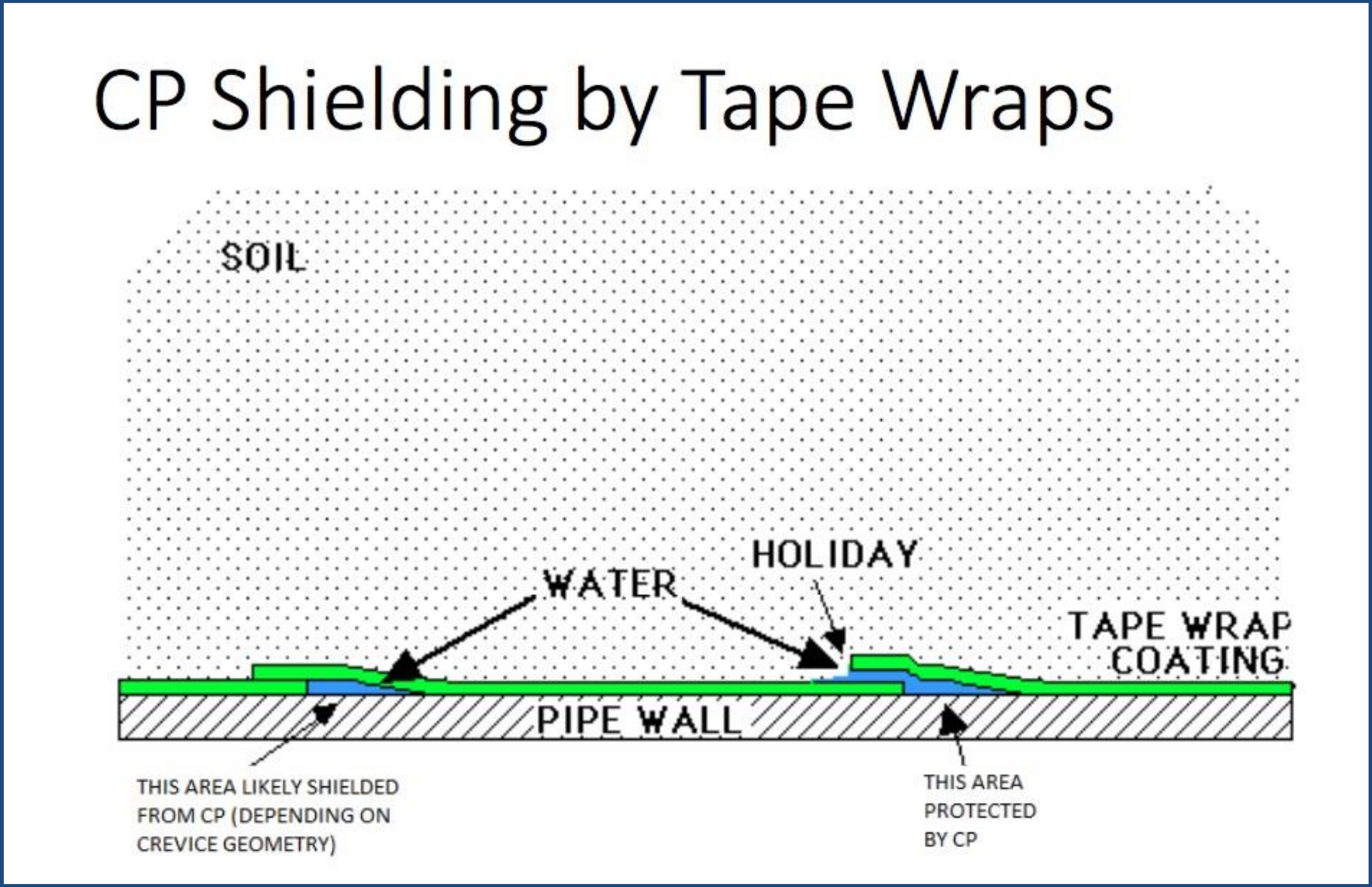
Potential Distributions and Shielding



Shielding and Coating Dis-bondment



CP Shielding



Under-Appreciated Facts About CP Shielding

- CP shielding is not an inherent coating property, it is a <u>set of conditions</u> which must be met
  - "Proving" shielding is very difficult – always other factors
- Other features can result in CP shielding:
  - Pipe buried in area with significant bedrock
  - Obstructions – vaults, sheet under-liners (tank farms)
  - Poorly designed / installed CP system
- To date, there have not been any reported cases of CP shielding in subsea pipelines
  - High electrolyte conductivity lead to low IR drop

CP Shielding

1. Regulatory reasons:
   – CRF192.112: to operate at alternative MAOP:

Coating	(1) The pipe must be protected against external corrosion by a non-shielding coating.
	(2) Coating on pipe used for trenchless installation must be non-shielding and resist abrasions and other damage possible during installation.
	(3) A quality assurance inspection and testing program for the coating must cover the surface quality of the bare pipe, surface cleanliness and chlorides, blast cleaning, application temperature control, adhesion, cathodic disbondment, moisture permeation, bending, coating thickness, holiday detection, and repair.

- Not clear or obvious what is meant by non-shielding coating
- Interpretation left to individual, or to regulator

Why is this distinction important? Important Note

2. Integrity Management
    a) Pipeline Integrity is mostly managed by close interval surveys (CP potentials) and remote coating surveys – DCVG, ACVG, Pearson Survey, coating conductance, others
    b) Pipeline Integrity can be managed by ILI, but only in piggable sections, and is a lagging indictor of a corrosion mitigation problem

- When CP shielding is present, must overlay (a) and (b), then identify that a problem exists

- No actual inspection tool for CP shielding, so difficult to address with integrity management plans

Failures / Damages from CP Shielding

- In cases where CP shielding is present, there are two degradative mechanisms:
  - Corrosion – rate will be at or less than ordinary corrosion rates in the local groundwater
  - Stress Corrosion Cracking (SCC) – rapid failure mechanism, but takes ~20 years before SCC initiates and becomes an integrity threat
- The most insidious factor for CP shielding is that it can exist for decades and will not be recognized, detected, or mitigated until an incident (Corrosion/SCC) occurs

CP Shielding Evaluation

- Evaluate <u>all</u> factors involved in shielding
- Possible for shielding tendency to vary significantly along the same pipeline system

LOW	SHIELDING TENDENCY		HIGH	
→				
FBE			PE TAPE	COATING TYPE
LOAM			BEDROCK	SOIL TYPE
SALT WATER			RAIN WATER	GROUND WATER

Summary / Conclusions
Important Note

- CP shielding is a complex issue, it is not an intrinsic coating property
- All coatings designed to be good insulators – key is knowing how a coating tends to fail
- Historically, FBE coatings show lowest tendency to shield CP, PE wraps show highest tendency

Important Notes

- 5.1.2.3

Pipeline external coating systems shall be properly selected and applied to ensure that adequate bonding is obtained.

Unbonded coatings can create electrical shielding of the pipeline that could jeopardize the effectiveness of the CP system.

