Electrochemical Noise Sensors for Detection of Localized and General Corrosion of Natural Gas Transmission Pipelines

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Natural Gas Infrastructure Reliability

Inspection

Corrosion Monitoring Methods

Real-Time Monitoring	After-the-fact Detection
Linear Polarization	Coupons
Harmonic Distortion	Section Loss Measurements
Electrochemical Impedance Spectroscopy	Crack and Pit Detection
Electrochemical Noise	Failure Analysis

Outline

- Purpose
- Electrochemical Noise and Sensors
- Year One Tests
- Conclusions
- Future Work

Purpose

To demonstrate the use of electrochemical noise (EN) sensors for measuring the internal and external corrosion of natural gas transmission pipelines.

Principles of EN

- Potentials – equilibrium driving forces
- Currents – kinetics of corrosion
- Signal noise in potentials or currents from one spot on a surface to another creates a "signature" to be interpreted.
- Isolation of the different locations allows the signal to be measured.

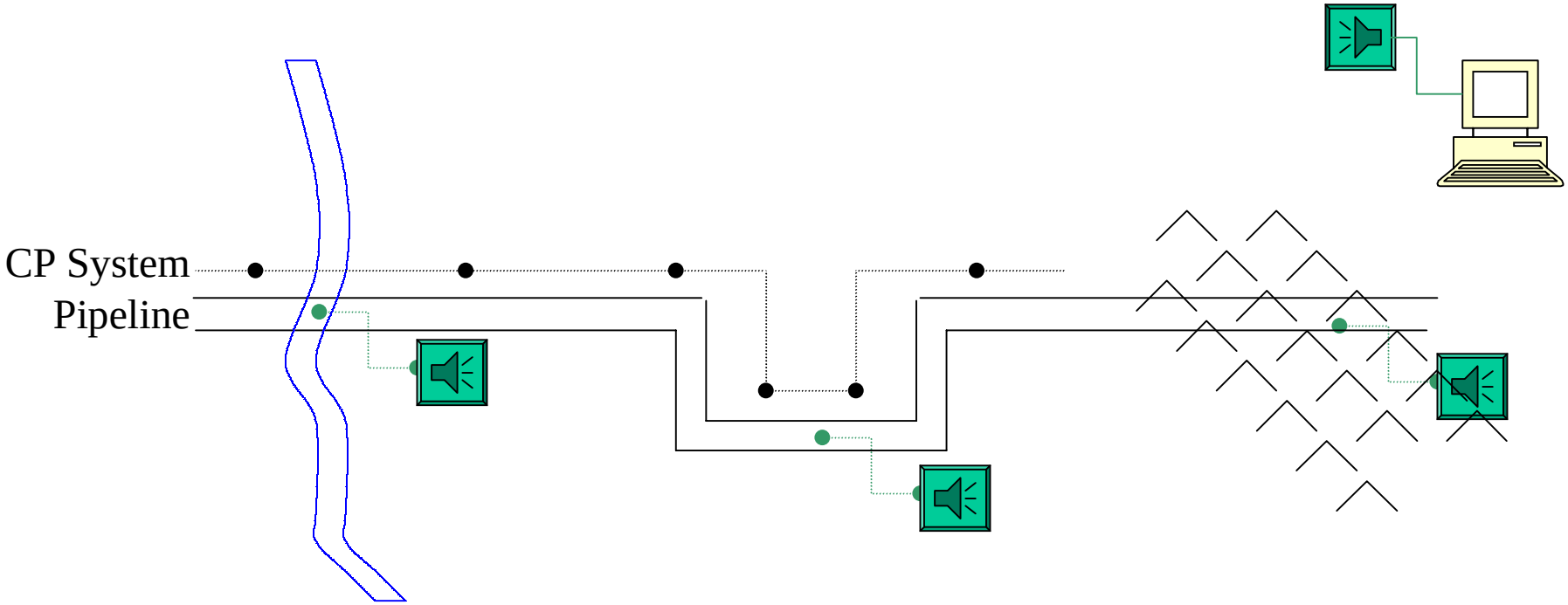
What are EN Sensors?

