Chapter 6
Corrosion Control for Pipelines

Presented By:

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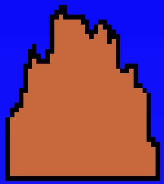
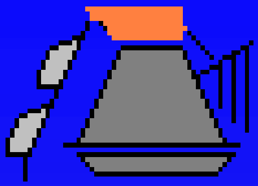


IRON OXIDE +



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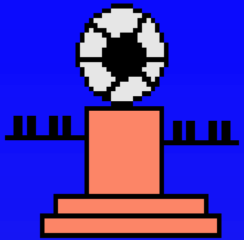

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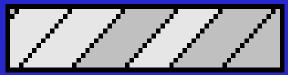
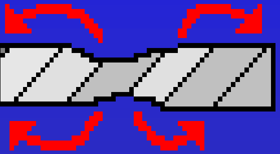


STEEL +



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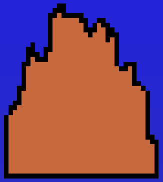
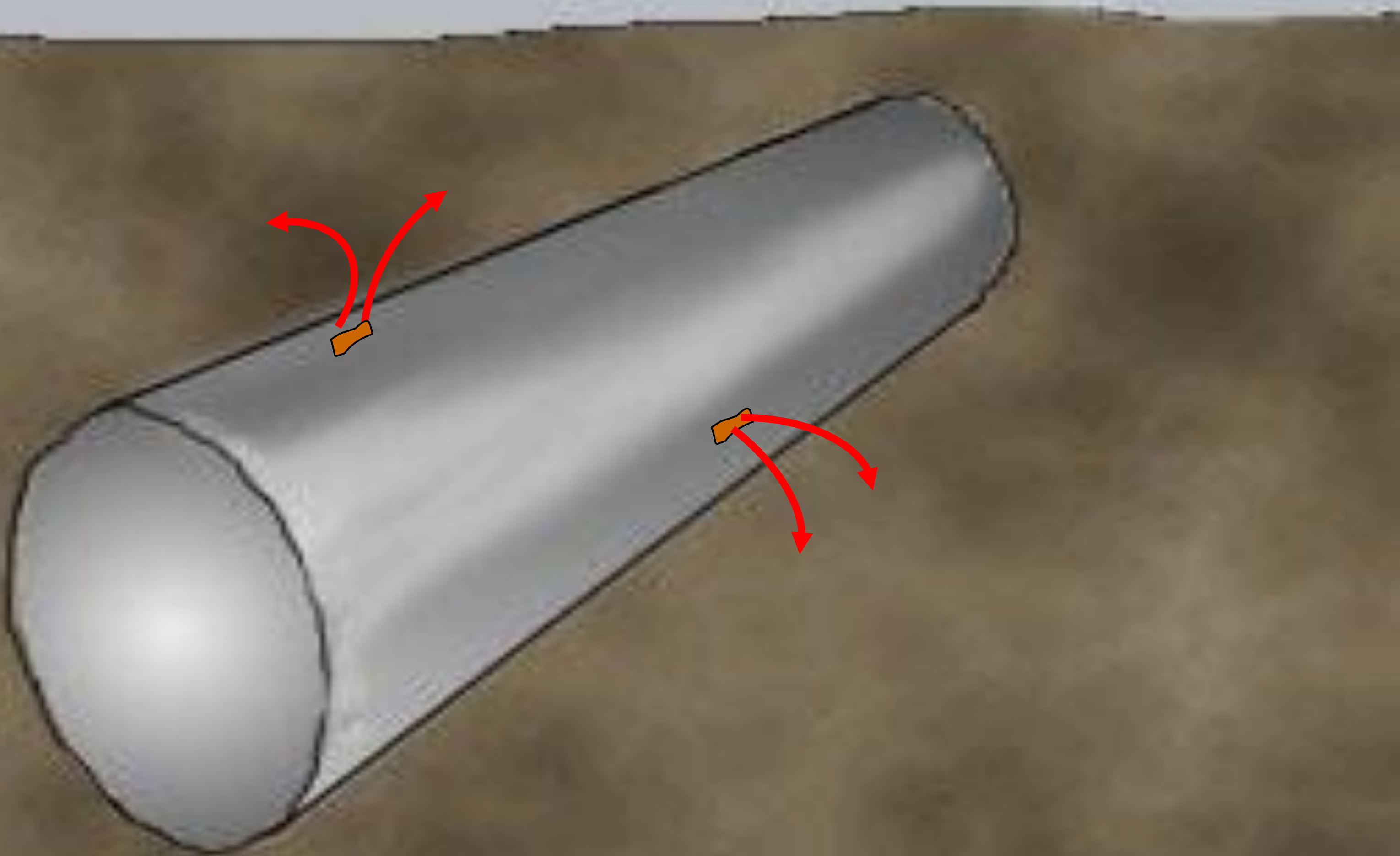
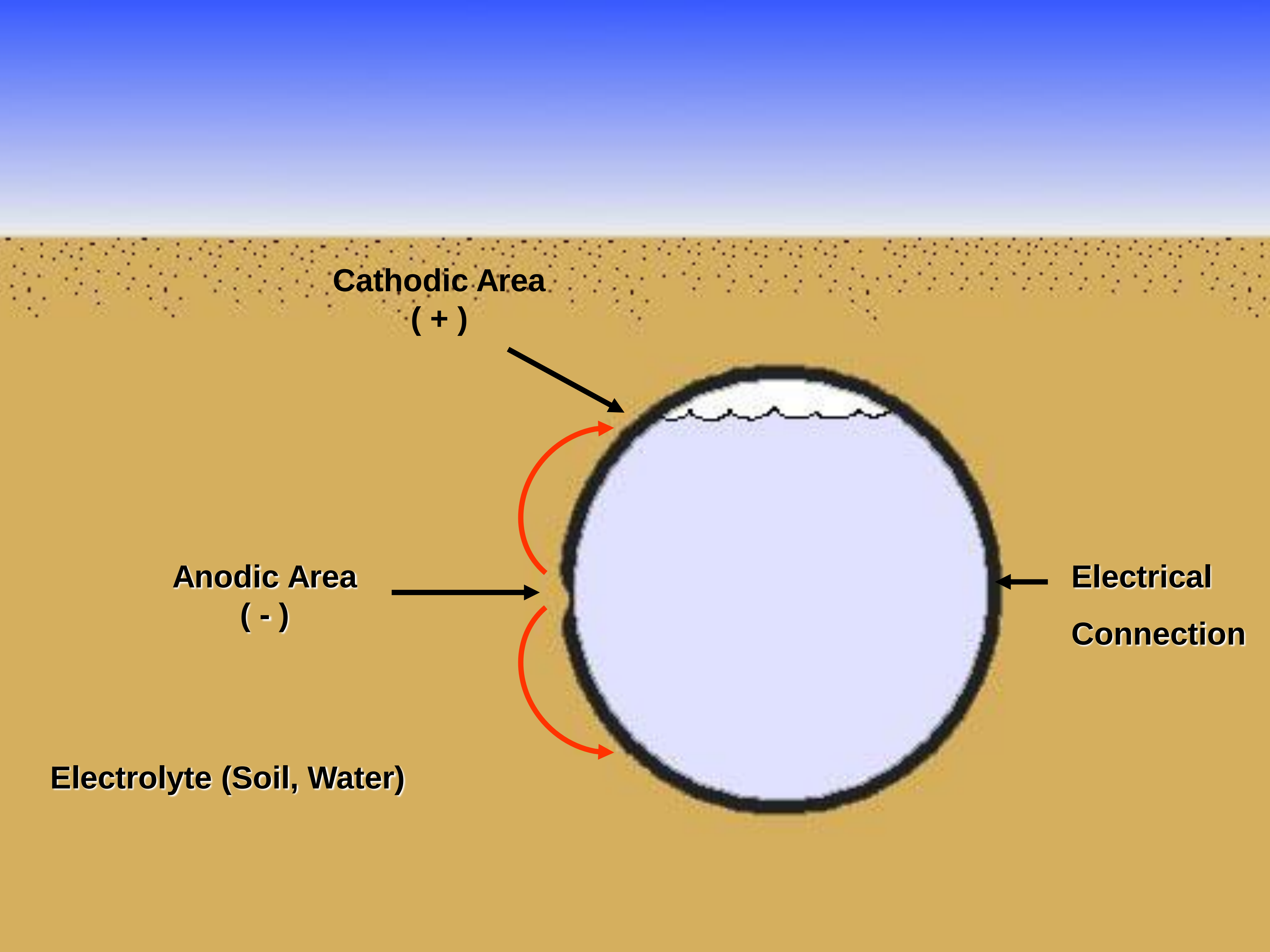


IRON OXIDE

THE PROBLEM…..

Corrosion of Piping





Cathodic Area
(+)
Anodic Area
(-)
Electrical
Connection
Electrolyte (Soil, Water)

Pipeline Corrosion Control

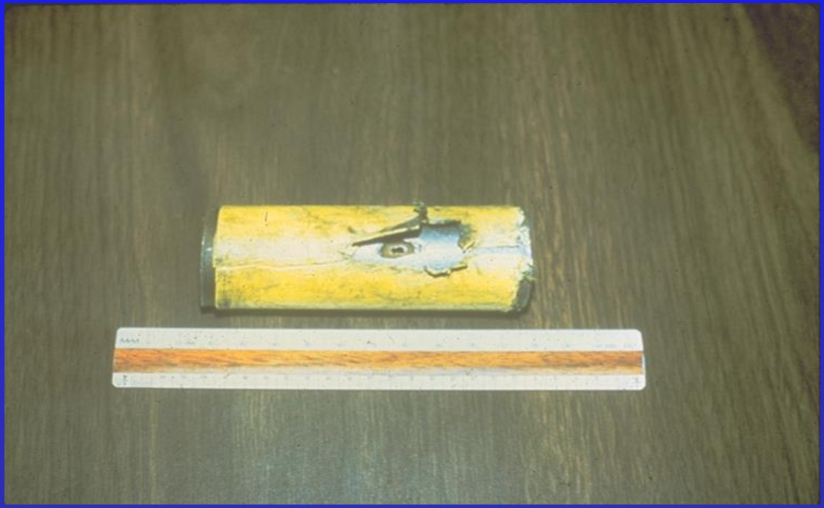
Pipelines were laid bare (uncoated) in the early 20th century and as a result, deterioration of the uncoated system was rapid.

Experience soon indicated that corrosion mitigation could be done more effectively and economically by using a combination of coatings and cathodic protection.

First attempts to control pipeline corrosion relied on the use of coating materials with the reasoning that if the pipeline metal could be isolated from contact with the surrounding earth, no corrosion could occur. A coating will be completely effective as a means of stopping corrosion if:

1. Coating material is an effective electrical insulator.
2. Applied with no breaks and remain so during the transport and backfilling process.
3. It constitutes an initially perfect film, which will remain so with time.

A properly selected and applied coating will provide all the protection necessary on “most” of the pipeline surface to which it is applied. On a typical well-coated pipeline this should be better than 99%. However, the remaining 1% can cause us a lot of grief.



Good practice in modern pipeline corrosion control work comprises the use of good coatings in combination with cathodic protection.

The four fundamental elements of a successful coating system involve:

1. Material Selection
2. Specification
3. Application
4. Inspection

Coatings

- Atmospheric Coatings
- Transition Coatings – Air/Soil
- Underground Coatings
- Internal Coatings

Atmospheric Coatings **are used to protect surfaces exposed to the atmosphere. Various types of coatings are specified depending on service requirements – industrial, marine, urban, high temperature, etc.**

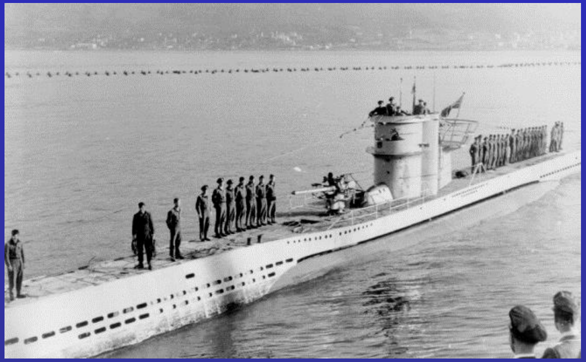
"What works well for atmospheric corrosion control may not perform well underground"

Transition Area Coatings **are used to transition an underground coating to above ground service. These coatings normally cover up the underground coating to protect it from ultraviolet lights, abrasion, ground movement, etc. and transition from 6 inches above ground to 12 inches below ground.**

History of Pipe Coatings

The first generation of buried steel pipelines were installed without coatings and subsequent corrosion related failures were experienced. In the 20's and 30's, greases, coal tars were commonly used without cathodic protection. Basically, many of the coatings were experimental. It is also important to note since there was no set coating standard at the time.

During World War II, there were many instances where pipe was installed bare. Transporting energy quickly for the wartime effort was of primary importance.



In the mid to late forties, plant-applied coal-tar enamel (hot coal-tar pitch w/ felt) became the standard. Many of the coating plants were situated in the eastern U.S. near steel mills. Coating mills were better able to economically source the coal-tar pitch, which is a by-product of coke used in the manufacturing of steel.

Around 1956, the X-Tru-Coat (40-60 mil yellow-jacket) process of coating pipe was developed by Republic Steel. Republic Steel licensed coating plants in certain areas of the U.S. and Canada.

Over-the-ditch polyethylene tape was introduced in the 1950's originally in the Western areas of the U.S. and Canada, where there weren't a lot of coating mills and where the terrain was flat. The polyethylene tape system consisted of an innerwrap (coating), outerwrap (mechanical) . Typically, the coating system was applied with a motorized, over-the-ditch wrapping machine.

The application cost associated with installing over-the-ditch cold-applied polyethylene tape was very minimal. Over-the-ditch tape w/primer was far cheaper than any other coating system. Eventually, once coating plants got the proper tooling and experience, they could properly apply tape in a cost effective manner.

Condition of Coatings

Tape Wrap Coatings

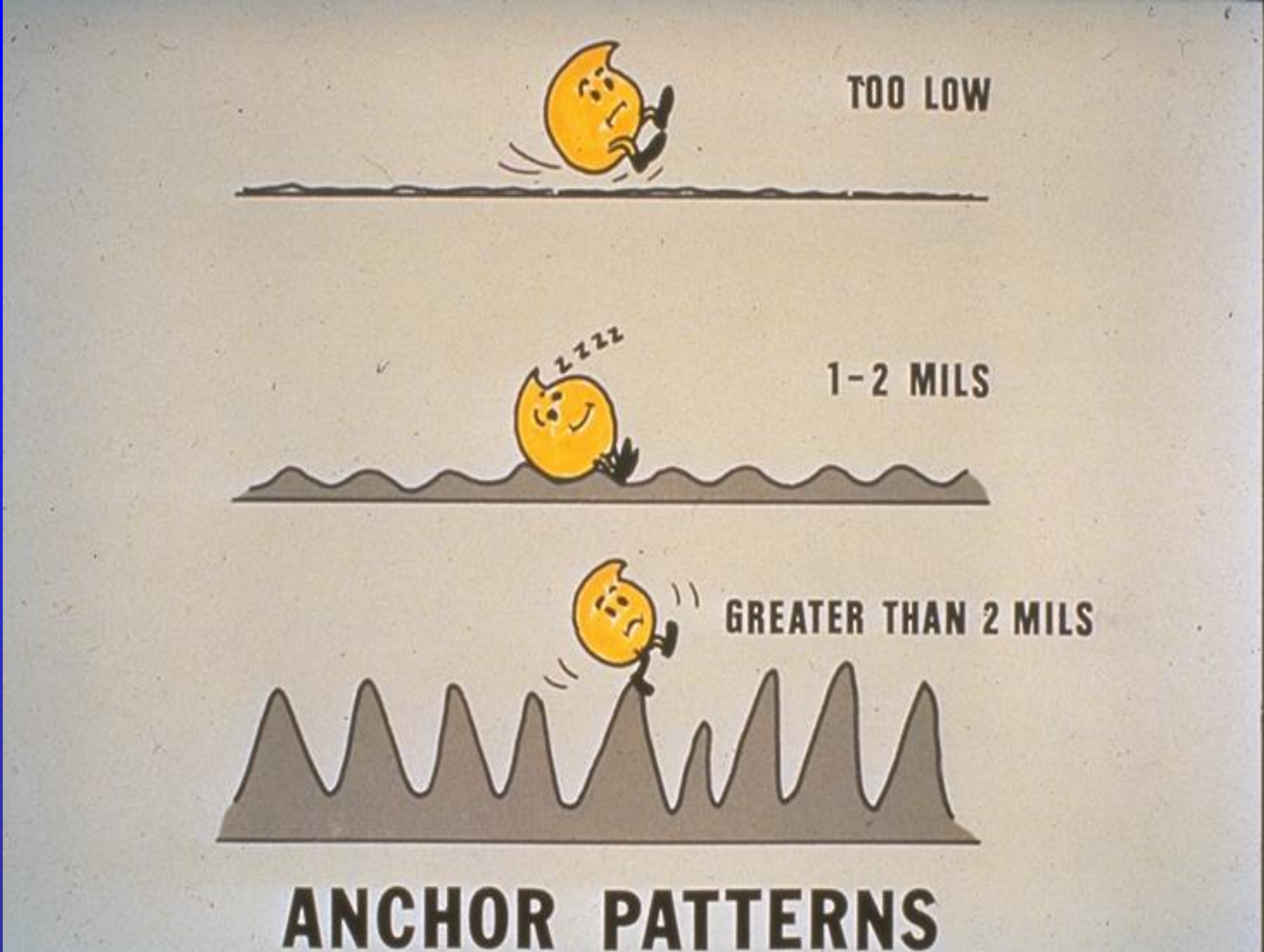
Fusion Bonded Epoxy

Fusion-bonded coatings came onto the marketplace in the late 70's and early 80's. There was slow acceptance among coating mills due to the high cost of equipment necessary to produce product. There was also a high rejection rate of the coating due to initial quality control issues. However, fusion-bonded coating became accepted and is considered the standard plant-applied coating today.

Bare Steel Pipe

The pipe enters the mill and is ready for the abrasive blasting procedure

The pipe exits the blasting booth with a near-white surface finish and the required anchor profile

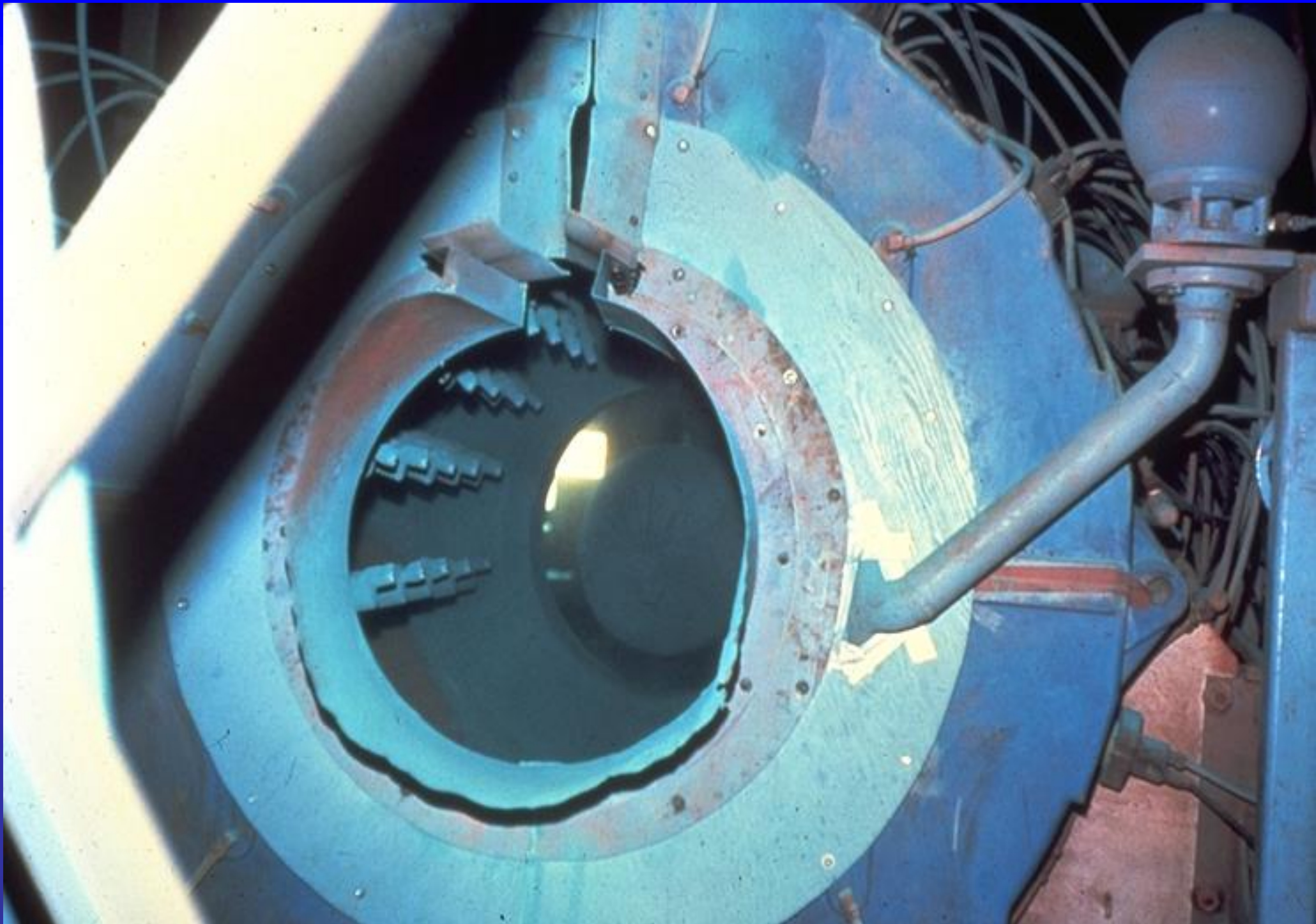

TOO LOW
1-2 MILS
GREATER THAN 2 MILS
ANCHOR PATTERNS

The pipe then enters an acid bath to remove surface contaminants.