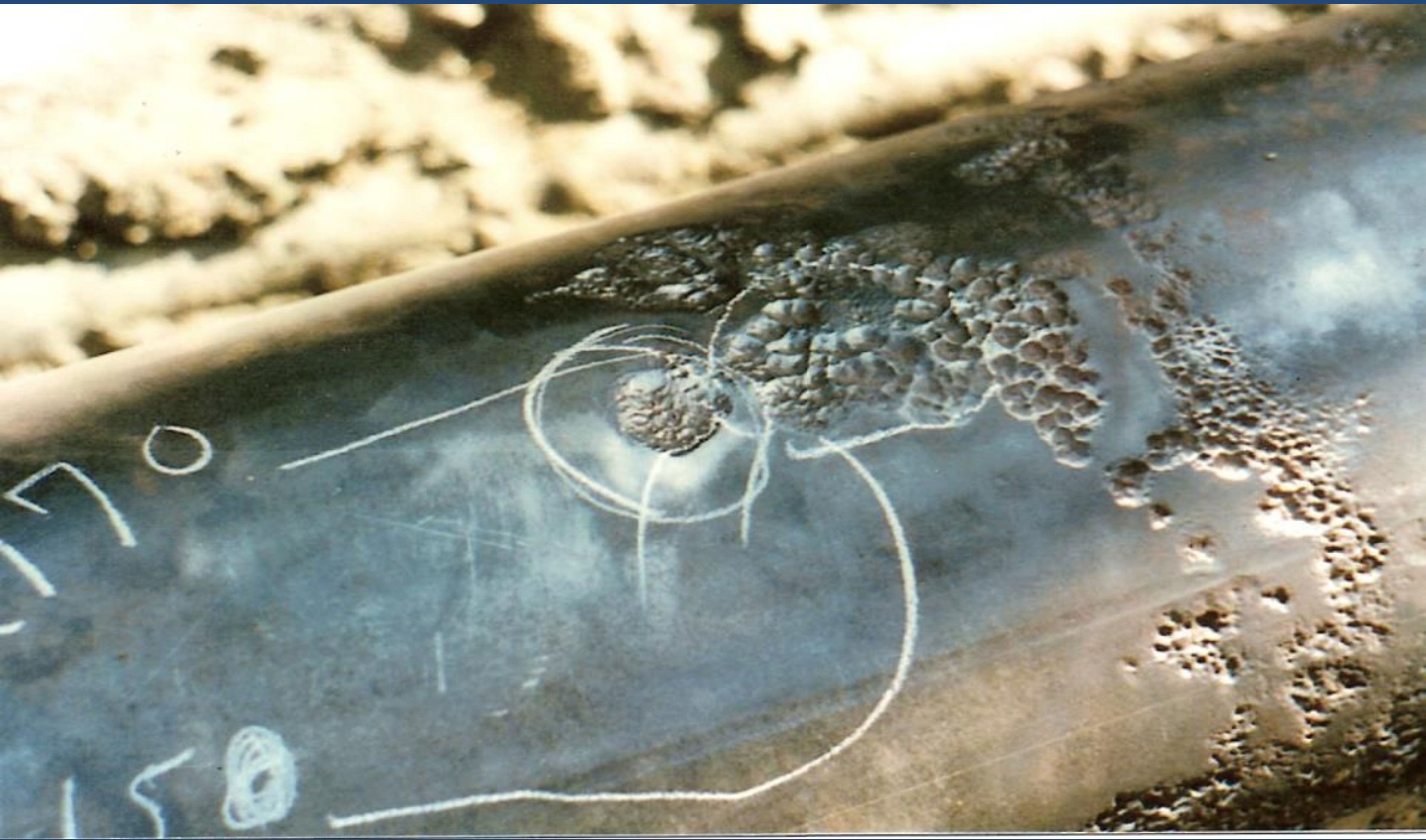
This means use of un-bonded coatings, coatings that disbond after application or are improperly applied can shield the CP current!

Corrosion Under Coating That Shields CP

Pits Under Dis-bonded Coating

Coating That Shield Cathodic Protection

Acclerated Corrosion Due to CP Shielding



CP Shielding

CP Shielding

Corrosion Under Disbonded Coating

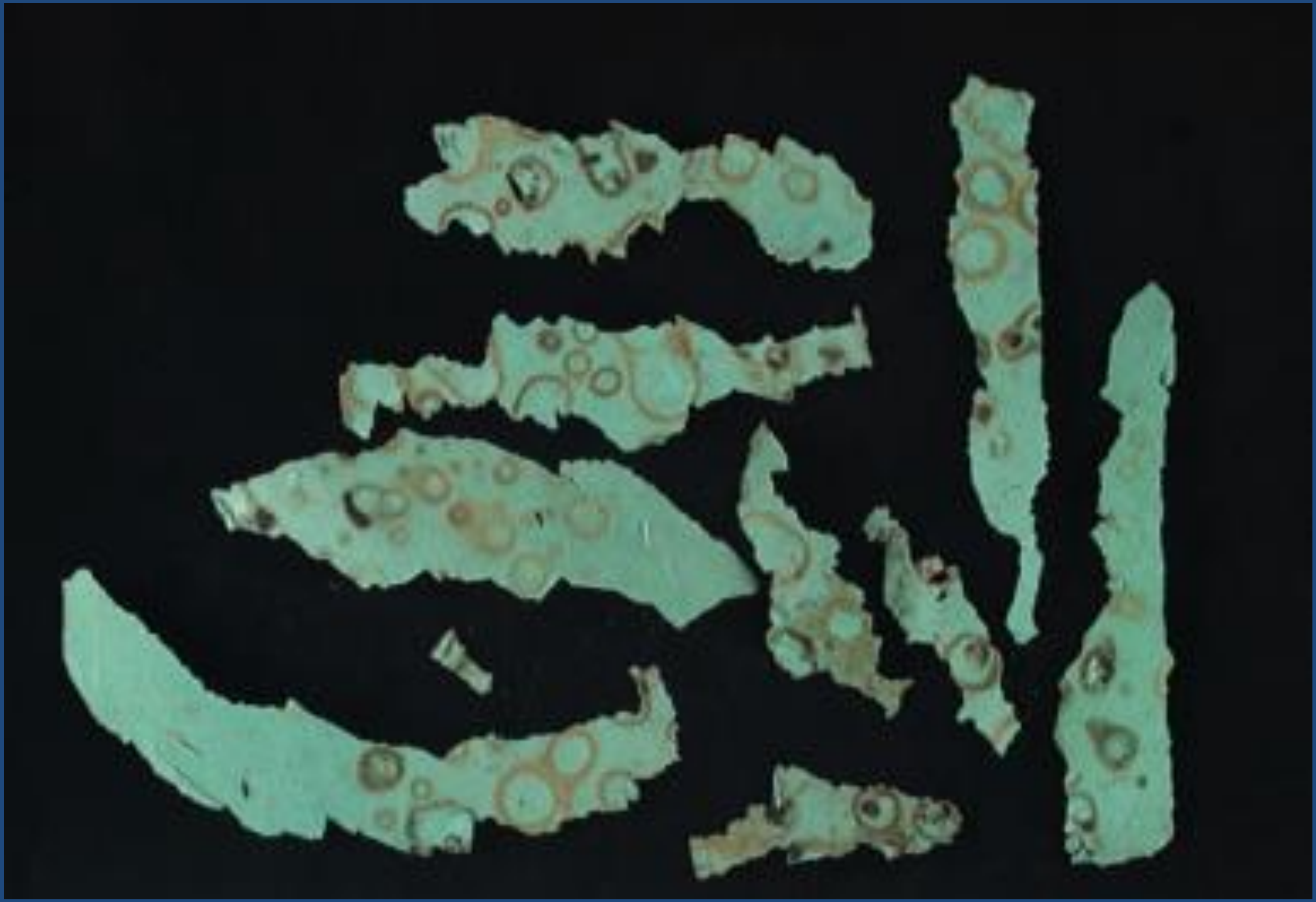
Coatings That Do Not Shield Cathodic Protection

Fusion Bonded Epoxy (FBE)

What’s cooking inside the blister?