- 2 or 3 isolated pieces of pipeline metal (electrodes)
- Fixed in place
- Sensor signals collected and analyzed at computers remote from the sensors

EN Sensor Placement

- Internal Placement – Areas of Interest
  - Low points that collect water
  - Following compressors (higher temperatures)
  - Limited pigging sections
- External Placement – Areas of Interest
  - Areas without CP

EN Sensor Array



Under River
Low Section

Sharp Turns
No Pigging

Too Rocky
No CP

Internal Sensors
Flanges or Inserts

Internal Sensors

Contoured Inserts

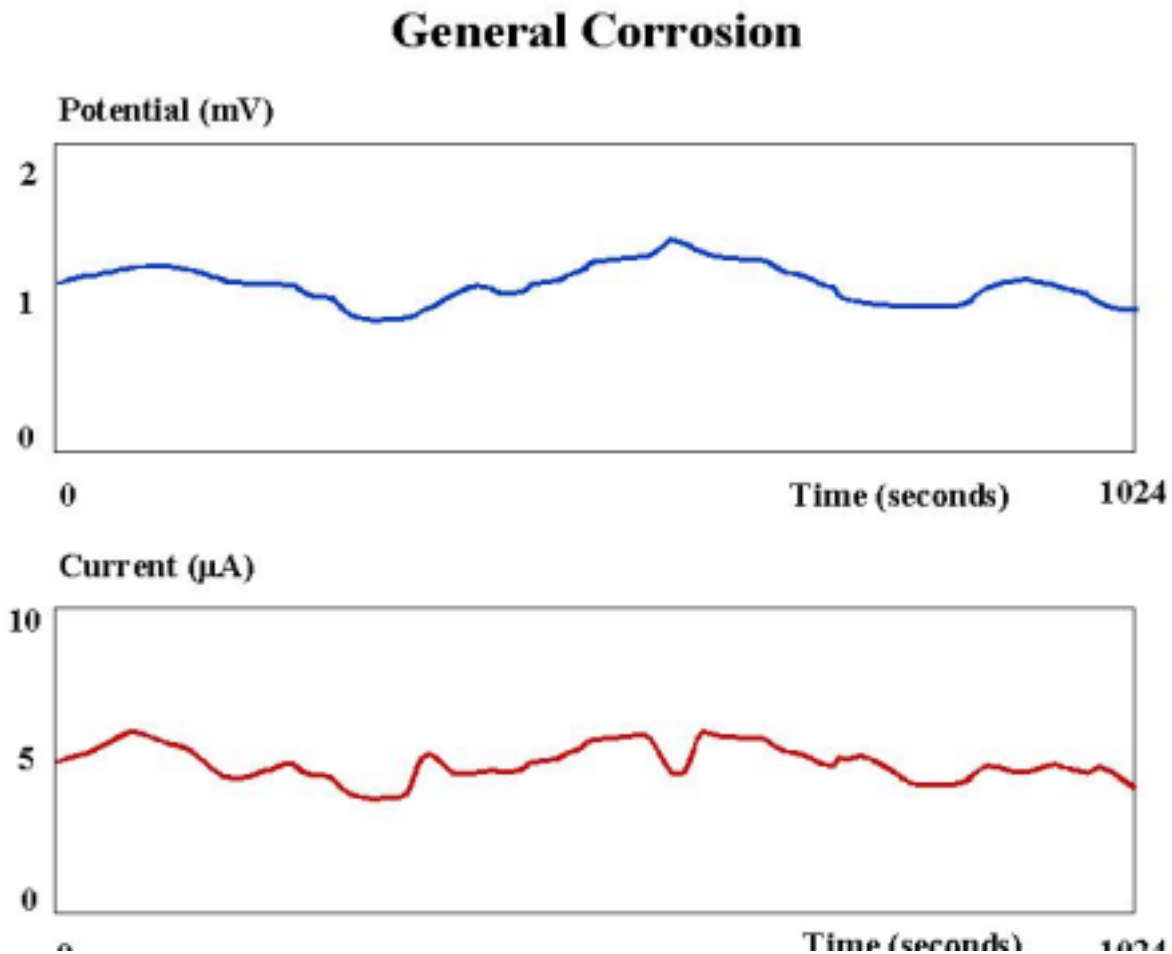
External Sensors

- Much like coupons currently used in CP systems
- Could be stressed to give SCC tendencies
- For systems without CP

