IMPro Technologies

- IMPro Guided Wave Advancements
  - DAC calibration (Pipe WT thickness and height of weld)
  - Dual Collar Pitch Catch – Adjustable transducers
  - Error Band +- 1% to 10% - Unrolled Pipe Display (Frequency and Bandwidth Sweeping to max Signal to noise ratio at anomaly)
  - Software Discrimination
    - Corrosion
    - Spacers
    - Coating faults
    - Other defects
  - GUL Focus improves Accuracy
  - Hydro test Equivalency - RSTRENG/B31.G/Modified (Based on Prove Up)

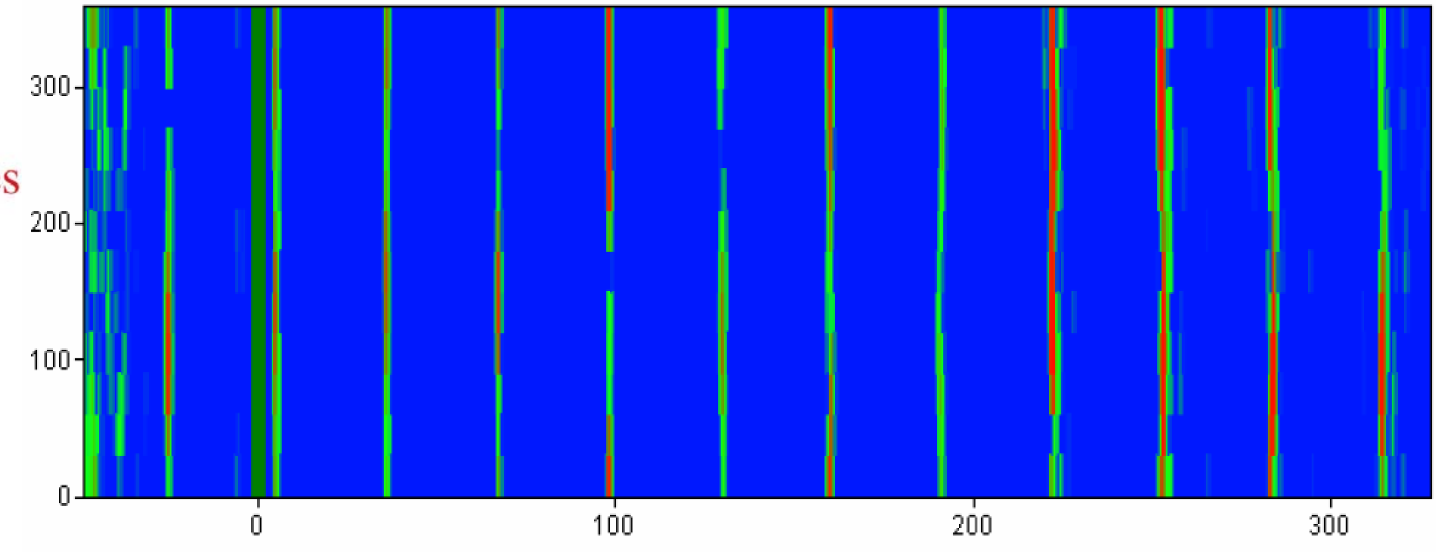
IMPro Technologies

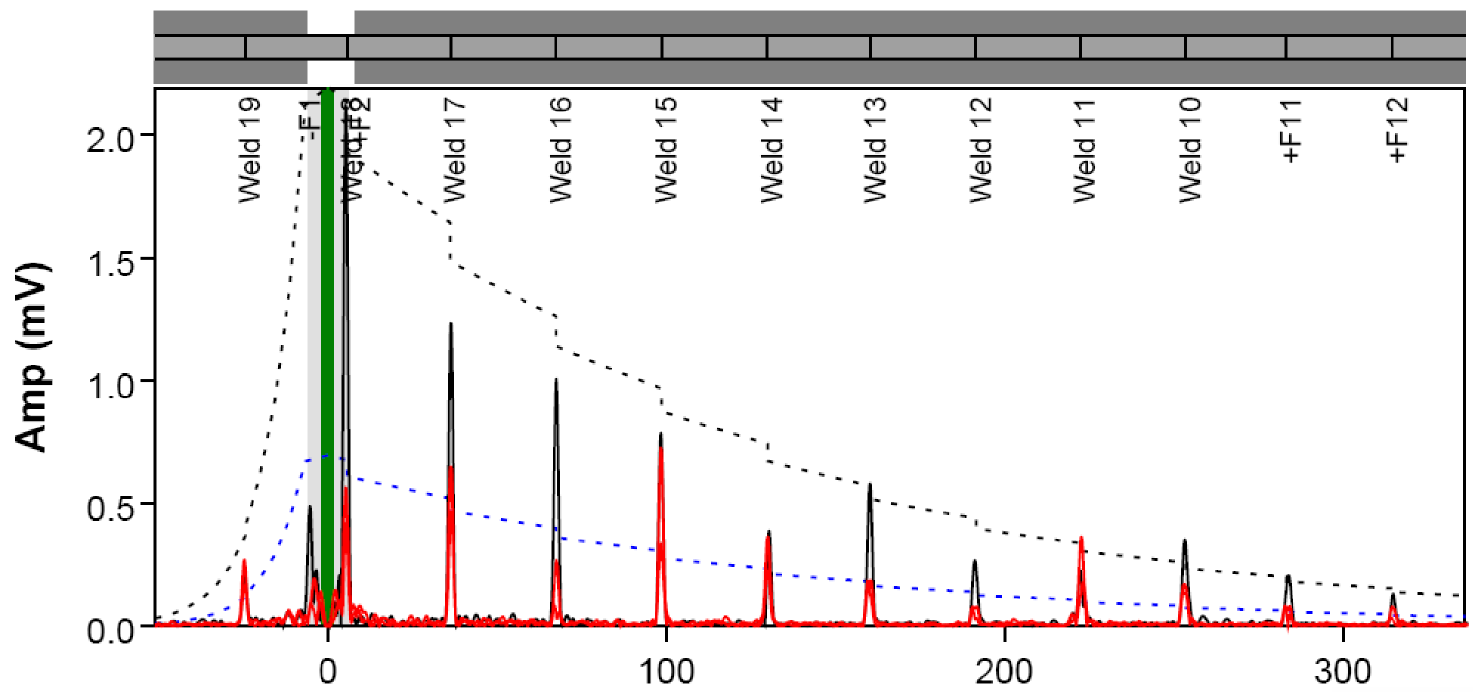
VIS 2000 Pro Service Camera

Monitor
Size: 10.5“ x 7.8“ x 2.4“
TFT size: 6.5“
Resolution: 768 x 512 (NTSC)
640 x 480 (PAL)
CF-Card: 128 MB, 1 GB max.
Video out: Standard Video Signal
Weight: 12 oz.
Operating Time
approx. 1 hr.
2“ Pan & Tilt Color Camera Head
Sensor type: 1/4“ CCD
Senitivity: 0.4 Lux
Resolution: 542 x 586 pixel
Lens system: f=2.0mm, F=2.0
Field of view: 98° x 75°
Lightsource: 4 bulbs with diffuser and 6 switchable superbright white LEDs.

IIMPro Technologies

IMPro Technologies



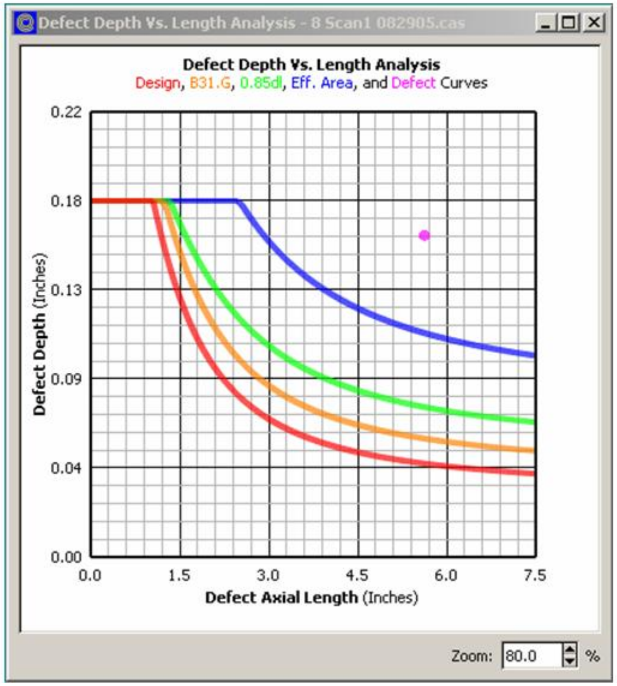


IMPro Technologies

– Other Supporting Prove Up (Validation) Technologies

- Conformable Array
- Borescope
- PECC Tool
- PIMS

Defect Depth Vs. Length Analysis



- Casing DA Approach
  - Potential solutions
  - Identification of Metallic Shorts, Electrolytic Conditions and Atmospheric Corrosion using NACE and Industry Protocols
    - Preliminary Electrical Testing
      - » Potential method
      - » Internal Resistance
      - » 4 Wire IR Drop
    - Secondary Electrical Testing
      - » Electromagnetic
      - » ACVG/DCVG
    - Long Range Guided Wave
    - Other Technologies (Validation and Prove Up)
  - Identification of Atmospheric Corrosion
  - Risk Assessment
  - Environmental (Soil and electrolyte analysis)

