



# **Corrosion Prevention for AST's and Piping Systems**

## **2004 OSC Readiness Training Program**

***Presented by:***

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***330-723-5082***



# Corrosion of Tanks and Piping

James T Lary  
November 16, 2004  
OSC Readiness Training



## **NACE International – The Corrosion Society**

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1. NACE International Overview
2. Cost of Corrosion
3. Aboveground, Underground Storage Tanks, and Associated Piping Systems
4. NACE Resources



## NACE International – Overview

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### Our Vision

NACE International will be recognized as a world-class corrosion society by contributing significantly to the enhancement of global corrosion efforts.

### Our Mission

To reduce the impact of corrosion.



## NACE International – Overview

- Global Forum for Corrosion Technology
- Global Source for Corrosion Education & Training
- Internationally Recognized Standards





## NACE International – Overview

- 60<sup>th</sup> Anniversary
- Not-for-Profit Organization
- 15,000 Individual Members in 91 Countries
- 275 Corporate Members
- Organized in 82 Sections



## NACE International – Overview

- Education Programs
- Professional Recognition
- Coating Inspector Training
- Cathodic Protection Certification



## NACE International – Overview

- NACE Standards
- Conferences/Expos
  - CORROSION/2004 – Houston, TX. March 2005
  - Corrosion Technology Week 2004 – Phoenix, AZ, Sept. 2004
- Periodicals
- Publications & Software





## NACE International – Education & Certification

NACE Education Classes Designed To:

- Introduce fundamentals of corrosion control
- Expand existing knowledge
- Provide professional recognition & certification



## NACE International – Education & Certification

### 10 Certification Categories

- Coating Inspector Program
  - Three Courses
  - 5,500 recognized individuals – worldwide
- Cathodic Protection Certification



## NACE International – Education & Certification

- NACE Certification Specified Worldwide
- Qualified Personnel
- Ensure Safe Operations
- Extend Asset Life
- Reduce Downtime
- Improved Quality Assurance



## NACE International – Standard & Reports

### Standards Recognized Worldwide

- 118 NACE Standards
  - 19 Material Requirements
  - 69 Recommended Practices
  - 30 Test Methods
- 60 Technical Committee Reports



# What is the Cost of Corrosion?





# \$276 Billion

The United States Cost of Corrosion Study



## Cost of Corrosion

- All costs are direct corrosion costs
  - Cost of labor attributed to corrosion management activities
  - Cost of the equipment required because of corrosion related activities
  - Loss of revenue due to disruption in supply of product
  - Cost of loss of reliability
  - Cost of lost capital due to corrosion deterioration

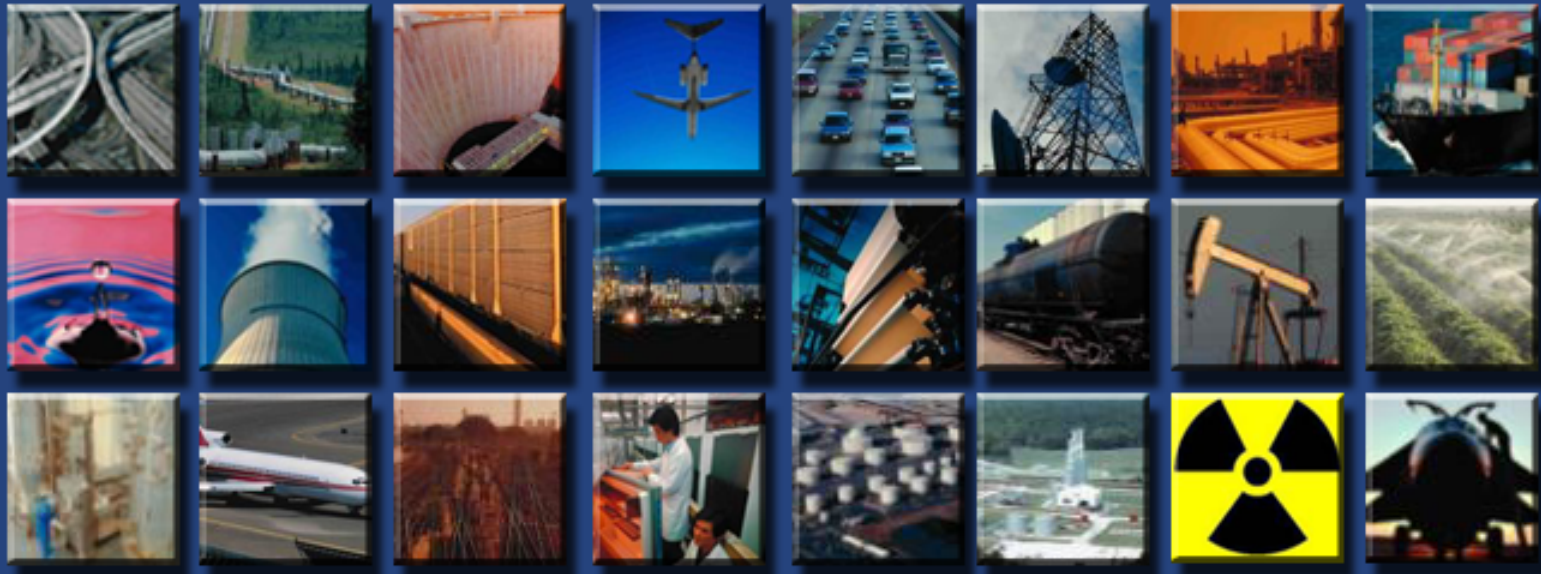


## Methods & Services

- All costs are direct corrosion costs
- Disadvantage: many costs are missed
  - Cost of labor attributed to corrosion management activities.
  - Cost of the equipment required because of corrosion-related activities.
  - Loss of revenue due to disruption in supply of product.
  - Cost of loss of reliability.