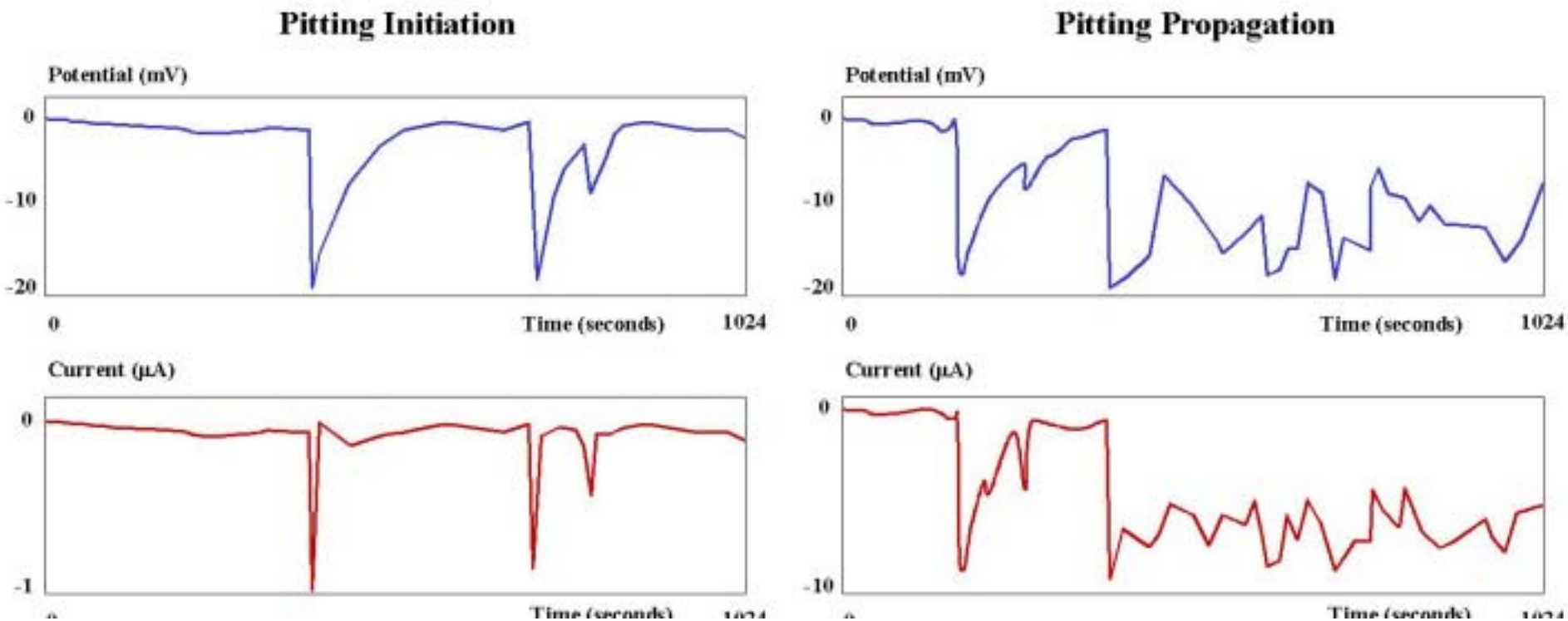
Detection Capabilities

- Corrosion levels
  - Monitoring history gives cumulative section loss
  - Inhibitor effectiveness
- Corrosion types
  - General, pitting, SCC
- Flow types (e.g. slugging in 2-phase flow)
- Chemistry indications of corrosive species (CO_2 and O_2 levels)

General Corrosion



Pitting


Pitting Initiation
Potential (mV)
0
-10
-20
0
Time (seconds)
1024
Current (µA)
0
-1
Pitting Propagation
Potential (mV)
0
-10
-20
0
Time (seconds)
1024
Current (µA)
0
-10

Signal Interpretation - Tools

- Visual
- Sequence independent
  - Mean
  - Standard deviation
  - Skewness (deviation from normal distribution tails)
  - Kurtosis (deviation from normal distribution peak)
- Sequence dependent
  - Power Spectra
  - Chaos theory