Electromagnetic Tools

How PEC technology works

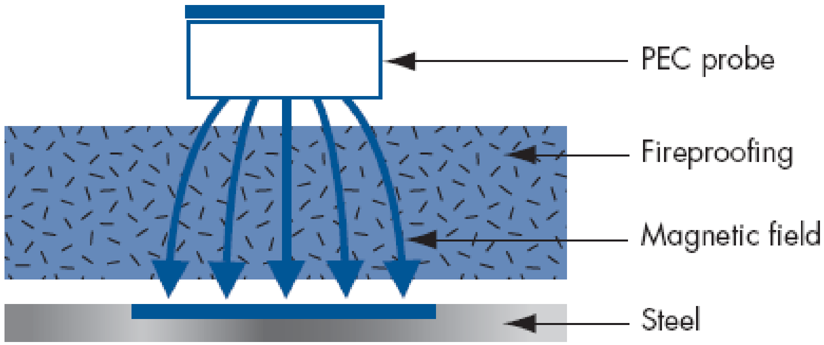
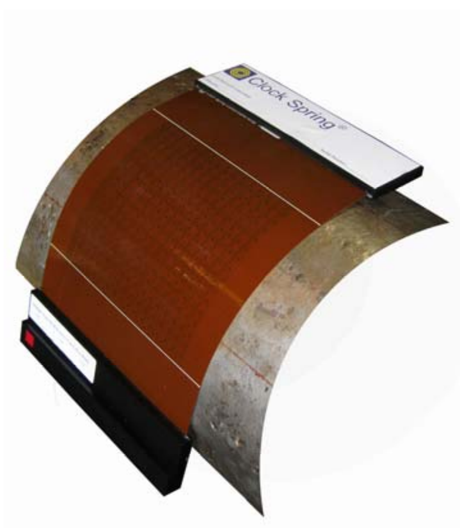
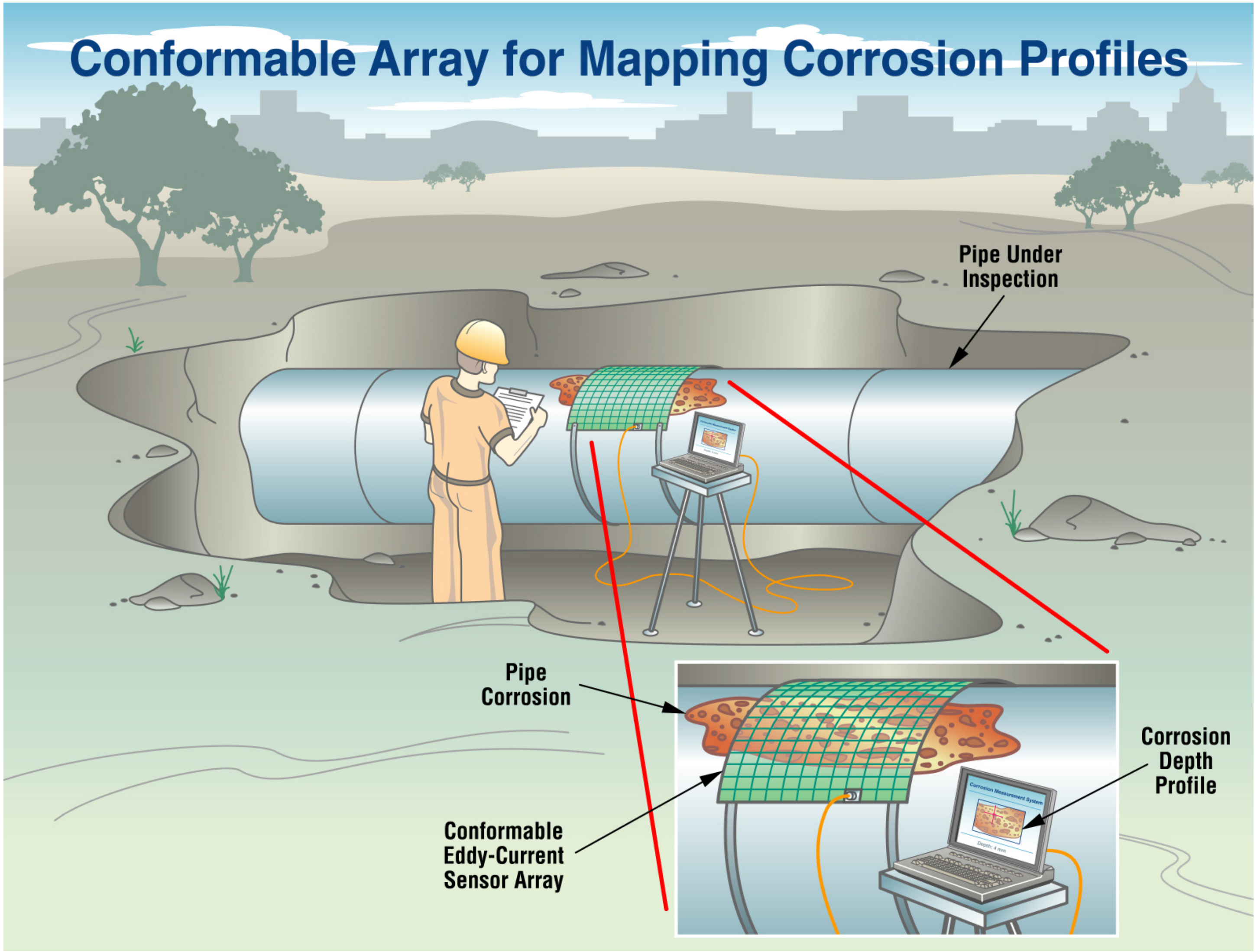


Figure 3: The basic principles of PEC technology.



IMPro Technologies

Conformable Array for Mapping Corrosion Profiles



IMPro Technologies
7210 Jadewood Dr.
Houston TX 77088

12 Questions – July 15/16 Cased Pipeline Workshop

- What are some of the successes with your process or equipment?
  1. **Explorer Pipeline, Dow Pipeline, Shell Pipeline, Buckeye, Laclede Gas, Oxy, AERA**
- Are there any limitations with your process or equipment that has caused an unsuccessful assessment?
  2. **Yes – Highly attenuating coatings limiting shot range to meet 18 Point Guideline – Lack of proper site preparations.**
- Have there been any situations where your process or equipment is not suited for cased crossings?
  3. **Yes – If access to the straight run carrier pipe was not possible**
- On what type of pipelines have you used your equipment or process to evaluate?
  4. **Gas, Liquid, Steam, Refinery/Petrochem, Pipeline, On/Offshore, Buried & Above Ground**
- What are the standards used for successful cased pipeline crossing evaluations: GWUT-18 Point Checklist, other measures?
  5. **Latest generation GUL G-3 instrument and software with unrolled pipe, clock position and focus. 16 Channel Enhanced Circumferential Collars, Adjustable spacing transducers. GUL certified Advanced Level Operators, (not in-house cert), Advanced Level 1 Operator with Buried Pipe and Roadcrossing endorsement from GUL England, Only. A GWUT procedure, (see handout), developed with the Client to insure PHMSA 18 Point compliance. "Other Measures" – Do not perform GWUT as "Stand Alone Technology" – Properly incorporate GWUT into the ECDA process with Complimentary Technologies.**
- Can your process/equipment size an anomaly feature, if so to what accuracy?
  6. **Yes – Depending on S/N ratio which allows the sensitivity level at the anomaly to insure PHMSA compliance of 5% or greater, the cross sectional wall loss/remaining wall as determined by subsequent prove up has run between + or – 10% or + or – 1%**
- Can you provide some satisfied customer contacts for your process or equipment?
  7. **Yes**
- Do you have any statistics on the success rate of your process or equipment of finding anomalies in cased pipelines?
  8. **Yes – 98% success where metal loss anomalies were called within the 5% sensitivity range of the shot AND when subsequent prove up was done. Without prove up no % success estimate is possible**
- What is the false positive rate?
  9. **Less than 2% - See GTI study results published January 2006**
- Any false negatives?
  10. **Less than 2% - See GTI study results published January 2006**
- Can you provide your customers with any quality guarantees, such as similar to ILI vendors?
  11. **Possible - Have not seen the basis for the ILI vendor's quality guarantee**
- Do operators have to do any preparation work to use your process or equipment?
  12. **Yes – Remove casing End Seals, very important, prepare location for GUL collar 24" – 36" wide by removing any thick, Bitumen coating or Coal Tar Enamel or the old Bitumen impregnated felt, if Dual Collar Pitch/Catch is to be used, 18" if using single collar, No Closer than 5' -6' from casing entrance if at all possible. Best results are gained if collar is placed on straight run carrier pipe going into casing.**

New Technologies for Direct Assessment Monitoring Techniques
Carrier Pipes within Cased Crossings

By Joseph Pikas
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Impro-Technologies
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Abstract

Transmission and distribution pipelines have been installed in cased crossings since the days when railroads mandated their use back in the early 1900's. As a result of these actions and years of being in service, carrier pipes in cased crossings have experienced a variety of problems from metal to metal contacts, electrolyte in the annulus to atmospheric corrosion. Because of these problem(s) experienced on carrier pipelines within this difficult environment, new technologies have been developed these to assess critical problem areas. This paper will discuss the latest technologies, techniques and solutions to monitor these difficult areas of concern.

Keywords: Metallic Short, Electrolytic Condition, Open Circuit Potential, Current Attenuation, Long Range Guided Wave, Pulsed Current Conformable Array, etc.

Introduction

NACE RP02000 Steel Cased Casing Practices has been around for a number of years; however, with new emphasis by Pipeline Hazardous Material Safety Administration (PHMSA) in determining the integrity of carrier in cased crossings, new technologies and tools must be part of the overall strategy to assess the status of each cased road or railroad crossing tested. Many practitioners assume that taking a pipe and casing to electrolyte potential is adequate. Since this may not be the case, this paper will primarily focus on the type of corrosion found, new testing technologies to assess the carrier pipe and mitigation.

Corrosion and Causes

Coatings

Older coatings on carrier pipes experience degradation from a variety of factors from age, type, application, corrosive nature of electrolyte or atmosphere, number of holidays, application and construction practices. When all these factors are analyzed, many of the older carrier pipelines were coated with enamel type coatings which were field applied. Combined with poor or older construction techniques and with the corrosive nature of the environment inside a cased crossing, then the likelihood of corrosion issues becomes a reality. Researching these factors (Pre-Assessment) is necessary in order to get a better understanding of the annulus condition of road and railroad cased crossings.

Shielding

Casing spacers and insulators have been found to shield the carrier pipe. Whether it is from oxygen differential conditions, bacteria, or lack of cathodic .protection, electrolyte present in the annulus, these conditions could cause problems depending on the coating condition of the carrier pipe.

Metallic Short

According to the NACE definition “A direct or indirect metallic contact between two metallic structures”. Most metallic shorts exist at the ends of casing; however, there are cases where metallic spacers combined with steel cables have resulted in an indirect contact between the carrier pipe and casing. When two metallic structures are in contact with each other, the resistance between them is a very low with a value of (0.001 ohms or less). However, conventional measuring techniques using standard volt-ohm-meters (VOM) or a soil resistivity meter generally have an accuracy of +- .01 ohms. These are generally acceptable values for determining a metallic short.

Metallic shorts tend to be current sinks in which they drain large amounts of cathodic protection current away from the carrier pipe. Basically they are a huge holiday and may lower the potentials of the carrier pipe where the integrity is compromised both inside and outside the cased crossing. In addition, there is a chance of a stress concentrator being located at the point of contact.

Electrolytic (Ionic) Contact

Ionic contact between two metallic structures via an electrolytic condition is basically having water between the carrier pipe and casing. Most cased crossings have some moisture in the annulus except in dry desert regions. Take the East, West or Gulf Coast areas of the USA where the water tables are high enough and carrier pipe may be partially or totally immersed in an electrolyte. If the casing is bare, then CP can easily reach any of the exposed holidays. However, if the water table fluctuates due to seasonal variations, then the area above the water line and above may be subject to atmospheric corrosion.

Atmospheric Corrosion

Little or no information has been said about atmospheric corrosion by NACE RP02000 regarding this condition even though several pipeline major pipeline failures and multiple leaks have occurred over the years. Operators have used a variety of mitigation techniques to offset this condition from inert gases, heavy grade oil, grease wax, inhibitive powders etc.

However, as long as the carrier pipe coating is in good condition, little difference exists between the pipe surface and air temperature, oxygen and humidity levels stay stable, then the likelihood of corrosion will be minimized. However, if any of these conditions change, then the likelihood of corrosion will go up significantly. This is one of the more difficult conditions to monitor using above ground techniques. This paper will examine more advanced techniques in determining if corrosion exists on a carrier pipe even though no metallic contact exists.

Cased Crossing Criteria

The first step before analyzing if there is a corrosive condition at a cased crossing is to establish if criteria for a shorted condition. In accordance to NACE RP0200:

"A shorted casing may exist if there is a small differential or there is no differential between the pipe to electrolyte and casing electrolyte potential."

Based on this definition, the following potential criterion can be derived.

- **Severe Indication -** Pipe to Electrolyte "ON" Potentials are less than -850 mV and the difference in the Pipe and Casing Potential is less than 10 mV.