## Cost of Corrosion – Industry Sector Analysis







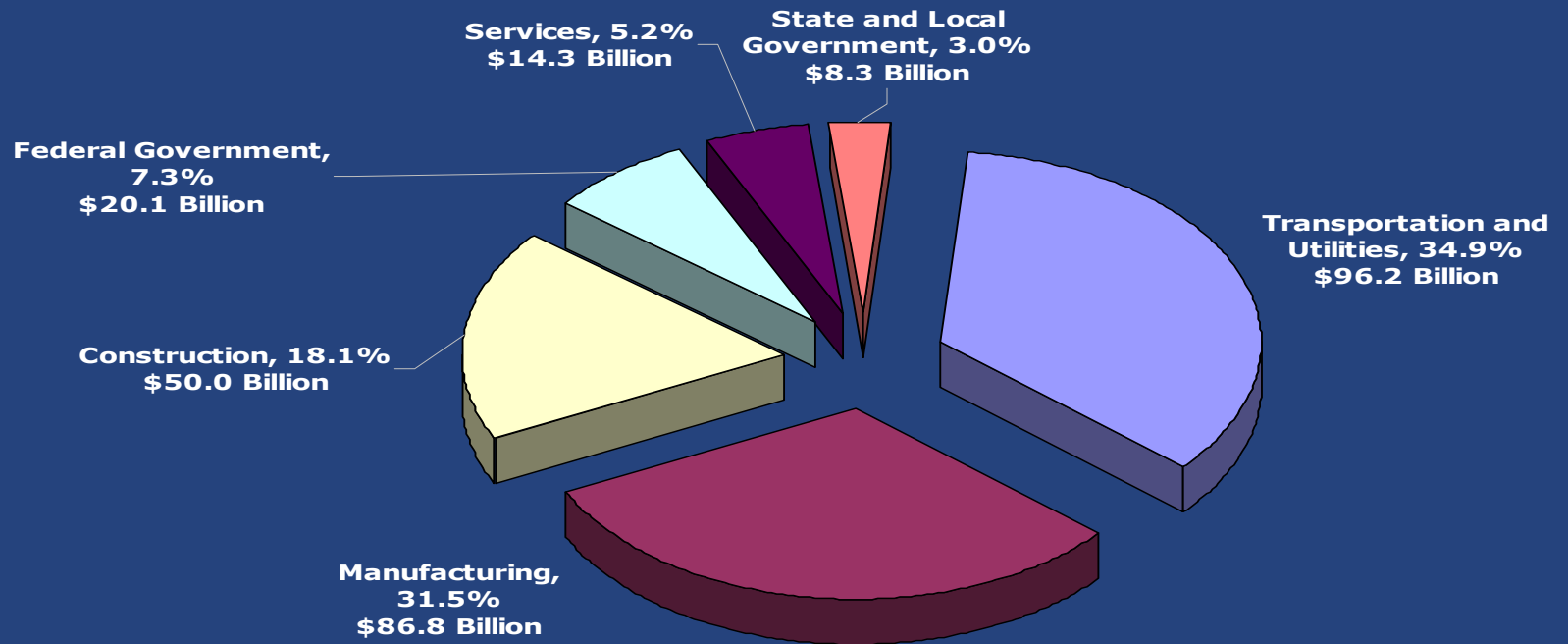




AIRCRAFT ACCIDENT REPORT  
ALOHA AIRLINES, FLIGHT 243  
BOEING 737-200, N7371I,  
NEAR MAUI, HAWAII  
APRIL 28, 1988



## Extrapolated Corrosion Costs: \$276 Billion, 3.1% of GDP



## Non-Technical Preventive Strategies

- Increase awareness of the widespread effects of corrosion
- Build awareness of the huge cost associated with corrosion
- Build awareness of potential savings
- Change the misconception that nothing can be done about corrosion
- Change policies, regulations, standards, and management practices to increase corrosion savings
- Improve education and training of staff





## Technical Preventive Strategies

- Advance design practices for better corrosion management
- Advance life prediction and performance assessment methods
- Advance corrosion technology through:
  - Research
  - Development
  - Implementation

Recognize the commonality of the problem regardless of the structure; but also that corrosion may manifest itself differently in each application.



# Aboveground and Underground Storage Tanks and Associated Piping Systems



# Impact of Corrosion

8.5 million tanks in the U.S. (regulated and non-regulated)

\$ 4.5 Billion Cost to AST

\$ 2.5 Billion Cost to UST

Total Cost of \$7 Billion annual cost

Corrosion is one of the leading causes of storage tank and piping failures



# Corrosion Control Regulations

- By the Oil Pollution Act of 1990:
  - The owner must have a Spill Response Plan
  - The owner must put in place measures, practices, etc. to limit the possibility of releases based upon industry accepted sound engineering practice in design, operation, and maintenance of the facility
  - The reg. does not regulate corrosion control, but does say prevent release.
- 1998 EPA Regulation for UST – Requires that all tanks to have corrosion control, as well as overflow and spill protection



# Corrosion Control Regulations

## Spill Prevention Control and Countermeasure (SPCC) Regulation

- *Provide buried piping that is installed or replaced after August 16th, 2002 with a protective coating and cathodic protection.*
- *Should a section of line be exposed for any reason it must be inspected for deterioration. If corrosion damage is found you must take additional examination and corrective action.*





# NACE Standards

NACE has either developed or is in the process of developing standards to address Tank and Pipeline integrity:

- RP0169-2002, Control of External Corrosion on Underground or Submerged Metallic Piping Systems
- TM0101-2001, Measurement Techniques Related to Criteria for Cathodic Protection
- RP0193-2001, External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms



## NACE Standards (con.)

- RP0285-2002, Corrosion Control of Underground Storage Tank Systems by Cathodic Protection
- TM0497-2002, Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems



# API Standards

- API 570 Piping Inspection Code
- API 651 Cathodic Protection of Aboveground Petroleum Storage Tanks
- API 652 Lining of Aboveground Petroleum Storage Tanks Bottoms
- API 653 Tank Inspection, Repair, Alteration, and Reconstruction
- API 1632 Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems



## NACE International – The Corrosion Society

Thank You!