Fusion Bonded Epoxy

Back Side of FBE Samples



Materials Don't Fail, People Do!

Materials Follow Laws of Physics and Chemistry Perfectly

2nd Law of Thermodynamics

Disorder is the trend, not the order!
Mother nature does not like the things she did not create.

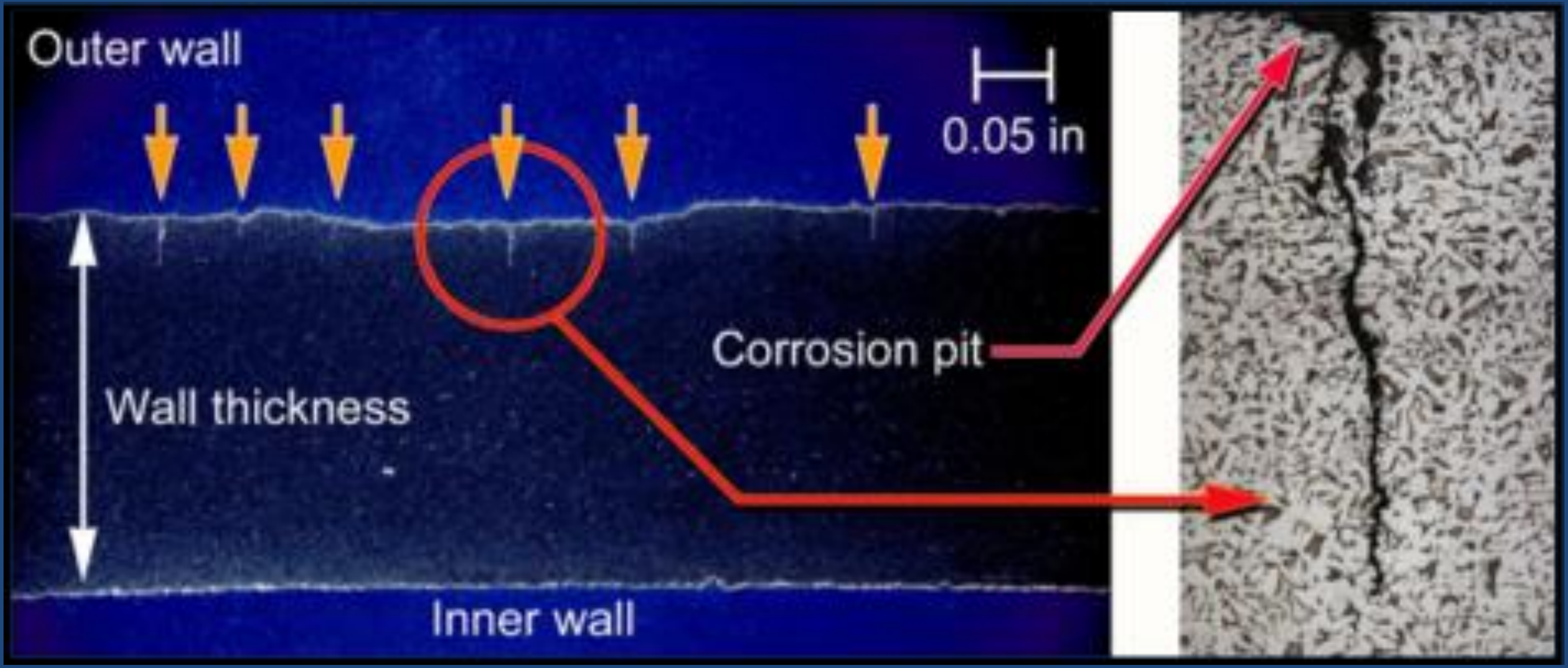
Conditions for Corrosion Failures

- Aging Pipelines: Baby boomer pipes >40 years
- Corrosion and Fatigue
- Corrosive Soils
- Inadequate cathodic protection: “On” vs “Off”
- Coatings that Shield Cathodic Protection
- Shielding in General
- AC /DC Interference

Stress Corrosion Cracking

- The occurrences of incidents caused by stress corrosion cracking were clustered in pipelines with years of installation between 1947 and 1968.
- This is probably attributable to the fact the pipelines installed in that era were operated in a manner that allowed gas discharge temperatures to be as high as 180°F.
- Not only did this, in some instances, lead to coating damage, it also facilitated the occurrence of a type of stress corrosion cracking that grows at higher rates with increased temperature.

Stress Corrosion Cracking



Consequence of Corrosion Failure

Consequence of Gas Pipeline Explosions!

Important Notes

- The **non-shielding to CP properties only work when there is a disbondment** allowing electrolyte between the pipe and coating so excessive CP use is not an issue for these coatings when well bonded.
- Many do not understand the relationship of dielectric strength, water absorption, water vapor transmission, CP and pipeline coatings.
- The time is right for further test development and test methods for determining the CP shielding /non-shielding characteristics of pipeline coatings.


0.1045
2360
0.4055

Coatings

- A second factor is that conditions that promote another type of stress corrosion cracking are most prevalent with a particular coating type (plastic tape wrap) that can dis-bond intact from the pipe surface so as to trap moisture.
- In addition, the plastic tape has a high dielectric value that shields the pipe from the cathodic protection current.
- This type of coating for new construction was common in the 1960s and 1970s.