- **Moderate Indication -** Pipe to Electrolyte "ON" Potentials are borderline -850 mV and the difference in the P/S & C/S potentials is greater than 10 mV and less than or equal to 100 mV .

- **Minor Indication -** Pipe to Electrolyte "ON" Potentials are greater than -850 mV and the difference in the P/S & C/S potentials is greater than 10 mV and less than or equal to 100 mV .

- **Electrically Clear** – Pipe to Electrolyte "ON" Potentials are greater than 1000 mV and the difference P/S & C/S potentials is greater than 150 mV.

Taking the potential criterion one more level, the following classification table can be used to assess a carrier pipe in an HCA. This table will help prioritize in the selection of tools to indirect assess the level of severity of a casing condition.

Classification Table - Carrier Pipe within Bare Cased Crossing

Test Description	Severe (Metallic Contact)	Moderate (Electrolytic Path with Moderate Holidays)	Minor (Electrolytic Path With Minor Holidays)	Electrically Clear	Remarks
Pipe to Electrolyte Potential (Industry Standard)	Pipe to Electrolyte Potentials are severely depressed and below -850 mV Criterion	Pipe to Electrolyte ON Potentials are borderline near casing	Pipe to Electrolyte ON Potentials are slightly depressed near casing structure and are above -850 mV criterion	Pipe to Electrolyte ON Potentials show no or little influence from casing proximity	Pipe, Casing and OCP Potential Tests Should Always be Run Together
Casing-to-Electrolyte Potential (Industry Standard)	Casing to Electrolyte Potentials track Pipe Potentials and the difference in the Pipe and Casing "ON" Potentials < than 10 mV.	Casing to Electrolyte ON Potentials partially track Pipe Potentials and the difference in the P/S & C/S "ON" potentials is greater than or equal to 10 mV and less than or equal to 100 mV.	Casing to Electrolyte ON Potentials partially track Pipe Potentials and the difference in the P/S & C/S "ON" potentials is greater than100 mV.	Difference in the P/S & C/S "ON" greater than 150 mV and are below bare steel potential for that environment	Pipe, Casing and OCP Potential Tests Should Always be Run Together
Open Circuit Potential (OCP) between Casing and Pipe **(Industry Standard)**	Difference in Pipe and Casing Structure Potential < 10 mV	Difference in the P/S & C/S "ON" greater than or equal to 10 mV and less than or equal to 100 mV.	Difference in the P/S & C/S "ON" greater than100 mV.	Difference in the P/S & C/S "ON" greater than 150 mV.	Pipe, Casing and OCP Potential Tests Should Always be Run Together
Internal Resistance **(Industry Standard)**	Pipe-to-Casing (P/C) resistance less than or equal to 0.01 Ω	P/C resistance greater than 0.01 Ω and less than or equal to 0.1 Ω.	P/C resistance greater than 0.1 Ω.	P/C resistance greater than 0.15 Ω	Internal Resistance Test will determine metal to metal contacts

Cycling the Rectifier **(Subjective)**	Difference in the P/S & C/S shifts less than 10 mV "OR" C/S shift greater than 75% P/S shift	Difference in the P/S & C/S shifts greater than or equal to 10 mV and less than or equal to 100 mV "OR" C/S shift greater than or equal to 25% P/S shift and less than or equal to 75% P/S shift	Difference in the P/S & C/S shifts greater than 100 mV "AND" C/S shift less than 25% P/S shift	Difference in the P/S & C/S shifts greater than 150 mV "AND" C/S shift less than 10% P/S shift	Subjective
Current Attenuation	Near total signal loss from both directions large spike in mb/ft (C-Scan) or > 80 dBmA (PCM)	Moderate Spike mb/ft (C-Scan) or < 80 dBmA (PCM)	Minor spike or signal loss for either C-Scan or PCM	No significant signal loss (Normal Attenuation)	Subjective except for direct metal to metal contact
Polarization Test (Panhandle Eastern Method) **(Subjective)**	P/C resistance less than or equal to 0.01 Ω	P/C resistance greater than 0.01 Ω and less than or equal to 0.1Ω.	P/C resistance greater than 0.1 Ω.	Additional testing required to define	Subjective
Casing-to-Pipe (C/P) Capacitance **(Not Proven by Industry)**	"Shorted" display	Not Defined	None	"Clear" display	Not Proven by Industry

Note: Many tests were determined subjective because the results have not been proven up empirically or by standards.

Procedure for Conducting a Casing Test

Using NACE ECDA RP0502 methodology is an excellent method to determine the integrity of a carrier pipeline in cased crossing. However, additional test methods must be used in order to get a truer assessment of the carrier pipe as stated above. The first step of pre-assessment consists of the data gathering phase which is as follows:

Pre-Assessment

- Operations
  - Temperature, Stress Levels, Dig Reports, etc.
- History
  - Year installed Leaks, Shorts, Cathodic Protection, Microbiological Influenced Corrosion (MIC), etc.
- Pipe/Casing Attributes
  - Diameter, Wall Thickness (WT), Specified Minimum Yield Strength (SYMS), Welds, etc.
- Construction Practices
  - End Seals, Spacers, Seam type, Problems, Vents, etc.
- Soils and Environmental
  - Drainage, Topography, Land Use, Water Table Fluctuations, etc.
- Corrosion Control
  - Coating type, Coating Condition, Current Demand, Potentials of Pipe/Casing, Test Stations, etc.

Indirect Inspection - Initial Electrical Field Tests

Just as with ECDA two or more field tests are required. The potential survey and resistance test should be the gold standard as the initial test. However, if data does not compliment each other, then consideration should be given for one or more of the other tests listed. See below for Potential, Internal and Four Wire IR Drop Tests.

- *Potential Survey*

    - *This method is the initial test conducted to identify a shorted casing. A voltmeter and a reference electrode are used to conduct these tests.*
        - *Pipe to Electrolyte*
        - *Casing to Electrolyte*
        - *Open Circuit Potential (OCP)*
- *Internal Resistance*
    - *This method indicates whether direct metal-to-metal contact exists between a carrier pipe and the casing pipe by measuring electrical resistance.*
    - *Metal to metal <0.01 ohms*)
- Four Wire IR Drop
    - This method indicates the existence and location of a short.
- Cycling Rectifier
    - Cycling the cathodic protection rectifier is another method used to evaluate the electrical isolation between pipe and casing.
- Casing Depolarization
    - Panhandle Eastern Method
- AC Signal (Current Attenuation) – Pipe Locator
    - This method uses a signal generator and receiver to detect signal loss at a metallic short or a coating defect with an electrolyte.
- Capacitive (Go-no-Go Type Test**)**

Verification Tests

Because the carrier pipe is not assessable through direct examinations, it is recommended that one of the following tests be conducted where likelihood of atmospheric corrosion may exist, a metallic contact, poor construction, history of leaks, MIC, or any other threats that may cause an integrity problem. One or more of the following prove up tests are recommended based on operating conditions of the pipeline.

- Long Range Guided Wave

    - This method use torsional data as well as compressional wave modes to detect cracks, metal loss and other defects on a carrier pipe inside a casing.
- In Line Inspection or Tethered Pigs
    - ILI is used to determine the presence or absence of pitting-corrosion damage on carrier pipe inside a casing.
- Hydrostatic Test (Go-no-Go Type Test)

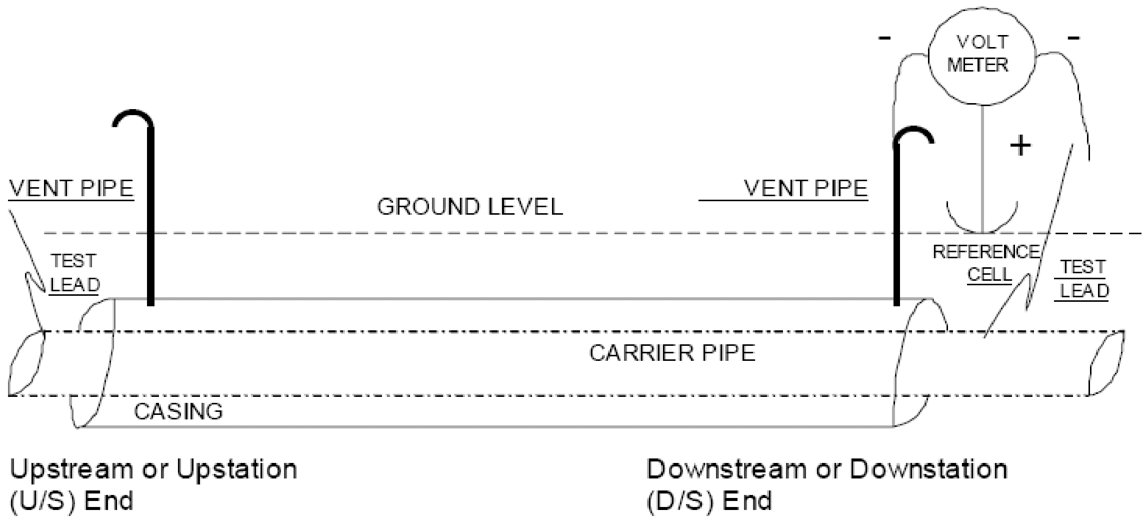
Direct Examination

A direct examination is generally done whenever, the likelihood of corrosion or indications are found from indirect surveys.

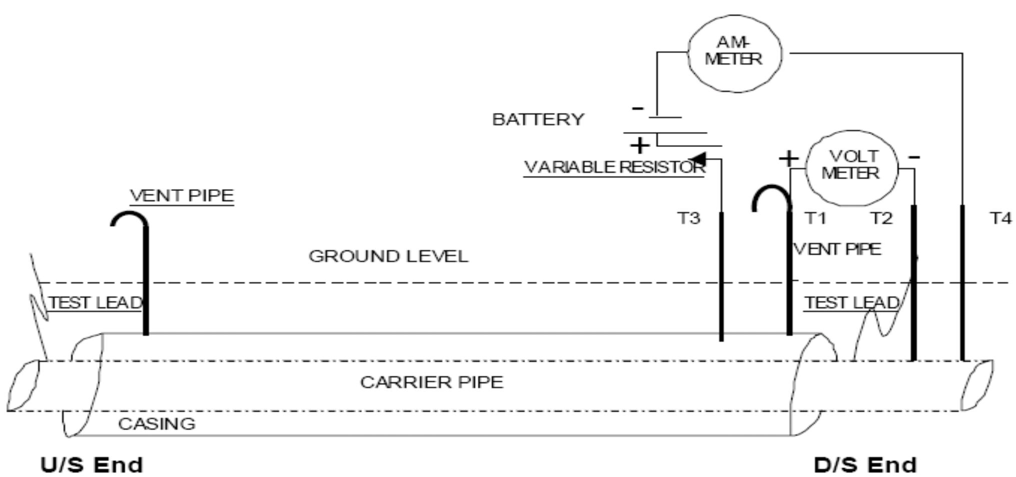
- Location
    a. Engineering Station # and GPS
- Pipe/Casing Attributes
    a. Wall Thickness. Diameter, SYMS, Welds, etc.
- Reason for Inspection
- Coating Type's) and Evaluation
- Environment (Soil/Water – Field/Lab)
- Evidence of
    a. Corrosion, Stress Corrosion Cracking, Defect, Damage, etc.
- Repair
    a. Recoat, Composite Sleeve, Replace, etc.
- Type of Tests Performed
    a. MIC, Ultrasonic Thickness, Magnetic Particle, Dye Penetrant, pH, Resistivity, Conformable Array, Pulsed Eddy Current Tool for Concrete Coating, etc.