# **Corrosion Control & Cathodic Protection for Storage Tanks and Piping Systems**

***Presented by:  
James T. Lary  
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1090 Enterprise Drive  
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330-723-5082***



# **What we will cover....**

- **Causes of Corrosion**
- **Regulatory Issues (State/Federal)**
- **Cathodic Protection for Tanks and Piping**
- **Operation & Maintenance**



# API Definition

**1.2.1 An aboveground storage tank is a stationary container of greater than 500 barrel capacity, usually cylindrical in shape, consisting of a metallic roof, shell, bottom, and support structure where more than 90% of the tank surface is above grade**

# **AST Storing**

- Gasoline**
- Diesel**
- Kerosene**
- Aviation Fuel**
- Fuel Oil**
- Hazardous Material/Chemicals**

# **Spill Prevention Control and Countermeasure (SPCC) Regulation (Implementation Required by 8/16/06)**

- Provide buried piping that is installed or replaced after August 16th, 2002 with a protective coating and cathodic protection.*
- Should a section of line be exposed for any reason it must be inspected for deterioration. If corrosion damage is found you must take additional examination and corrective action.*

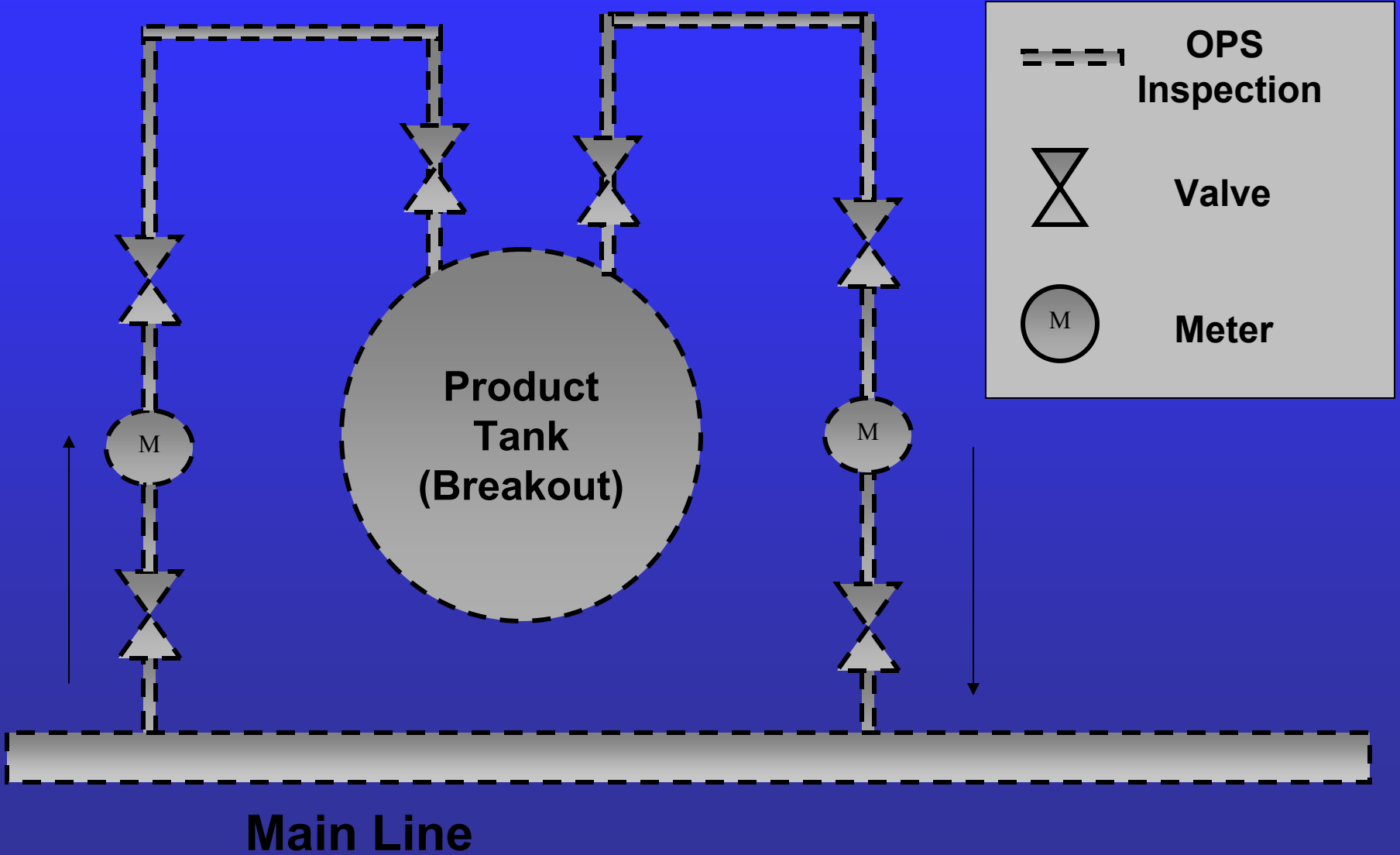
# **Spill Prevention Control and Countermeasure (SPCC) Regulation (Implementation Required by 2/18/05 )**

- Provide buried piping that is installed or replaced after August 16th, 2002 with a protective coating and cathodic protection.*
- Should a section of line be exposed for any reason it must be inspected for deterioration. If corrosion damage is found you must take additional examination and corrective action.*