Heating of Pipe

Temperature Monitoring

Application



Fusion Bonded Epoxy

Thickness Check

Holiday Detection in Mill

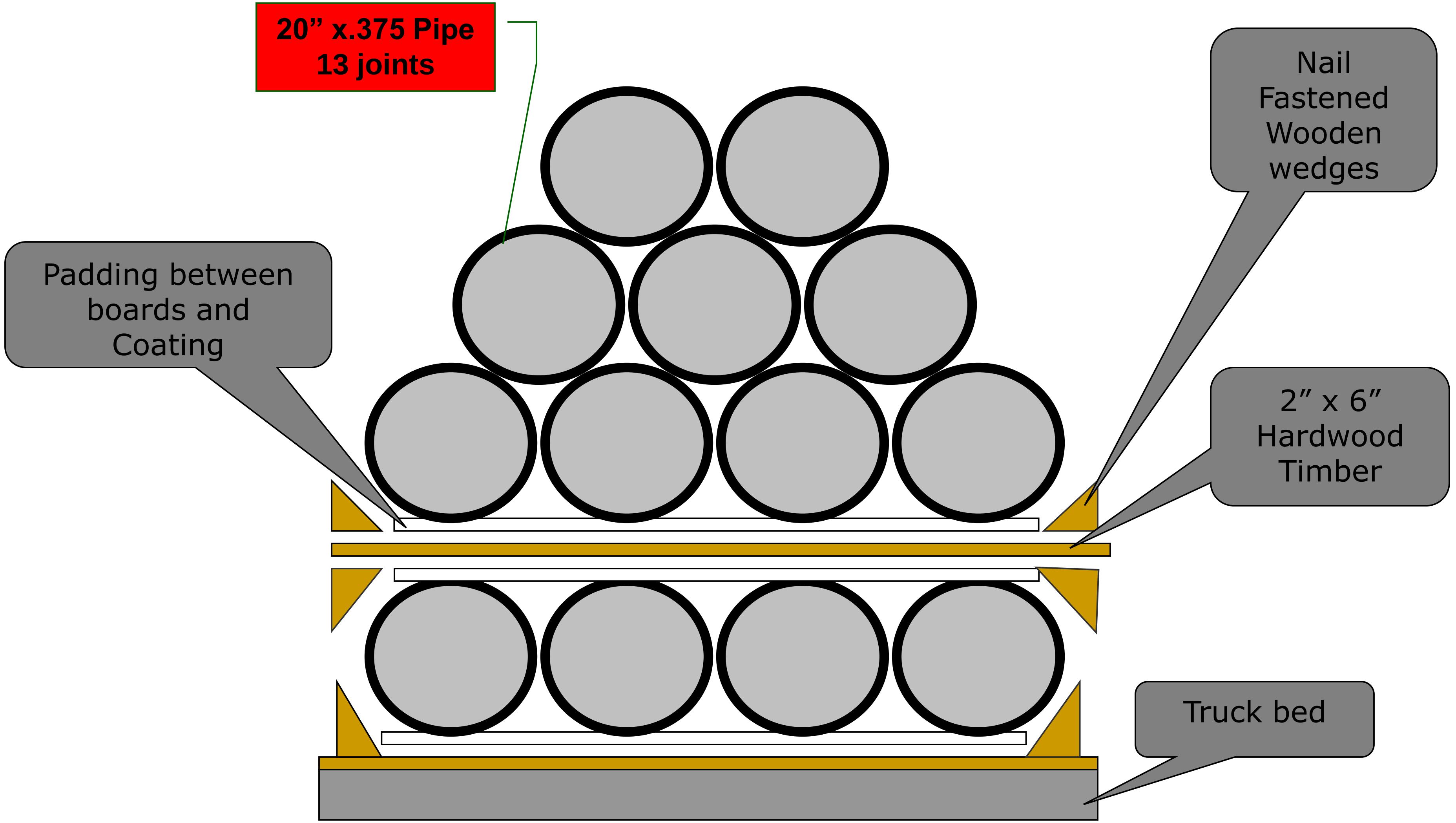
Mill Coating Repairs

Transporting Mill Coated Steel Pipe

Pipe sections should be handled carefully during loading for delivery by truck or railway train so that damage will be kept to a minimum. Pipes should be padded and adequately secured in order to avoid coating damage during normal shipping conditions and storage. If extended outside storage may be required the piping should be protected from UV exposure.

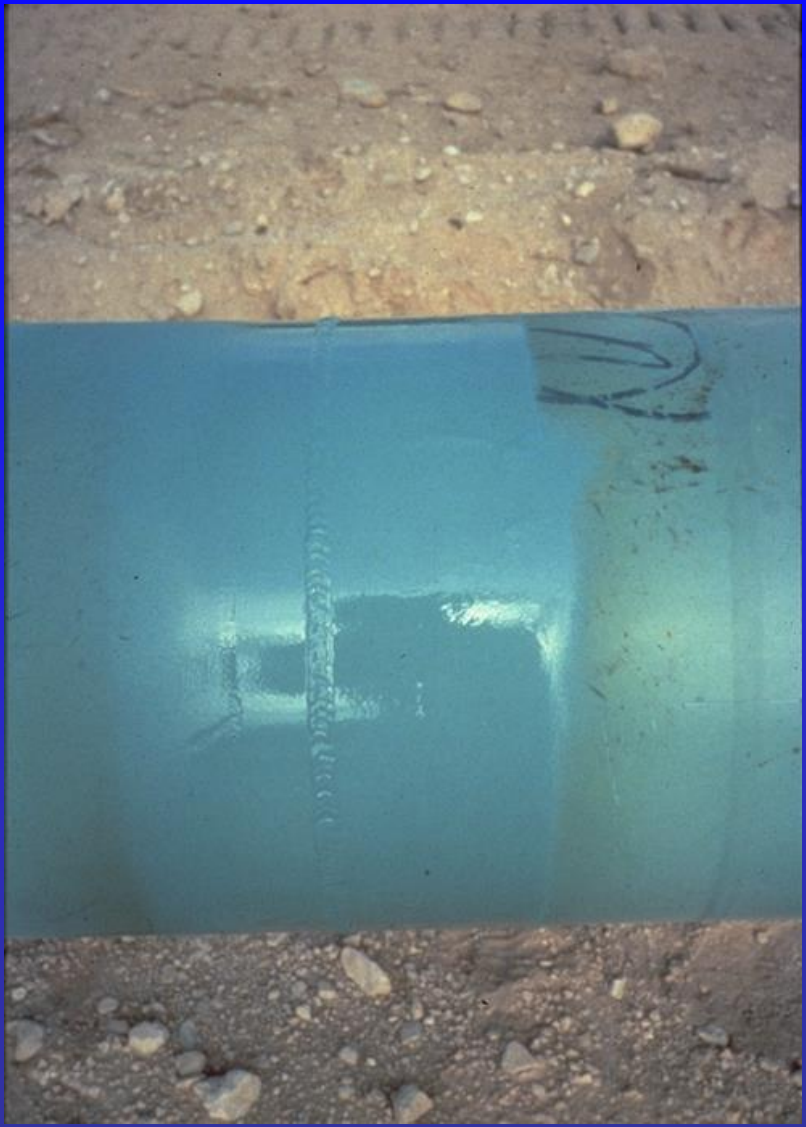
PIPE HANDLING/STORAGE

Pipe Load-out Configuration



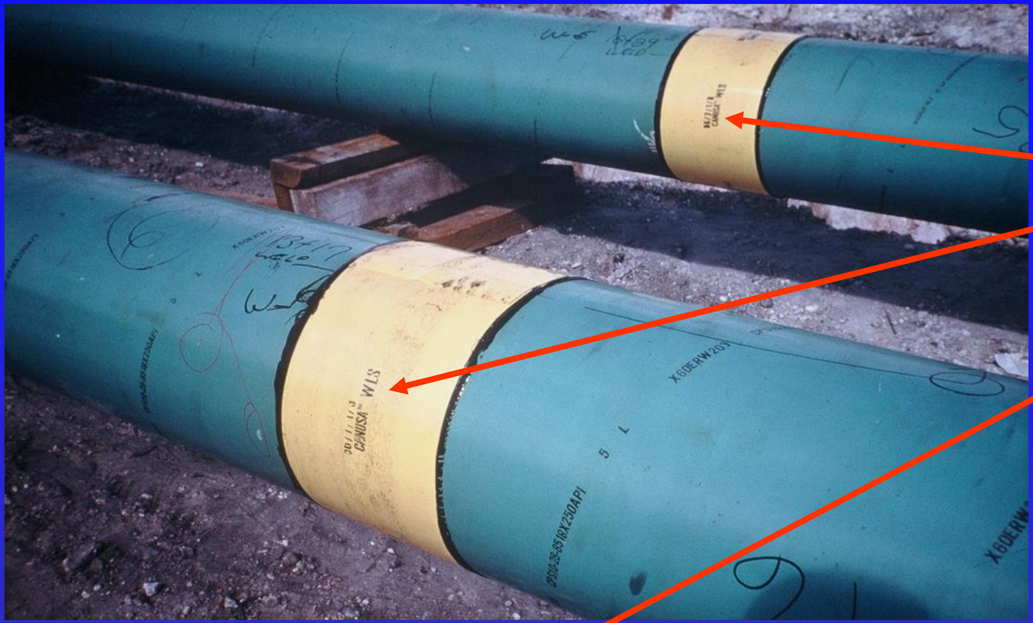
Field Repair of Coating Due to Damage in Transport


2



Mark pipe with appropriate paint and not crayons…

Field Joints



Note: Potential problem areas if not properly done In the field

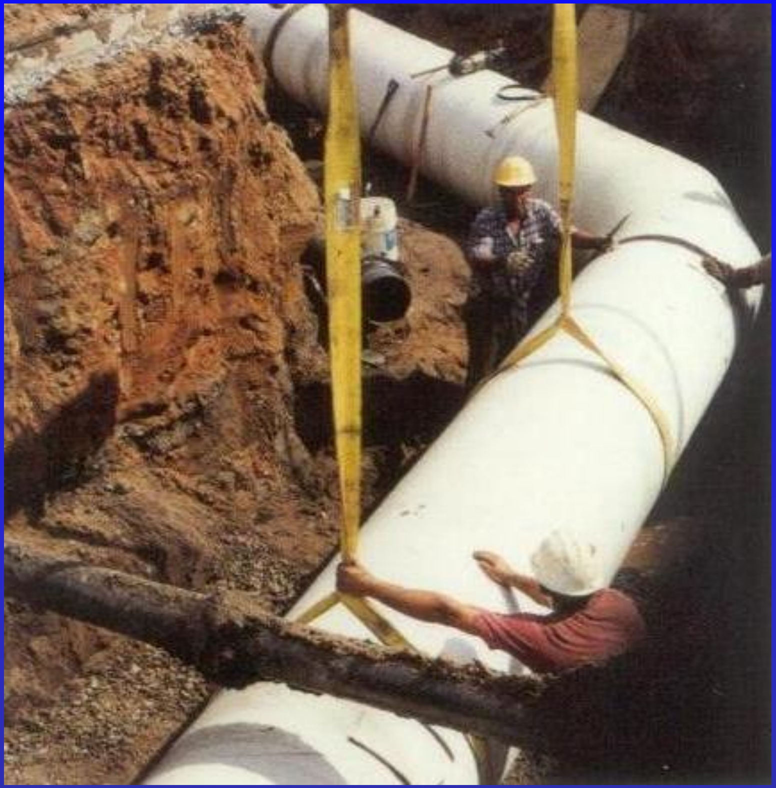
Holiday Detection Before Backfilling

Mill Applied Tape Wrap


PRE-ENGINEERED
sti-P3
PROVEN PROTECTION
DO NOT DISCONNECT
ANODE LEAD WIRE

Wax Tape

Proper Installation



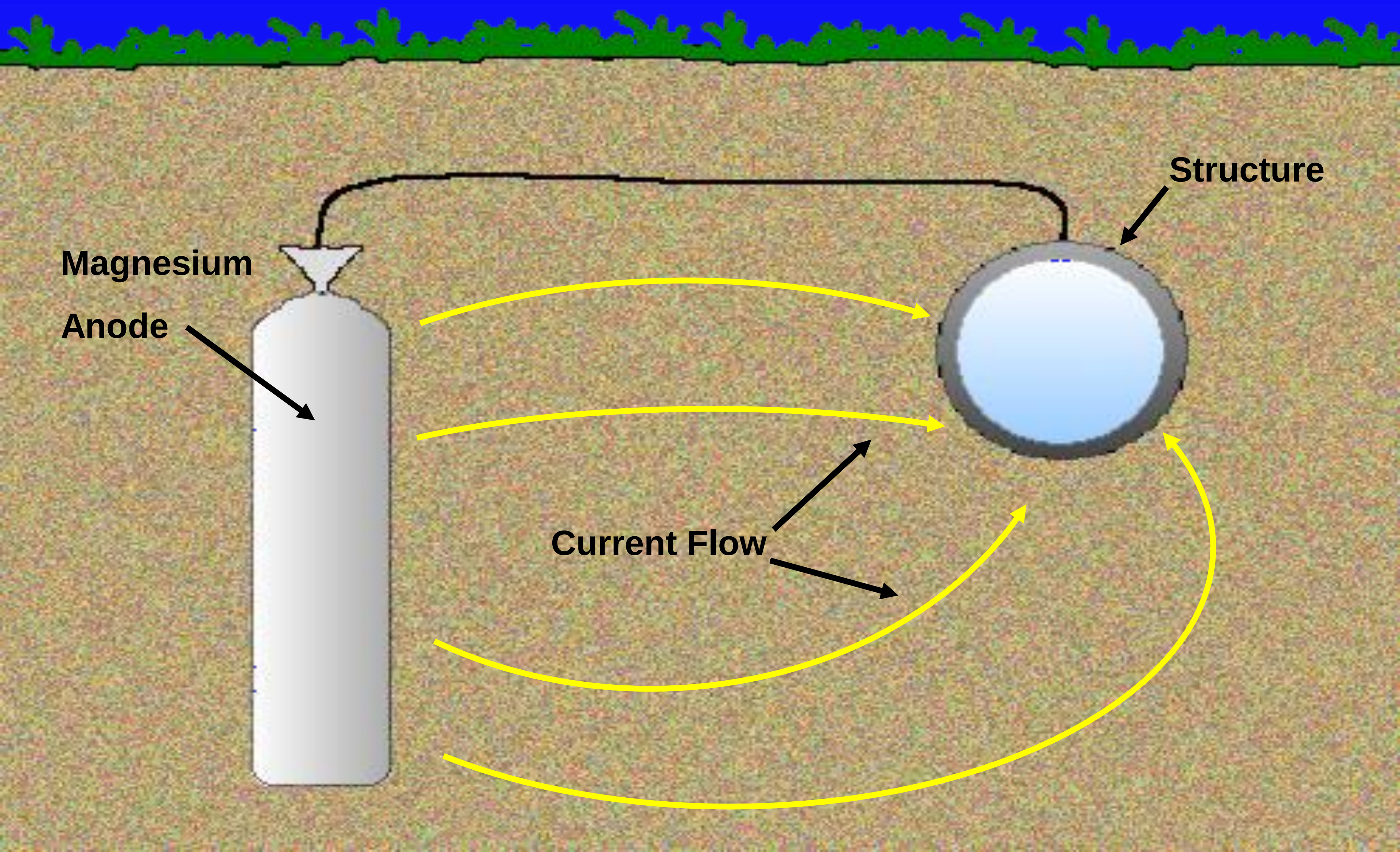
Procedures for Laying *Coated Pipe*

Before laying the pipe in the trench, the bottom of the trench must be cleared of any large stones or foreign material which may damage the pipe coating.

Piping should be lowered into the trench by means of belt slings or similar means, which would enable the pipe to be lowered slowly, and carefully into the trench, to avoid coating damage.

Pipeline Recoating

Galvanic Cathodic Protection



Surface Preparation

The "foundation" for a protective coating system is the surface preparation. To obtain planned and predictable results, one must start with a controlled, uniform and known foundation. Surface preparation is a key part of the performance for all coated surfaces.

Types of Surface Preparation

- Dry blasting
- Grit blasting
- Shot blasting
- Blasting with shot/grit mixtures
- Acid pickling
- Wet abrasive blasting
- Weathering off the millscale
- High pressure water blasting
- Solvent cleaning
- Power tool cleaning
- Hand tool cleaning

Coating Specification (Write a Tight One)

1. Condition of the bare pipe
2. Handling and storage – mill, transit, field
3. Atmospheric conditions – mill or field during surface preparation, application
4. Surface preparation
5. Application
6. Inspection
7. Post installation evaluation

The service life of a coating system is dependent on selection of the coating system, surface preparation, coating application, inspection, and maintenance (where feasible).

Compressor/Meter Stations

May be isolated and employ galvanic anode system

Pipe Coating Over the Ditch
Quality Control (weather, site conditions)

Coating materials must be handled carefully in the field. They must be kept clean of dirt and other foreign matter.

Holiday Detection and Repair

Holidays or flaws in the coating system may be detected by visual inspection or through the use of a holiday detector.

A holiday detector is a device which impresses an electrical voltage across the coating.

Inspection

Inspection begins from the time pipe is received at the coating mill and continues right up to the time of backfill in the ditch.

The purpose of inspection is to make sure that the specifications are being met.

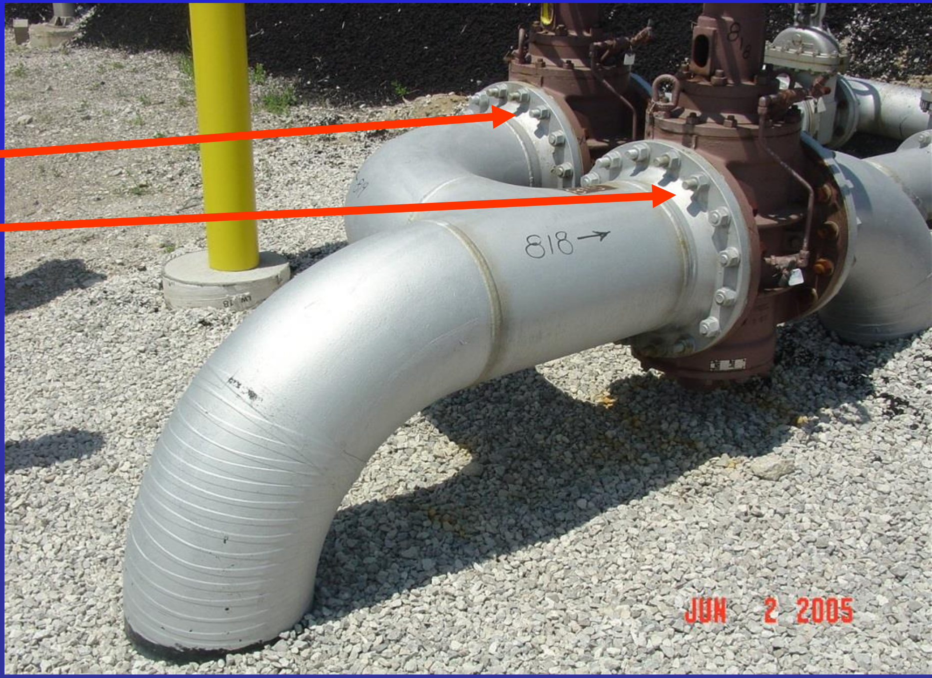
The “best” coating system will fail prematurely if the application procedures, conditions or workmanship are unsatisfactory of coatings failures result from poor application techniques.