Example of an Initial Field Test for a Metallically Shorted Casing

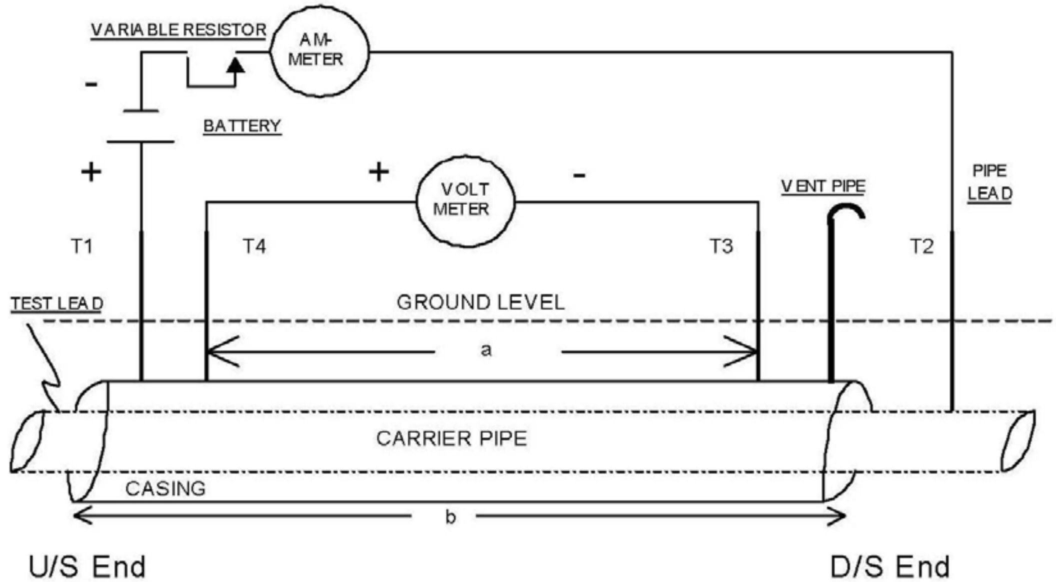
- Initial Potential Test (Voltmeter) Readings
  - P/S -700 mV
  - C/S -698 mV
  - OCP -2 mV



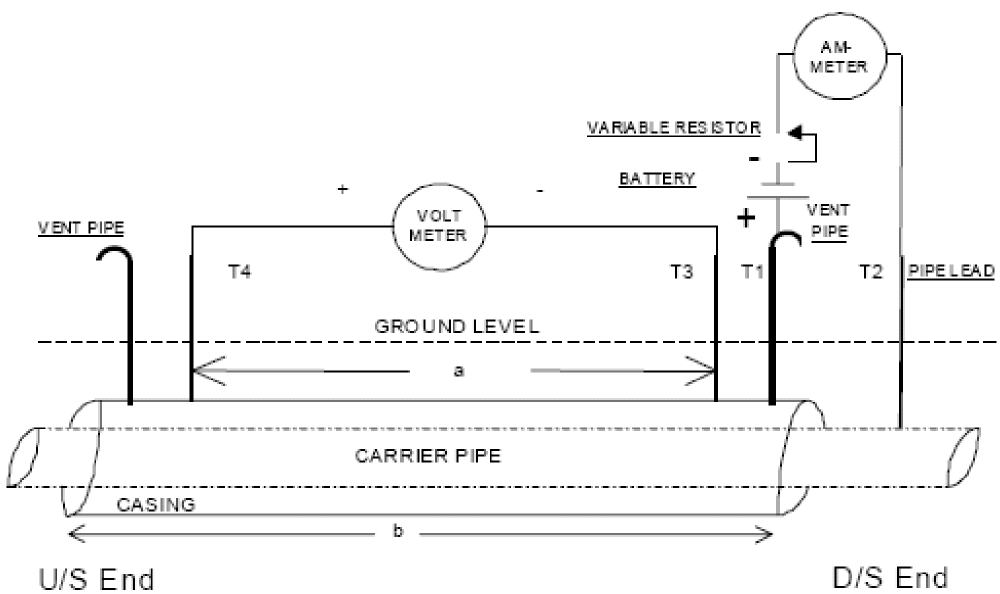
- Internal Resistance between Casing and Pipe (Resistivity Meter)
  - Ohms 0.0015



- Four IR Drop Test Method (Test 1 –Same current measured between terminals T4 and T3 as current applied between pipe and casing with battery.)



- Four IR Drop Test Method (Test 2 Optional – No Current measured between terminals T4 and T3 as applied between pipe and casing.)



- Current Attenuation (C-Scan or PCM)

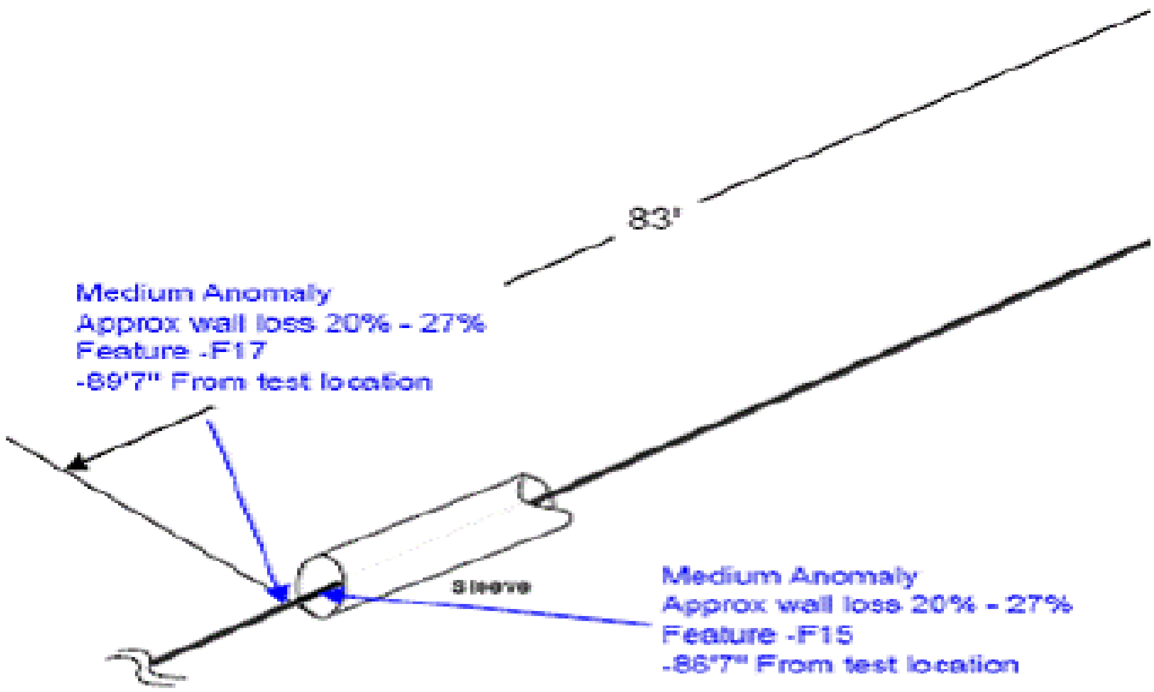
- Electromagnetic tool for screening coatings and defects on buried pipes to detect coating defects or metallic shorts.
  - Near signal loss or significant spike in signal current attenuation.

- Borescope (Typical Equipment Used to Monitor Annulus between Casing and Carrier Pipe)

  - No Coating Damaged
  - Temperature/Humidity
    - Pipe 60 F and Annulus 65 F with 70% Relative humidity

Results of Metallic Short with Corrosion

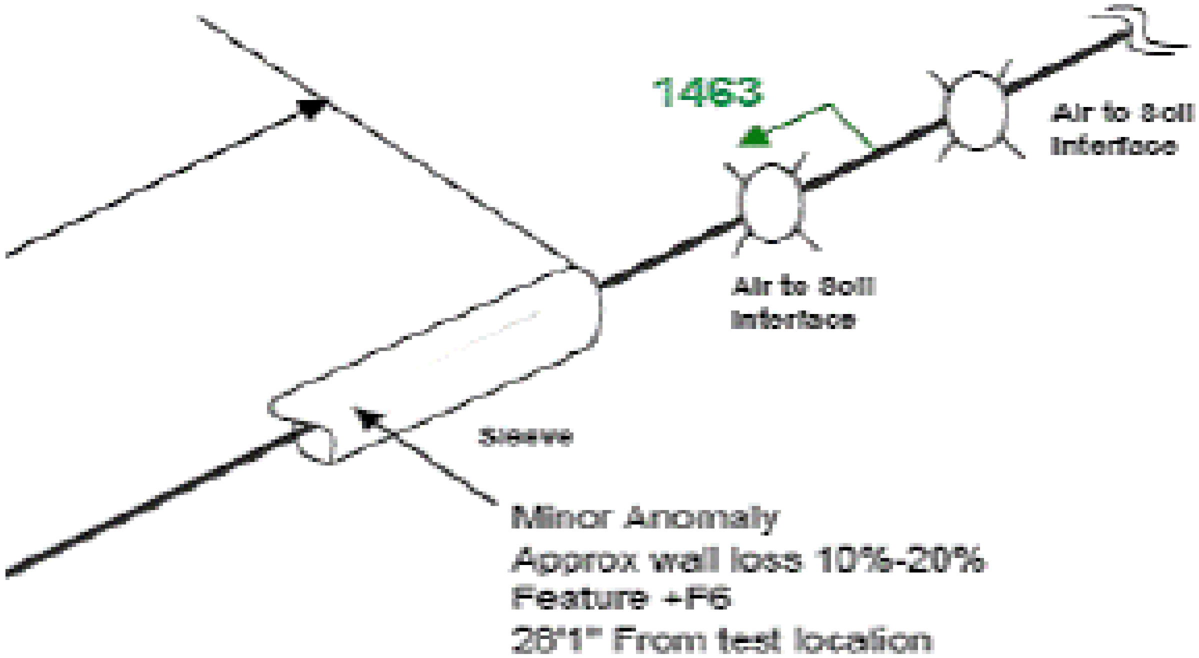
- Potential Test < 2 mV (Possible Short)
- Internal Resistance Test (< 0.015 ohms)
- Four Wire IR Drop (U/S side)
- Borescope (No Atmospheric Corrosion Found)
- Humidity (70% Relative Humidity and delta *t = 5 F*
- Long Range Guided Wave Results
  - 20 to 27% metal loss in the 11 o'clock position 3' outside U/S end of casing



Test Area 89.7' from Indication

Results of Atmospheric Corrosion (Electrolyte in Casing)

- Pre-Assessment – Fluctuating Water Table
  - Temperature/Humidity (90% Relative Humidity and delta *t = 15 F*
- Initial Potential Test (Voltmeter)
  - P/S - 900 mV
  - C/S - 800 mV
  - OCP - 100mV
- Internal Resistance between Casing and Pipe (Resistivity Meter)
  - Ohms 0.095
- No Four Wire IR Drop or Above Ground Tests Conducted
- Electromagnetic (C-Scan/PCM Tests Found Possible Coating Defect D/S Side)
- Borescope (Possible Atmospheric Corrosion Found)
- Long Range Guided Wave – Verification
  - 10% to 15% D/S - (Corrosion Inside Casing)
- Confirmed Corrosion Using Conformable Array Tool



Conclusions

The following conclusions were made from the two different type casing surveys:

- **Metallic Short - U/S side of Road Crossing**
  - Potential, Resistance and 4 Wire Tests indicated a metallic short
    - Low P/S, C/S & OCP potentials
      - Little or no potential difference between each one.
    - Low internal resistance between casing and pipe
    - Four wire drop test U/S side
  - Electromagnetic test showed spike or near signal loss
  - Verification using Long Range Guided Wave showed 20 to 27% metal loss
  - Prove up using a bridging pit gage or conformable array to measure metal loss

- **Atmospheric Corrosion on D/S Side of Road Crossing**
  - Pre-assessment indicated likelihood of atmospheric corrosion
  - Potential and Resistance tests indicated possible electrolyte in casing
    - P/S, C/S and OCP potentials within 100 mV of each other
  - Electromagnetic (C-Scan/PCM) indicated a minor indication
  - Borescope showed indication of atmospheric corrosion
  - Verification using Long Range Guide Wave showed 10 to 20% metal loss

- **Indirect Tools to Find Indications**
  - Potential Surveys using voltmeters.
  - Megger or equivalent to measure resistance of pipe to casing
  - Electromagnetic surveys
  - Borescope, Temperature, Humidity, etc.