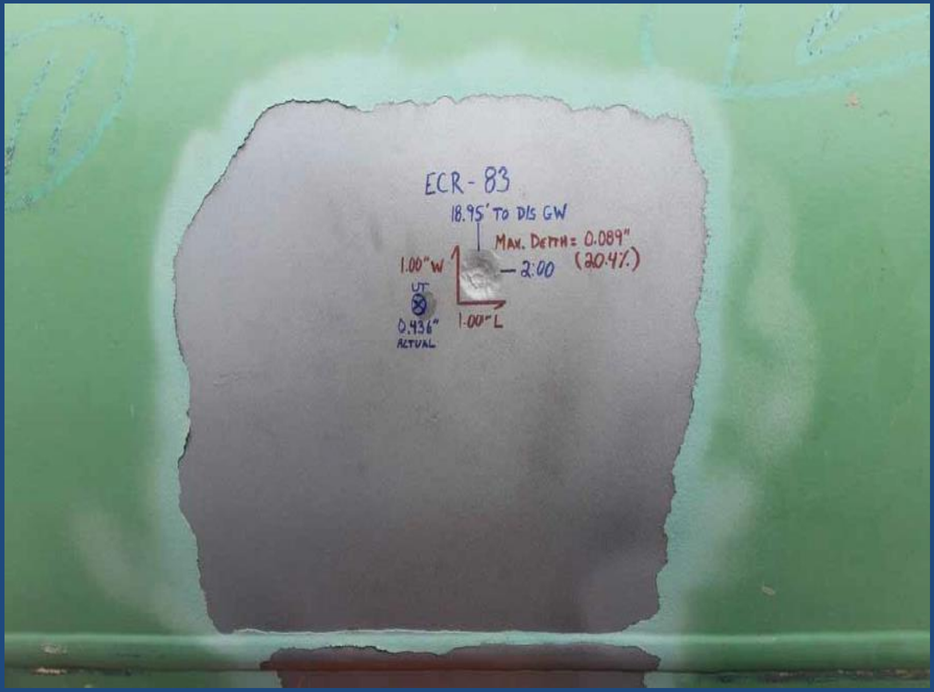

MOTOR GUARD CORPORATION / MAGNA PRODUCTS (800) 227-2822 Patent Pending

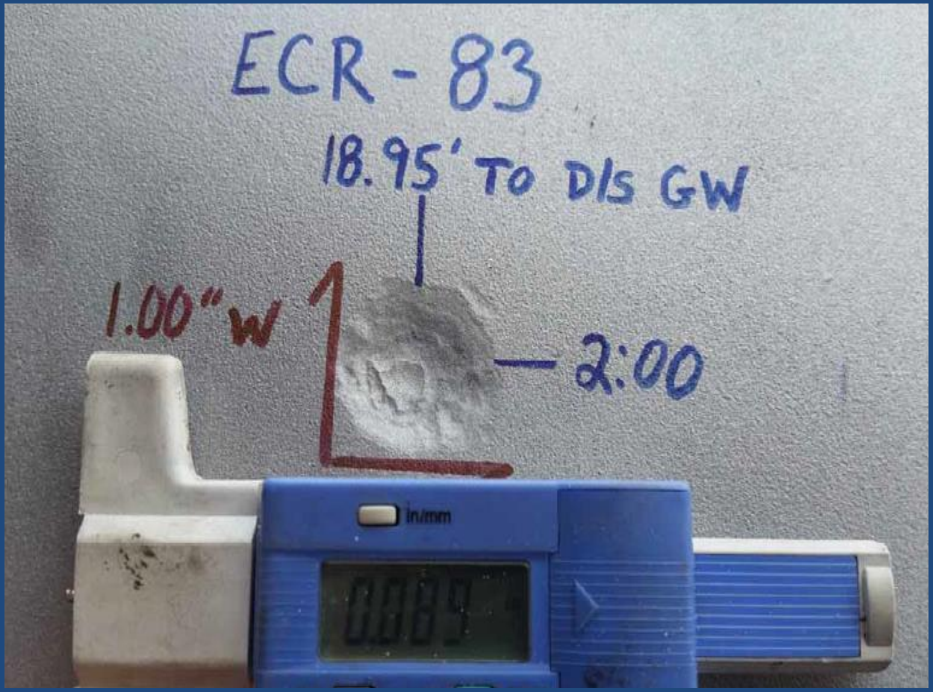
Cathodic Protection Shielding

Corrosion Mechanisms That Result in Catastrophic Failures

- Pitting Corrosion
- Stress Corrosion Cracking
- AC Interference/DC Stray Current