Year One
Demonstration Project Tests

- Commercial Unit
- External Corrosion
- Internal Corrosion

Commercial EN System

Easy Implementation to Field and Industry Use

Intrinsically Safe

EN, LP, and Harmonic Distortion Analysis

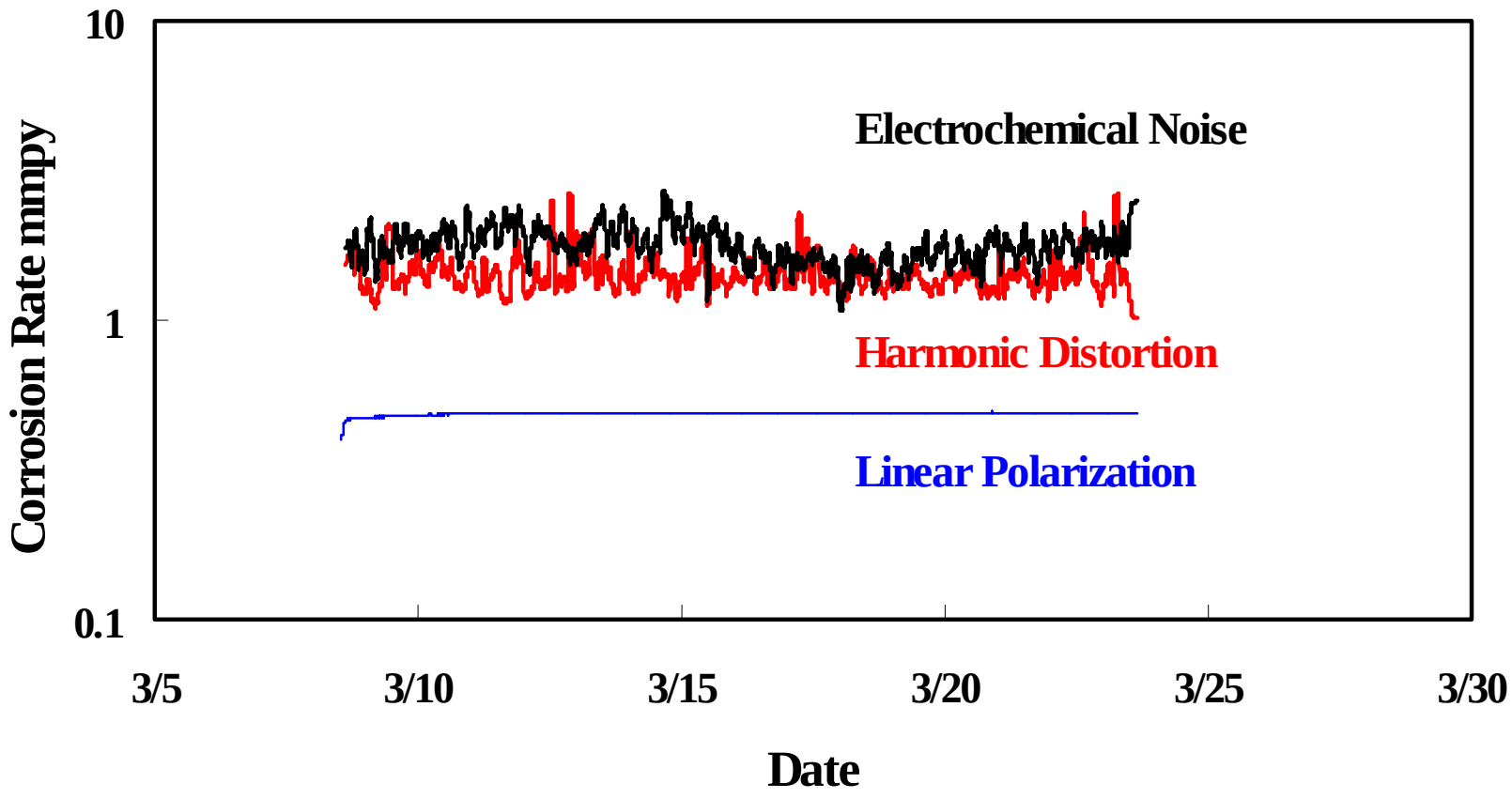
No Sequence Dependent Analysis

Converts and Doesn't Save Raw Data