- **Prove Up using Long Range Guided Wave Tools to Confirm Indications from Other Tools**
  - Long Range Guided Wave

- **Direct Examination to Verify Findings**
  - Conformable array can be used in inaccessible area between casing and carrier pipe and outside of casing to verify metal loss indications.

Operators now have the a number of new tools to monitor and assess the carrier pipes within cased crossings adequately even though carrier pipes in cased crossings have experienced a variety of problems from metal to metal contacts, electrolyte in the annulus along with atmospheric corrosion. Because of these problem(s) experienced on carrier pipelines within this difficult environment, these new technologies can help better assess critical areas while meeting company integrity and PHMSA requirements.

IMPro Technologies

Direct Assessment for Cased Crossings Monitoring and Criteria

By Joe Pikas

May 11, 2008

Overview

- Introduction
- Corrosion and Causes
  - Coatings
  - Shielding
  - Metallic Contacts
- Criteria for Casings
- Monitoring
  - Electrical Tests
  - Long Range Guided Wave
  - Other Technologies
- Maintenance
- Procedure for Testing Integrity of Carrier Pipe

Introduction

- Common Practice started w/RR X-ings
- End Seals
  - Concrete or Enamel w/Rope (Old Type)
  - Link, Hot Applied Sleeves, etc.
  - None - Concrete coated pipe w/open ends
- Spacers
  - Hemp Rope w/enamel (Old Type)
  - Non metallic
    - Plastics
    - Molded Epoxy Sleeves
  - Concrete coated pipe

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Corrosion and Causes

- Coating Deterioration
  - Age
  - Physical Damage to Coating during construction
- Shielding
  - Spacers
  - Insulators
  - Coating
- Metallic Contact (Generally @ End(s)
  - Galvanic
  - Drain on CP outside casing
  - Stress Concentrator
- Atmospheric
  - High Delta *t* (temperature difference between pipe surface and atmosphere)
  - Humid Environment in Annulus
  - Vent(s) supplying oxygen to the annulus

Criteria for a Short

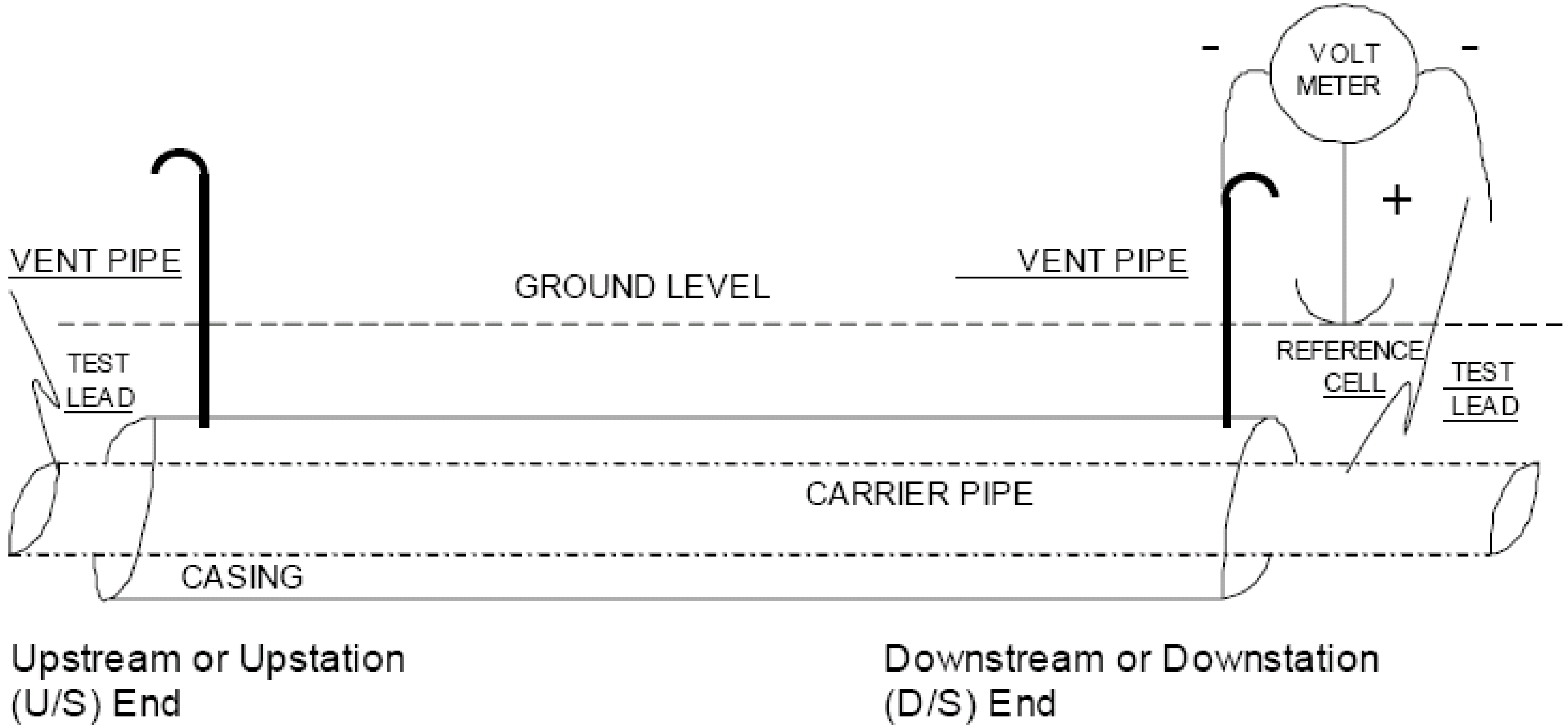
“A shorted casing may exist if there is a small differential or there is no differential between the pipe to electrolyte and casing electrolyte potential.”

- Severe Indication - Pipe to Electrolyte "ON" Potentials are less than -850 mV and the difference in the Pipe and Casing Potential is less than 10 mV.
- Moderate Indication - Pipe to Electrolyte “ON” Potentials are borderline -850 mV and the difference in the P/S & C/S potentials is greater than 10 mV and less than or equal to 100 mV .
- Minor Indication - Pipe to Electrolyte “ON” Potentials are greater than -850 mV and the difference in the P/S & C/S potentials is greater than 10 mV and less than or equal to 100 mV .
-

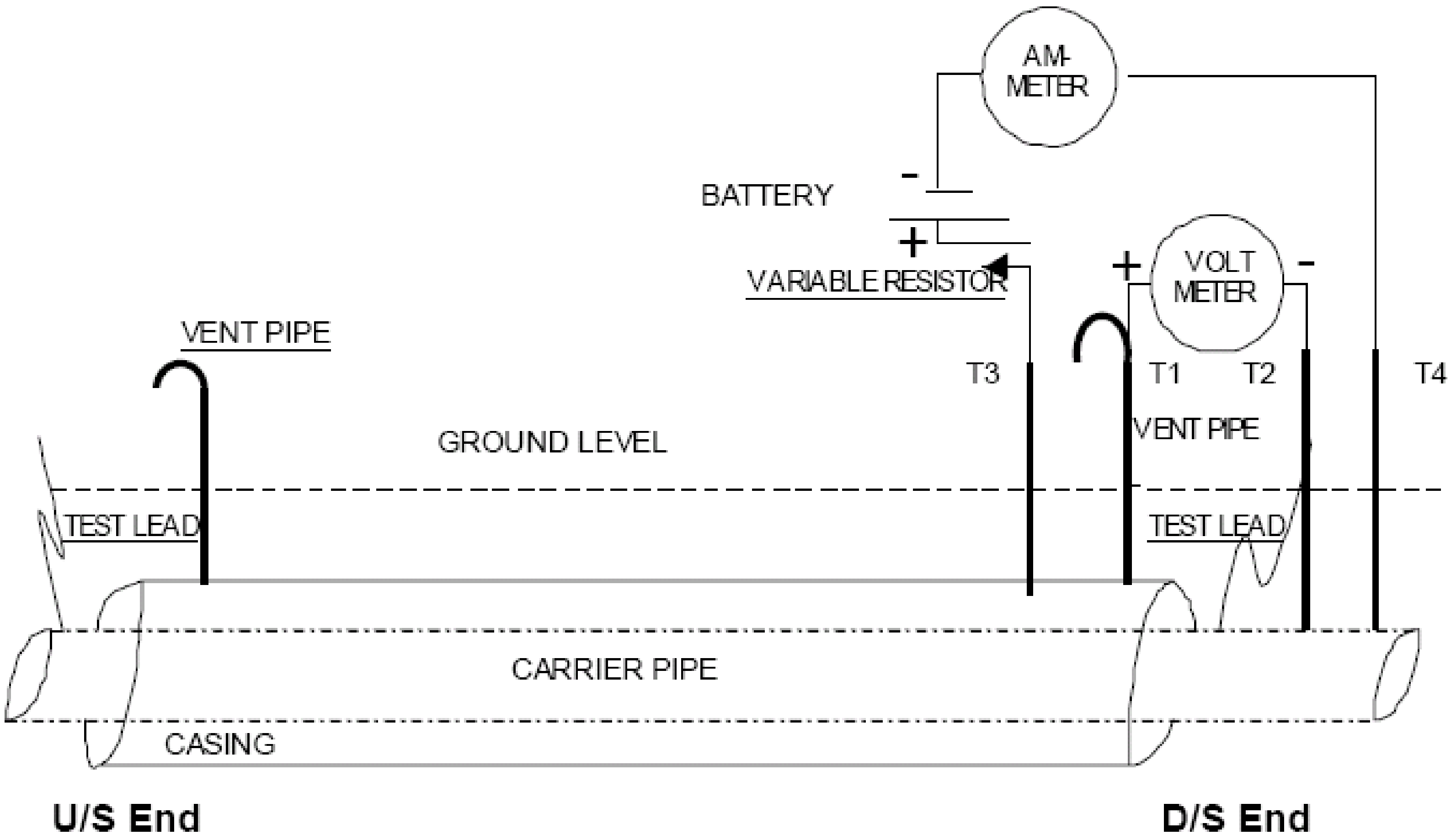
Monitoring

- Initial Electrical Field Tests
  - Potential Survey
    - This method is the initial test conducted to identify a shorted casing. A voltmeter and a reference electrode are used to conduct these tests.
    - P/S, C/S, & OCP
  - Internal Resistance
    - This method indicates whether direct metal-to-metal contact exists between a carrier pipe and the casing pipe by measuring electrical resistance.
    - Metal to metal <0.01 ohms)
  - Four Wire IR Drop
    - This method may indicate the existence and location of a short.