Localized Pitting Corrosion in Disbonded Area

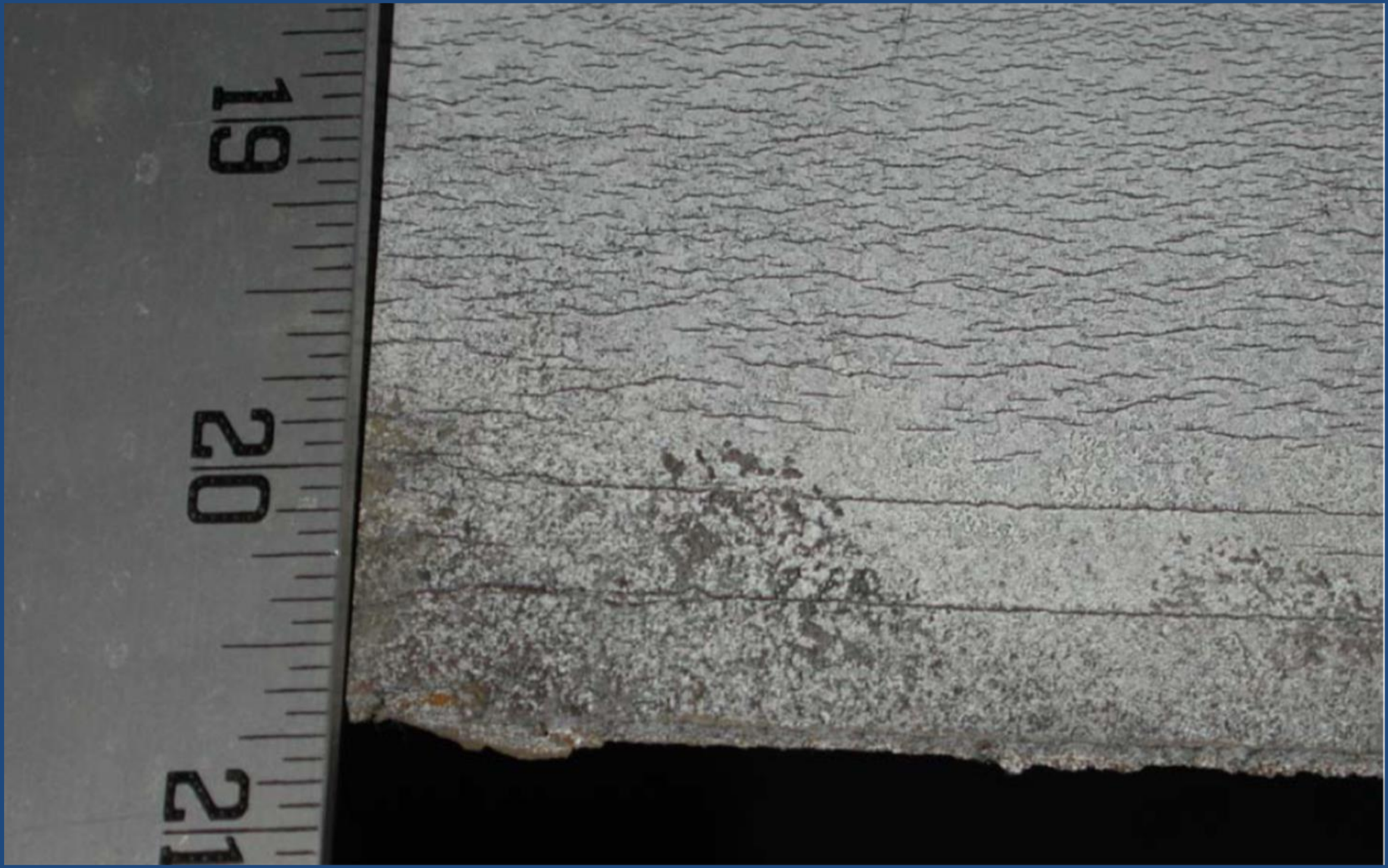




Stress Corrosion Cracking Steel

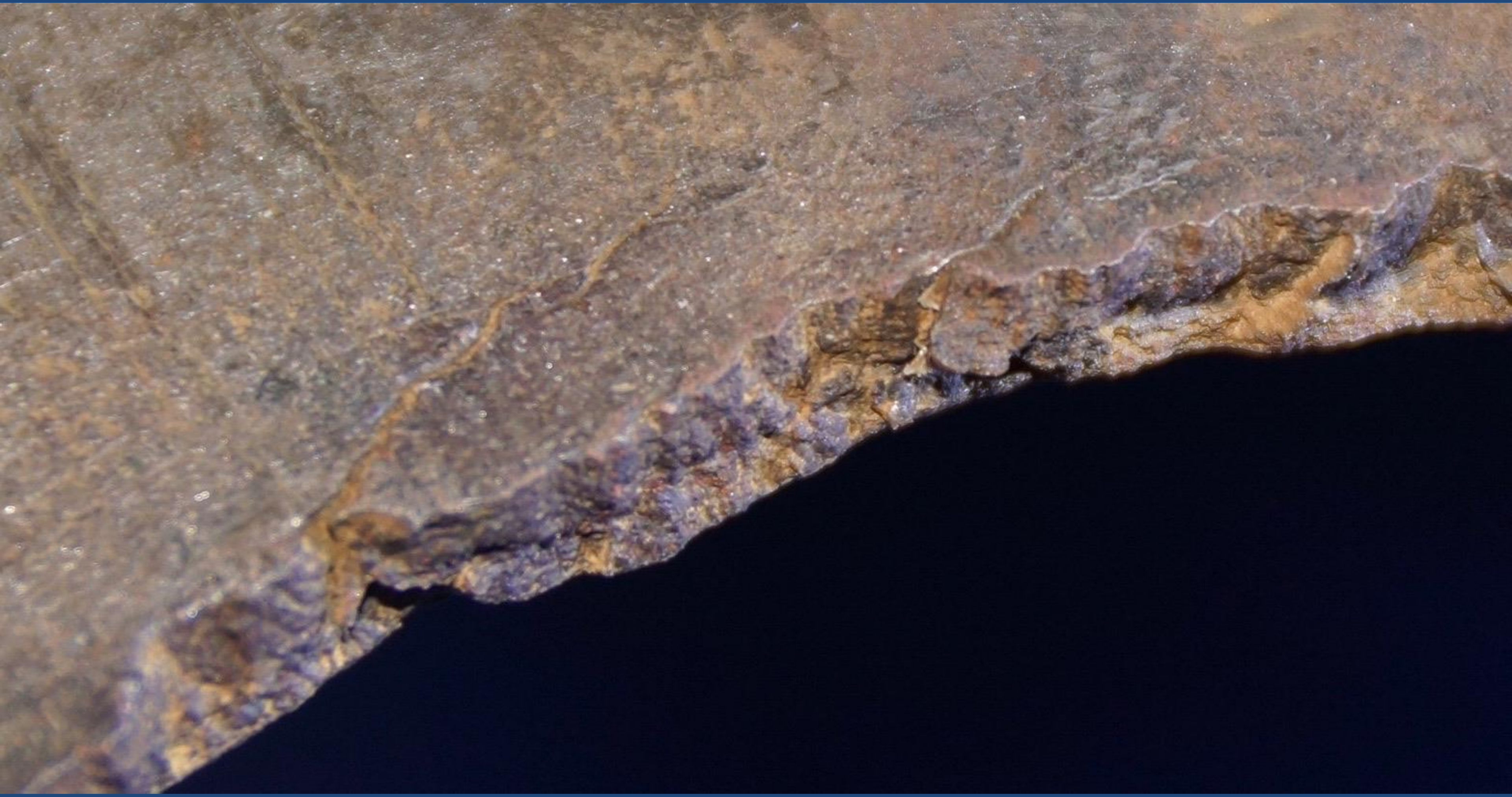
- Stress corrosion cracking (SCC) is defined as crack nucleation and propagation caused by synergistic action of tensile stress, either constant or slightly changing with time, together with crack tip chemical reactions or other environment-induced crack tip effect.
- SCC failure is a brittle failure at relatively low constant tensile stress exposed in a specific corrosive environment.
- The final fracture surface because is overload and no longer stress corrosion cracking.

Micro-Cracks



Exploded Pipe

Fracture Surface

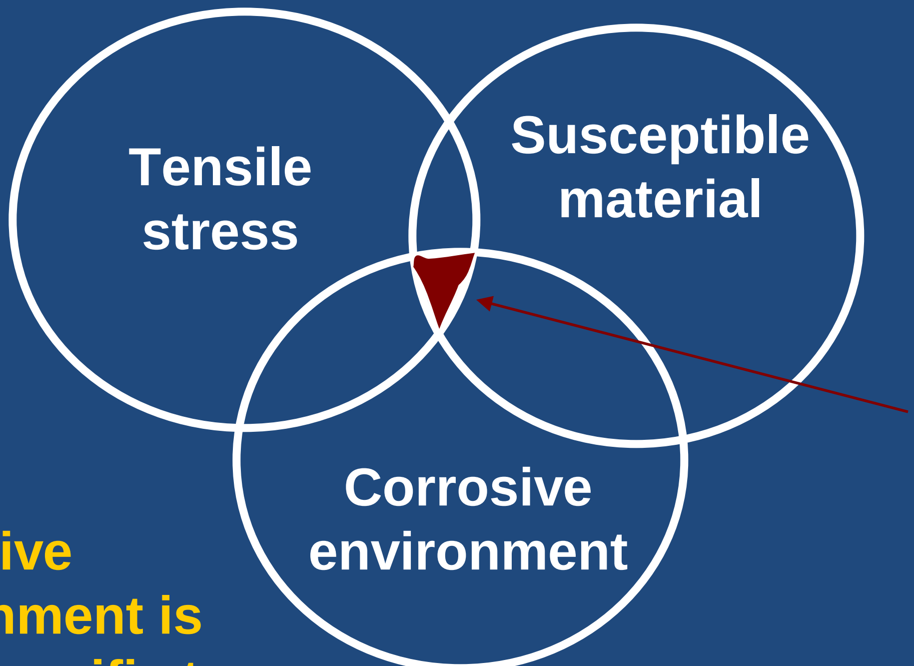


Pipe Section

Pipe Surface: Pitting

Pure metals are more resistance to SCC but and susceptibility increases with strength

Tensile stress is below yield point



Stress corrosion cracking

Corrosive environment is often specific to the alloy system

SCC of Pipelines

Three conditions must be present simultaneously to produce SCC:

- **a critical environment**
- **a susceptible alloy**
- **some component of tensile stress**

SCC of Pipelines

Two types of environments have been associated with external SCC:

1. High-pH SCC is caused by a concentrated solution of sodium carbonate and sodium bicarbonate with a pH that typically is between 9 and 10.5.