1. The coating systems and their dry film thickness must be as specified.
2. No thinners or additives be added to the coating except as allowed by the coating manufacturer’s written instructions.
3. Coatings must be applied in accordance with Steel Structures Painting Council SSPC-PA1 Shop, Field and Maintenance Painting and the specification.
4. No coating work shall be performed if conditions are outside the ranges allowed by the coating manufacturer.
5. Surfaces must receive the specified coating in a thorough and workmanlike manner in accordance with standard practices.
6. Coating material that has been readied for use must be used within the time specified by the manufacturer.
7. Coating materials must be dispensed on a “first-in”, “first-out” basis in order to prevent the shelf life from expiring.
8. Well-maintained application equipment must be employed.

What Does an Isolating Joint Do?

Isolating joints such as isolating flanges, unions, and couplings are used to electrically isolate various components of a pipeline system.

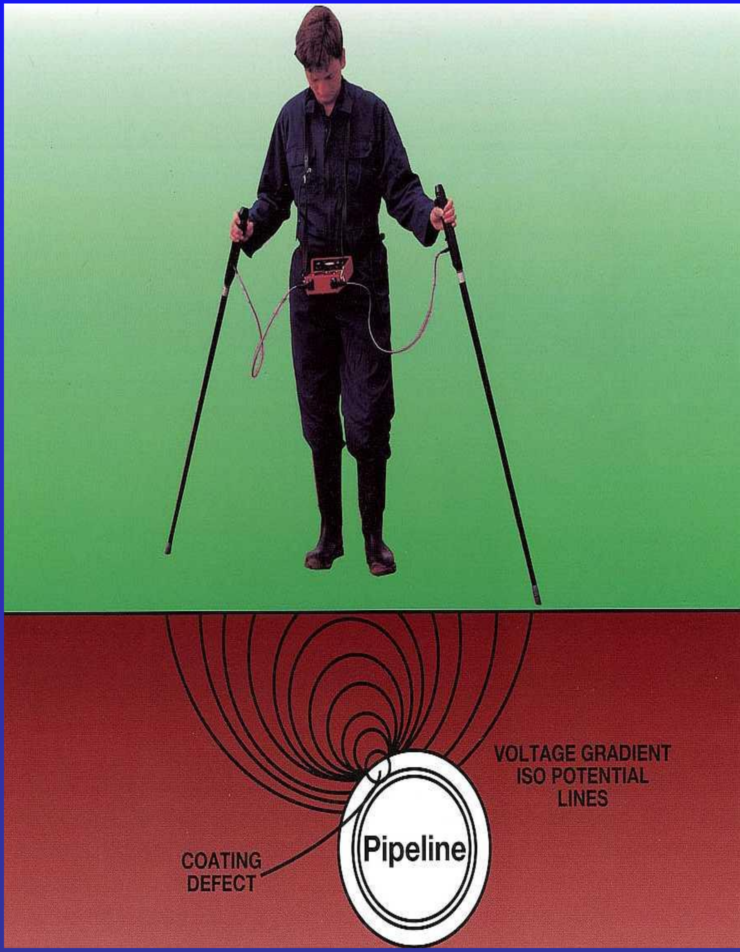
They are often used to isolate a pipeline into sections for cathodic protection purposes.



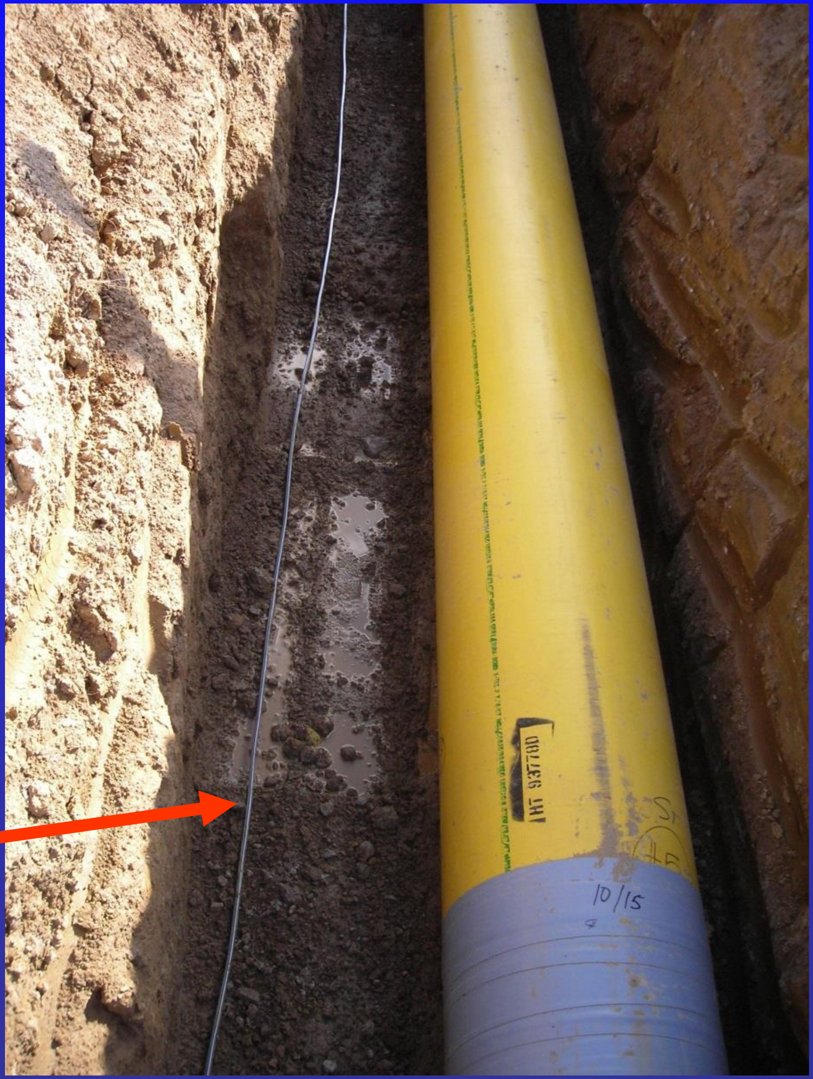
Holiday Detection after Backfilling

Various techniques include:

- Pearson Survey
- Direct Current Voltage Gradient (DCVG)
- Alternating Current Voltage Gradient (ACVG)



AC MITIGATION

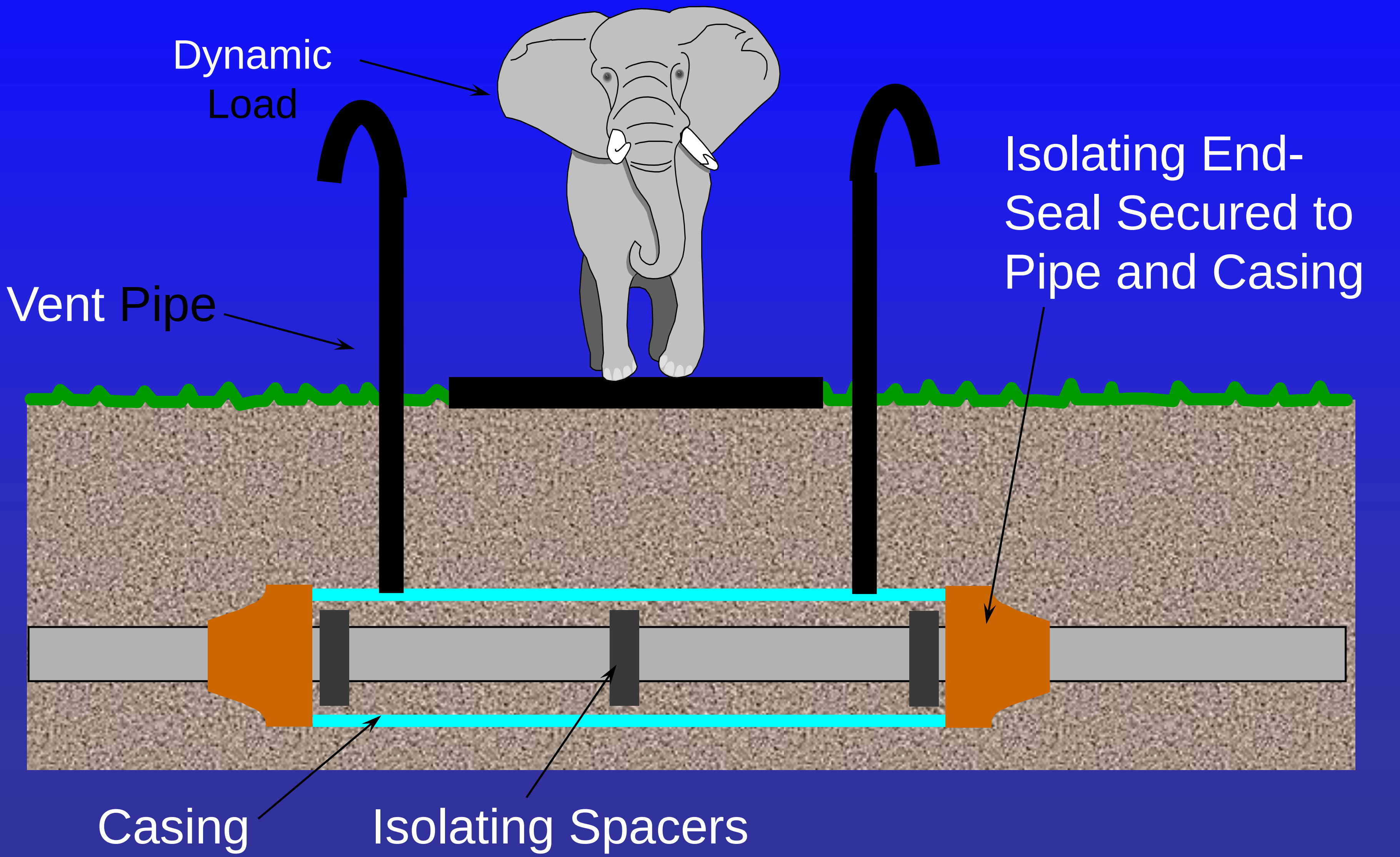


ZINC RIBBON
(Parallels Pipe)

Cased Crossings

A cased crossing is a point where the pipeline is routed through a steel or reinforced concrete tube/casing. The casing is used to provide mechanical protection to the pipeline. Casings are sometimes installed where pipelines cross under roadways and railways.

Casing Installation

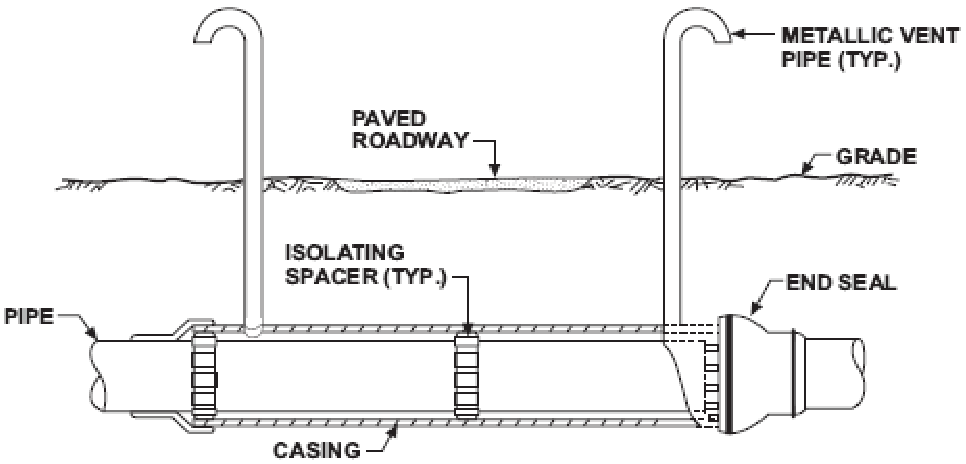


Component Parts of a Cased Crossing

The casing is normally constructed of steel. The size of the casing pipe used should be a minimum of two sizes larger than the pipeline being protected.

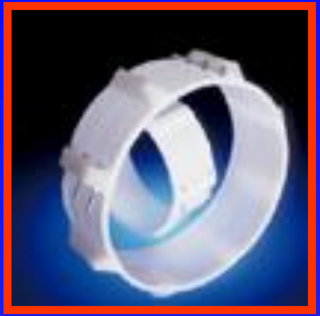
The isolating spacers are installed on the pipe being protected and are used to electrically isolate the pipe from the casing.

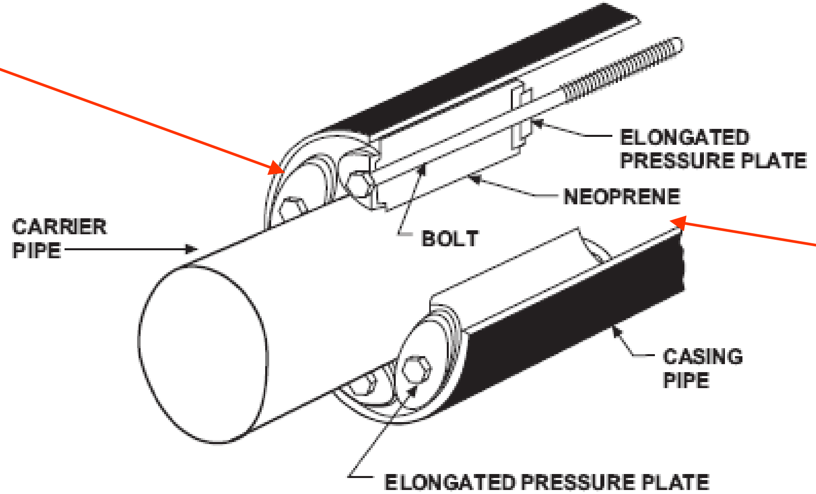
End seals are installed at each end of the casing. They are designed to provide protection against the entry of water, soil or other backfill material which may short the pipe to the casing or cause corrosion in the annular space between the pipe and casing.



TYPICAL ISOLATED CASING DETAIL

FIGURE 6-5A





“LINK SEAL” MODULAR WALL & CASING SEAL

FIGURE 6-5B

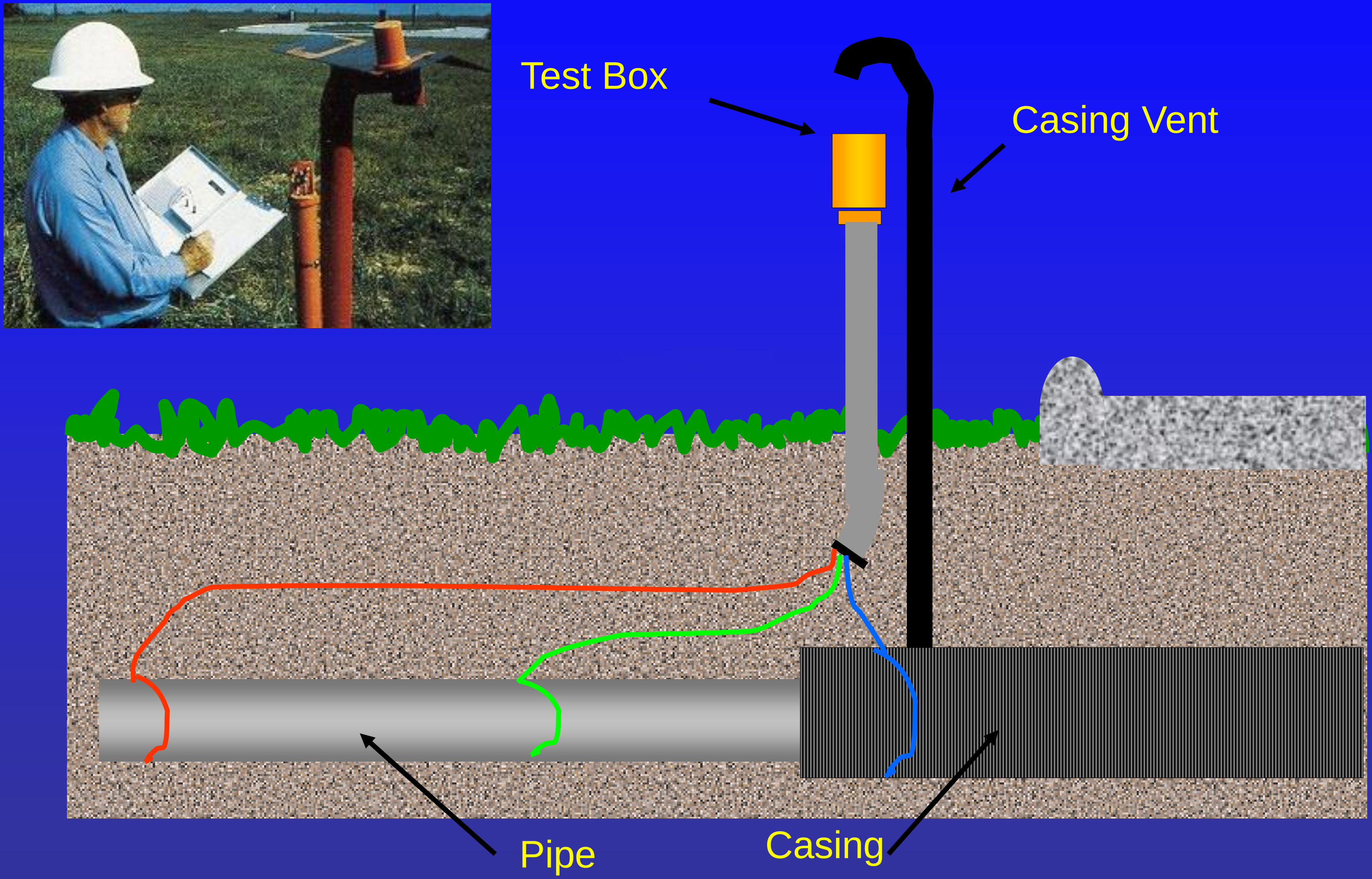
Testing Cased Crossings for Electrical Isolation

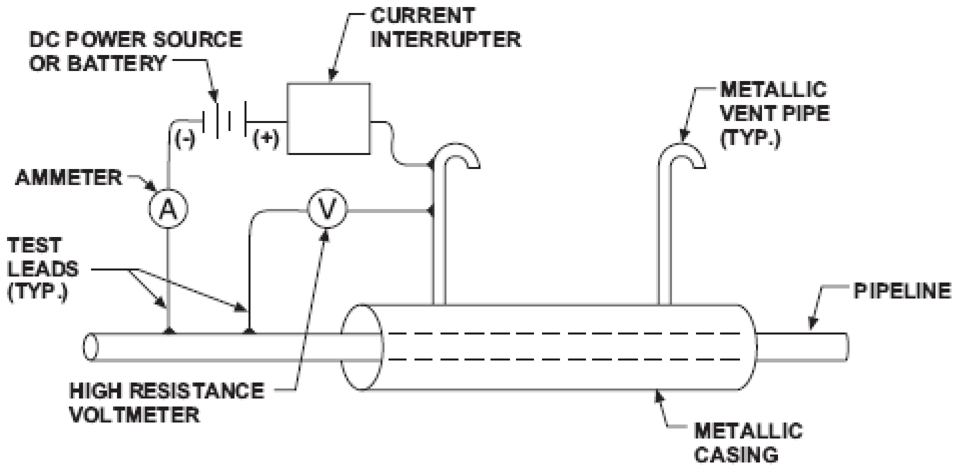
After the installation of a cased crossing is completed, the isolation between the pipe and the casing should be checked before the backfilling. The cost of repairs will be less if they are made prior to backfill of the crossing area.

Casings should be periodically checked using test stations normally installed at cased crossings. Casings may be properly isolated just after installation, but in time may become shorted due to one or more of the following conditions:

1. Too much strain on pipe when final tie-in was made.
2. Earth movement or settlement.
3. Movement of the casing for whatever reason.