# **Federal Level (Breakout Tanks)**

***a) Relieves surges in a hazardous liquid pipeline system or b) receive and store hazardous liquid transported by a pipeline for reinjection and continued transportation by pipeline***

# Breakout Tank





# State Level

- **Approximately 25% of States now require cathodic protection be installed and maintained on new, refurbished, or repaired tanks in contact with soil or sand foundations.**
- **A number of other states are in the process of implementing regulations governing AST's.**



# **Why is Cathodic Protection Important?**

- **Preserve Assets**
- **Reduce Maintenance Costs**
- **Reduce Inspection Cost**
- **Company/Government Requirement**
- **Preserve The Environment**



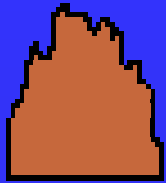
# Corrosion Can be Defined as Either:

## ▶ Practical

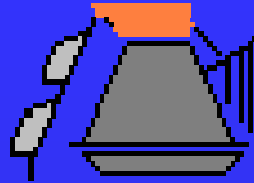
Tendency of a Metal to Revert to its Native State

## ▶ Scientific

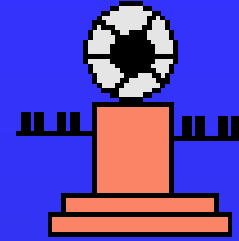
Electrochemical Degradation of Metal as a Result of a Reaction with its Environment