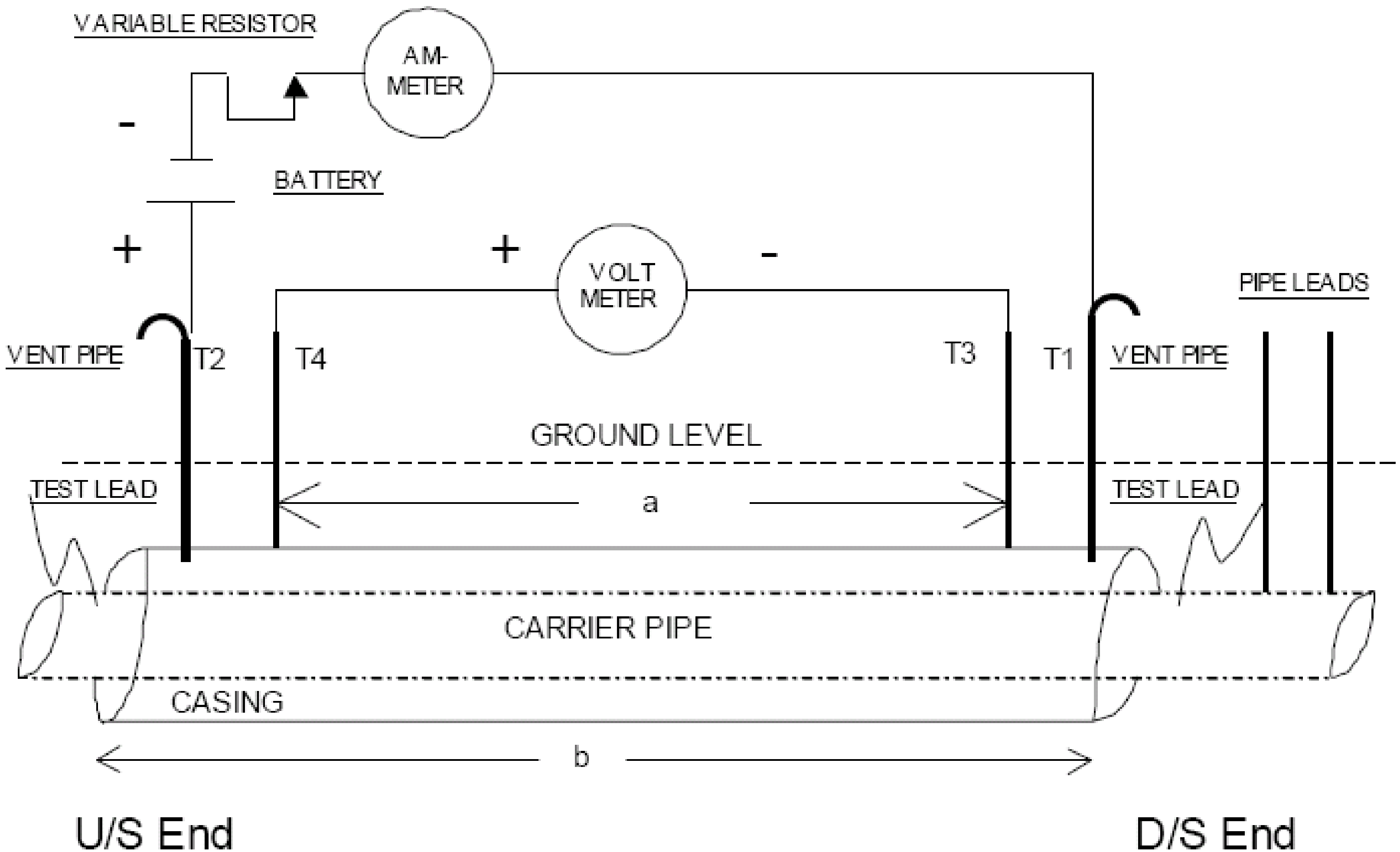
Potential Survey



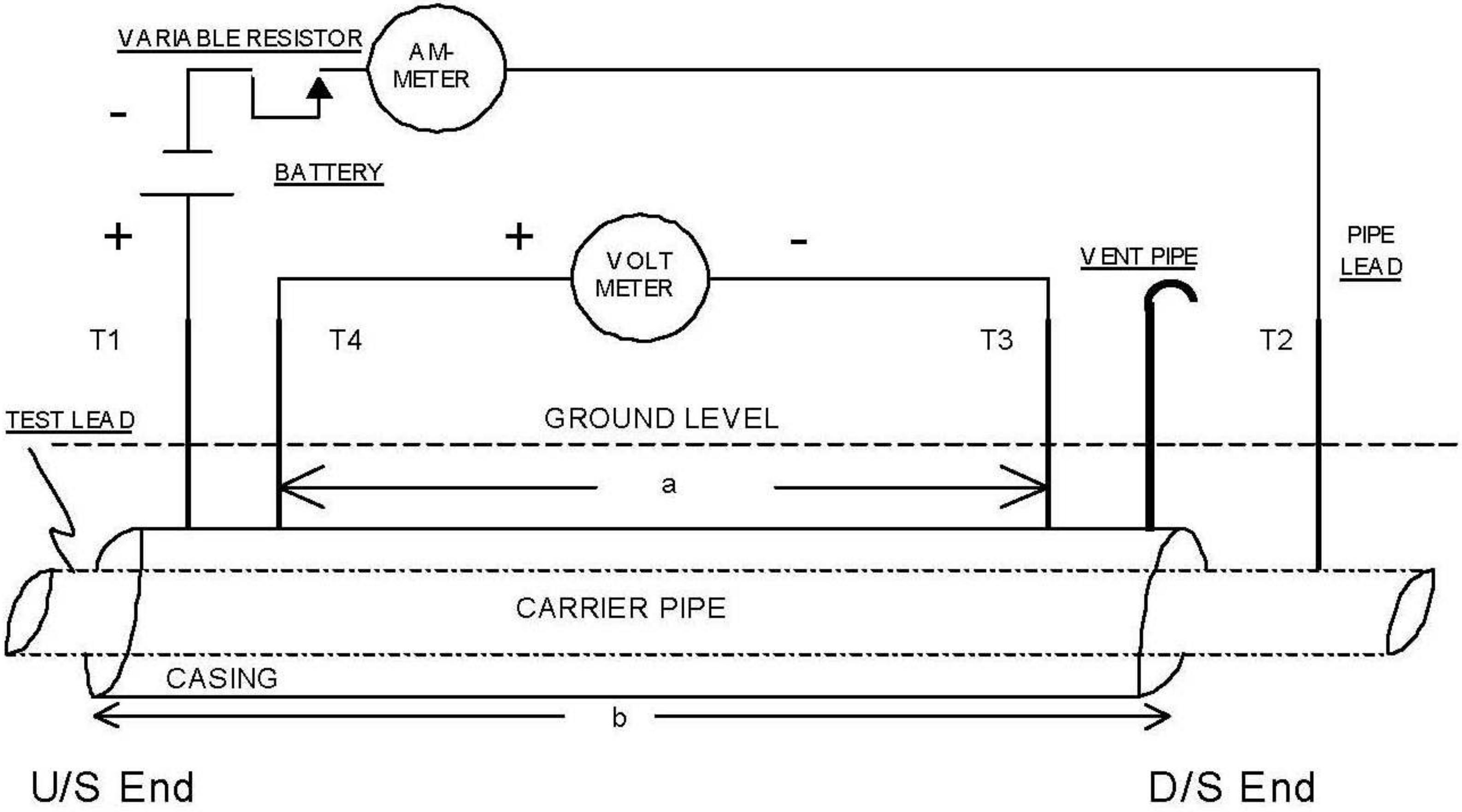
Internal Resistance



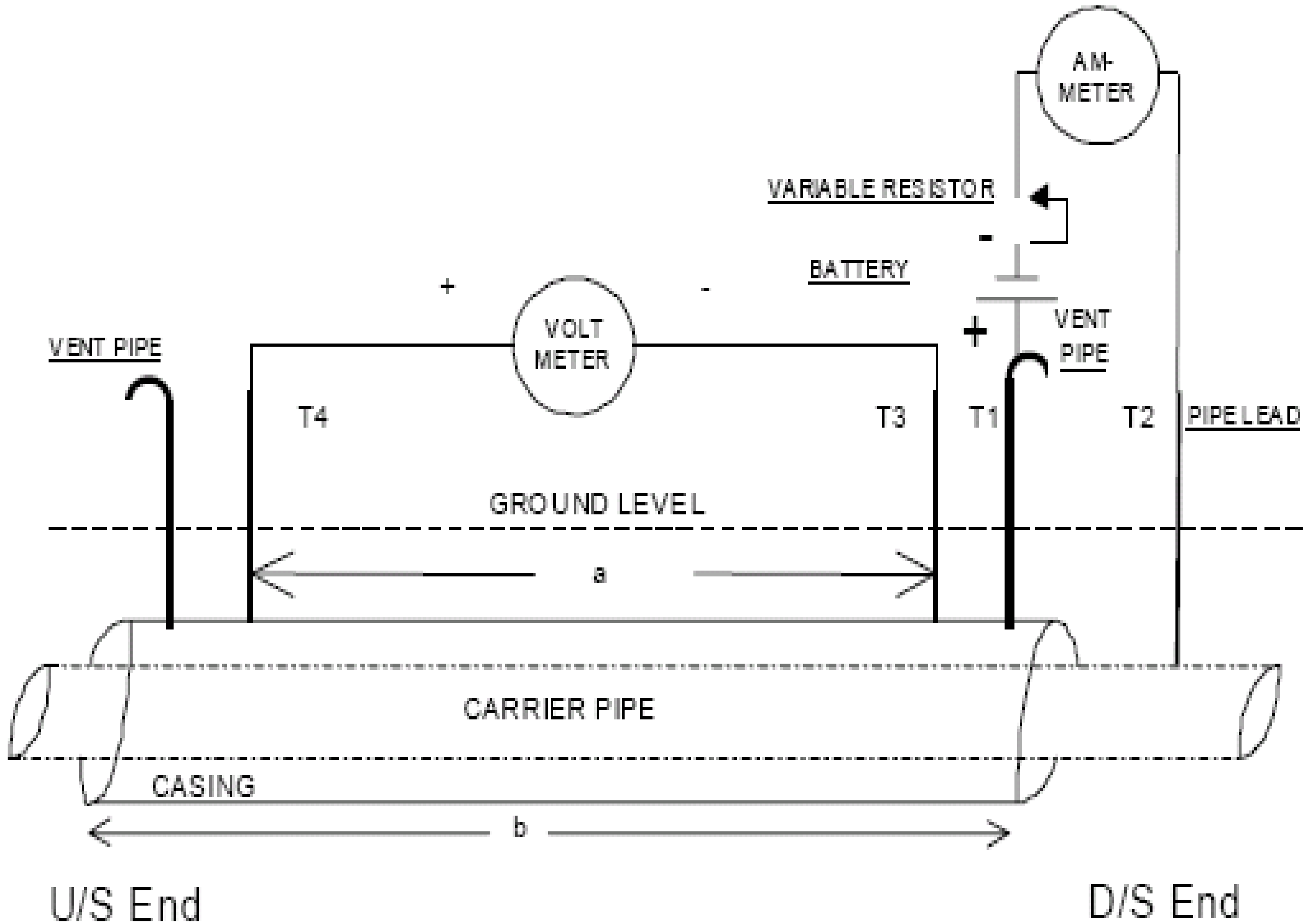
Four Wire Calibration



Four Wire U/S End



Four Wire (D/S End)