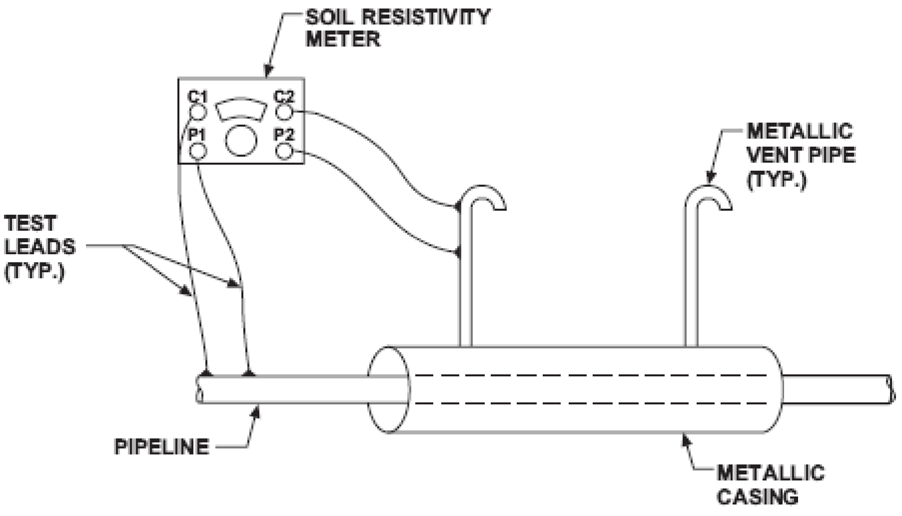
Casing Test Station





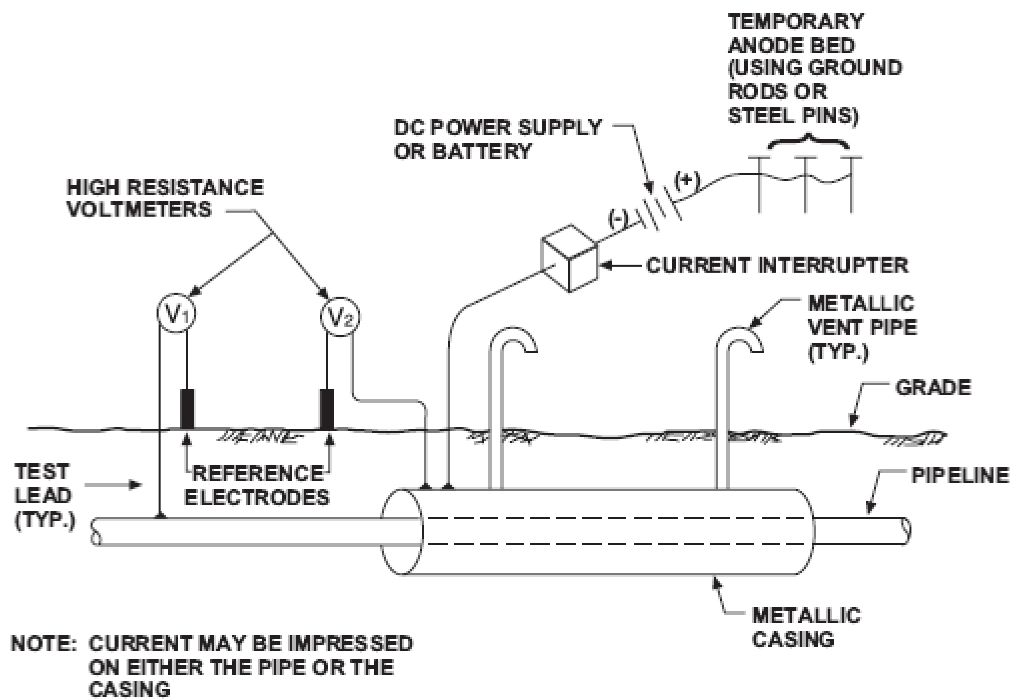
CASING-TO-PIPE RESISTANCE MEASUREMENT USING
AMMETER, VOLTMETER AND EXTERNAL DC POWER SOURCE

FIGURE 6-6



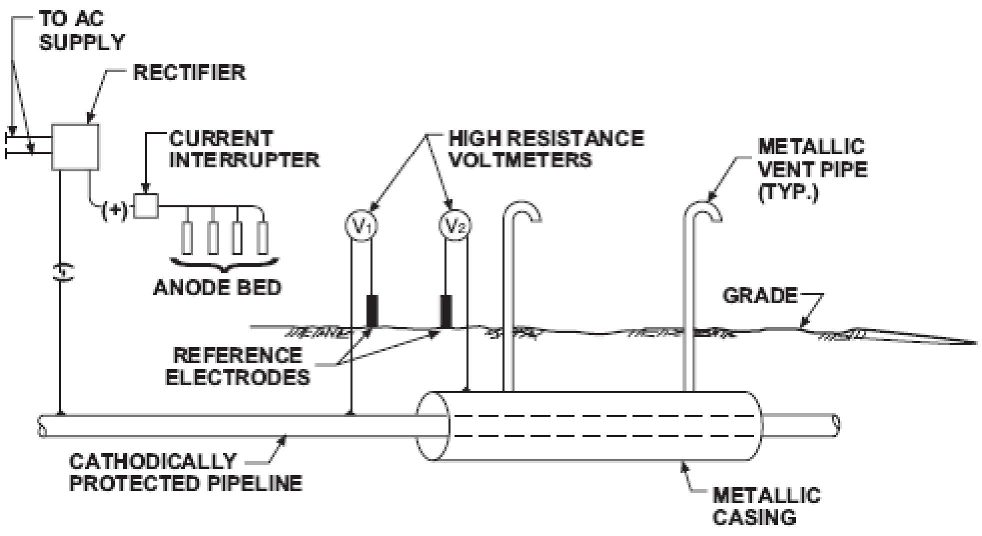
CASING-TO-PIPE RESISTANCE MEASUREMENT
USING SOIL RESISTIVITY METER

FIGURE 6-7



ISOLATION TESTING BY
IMPRESSING CURRENT ON CASING

FIGURE 6-8



ISOLATION TESTING USING EXISTING
CATHODIC PROTECTION SYSTEM

FIGURE 6-9

Shorted Casings

In the event that a casing is found to be shorted to the pipeline after construction activity in the area has been completed, there are only two acceptable alternatives which can be considered:

1. Excavate the cased crossing, locate the point of contact and clear it.
2. Pump a petrolatum or wax type product into the entire annular space through the vent pipes in order to inhibit corrosion.

Another approach that has been used in the past is to allow the short to remain and to increase the level of cathodic protection at the pipe/casing interface area. This approach does not preclude the possibility of corrosion of the pipe within the casing if water has gotten inside the annular space.

System Characteristics

Galvanic

- No external power
- Fixed driving voltage
- Limited current
- Small current requirements
- Used in lower resistivity environment
- Usually negligible interference

Impressed

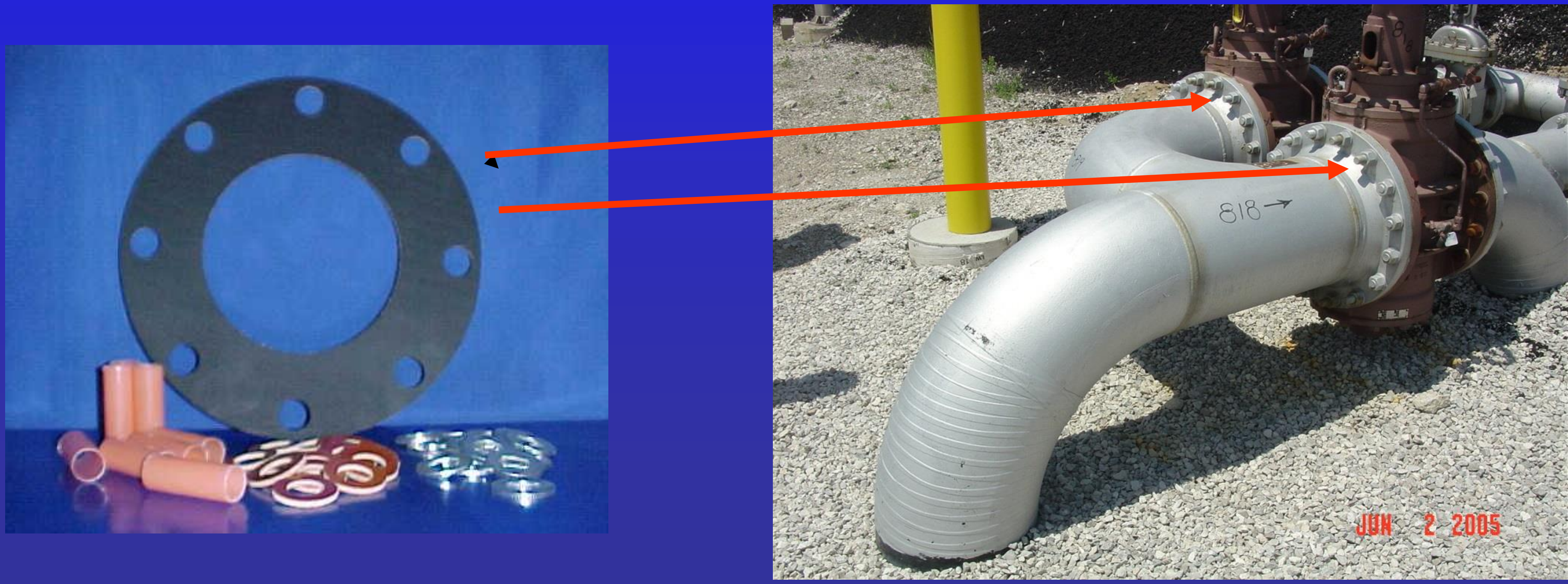
- External power required
- Voltage can be varied
- Current can be varied
- High current requirements
- Used in almost any resistivity environment
- Must consider interference with other structures

Casing Fillers

What Does an Isolating Joint Do?

Isolating joints such as isolating flanges, unions, and couplings are used to electrically isolate various components of a pipeline system.

They are often used to isolate a pipeline into sections for cathodic protection purposes.



Isolating Flanges

The most commonly used isolating joint is the isolating flange. Isolating flanges are available in various sizes and configurations and are constructed from a large variety of materials designed for specific temperature, product and pressure applications. An isolating flange has (3) isolating components. They are the gasket, the sleeves, and the washers.

Installation of Isolating Flanges

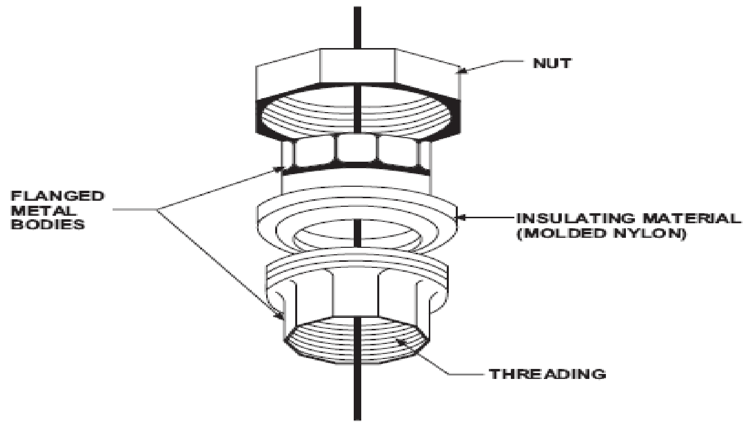
Isolating flange kits can only be installed on out-of-service pipes because the installation requires the opening of pipeline flanges.

1. For buried flanges, isolating washers should be installed only on the unprotected side of the flange, allowing cathodic protection to be provided to studs or bolts.
2. It is important that after the isolating flange is installed, the void area where the two flange faces meet be taped with two layers of plastic tape or equal.
3. Replace any broken or cracked sleeves or washers, as they will eventually result in an electrical short.

Fillers

Isolating Unions

Isolating unions are generally installed aboveground to provide electrical isolation for regulator stations, processing plants, gauge lines, fuel supply lines, water lines, and other pipeline applications.



TYPICAL ISOLATING UNION DETAIL

FIGURE 6-10B

FLANGE INSULATION KIT

INSULATING UNIONS

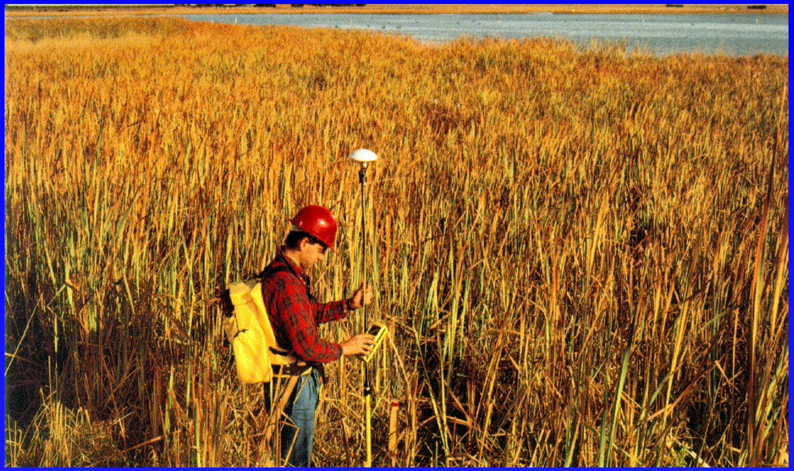
CP Objectives

- Provide sufficient distribution of current.
- Minimize interference on foreign structures.
- Achieve projected design life.
- Provide allowance for anticipated changes in current requirements with time.
- Install anodes and in locations where possibility of damage is limited and feasible.
- Comply with regulatory requirements, electrical codes, NACE recommended practices, etc.

Useful Information

- Route maps
- Existing or new pipeline
- Proposed construction dates (weather,
- Aerial, bridge, underwater crossings
- Casings
- Foreign pipelines and CP systems
- AC Power availability
- Performance of CP systems in the area
- Easements for possible ground bed sites
- Future expansions of pipeline or development of area
- Special environmental issues

Field Survey



- Anticipated current requirement, soil data
- Locate anode ground bed locations
- Electrical continuity/isolation
- Interference issues
- Deviation from construction specifications
- Leak history
- Construction equipment accessibility
- Prepare CP design approach for review

Design Challenges

Construction Equipment Access

System Characteristics

Galvanic

- No external power
- Fixed driving voltage
- Limited current
- Small current requirements
- Used in lower resistivity environment
- Usually negligible interference

Impressed

- External power required
- Voltage can be varied
- Current can be varied
- High current requirements
- Used in almost any resistivity environment
- Must consider interference with other structures

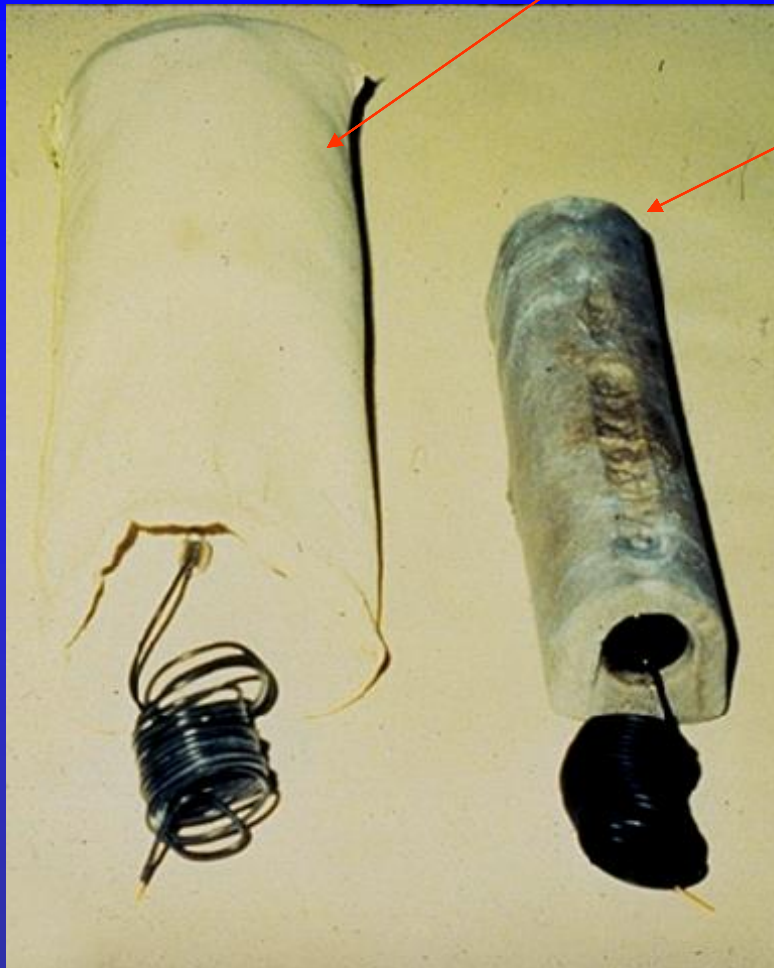
PRACTICAL GALVANIC SERIES

Material	Potential*
Pure Magnesium	-1.75
Magnesium Alloy	-1.60
Zinc	-1.10
Aluminum Alloy	-1.00
Cadmium	-0.80
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
Titanium	-0.20
Gold	+0.20
Carbon, Graphite, Coke	+0.30

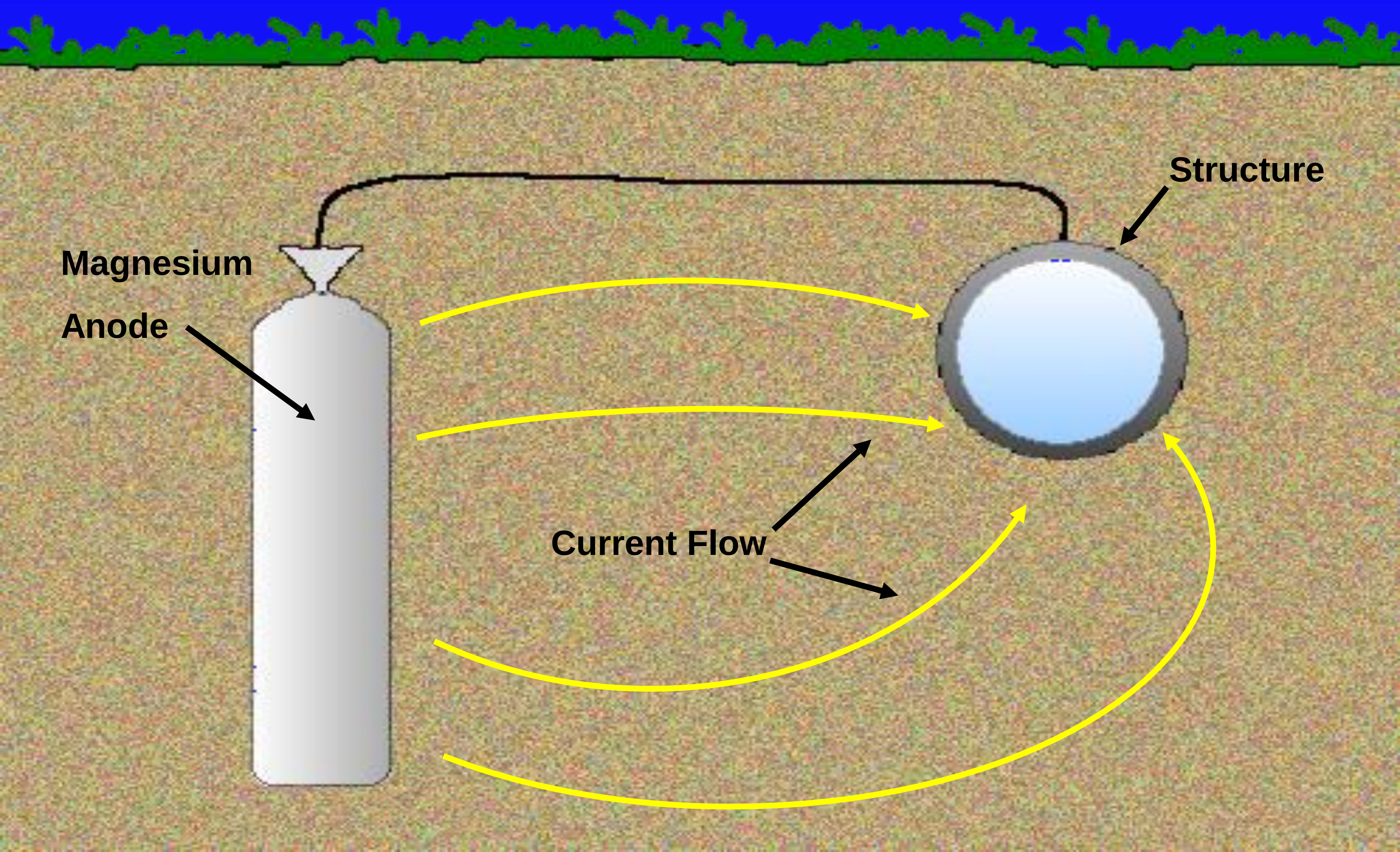
* Potentials With Respect to Saturated Cu-$CuSO_4$ Electrode