IRON OXIDE



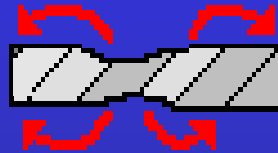
REFINING



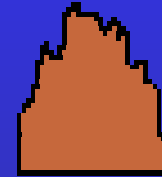
MILLING



STEEL



CORROSION

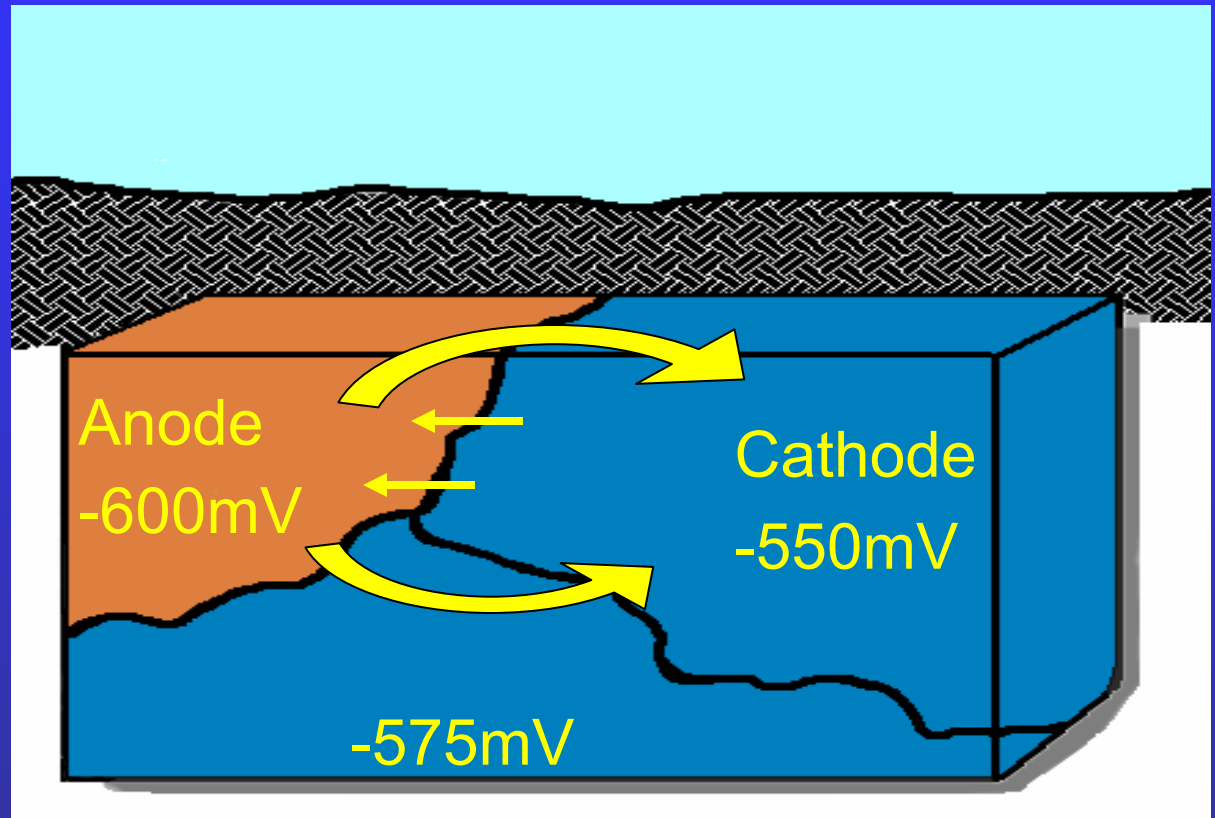


IRON OXIDE

***THE PROBLEM.....***

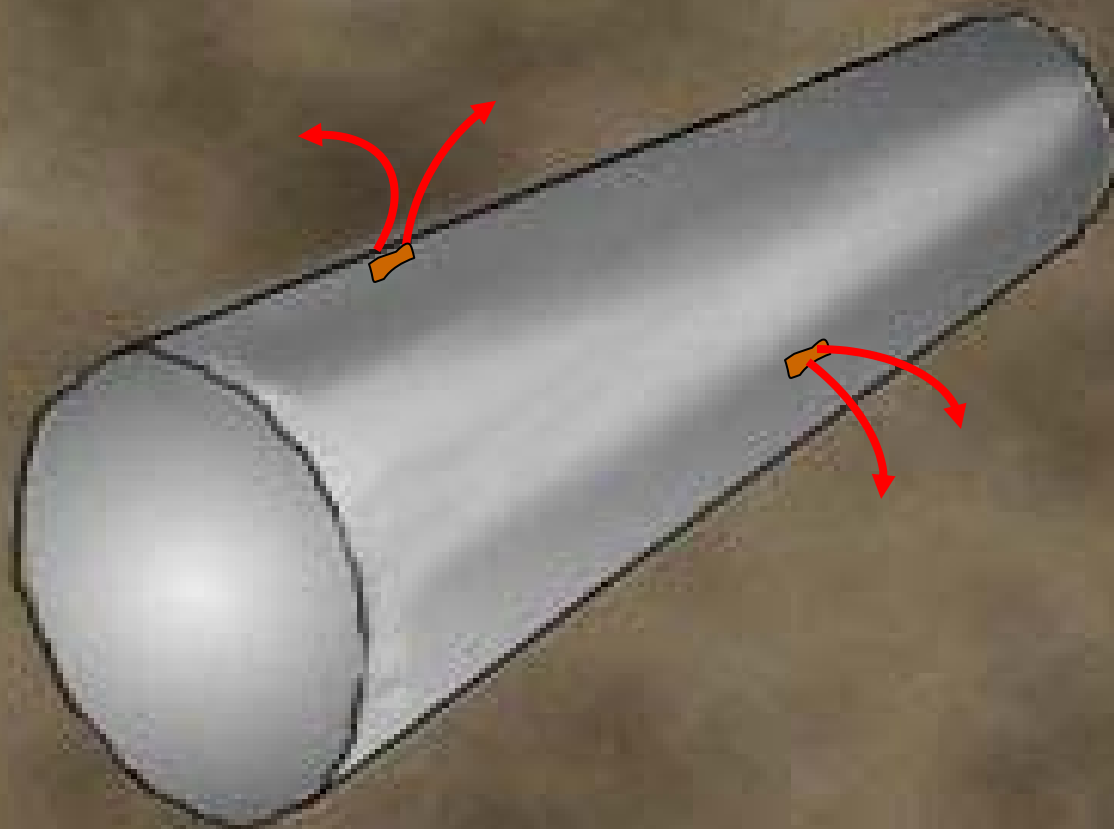