Monitoring

- Initial Electrical Field Tests (continued)
  - Casing Depolarization
    - Panhandle Eastern Method
  - Cycling the cathodic protection rectifier is another method used to evaluate the electrical isolation between pipe and casing.
  - AC Signal (Pipe Locator)
    - This method uses a signal generator and receiver to detect signal loss at a metallic short or a coating defect.
  - Capacitive (Go-no-Go Type Test)

Monitoring

Verification (Prove Up) Tests

- Long Range Guided Wave
  - This method use torsional data as well as compressional wave modes to detect cracks, metal loss and other defects on a carrier pipe inside a casing.
- In Line Inspection or Tethered Pigs
  - ILI is used to determine the presence or absence of pitting-corrosion damage on carrier pipe inside a casing.
- Hydrostatic Test (Go-no-Go Type Test)

Direct Examinations

- Excavate both (End(s) of Casing)
- Conduct Inspection on:
  - Condition of Carrier Pipe
    - Coating
    - Pipe Surface for defects
  - Condition of Casing & Components
    - Integrity of Casing Pipe, Vent Pipes, Welds, End Seals, Spacers, etc.
  - Electrolyte/Soil/Water Testing for Corrosivity
    - Lab and Field
    - Electrolyte inside casing annulus
    - Electrolyte outside casing

Cased X-ing Mitigation

- Eliminate metal to metal contact
- Remove casing
- Replace carrier pipe
- Provide supplemental cathodic protection to the carrier pipe
- Fill casing with a high dielectric material
- Apply coating or recoat the carrier pipe
- Replace end seals
- Remove flush electrolyte and debris from inside the casing
- Monitor the condition of the carrier pipe
- Install a new pipe crossing such as using a directional drill
- Inject vapor and or water based type inhibitor in annulus

Procedure for Casing Test

- Pre-Assessment
  - Operations
    - Temperature, Stress Levels, Dig Reports, etc.
  - History
    - Year installed, Leaks, Shorts, CP, MIC, etc.
  - Pipe/Casing Attributes
    - Diameter, W.T., SYMS, Welds, etc.
  - Construction Practices
    - End Seals, Spacers, Seam type, Problems, Vents, etc.
  - Soils and Environmental
    - Drainage, Topography, Land Use, etc.
  - Corrosion Control
    - Coating type, Coating Condition, Current Demand, Potentials of Pipe/Casing, Test Stations, etc.

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Procedure (Continued)

- Indirect Examinations - Initial Field Tests (2 or more tests recommended)
  - Potential Method
    - P/S,
    - C/S
    - OCP

    Note: If OCP is < 100 mV and P/S below -850 conduct or likelihood of atmospheric may corrosion exist, conduct additional verification tests for corrosion or no corrosion.
  - Resistance Test
    - 0.01 ohms or less Metallic Contact
    - >0.01 and less 0.10 ohms Possible Electrolytic Condition
    - >0.10 ohms - Little or no electrolyte in annulus
  - 4 Wire IR Drop Test – Determine End or Ends

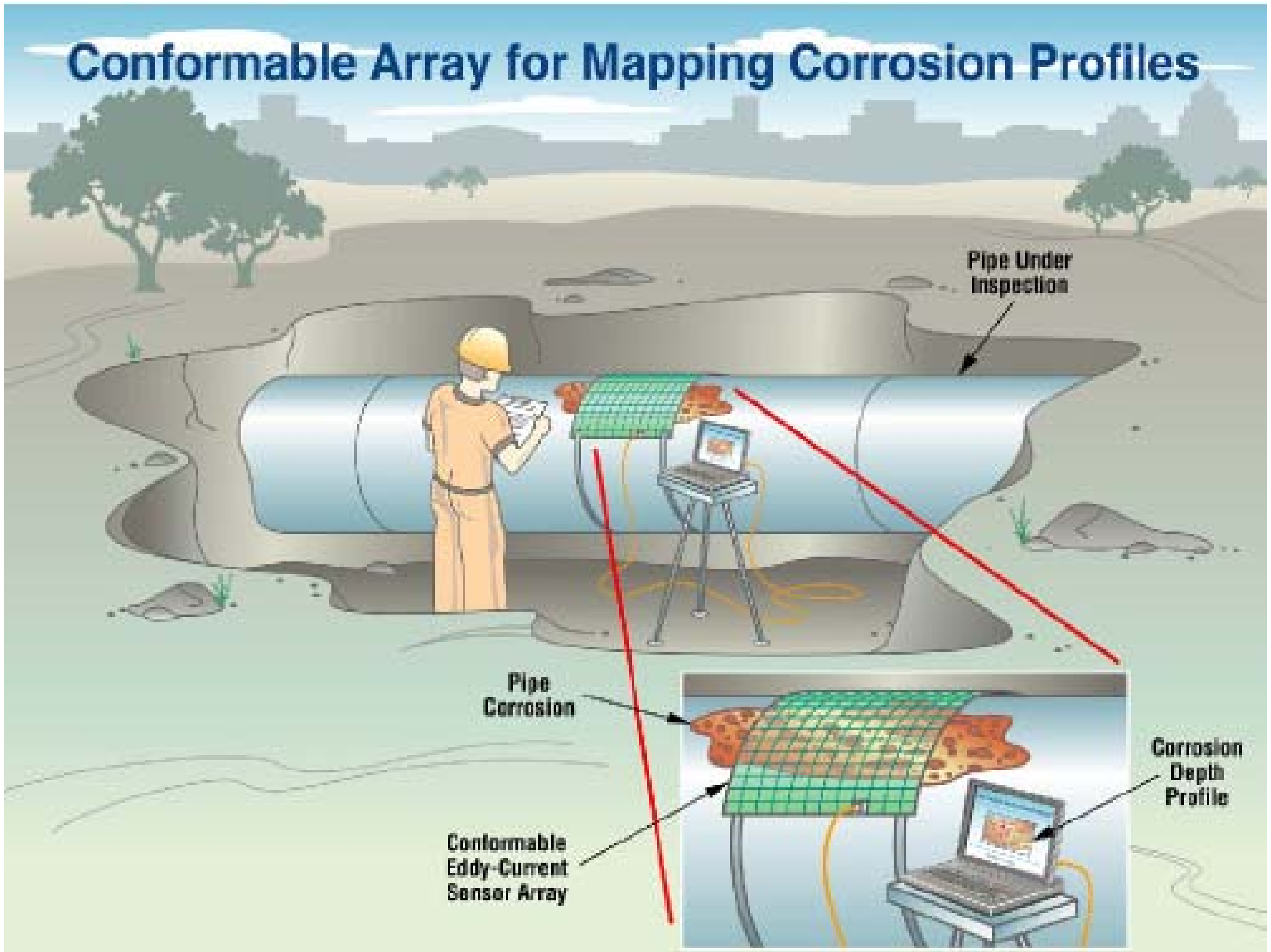
Procedure for Casing Testing

- Indirect Exams (Verification Field Tests)
  - Determine Likelihood of Galvanic or Atmospheric Corrosion
    - Conduct borescope, temperature and humidity tests
  - Conduct C-SCAN or PCM Tests
    - Determine if end or ends are metallically shorted
    - Determine coating holidays on carrier pipe where water is present
  - Conduct 18 Point Long Range Guided Wave Test
    - Verify the presence or no presence of corrosion
    - Determine depth and length of metal loss
      - B31.G calculations to determine integrity

Procedure for Casing Tests

- Verification Tests
  - Long Range Guided Wave
    - Use 18 Point PHMSA Guide
  - Smart or Tethered Pig
  - Hydrostatic Test
- Direct Examinations
  - Reason for Inspection
    - Location
    - Engineering Station # and GPS
    - Pipe Attributes
  - Coating Type's) and Evaluation
  - Environment (Soil/Water – Field/Lab)
  - Evidence of
    - Corrosion, SCC, Defect, Damage, etc.
  - Repair
    - Recoat, Composite Sleeve, Replace, etc.
  - Type of Tests Performed
    - MIC, UT, Mag. Particle, Dye Penetrant, pH, resistivity, Conformable Array, etc.

New Corrosion Mapping Tool



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Example of Metallic Shorted Casing

- Initial Potential Test (Voltmeter)
  - P/S -700 mV
  - C/S -698 mV
  - OCP -2 mV
- Internal Resistance between Casing and Pipe (Resistivity Meter)
  - Ohms 0.0015
- Four IR Drop (Shorted on U/S Side)
- Electromagnetic – (Coating Holiday U/S Side)
- Long Range Guide Wave
  - 20 to 27 % Metal Loss

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Example of Atmospheric Corrosion

- Pre-Assessment – Fluctuating Water Table
  - Temperature/Humidity (90% Relative Humidity and delta *t = 15 F*
- Initial Potential Test (Voltmeter)
  - P/S - 900 mV
  - C/S - 800 mV
  - OCP - 100mV
- Internal Resistance between Casing and Pipe (Resistivity Meter)
  - Ohms 0.095
- No 4 Wire or Above Ground Tests Conducted
- Electromagnetic Tests Found Possible Defect D/S Side
- Borescope (Possible Atmospheric Corrosion Found)
- Long Range Guided Wave – Prove UP
  - 10% to 15% D/S - (Corrosion Inside Casing)