Packaged Magnesium Anode

Magnesium Ingot

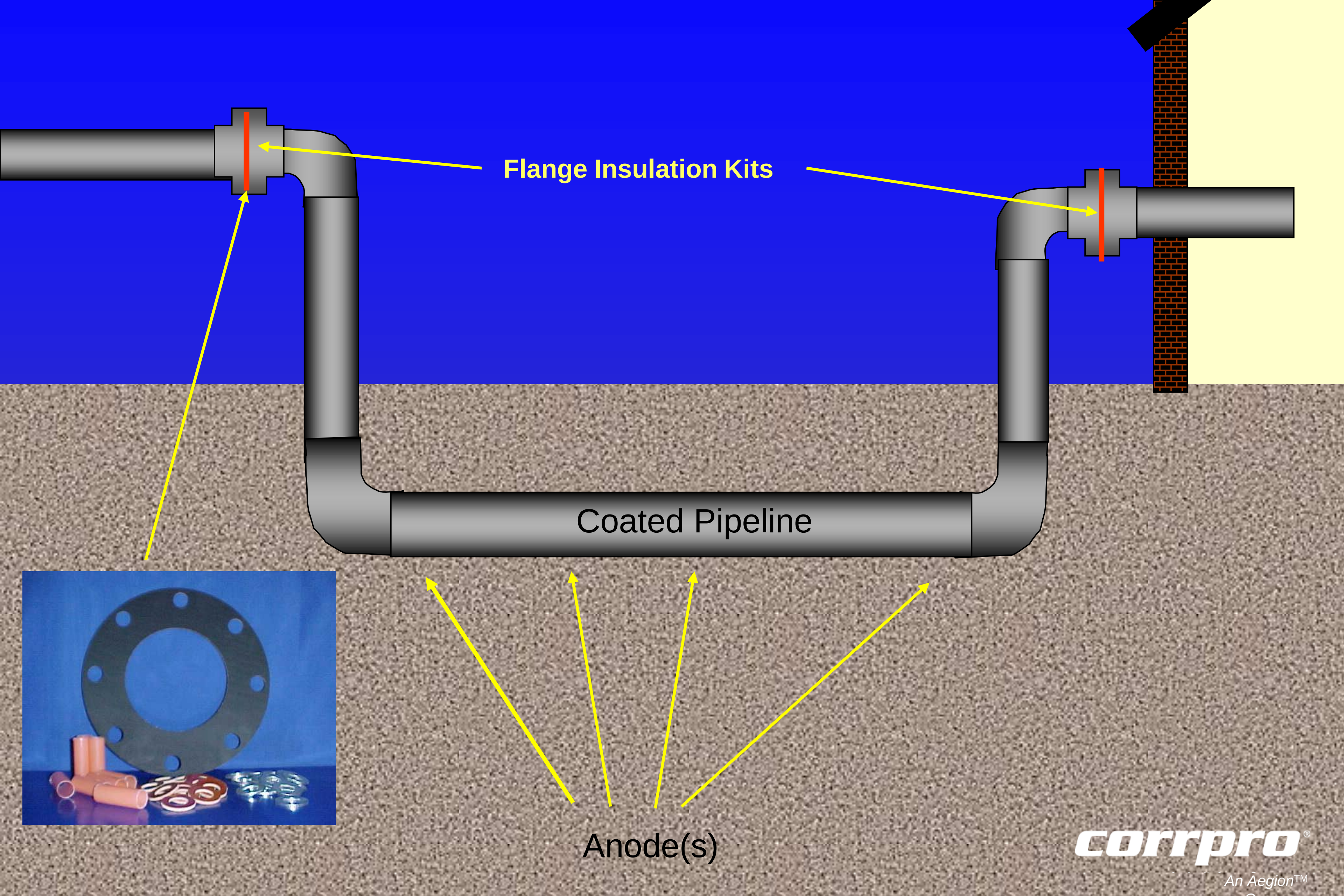


Galvanic Cathodic Protection

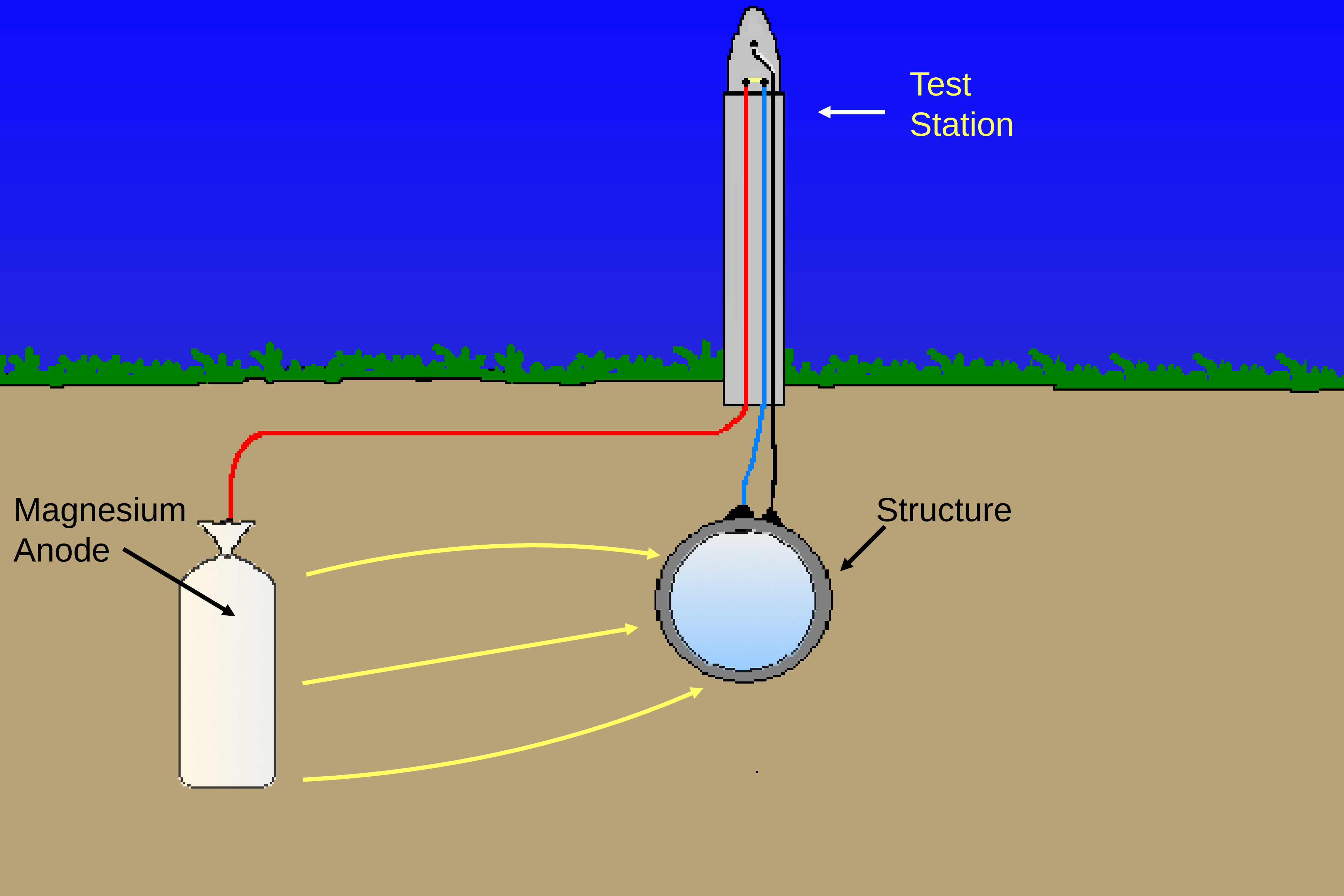


Tank to Soil Potential Measurements

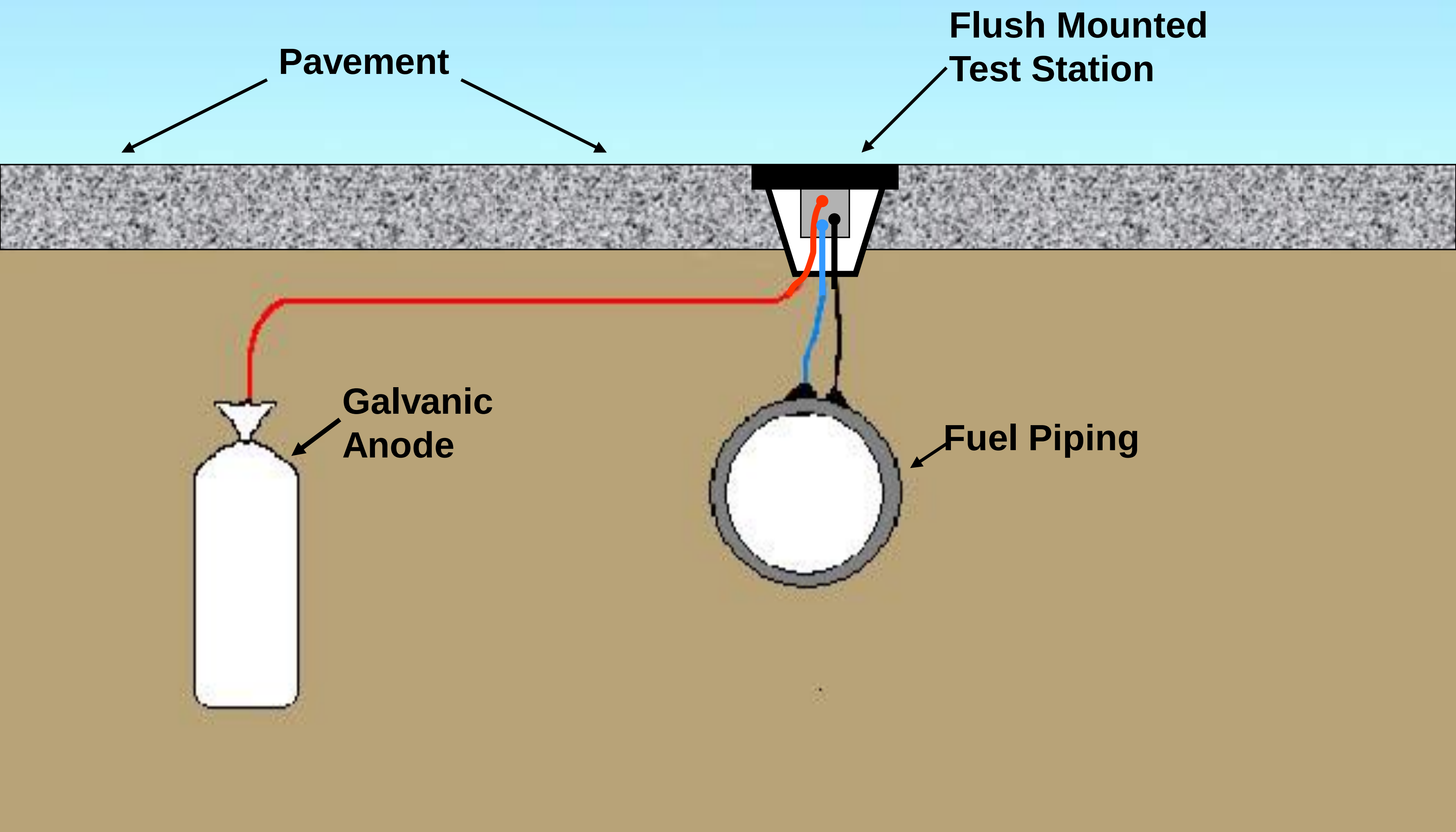
Electrical Isolation of Buried Piping



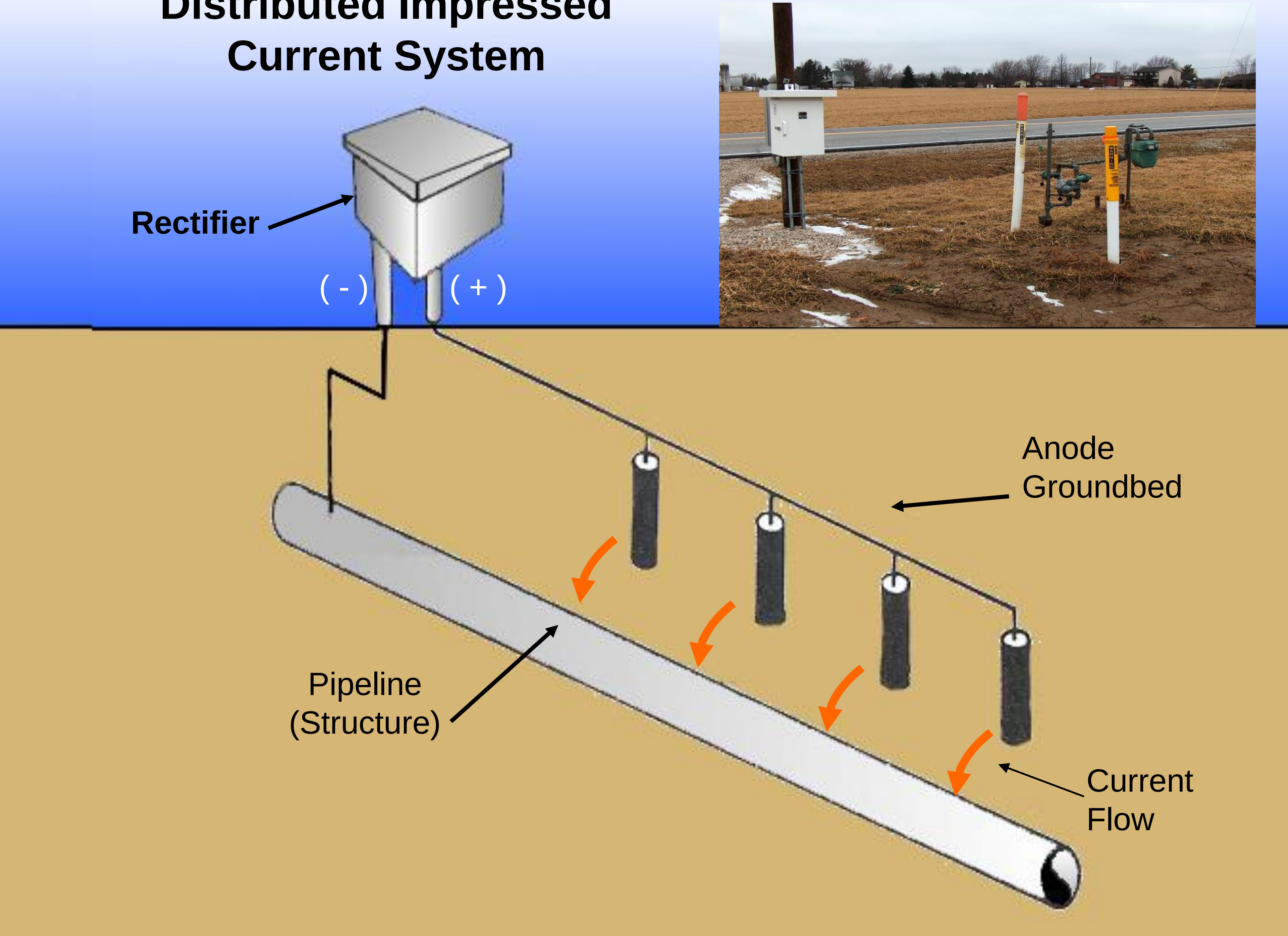
Cathodic Protection Test Station



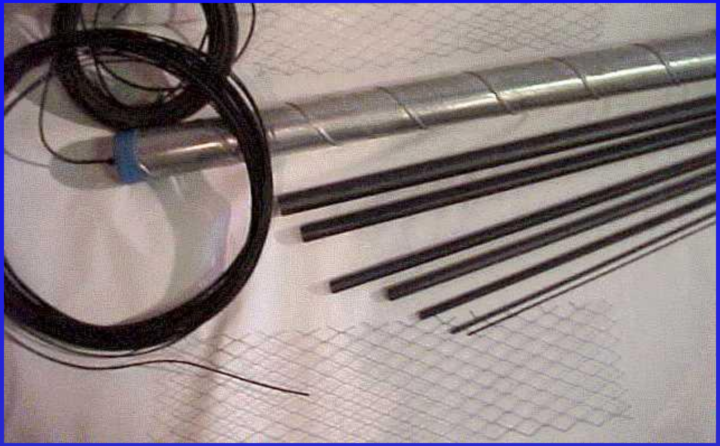
Flush Mount Cathodic Protection Test Station