- 1) ANODE
- 2) CATHODE
- 3) ELECTROLYTE
- 4) ELECTRICAL CONNECTION



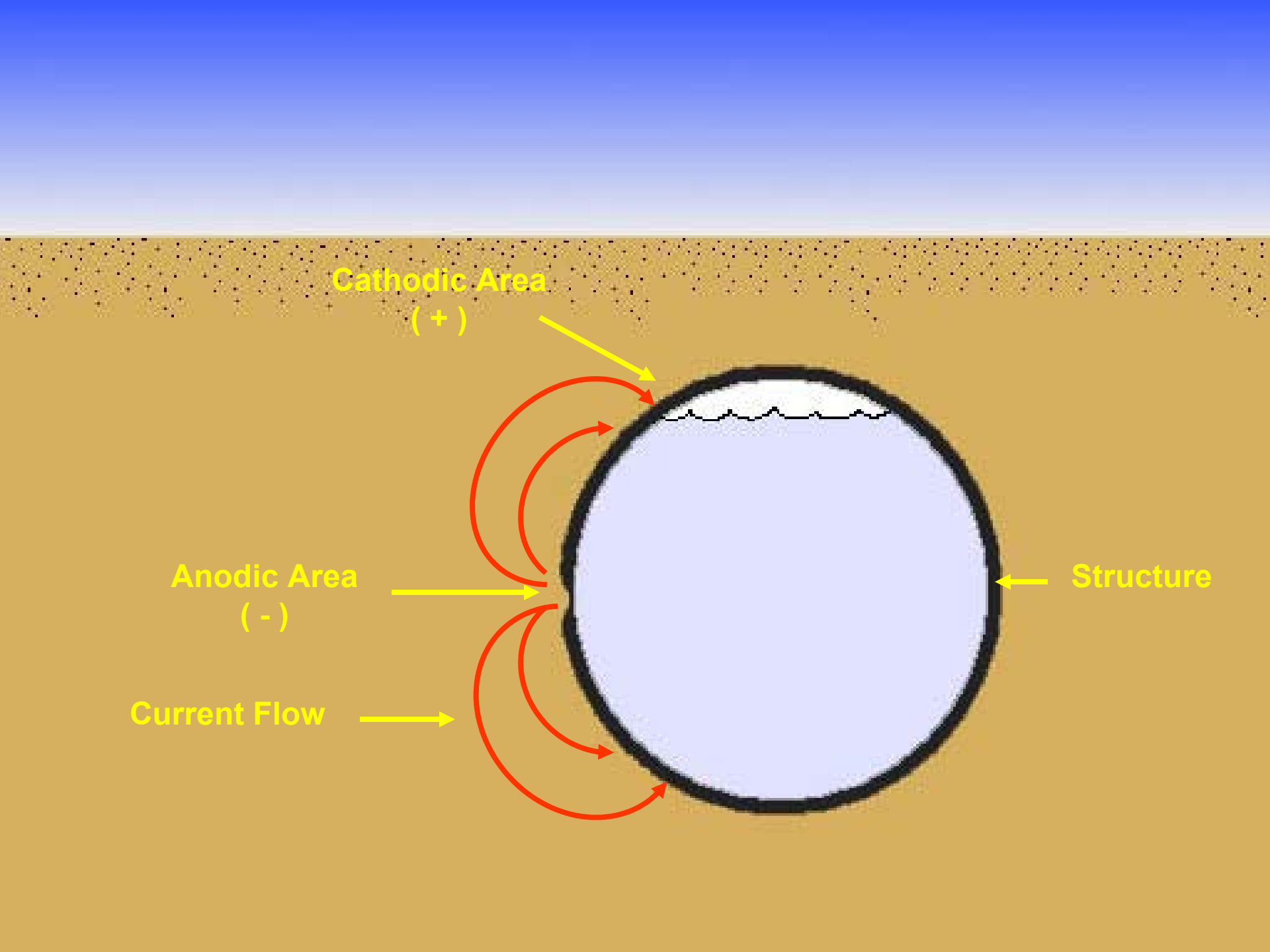


# Corrosion of Metallic Structure









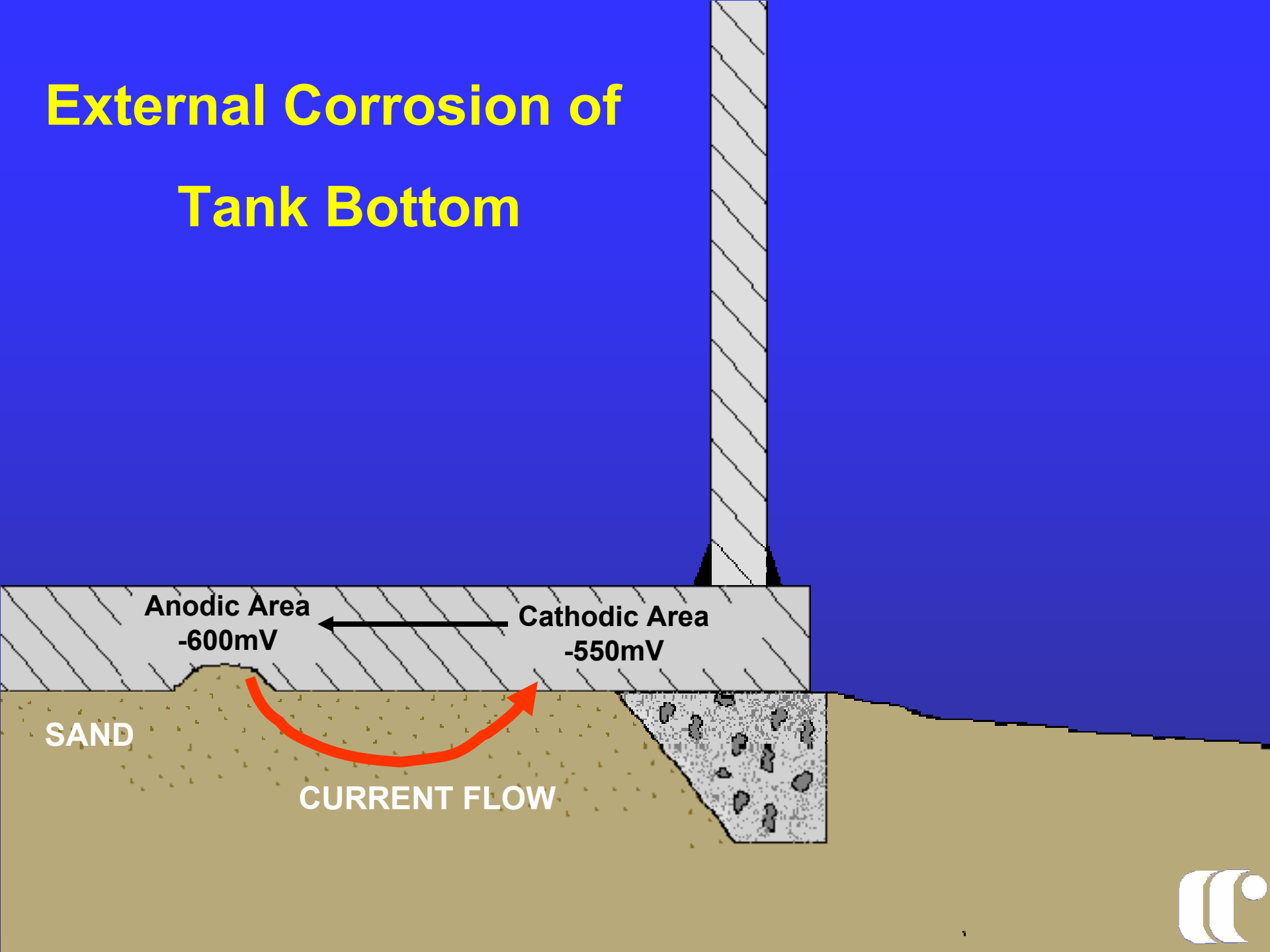
**Cathodic Area**  
(+)