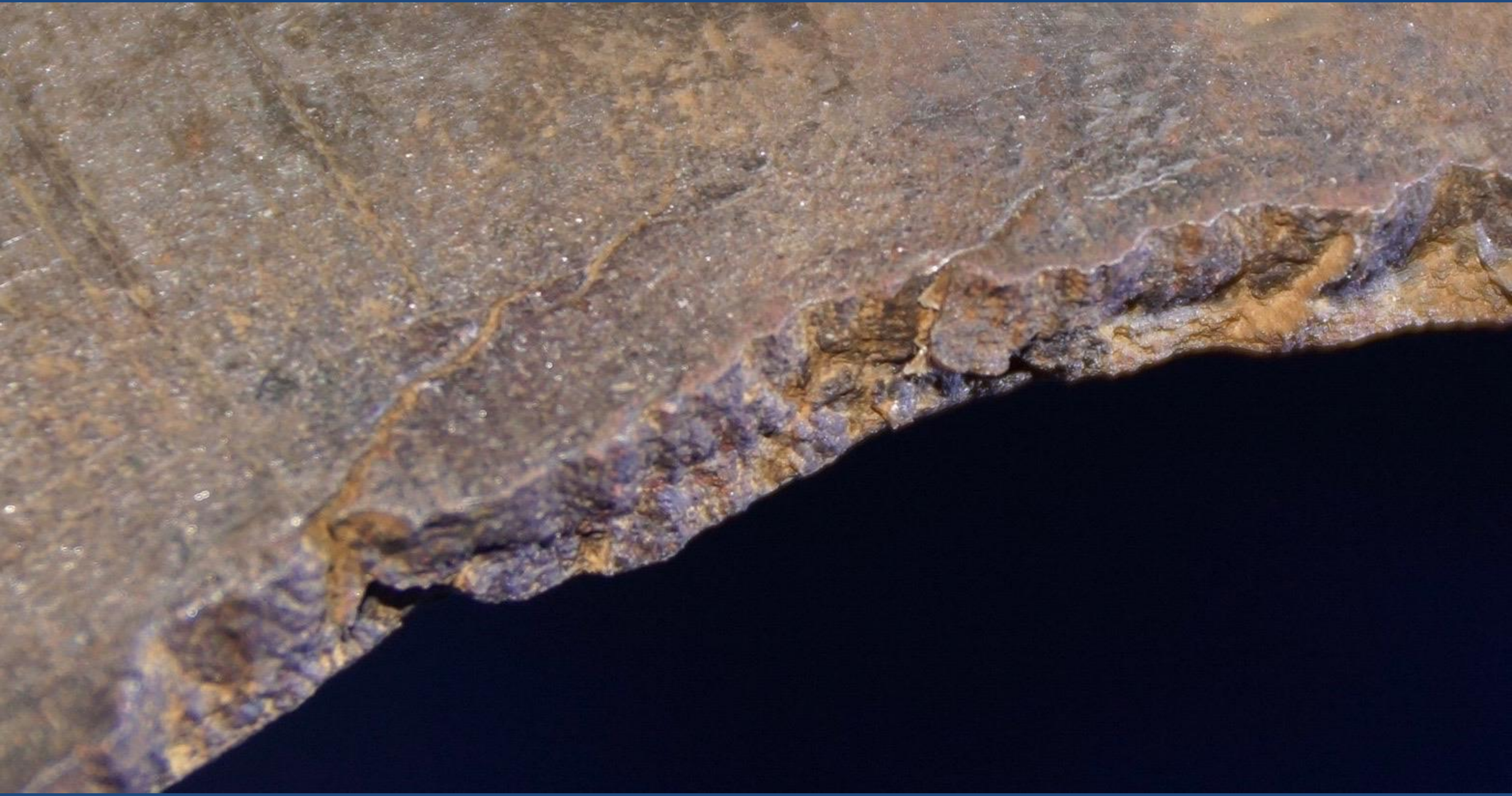
2. Near-neutral-pH SCC is caused by a relatively dilute solution of carbon dioxide and sodium bicarbonate with a pH that typically is between six and seven.

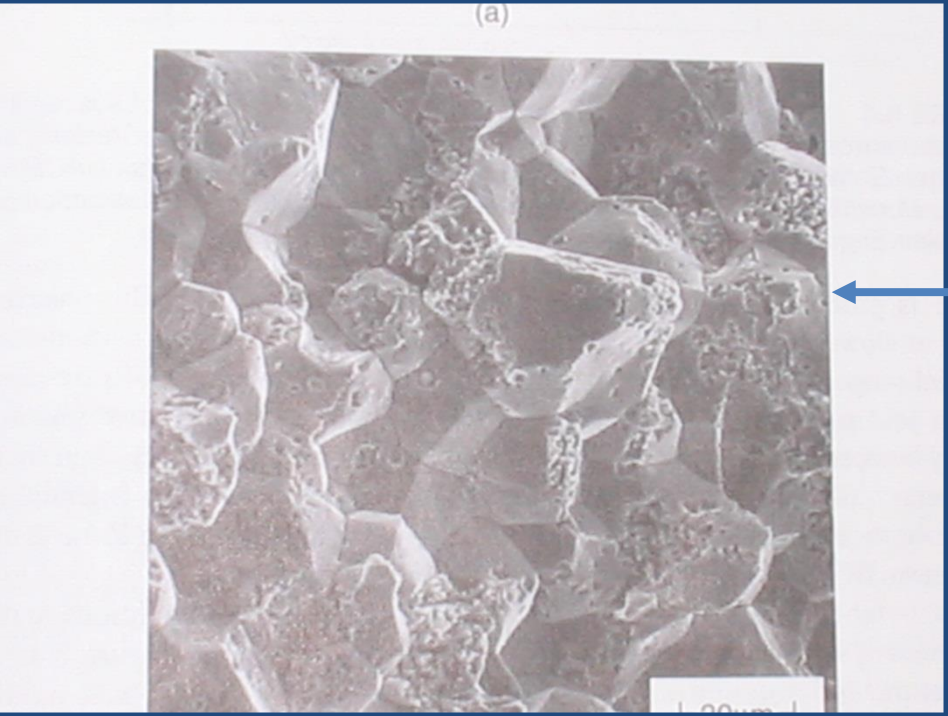
SCC Initiation and Growth

- Incubation
- Initiation
- Growth
- Coalescence
- Failure

Stress Corrosion Cracking Fracture

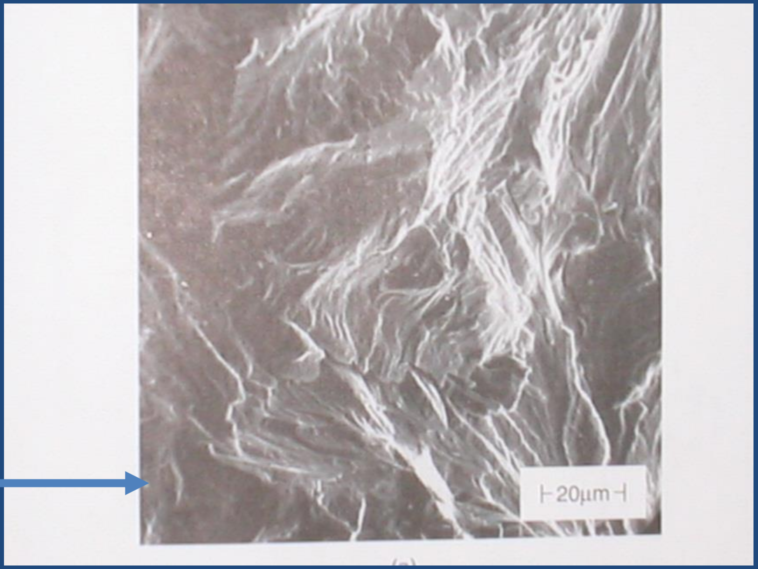
SCC Fracture Surface





Fracture surface of intergranular SCC on carbon steel

Fracture surface of transgranular SCC



SCC of Pipelines

Corrosion Damage Assessment Process

- Pre-assessment
- In Line Inspection
- Hydrostatic Testing
- Direct Assessment
- Post Assessment