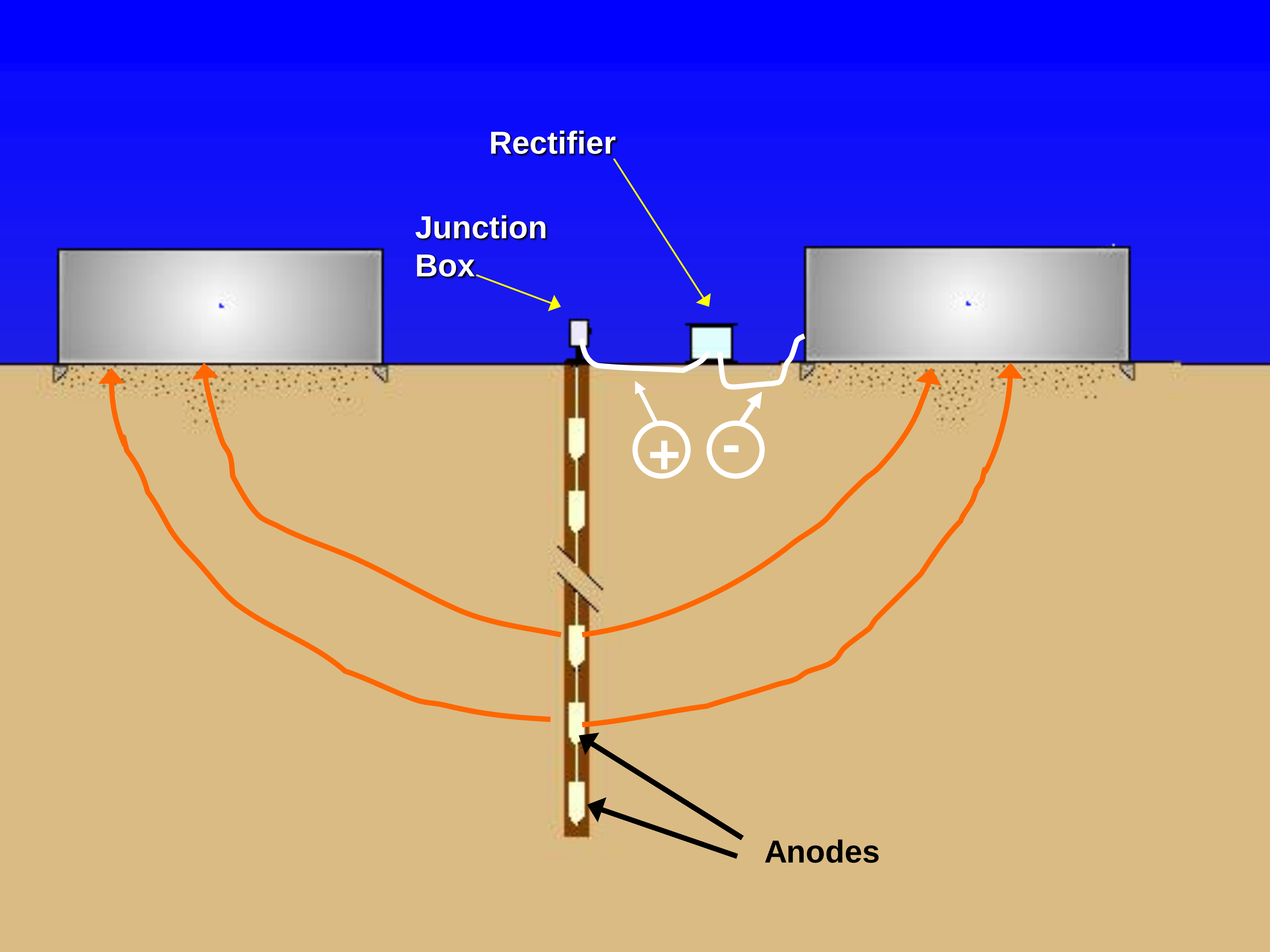


Distributed Impressed Current System



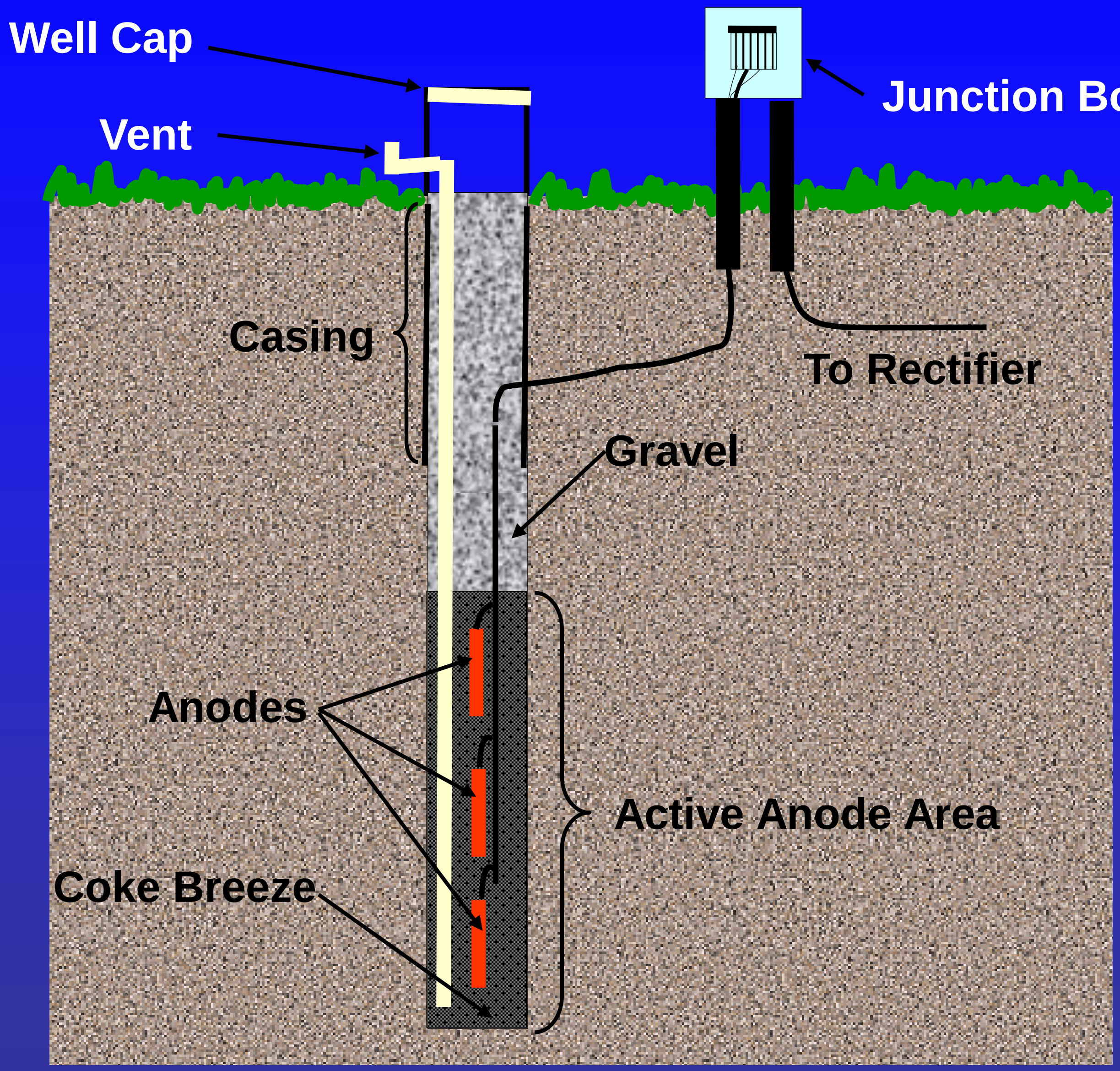
ICCP Anode Material





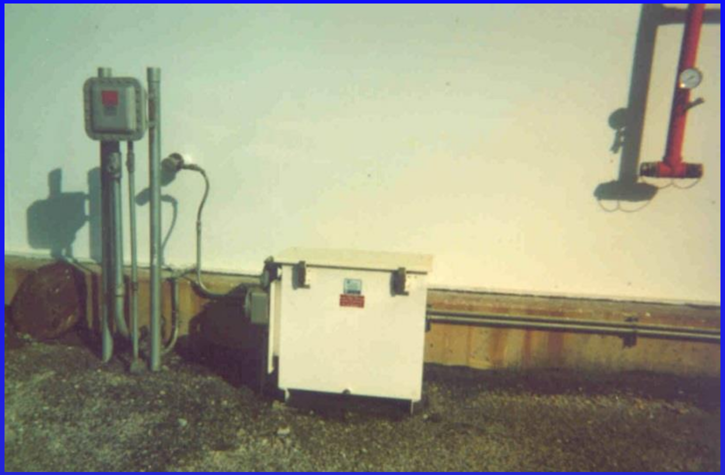
Rectifier
Junction
Box
+
-
Anodes

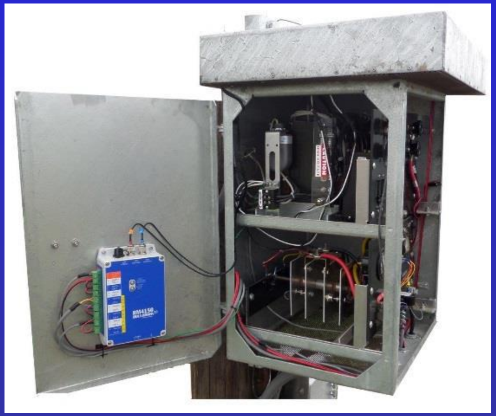
Deep Anode Installation



NOTE: Sealing may be required by state or local codes

Rectifier Units





(Classification of area, AC power input and availability, RMU)

Testing Isolating Joints

Testing the effectiveness of the installed isolating joint can be done using one or more of the following methods:

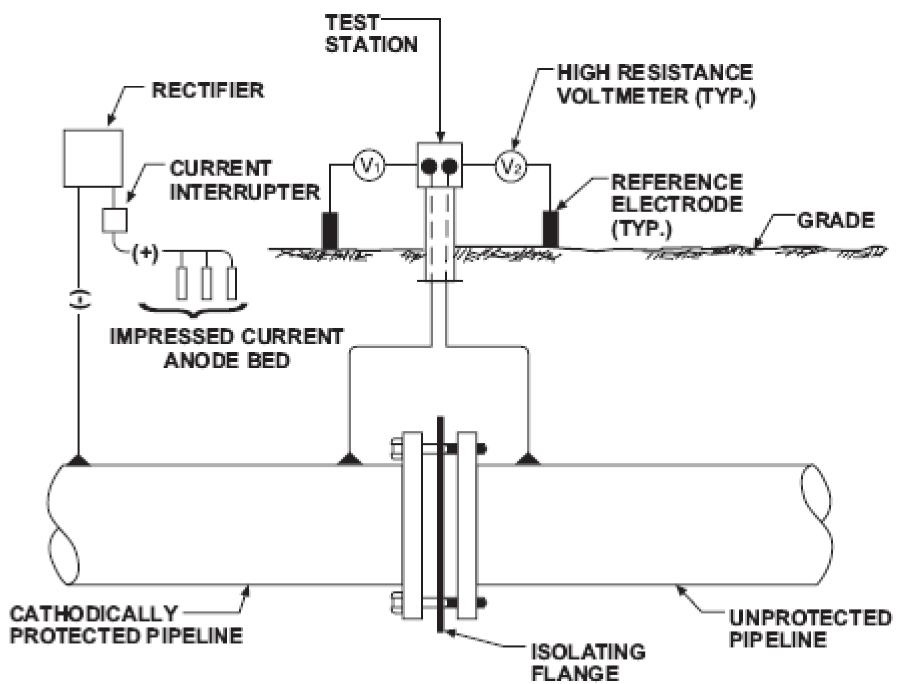
1. Interrupting cathodic protection source
2. Testing for shorted bolts on isolating flanges using a high resistance voltmeter
3. Using isolation checker instrument

Repair of Shorted Isolating Flange

If an isolating joint is found to be shorted/defective it may be possible to repair it without taking the line out of service. This is possible if the short is due to an isolating bolt sleeve which has broken down or was improperly installed. If this is the case, the shorted bolt can be removed and the isolation replaced or properly reinstalled.

If an isolating flange is found to be shorted, and the above test methods indicate a faulty gasket, the line must be taken out of service and the gasket replaced.

Before disassembling the joint for the replacement of the gasket, a thorough visual inspection of the gasket, a thorough visual inspection of the joint should be conducted. This inspection of the joint should be conducted. This inspection may lead to the discovery of foreign material between the flange faces or the existence of a metallic conductor across the flanges, which may be shorting the joints.



METHOD #1 – TESTING UNDERGROUND
ISOLATING JOINT

FIGURE 6-11

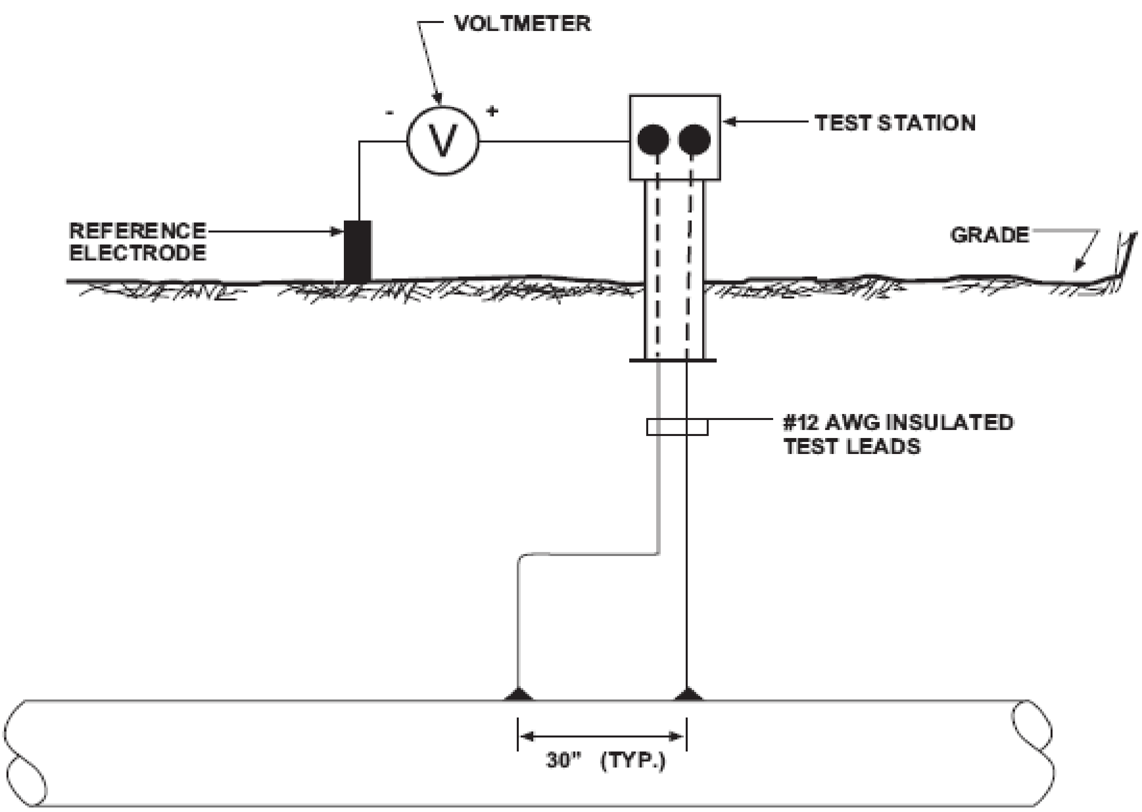
Test Points

The Purpose of Test Points

Test points are used to electrically contact a buried pipeline to facilitate the monitoring of cathodic protection levels and conducting tests associated with corrosion control. Each test station has a number of wires connected to the pipeline(s) on which test are performed. Usually each wire is color coded by the operating company. Test stations should be marked and GPS.

Types of Test Points

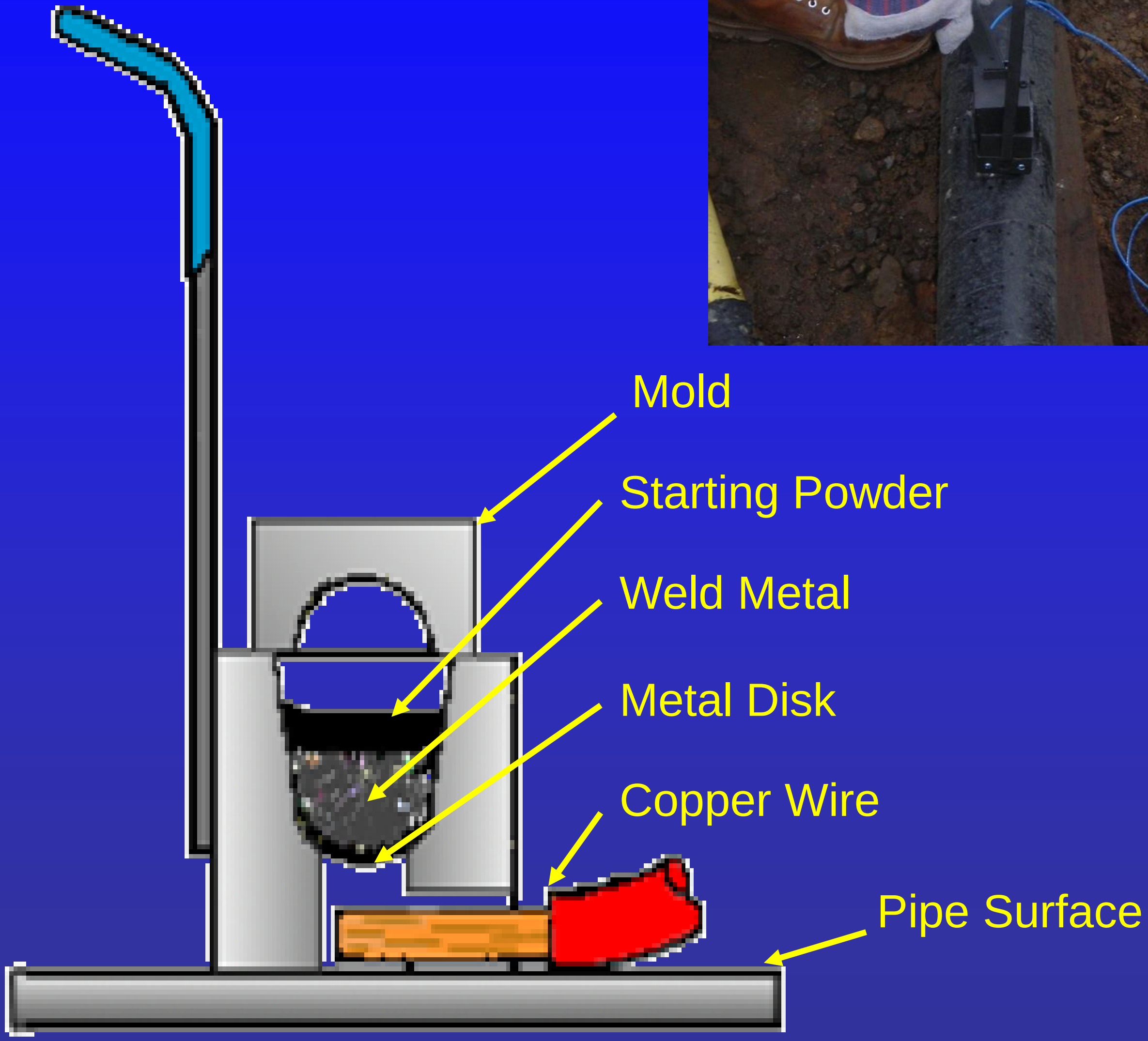
Each test point/station has a number of wires connected to the pipeline(s) on which tests are being performed. Usually, each wire is color coded by some scheme developed internally by the operating company. The test station should also be marked on as built drawings and GPS.