**Anodic Area**  
(-)

**Current Flow**

**Structure**

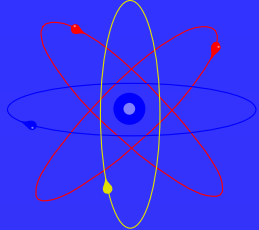
# External Corrosion of Tank Bottom











# 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 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

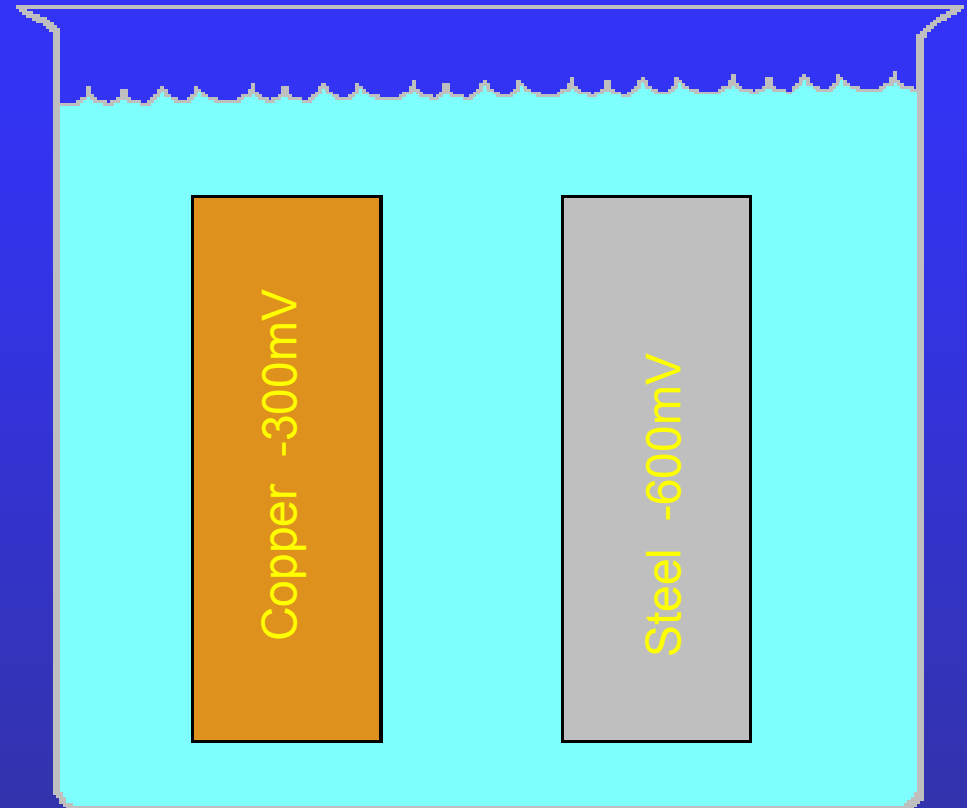
\* Potentials With Respect to Saturated Cu-CuSO<sub>4</sub> Electrode