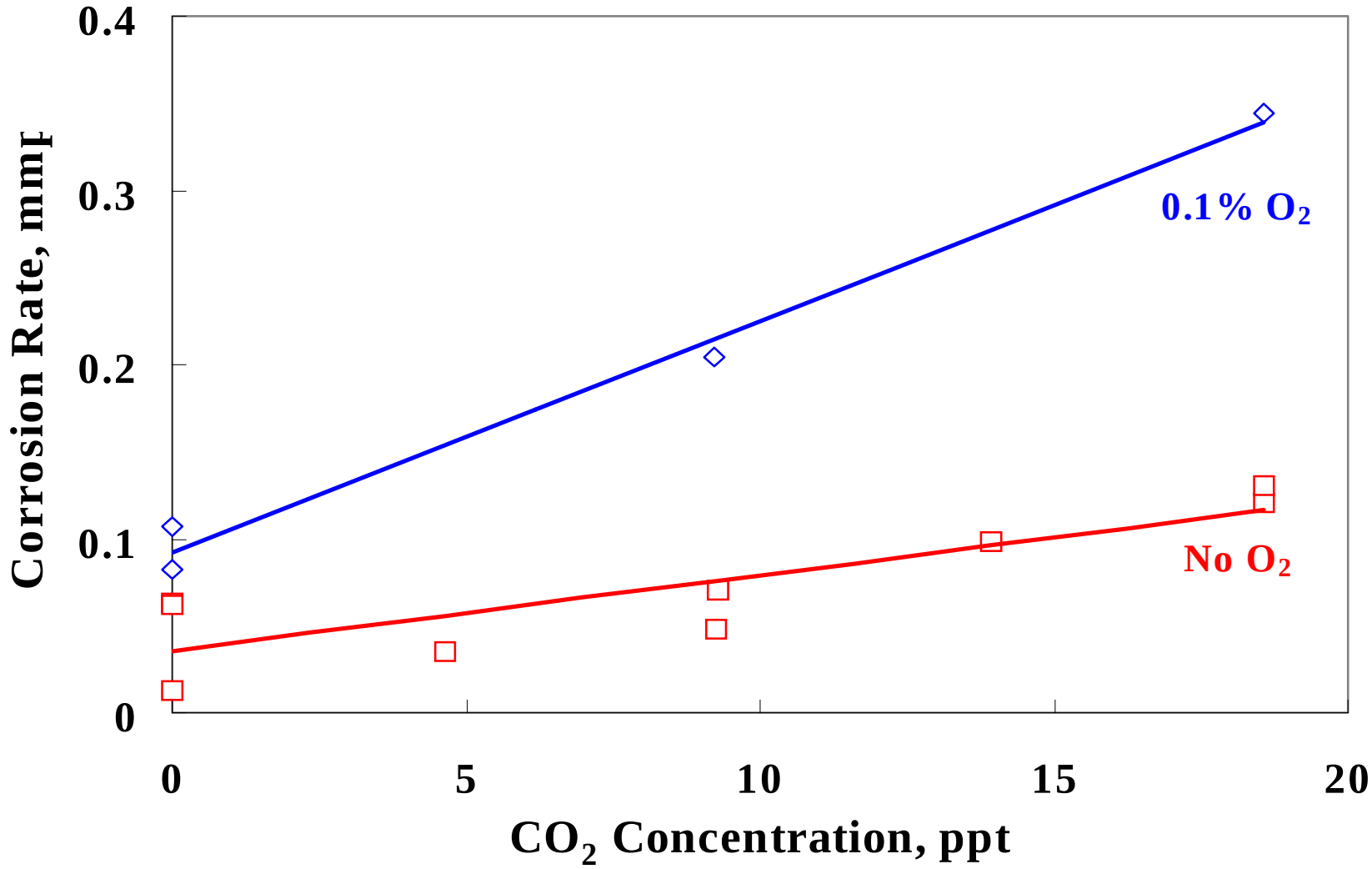
Internal and External

Aqueous Corrosion Test

0.5 N H_2SO_4


10
1
0.1
Corrosion Rate mmpy
Electrochemical Noise
Harmonic Distortion
Linear Polarization
3/5
3/10
3/15
3/20
3/25
3/30
Date

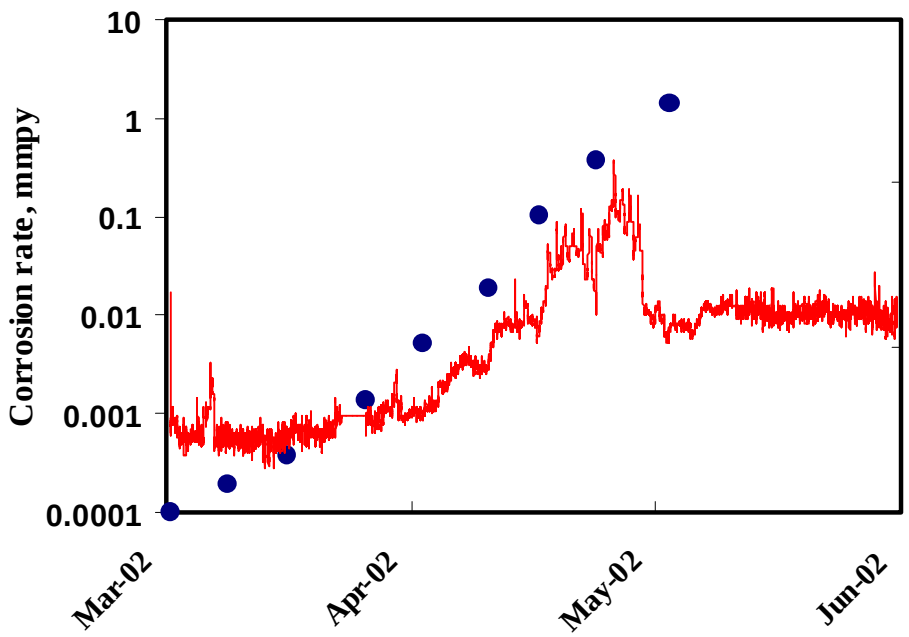
3.5% NaCl


0.4
0.3
0.2
0.1
0
Corrosion Rate, mmP
0.1% O_2
No O_2
0
5
10
15
20
CO_2 Concentration, ppt