TYPICAL TWO WIRE TEST STATION

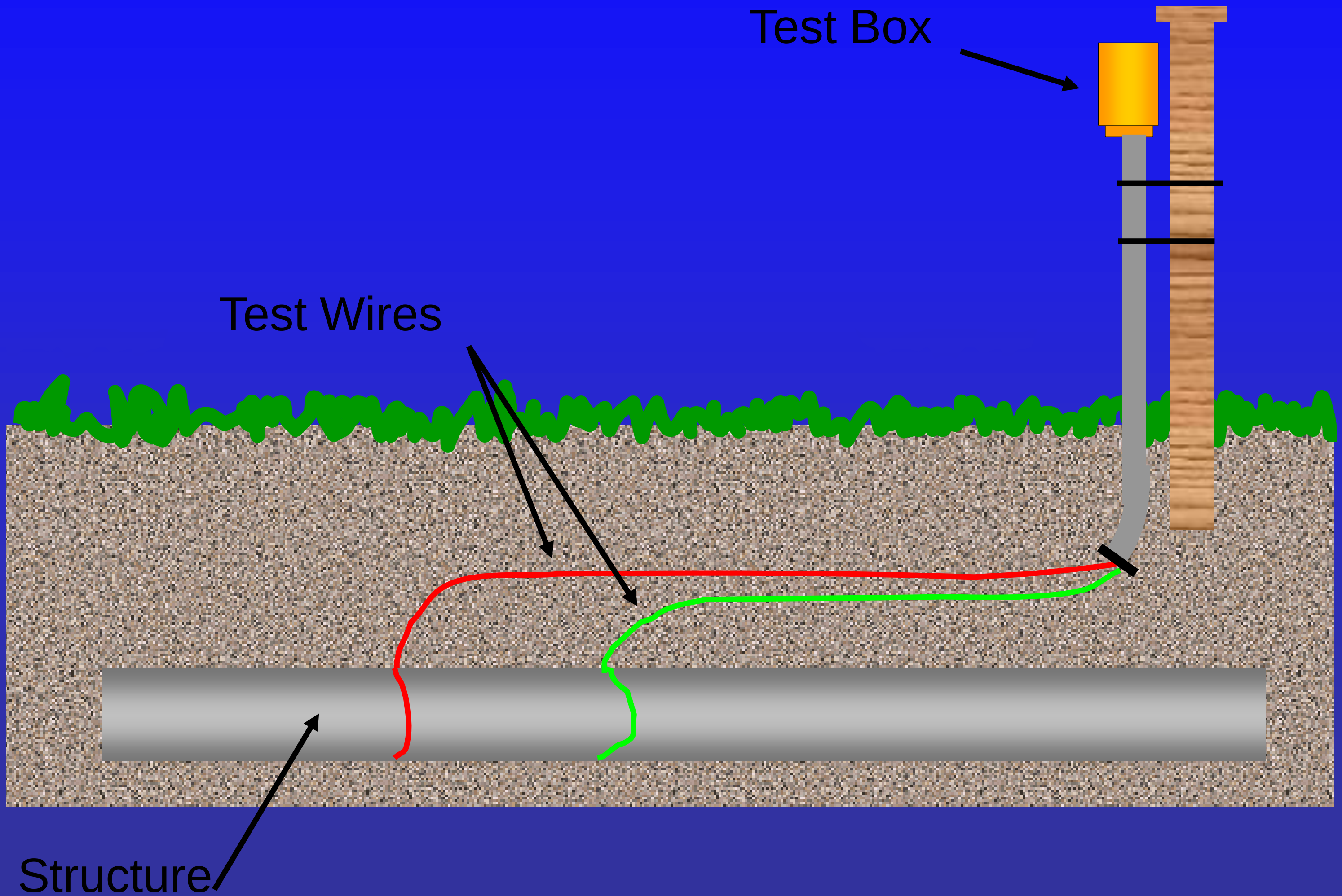
FIGURE 6-15

Exothermic (Thermit) Weld

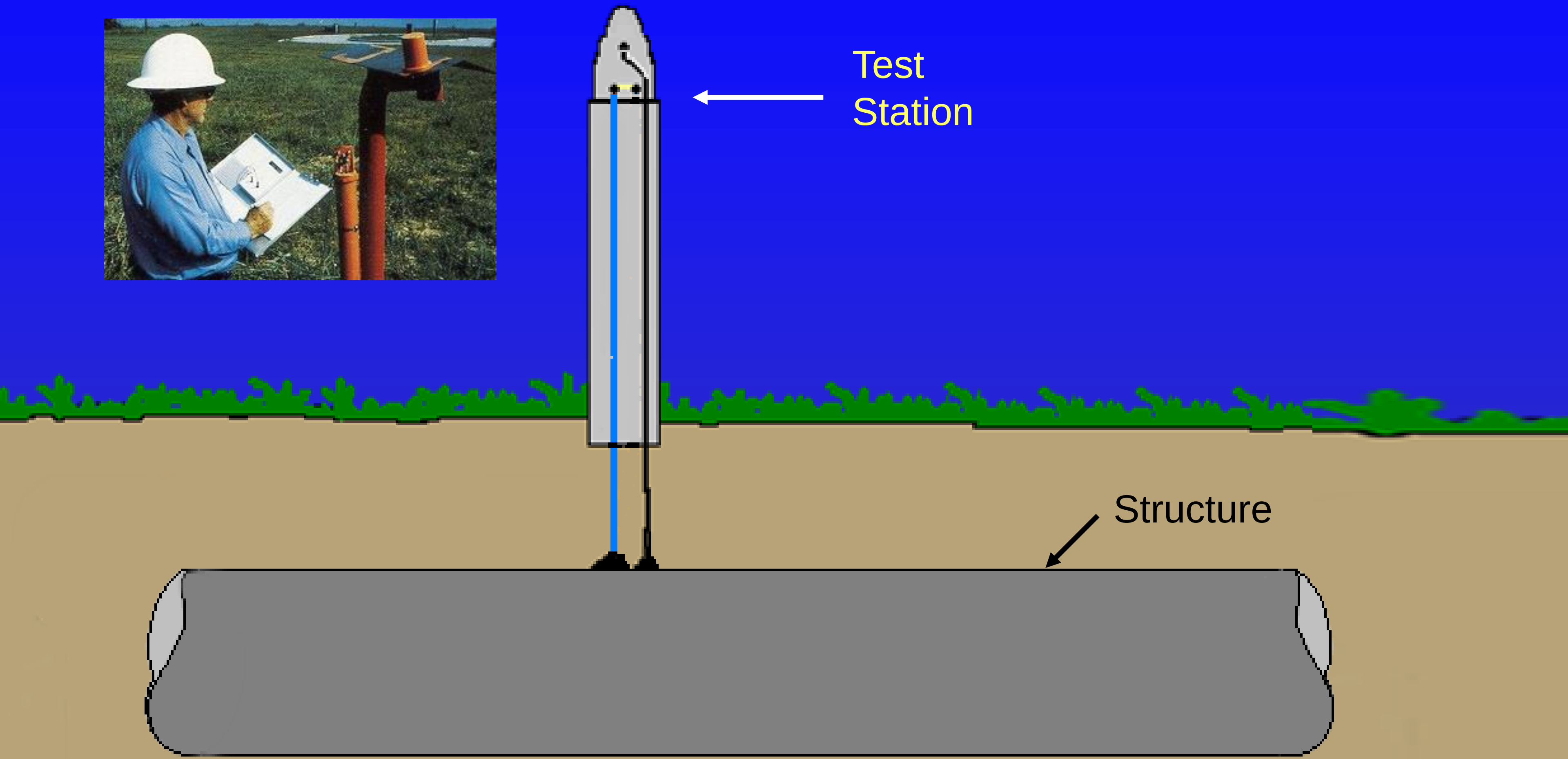



ON/OFF
SETTING
SAFETRACK

Post Mounted Potential Test Station



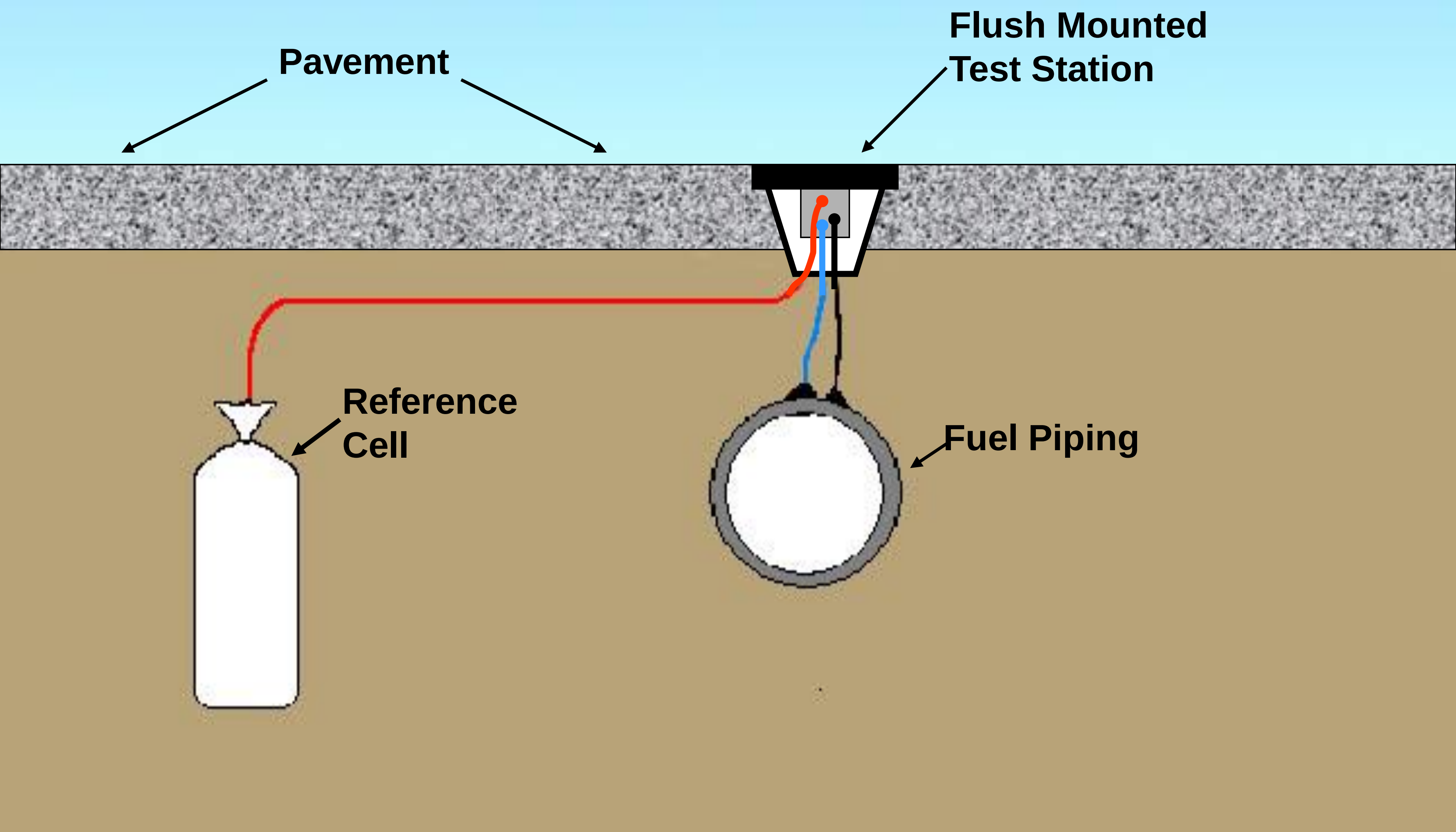
Test Station



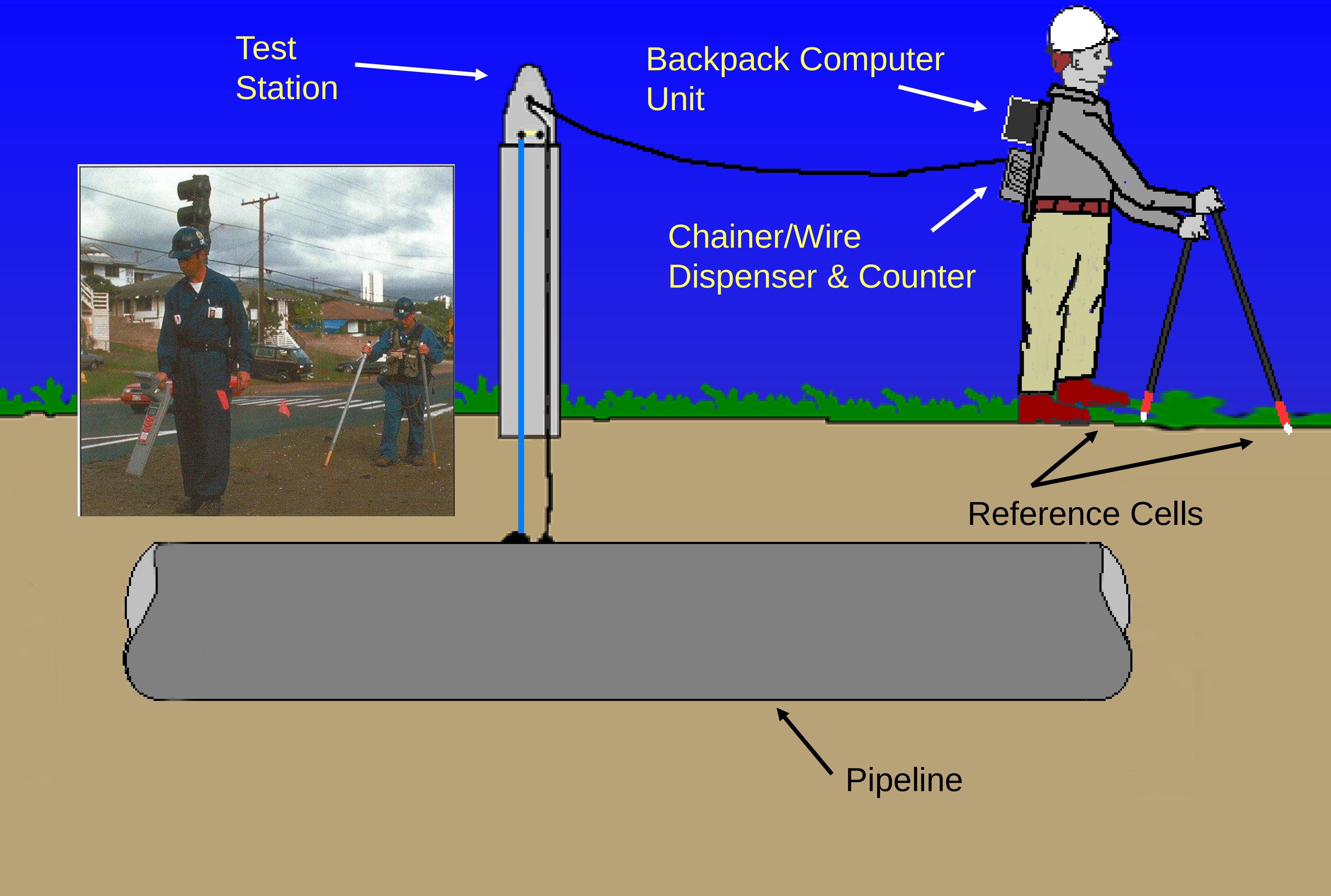

4000

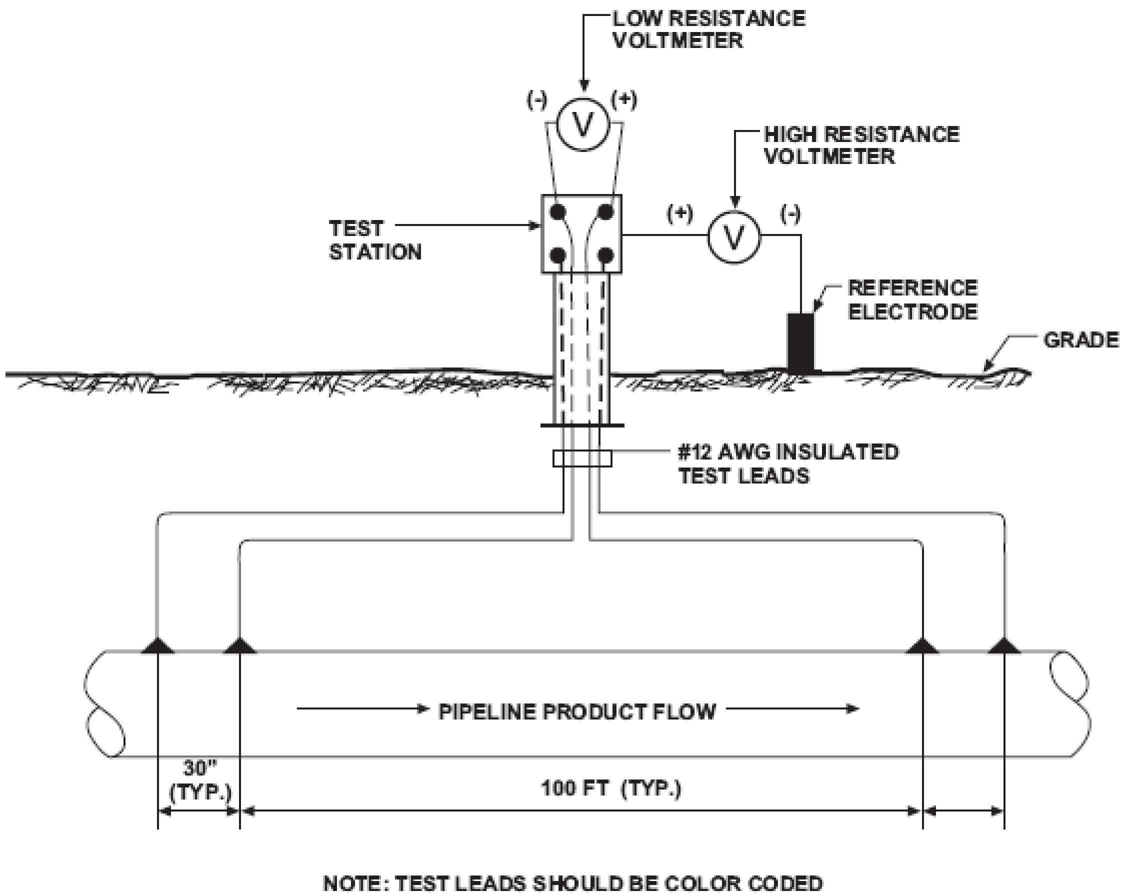

08 11 2005

Flush Mount Cathodic Protection Test Station



Computerized Potential Logging Survey

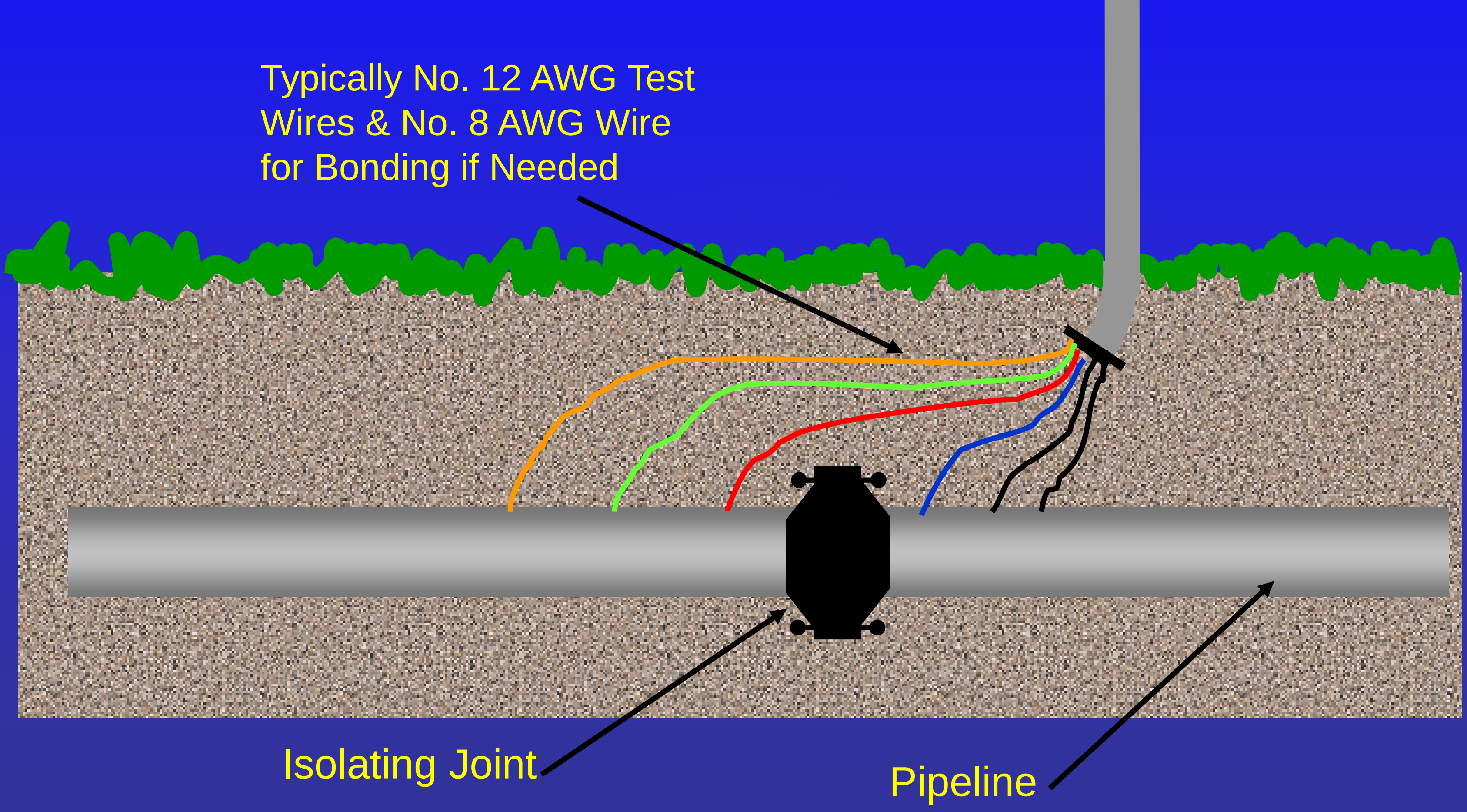


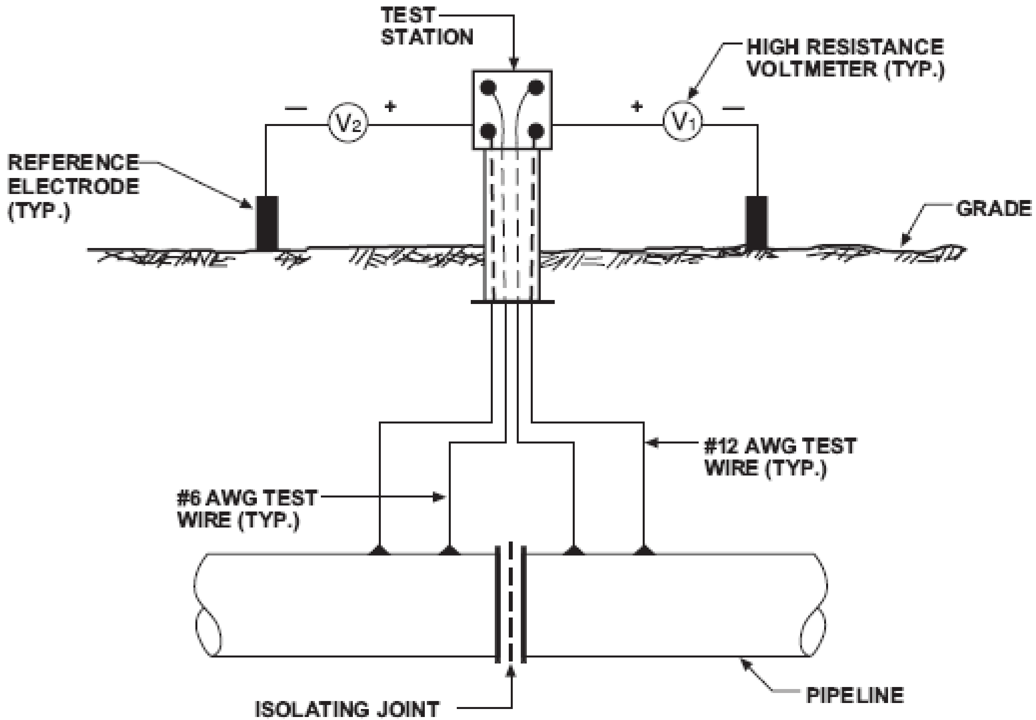


IR DROP TEST STATION

FIGURE 6-16

Isolation Joint Test Station

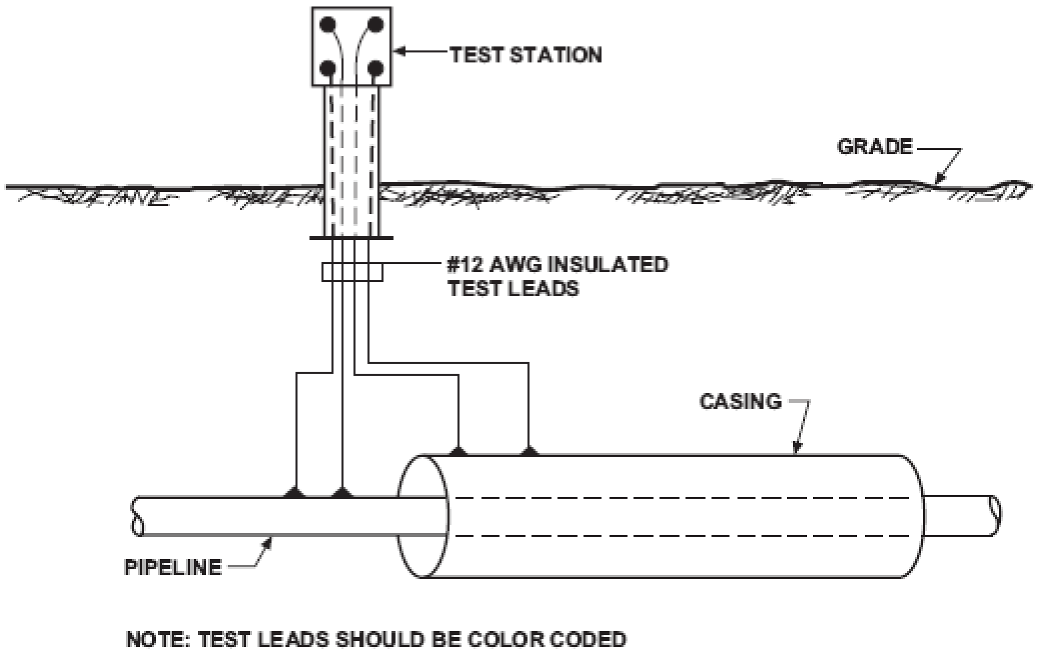




NOTE: TEST LEADS SHOULD BE COLOR CODED.