Conditions Prone to SCC

- Asphalt enamel coating that has disbonded, typically around the full circumference of the pipeline, and for a significant distance along the length of the pipe, but remains intact as a shell around the pipe.

- A film of water between the disbonded external coating and the pipe surface.

- Adherent surface deposits containing:
  - Rust-colored iron oxide,
  - Powdery white calcium carbonate, and
  - Pasty white iron carbonate.

- Shallow pitting corrosion.

- Families or colonies of parallel cracks aligned with the axis of the pipeline (circumferential SCC has not been observed). Most cracks are relatively shallow, but linked cracks have been sufficiently deep to cause the in-service failures at normal operating pressures.

Progression of Corrosion and Cracking

- Disbondment
- Blistering
- Delamination
- Pitting in the absence of adequate protection, no protection and or AC Interference
- SCC and rupture for shielding coatings
- Structural Corrosion Loss: Unacceptable Risk

Failure Analysis

Failure: Negative Term

Failure Analysis: Very Positive

Causes of Failure....

There are three basic types of human errors:

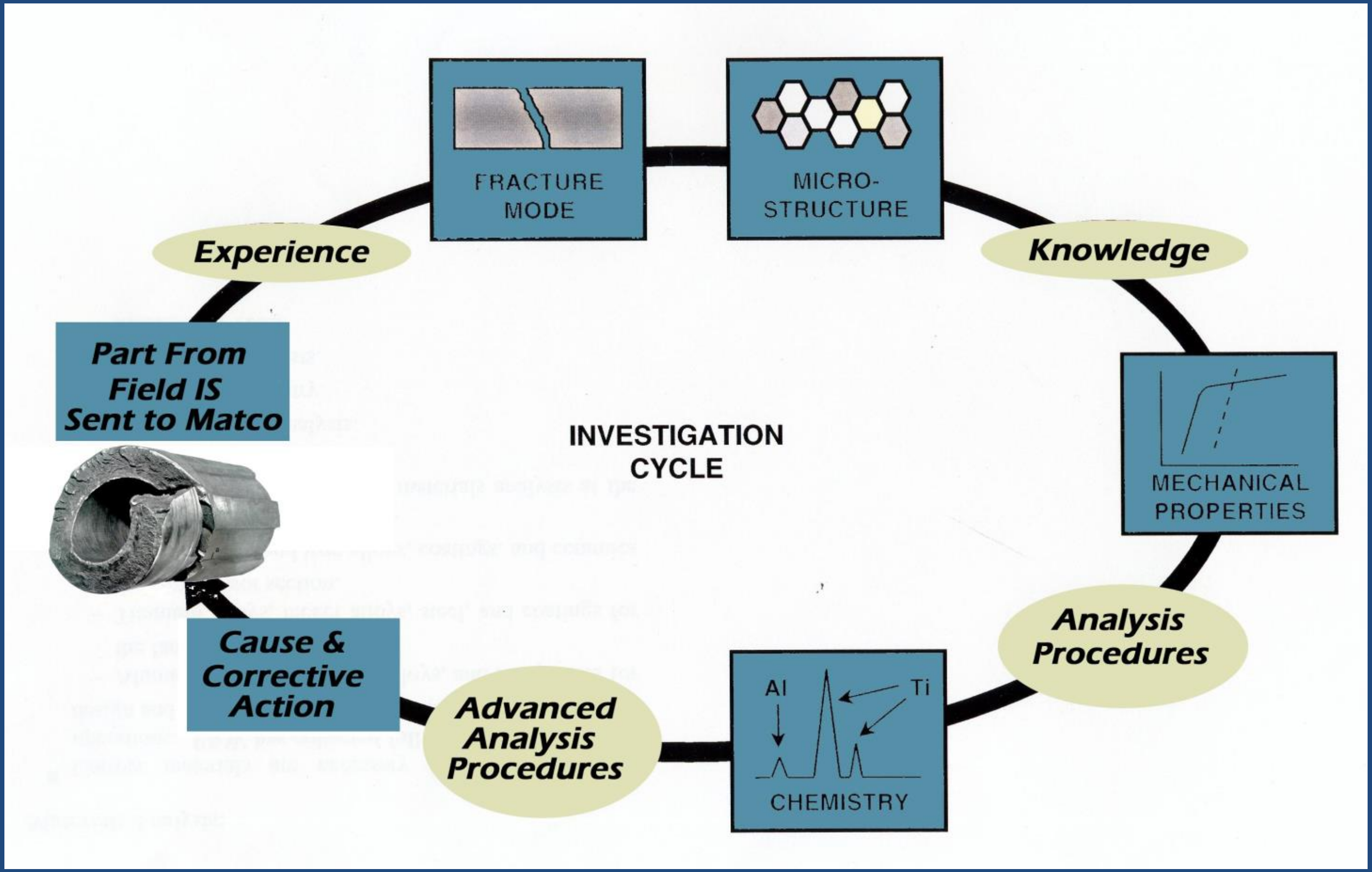
a) Errors of knowledge
b) Errors of performance (negligence)
c) Errors of intent (greed)

What is Failure Analysis?

- Failure analysis is the process of collecting and analyzing data to determine the cause of a failure and how to prevent it from recurring.

- It is an important in the pipeline industry to identify the primary cause of failure to avoid similar failures in the future or explosions.