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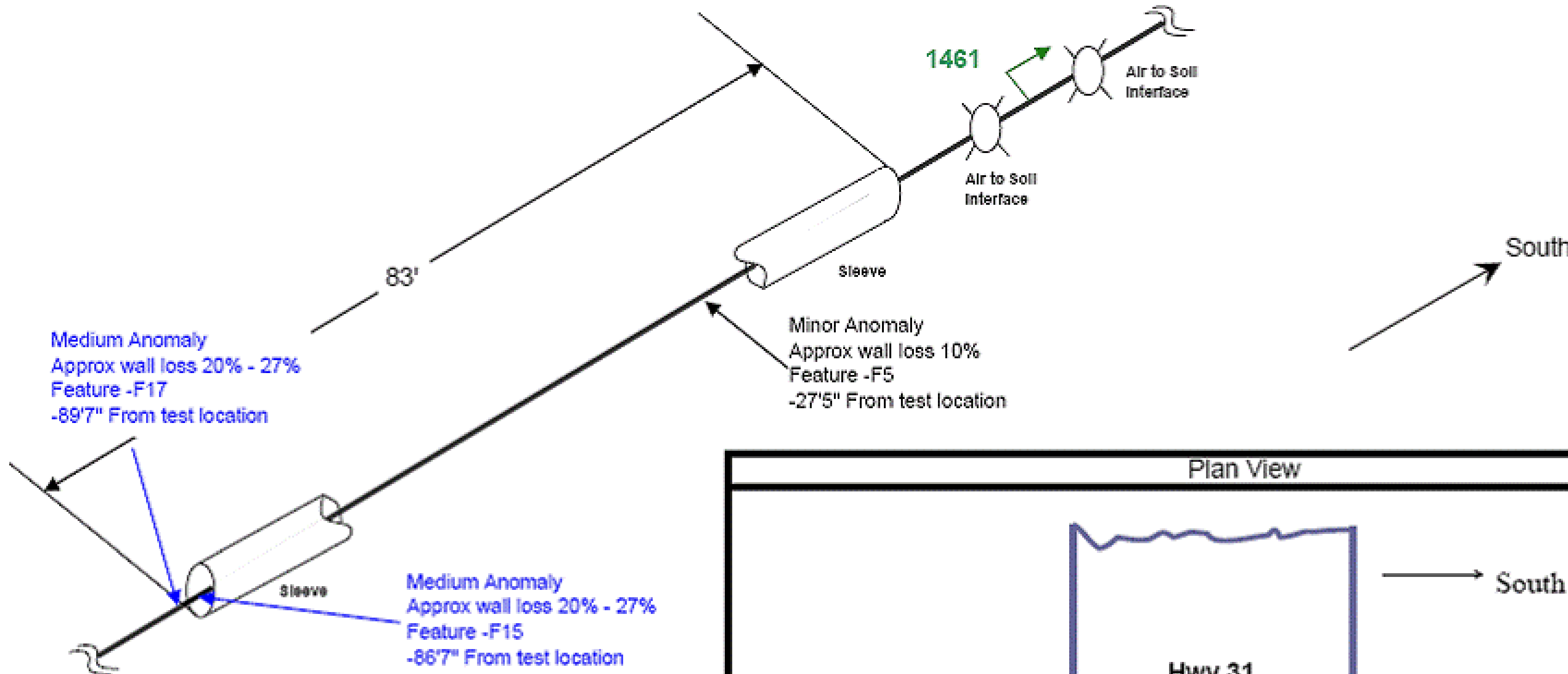
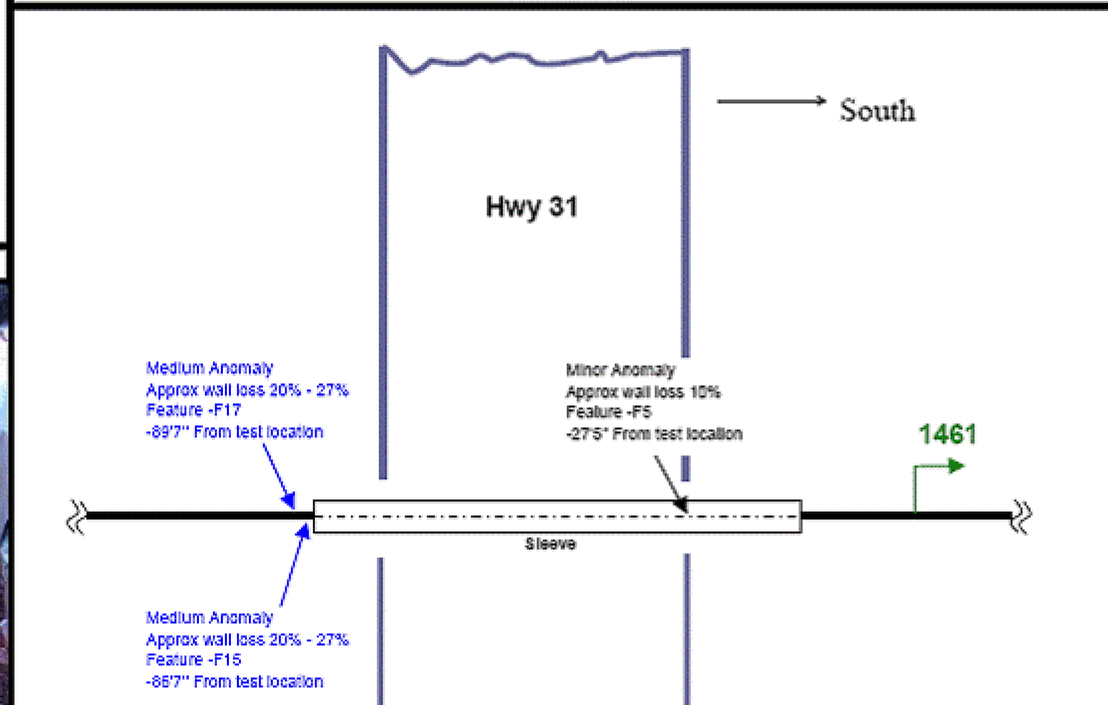
GUL – Shorted Casing

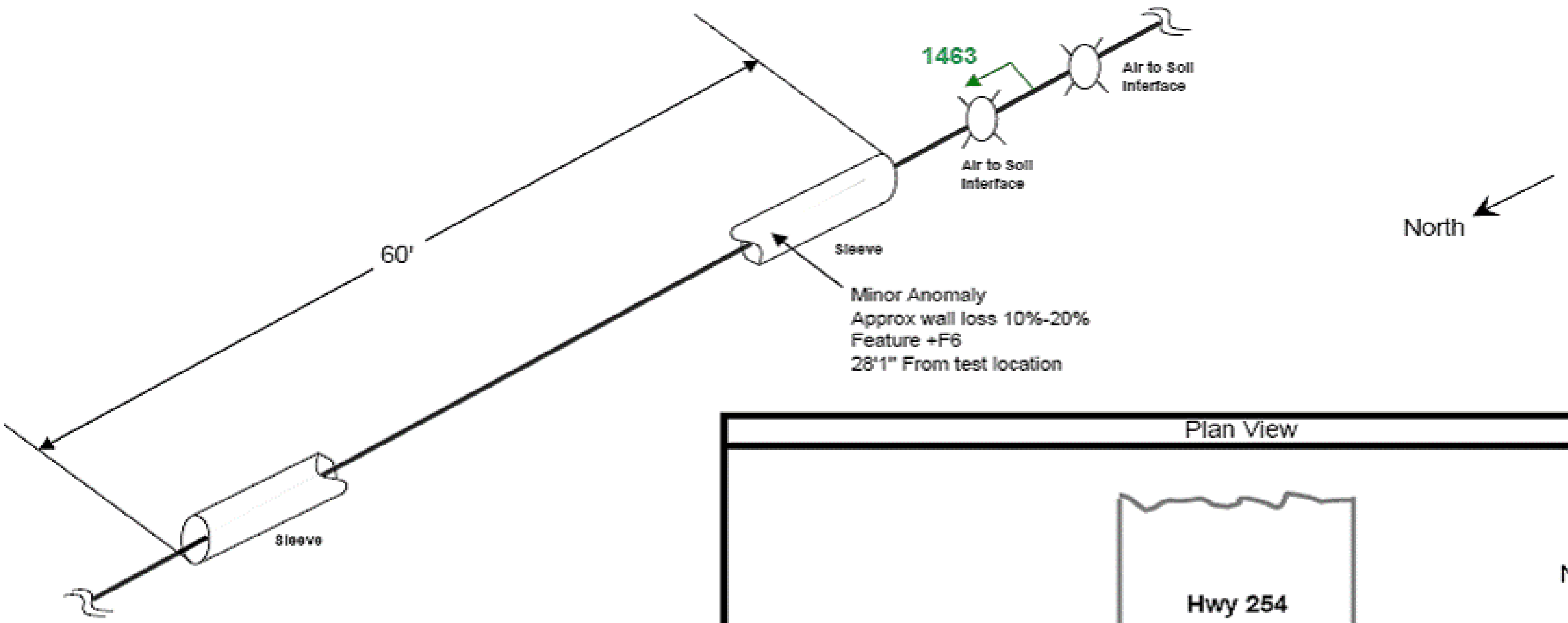


Picture of the test location

Plan View

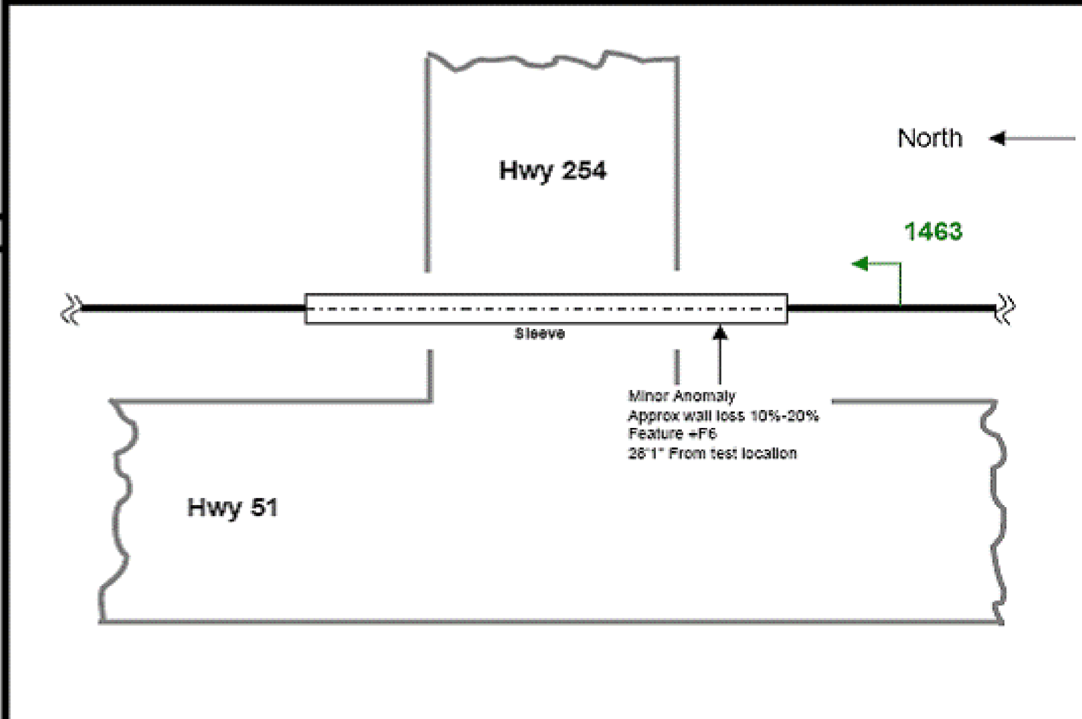


GUL Dual Collar, Pitch/Catch



Picture of the test location

Plan View



Conclusions

- Found metallically shorted U/S side
  - Potential, Resistance and 4 Wire Tests showed metallic short
  - Electromagnetic test showed coating indication
  - Prove up showed 20 to 27% Metal loss
- Found atmospheric corrosion on D/S
  - Pre-assessment showed likelihood of atmospheric corrosion
  - Potential and Resistance tests showed electrolyte in casing
  - Borescope showed likelihood of atmospheric corrosion
  - Prove up showed 10 to 20% metal loss

Questions

- Corrosion and Causes
- Criteria for Casings
- Monitoring
- Maintenance/Mitigation
- Procedures for Testing Integrity of Carrier Pipe
- Use of Long Range Guided Wave for Validation
- Other Technologies