TYPICAL ISOLATING JOINT TEST STATION

FIGURE 6-19

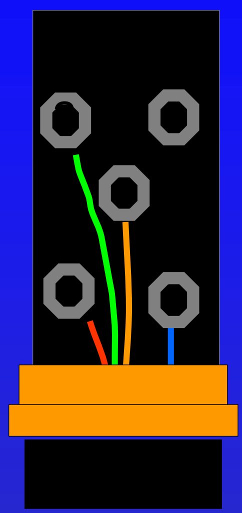


TYPICAL PIPELINE CASING TEST STATION

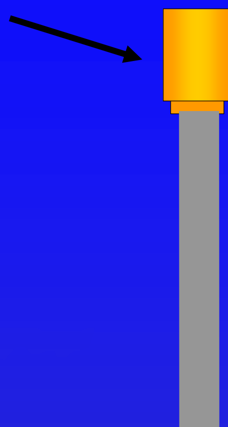
FIGURE 6-21

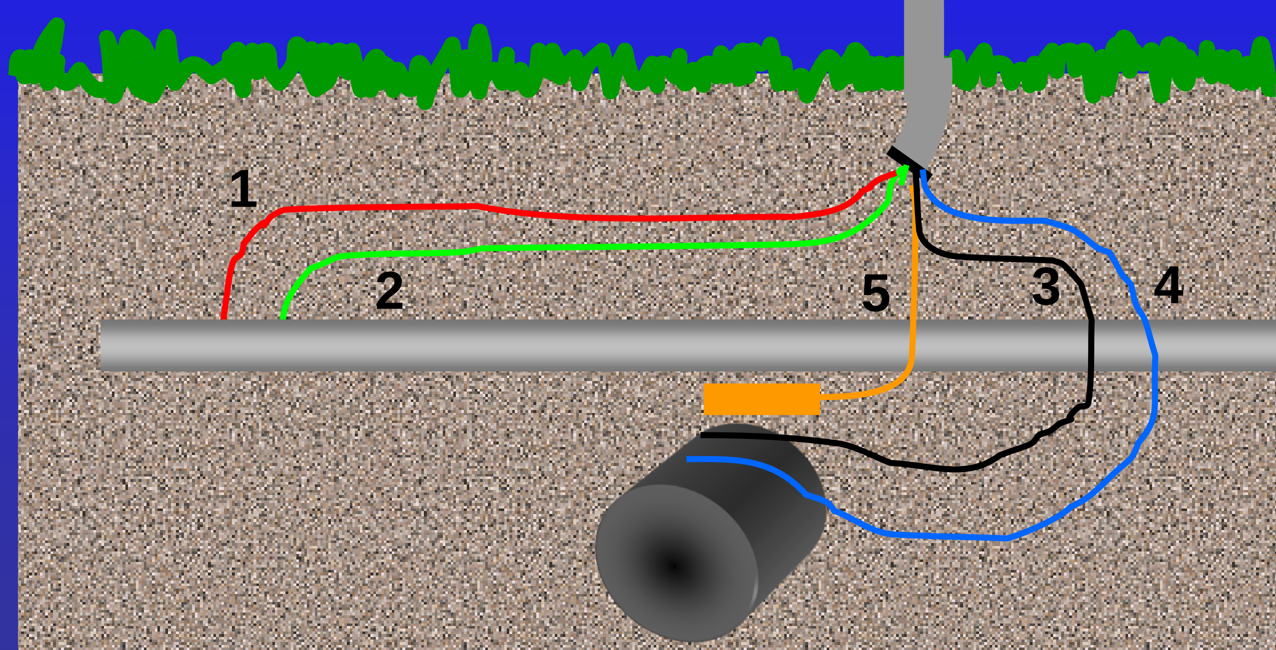

WARNING
GAS
WARNING
GAS

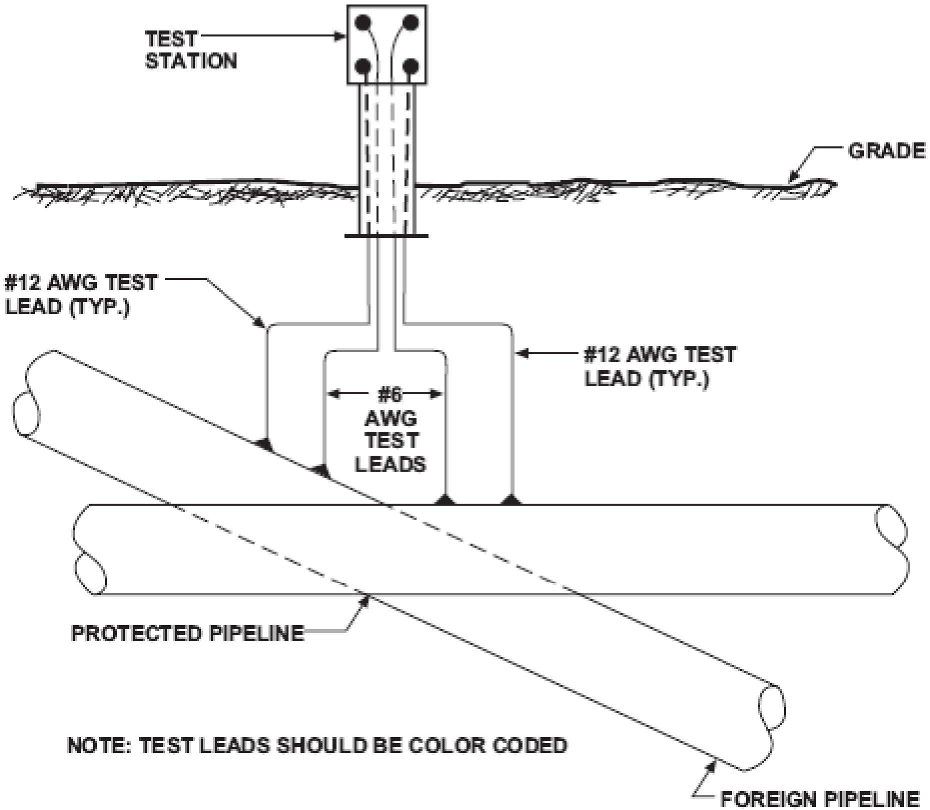
Foreign Line Test Station



Terminal Board



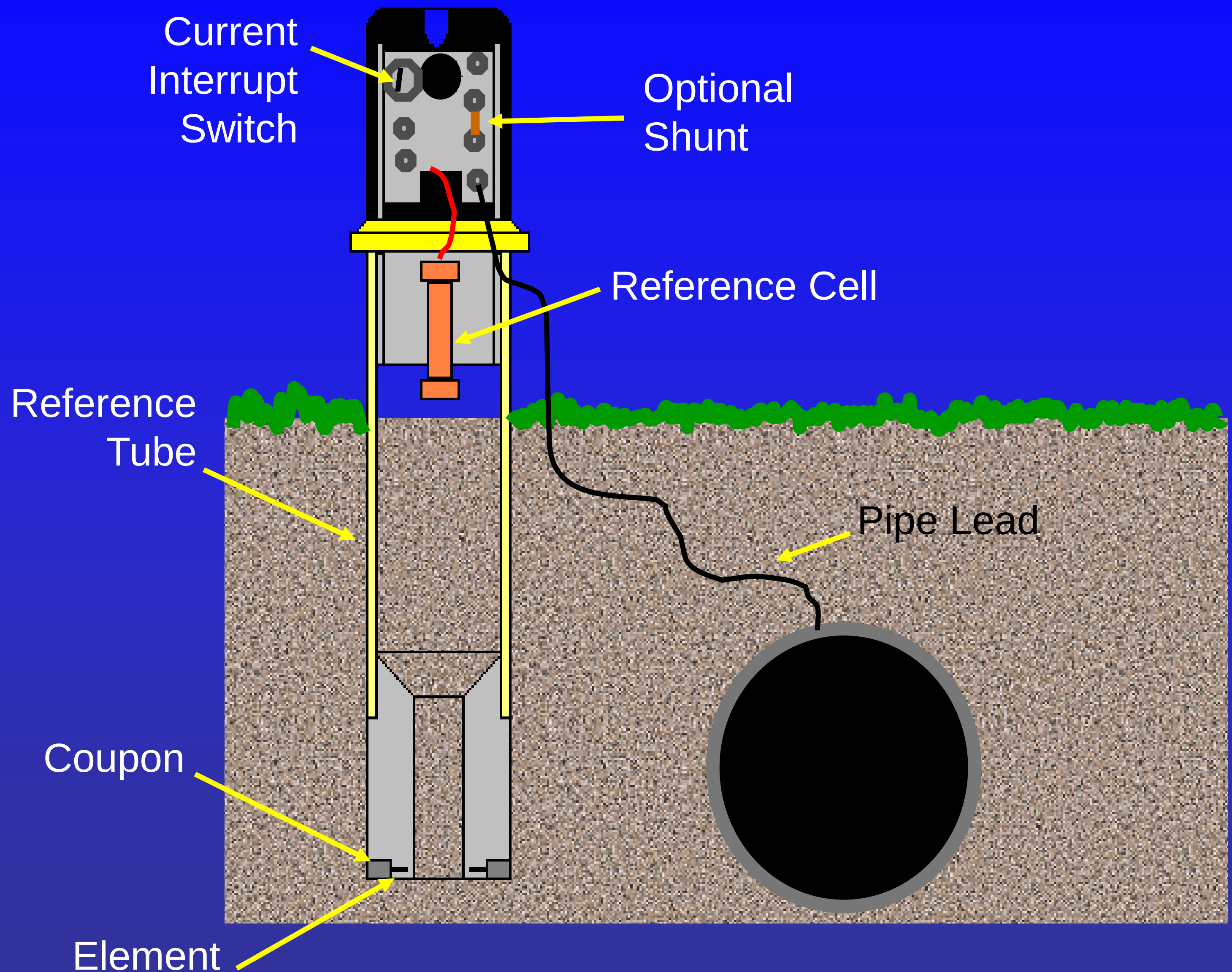




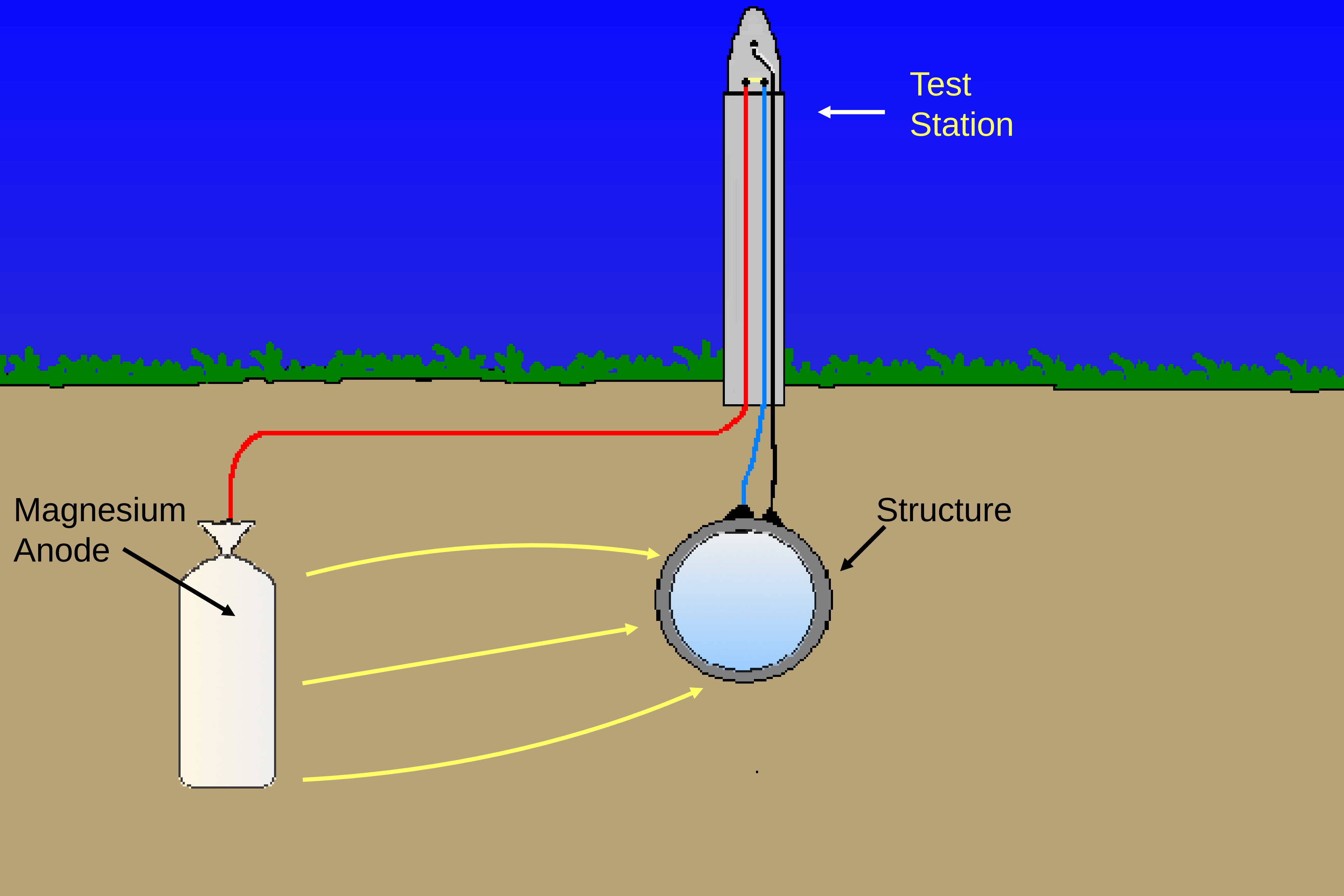
TYPICAL FOREIGN PIPELINE CROSSING TEST STATION

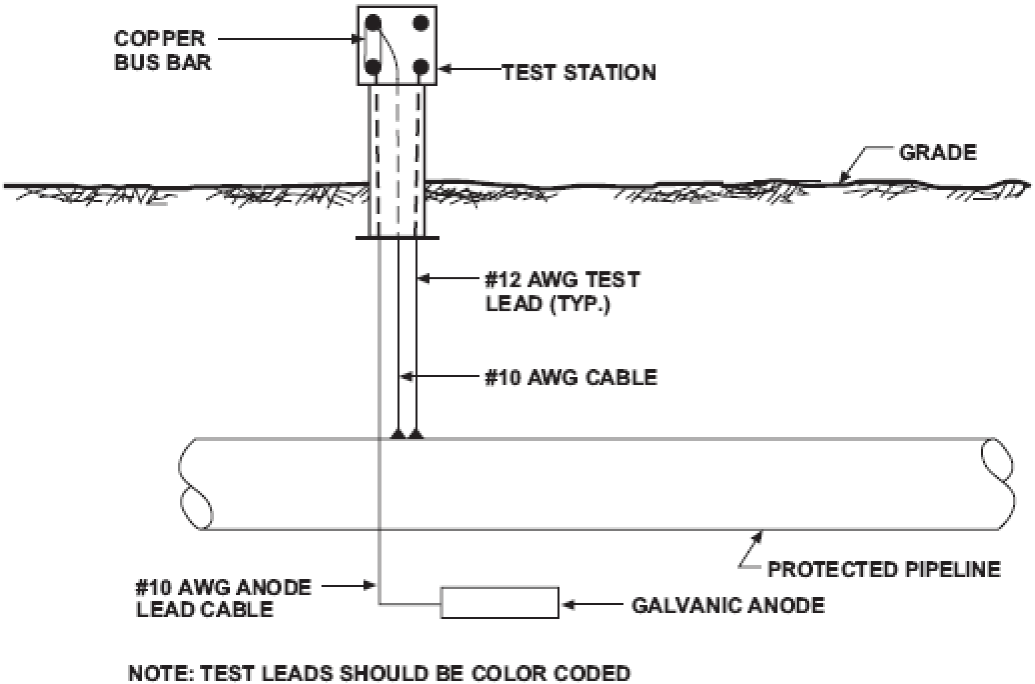
FIGURE 6-22

Coupon Test Station



Cathodic Protection Test Station





TYPICAL GALVANIC ANODE TEST STATION

FIGURE 6-23

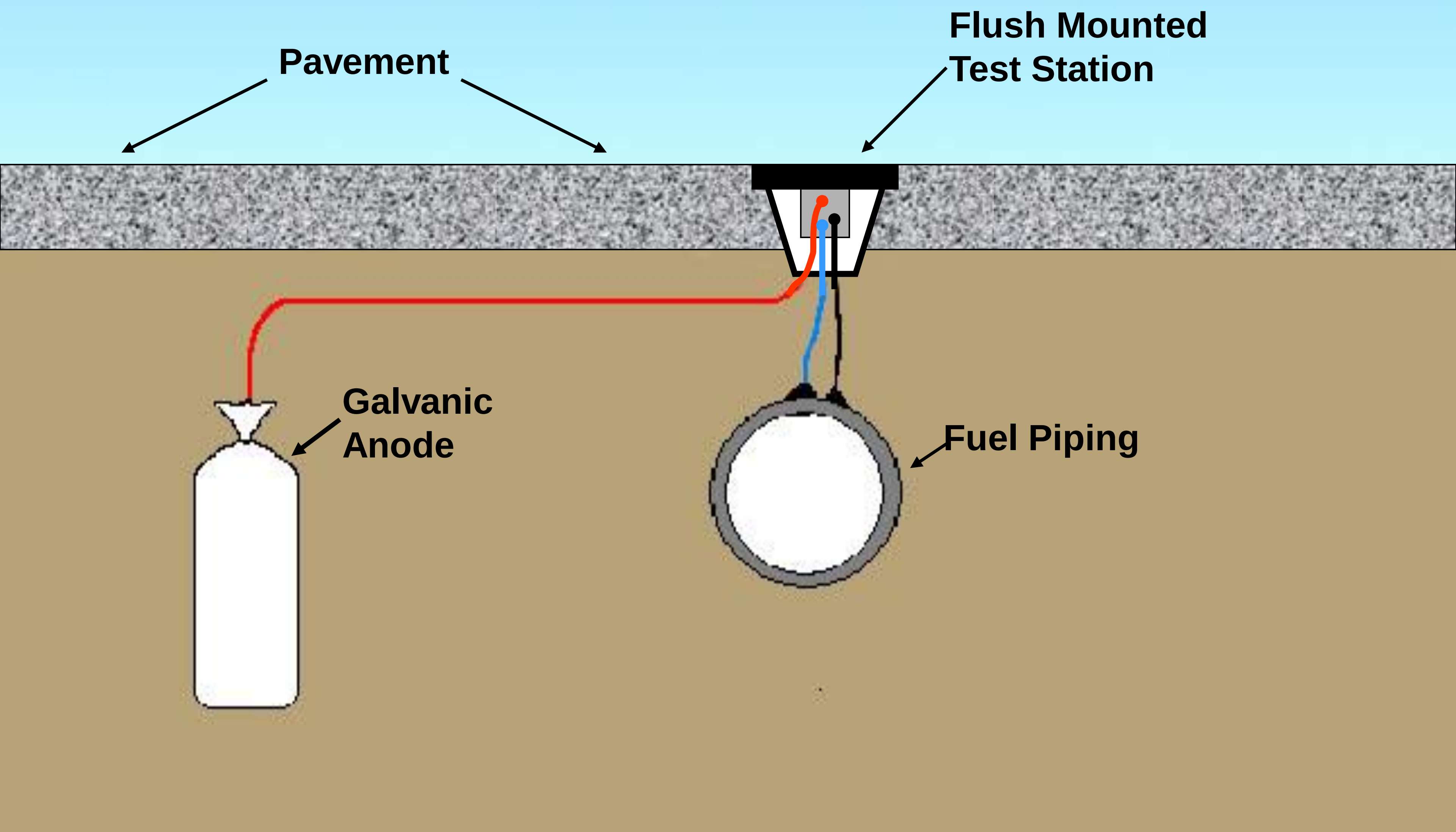
Installation of Test Points

Flush mounted test stations are normally used in areas where an aboveground mounted test station may not be feasible due to vehicular traffic in the area or due to right-of-way limitations.

Aboveground post mounted test stations, are normally used on cross country pipeline installations to facilitate the locating of test points for testing.

Accurate test station location drawings (and more recently GPS) and electrical termination details should be prepared identifying each test point. The importance of color coding and recording wires and their positions on the pipe cannot be overemphasized.

Flush Mount Cathodic Protection Test Station



Conclusions

Counter corrosion methods should be considered when designing a new pipeline installation. Corrosion control measures should include, but not be limited to, the use of protective coatings. A knowledgeable coatings engineer should make the selection of the protective coating system to be used. Cathodic protective systems must be used in conjunction with a good protective coating to ensure that the pipeline meets its designed life expectancy.

QUESTIONS ?

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