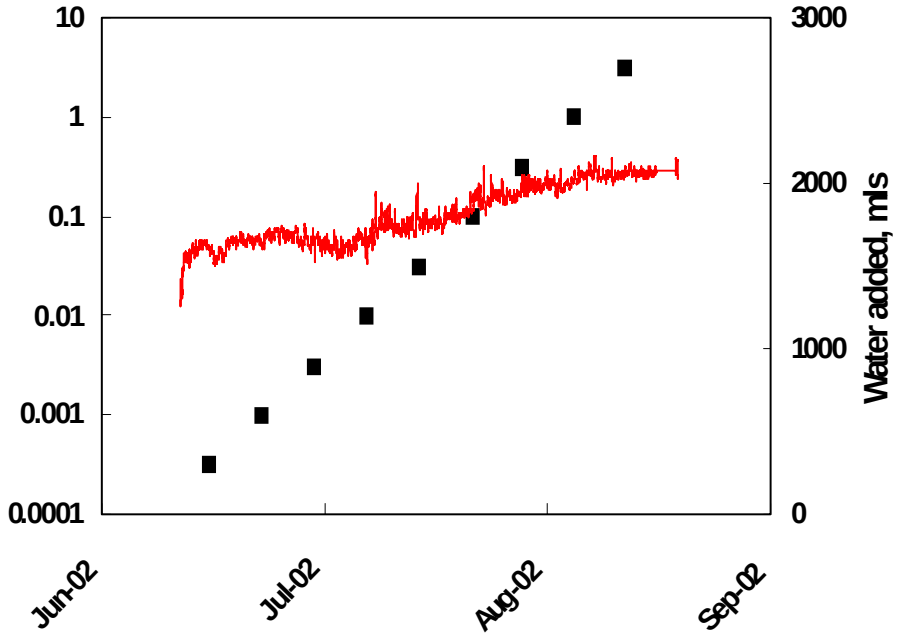
External Corrosion
Soil Corrosion Test

Corrosion Tests in Soil

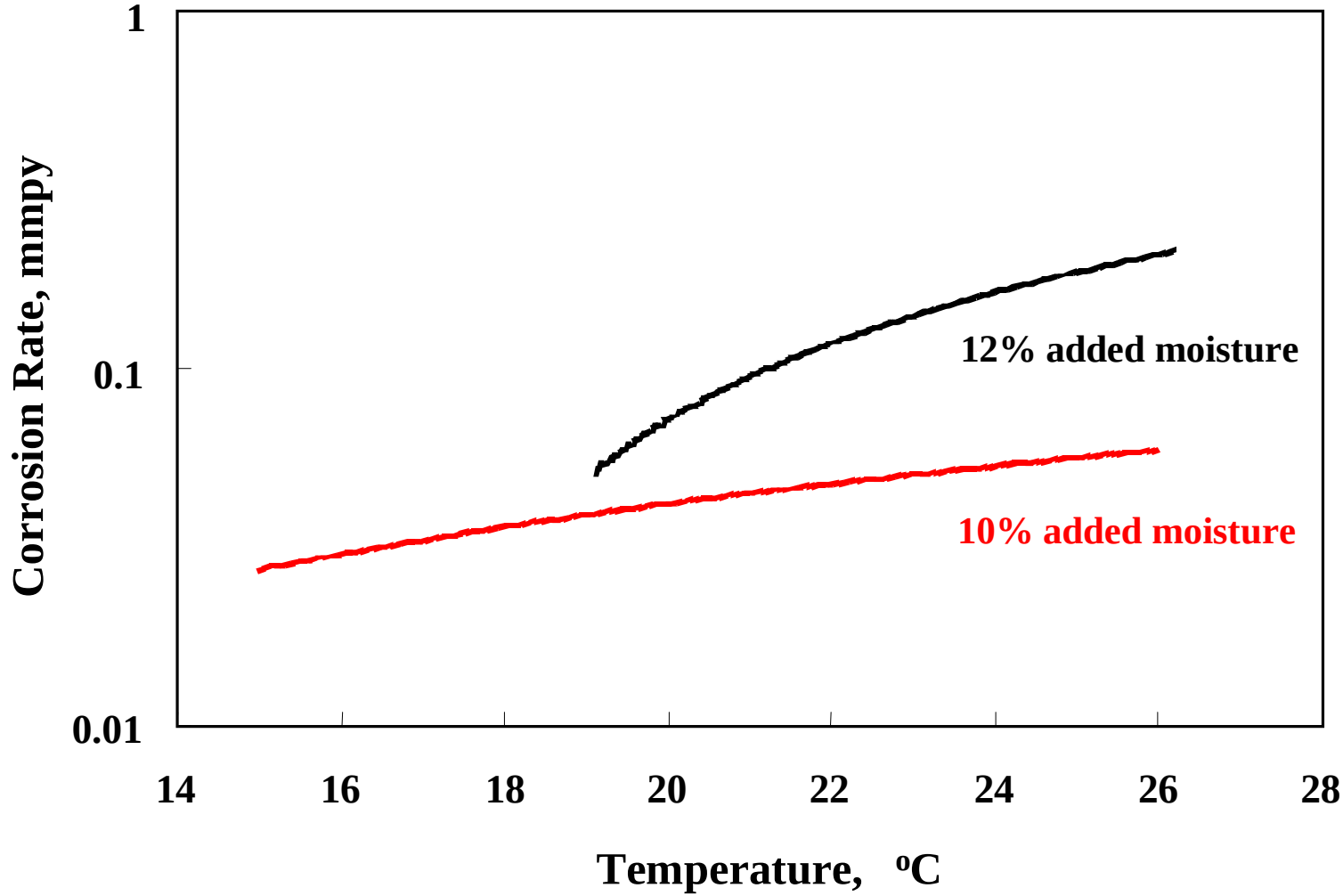
Soil



Soil + NaCl

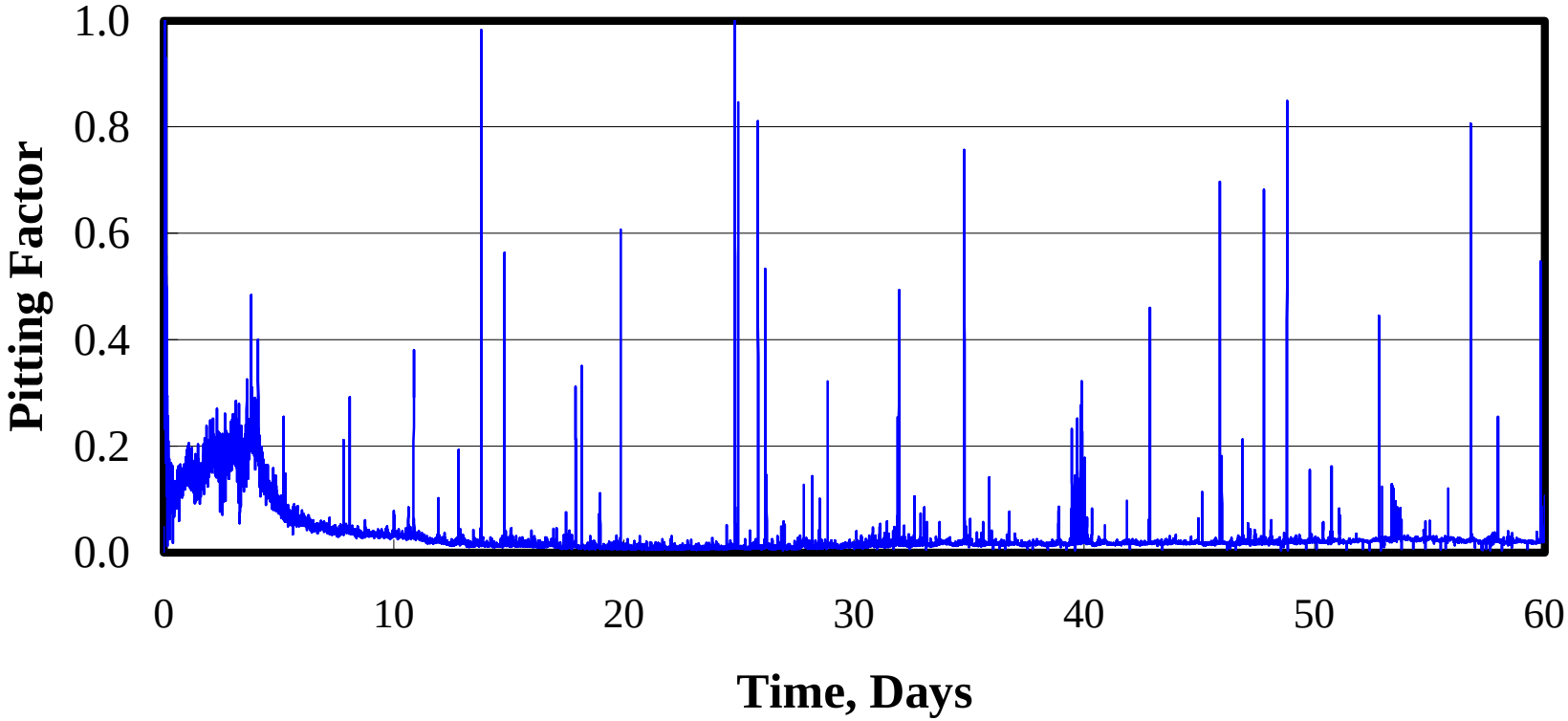


Corrosion Tests in Soil

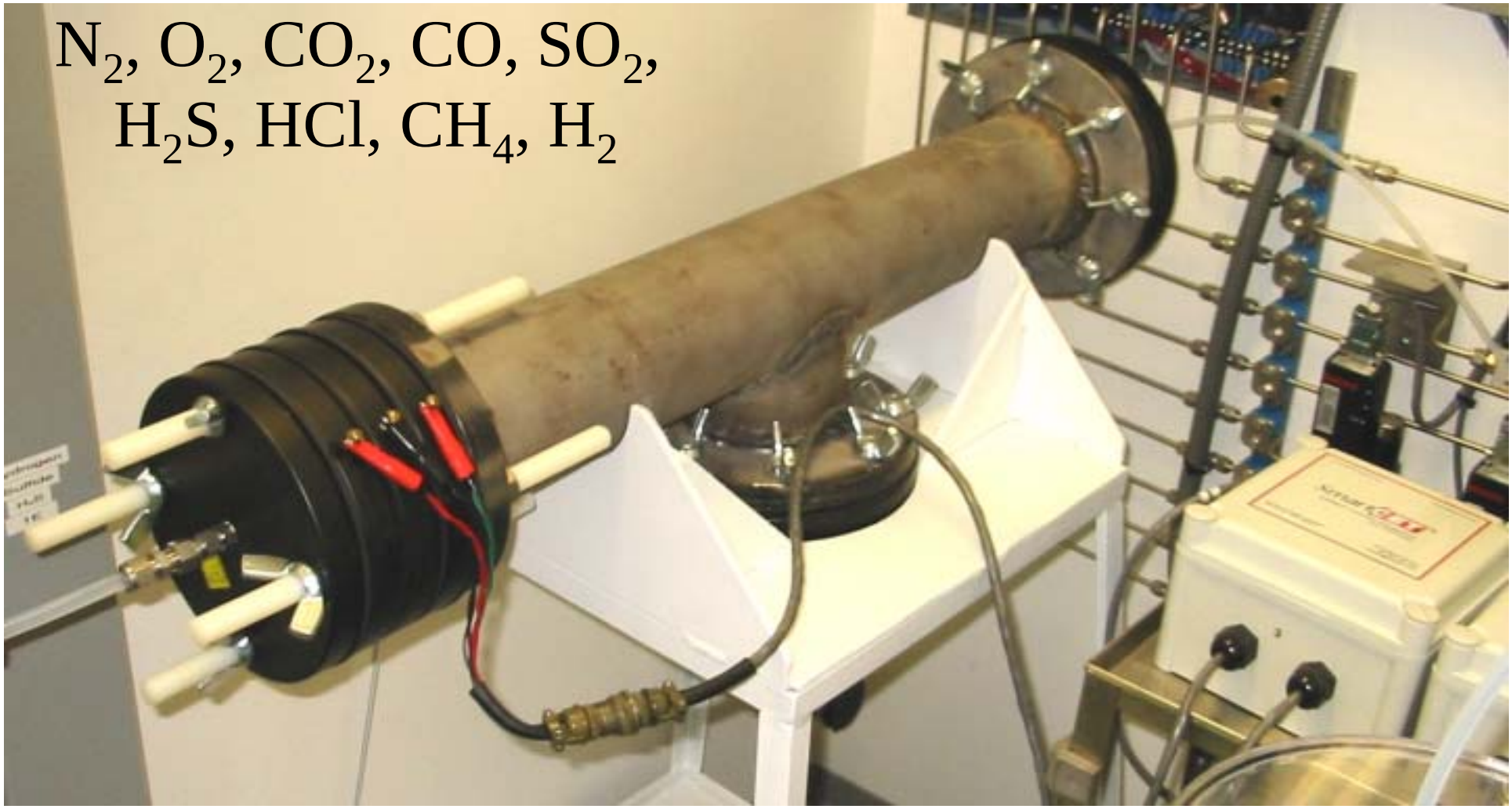


Corrosion in Soil with NaCl

Pitting Factor	Form of Corrosion
0-0.1	General Corrosion
0.1-0.2	Tendency to Localized Corrosion/Pitting
>0.2	Localized Corrosion/Pitting



Internal Corrosion Laboratory Pipeline Tests



Conclusions

- EN able to measure corrosion rates and pitting in internal and external pipeline corrosion.
- EN sensors able to be placed using commercially accepted methods of coupons (external) or flanges and inserts (internal)

Future Work

- Miniaturize the internal corrosion probe insert for use in high pressure pipeline.
- Signal signature identification for
  - Chemistry of corrosive constituents
  - Flow regimes
  - Inhibitor effectiveness
  - Stress Corrosion Cracking
- Field Tests of EN in Gas Pipeline
  - Rocky Mountain Oilfield Testing Center (RMOTC)
  - Seeking Commercial Pipeline for Field Tests