Steps In Failure Analysis



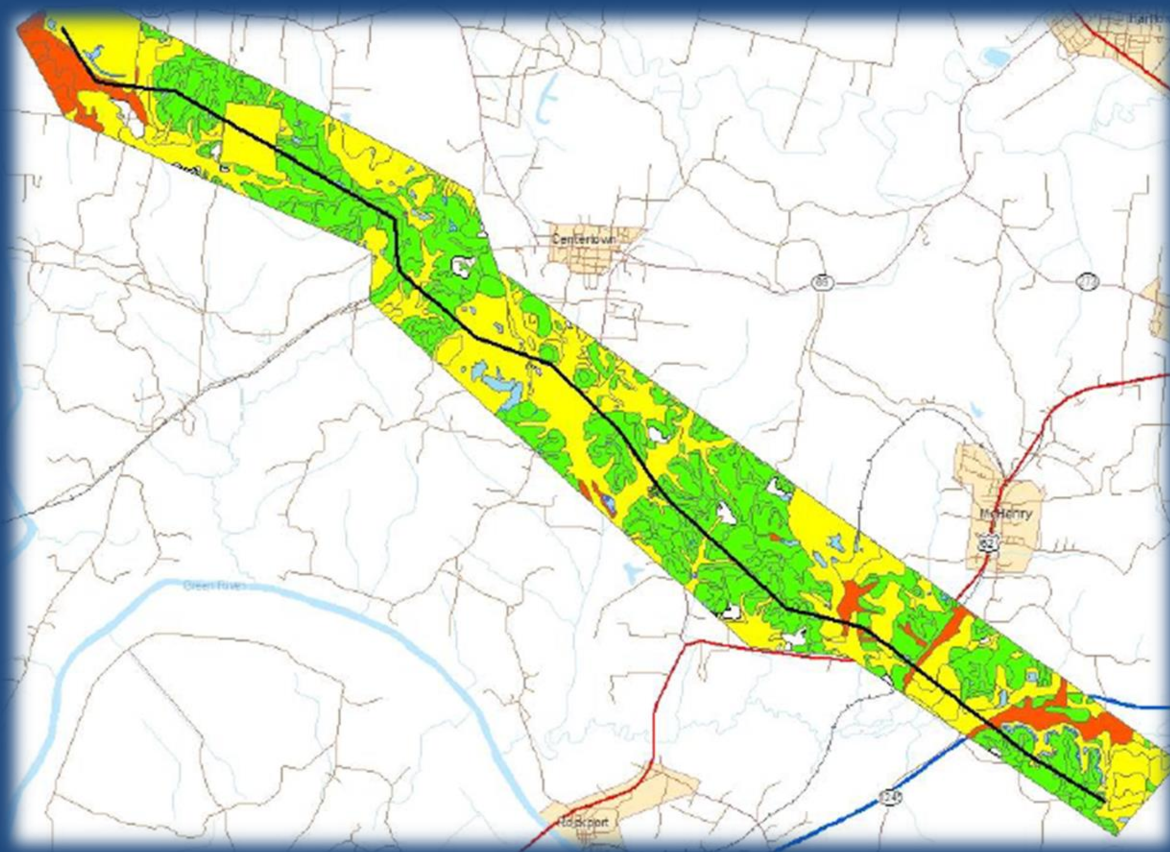
Just the facts...

- ✓ What happened? How did it fail? Mode of failure...
- ✓ Why did it happen? Root Cause Analysis
- ✓ Who was responsible? Designers, Contractors, Inspectors...
- ✓ Who should have done what? Codes, Standards...
- ✓ Reports, Technical Conclusions
- ✓ Engineering Solutions: Repair, Replacement, Inspection Frequency
- ✓ Legal Issues

Engineering Tools To Identify Active Corrosion

- Assessment of Leak Records
- In Line Inspection
- Hydrostatic Testing
- Visual Inspection (Direct Examination)
- Soil Corrosivity / Chemistry Assessment
- Wireless Potential Measurement
- Rectifier Data
- After the evaluation of data analysis we will consider controlled potential rectifier

Transmission Line Challenges



Rules of Thumb to Help Determine Corrosion Activity

Corrosion Parameter	Low	Moderate	Severe
pH	6.5-7.5	5.5-6.5	<5.5
Resistivity (ohm-cm)	>10,000	2,000-10,000	<2,000
Conductivity (mS/cm)	<0.2	0.2-0.4	>0.4
Chloride (ppm)	<50	50-150	>150
Sulfates (ppm)	<150	150-1150	>1,150
Sulfides (ppm)	<1	1-5	>5
% Moisture (% wt)	<20%	>20%	>20%
Redox (mV Std. H)	>200	100-200	<100

Assigning Soil Corrosivity Values

- The soil around each segment of pipe is assigned a soil corrosivity rating based on a number of parameters including soil resistivity, pH, chlorides, carbonates and bicarbonates, sulfates, MIC (Microbiologically Induced Corrosion) and electrochemical polarization.

- We have developed an algorithm to rate the corrosivity as it relates to buried structures.

Data Collection, Sorting and Analysis

- Mobile device compatibility
- GIS capable
- Multi-platform and multi-format capability
- Ease of data entry user interface is key
- Live data validation
- Live risk analysis based on risk algorithms
- Data management strategy & administration

Questions to be answered?

- Surface contamination during manufacturing and transportation
- Corrosive soils
- Less than adequate cathodic protection on the line.
- AC interference from nearby AC lines.
- This also depends on soil resistivity and moisture level in the soil, so your low AC current reads (<30 A/m^2) may exceed 100 A/m^2 depending on loads on AC lines and variation in soil resistivity.
- Cathodic electrodeposition of calcareous deposits that may shield CP currents.
- Delaminated coatings that shield cathodic protection.
- A combination of the above conditions.

Corrosion Mitigation For Aging Pipelines

- Plan ahead
- Develop corrosion management and risk assessment programs
- Require coating suppliers to provide scientific testing for coating recommendations and provide advanced notification of coating formulation changes.
-
- Assess
- Perform pre-assessment, corrosion risk assessment and post assessment. Utilize modern computer platforms for data collection, sorting and analysis.
-
- Manage Risk
- Consider protective coatings with adequate thickness in corrosive environments and consider non-corrosive backfills.
- Utilize wireless corrosion monitoring and inspection in corrosive areas.
- Consider adequate cathodic protection and AC mitigation in cases of AC interference.

Conclusion

- Soil corrosivity assessment in different segments of the pipeline
- Setting up remote monitoring which will add consistency to the data collected and remove any human error or varying copper sulfate electrode placements.
- The new test station locations will be determined by evaluating the ILI data as well as finding locations with extreme moisture/low soil resistance fluctuations.
- Feasibility of constant self-regulating current rectifiers or constant potential rectifiers should be explored
- Soil corrosivity, terrain type, soil moisture, pH, soil resistivity, MIC and corrosive ion concentration should be analyzed for corrosion mapping and early detection of corrosion activity and cracking.

CATASROPHIC FAILURE OF AGING UNDERGROUD PIPE, BRIDGES, and T&D STRUCTURES ARE LIKELY IN CORROSOIVE SOILS CONSIDERING THE CONDITIONS THEY ARE IN

- It is the intent of the law that matters - not minimum requirements that are required to be in compliance.

- Minimum requirements may not be enough for safety (compliance with regulations).

Training Seminars are Fantastic!

Final Words

- Catastrophic Failure of Aging Underground Pipelines Is Inevitable Given Corrosion Conditions and CP Shielding

- False Sense of Security is No Good

- Early detection and fail-safe system corrosion mitigation will prevent leaks and ruptures in aging pipelines

Load Bearing Member

I hope I've explained how important it is to consider coating shielding on pipelines, corrosion risk assessment and corrosion mitigation (coating, CP)

Is this Sun Rise or Sun Set?

The eye can lie.

Check the facts first before forming an opinion or making a decision – because we really don't know!

Do we?

Questions?

Thank you for your attention!