1) ANODE

2) CATHODE

3) ELECTROLYTE

4) ELECTRICAL  
CONNECTION

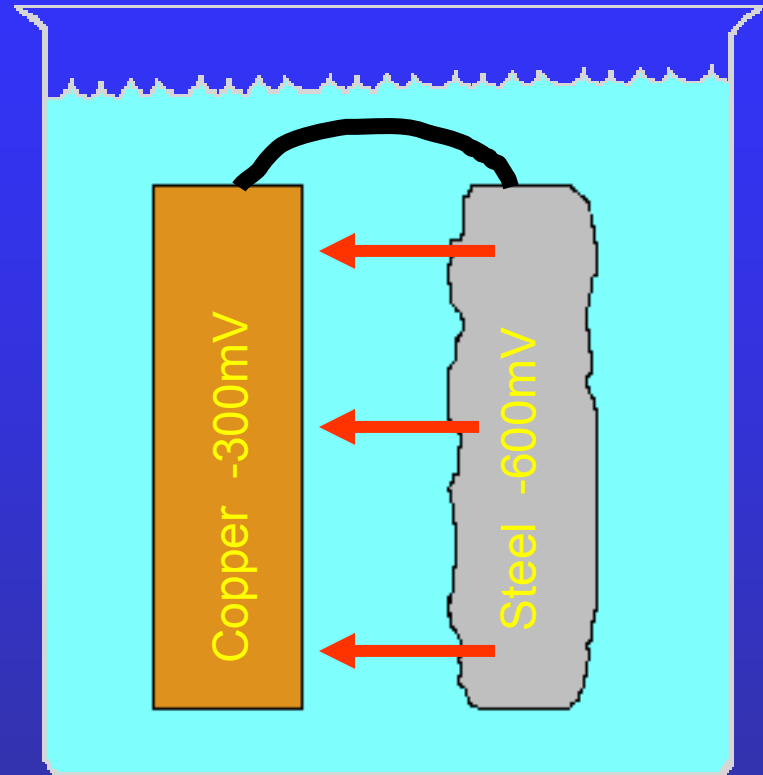


1) ANODE

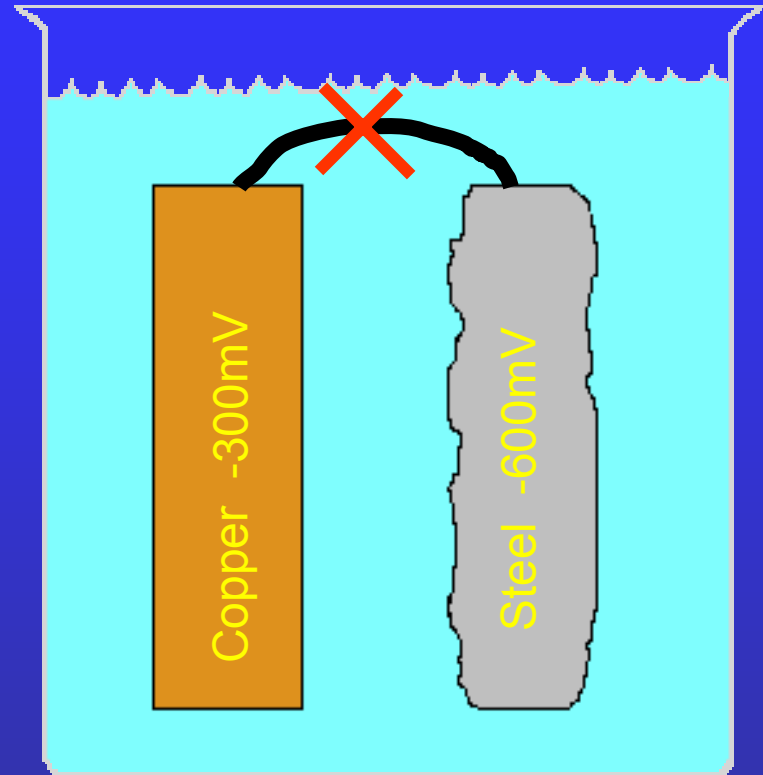
2) CATHODE

3) ELECTROLYTE

4) ELECTRICAL  
CONNECTION



- 1) ANODE
- 2) CATHODE
- 3) ELECTROLYTE
- 4) ELECTRICAL CONNECTION

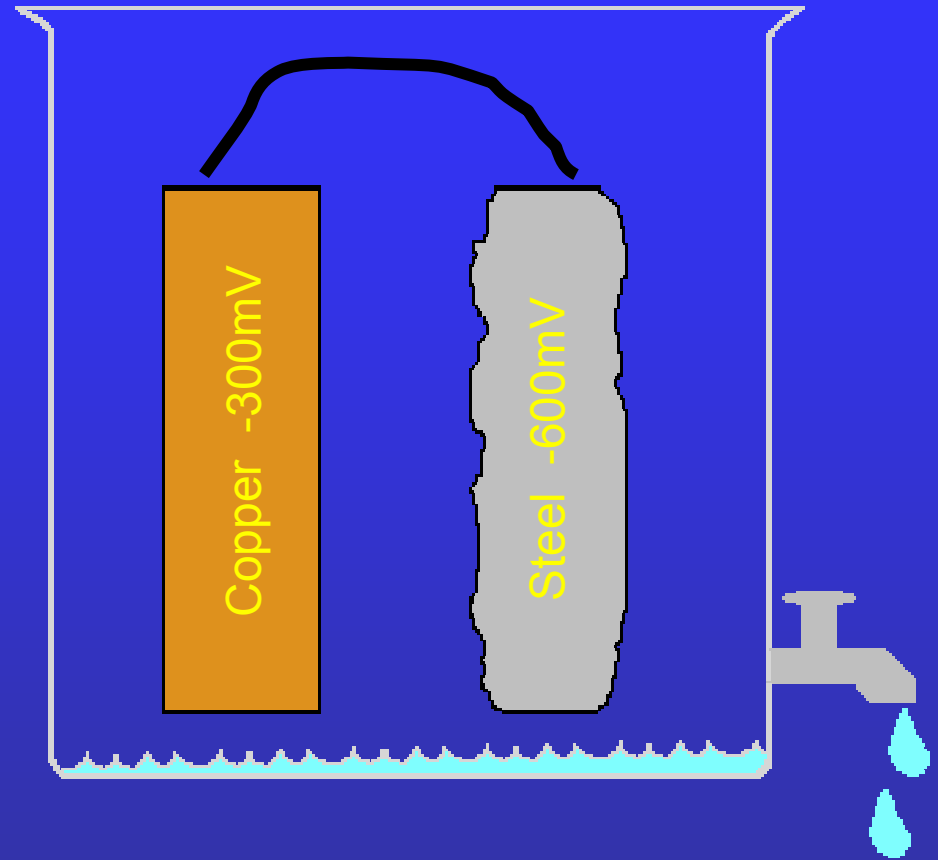


1) ANODE

2) CATHODE

3) ELECTROLYTE

4) ELECTRICAL  
CONNECTION

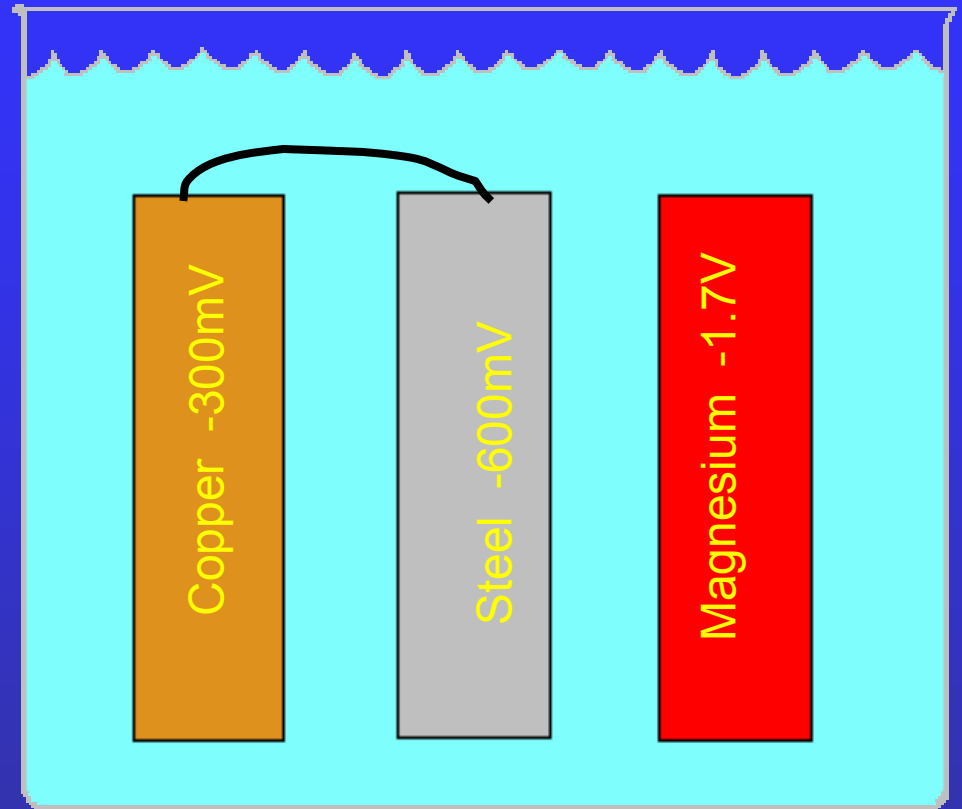


1) ANODE

2) CATHODE

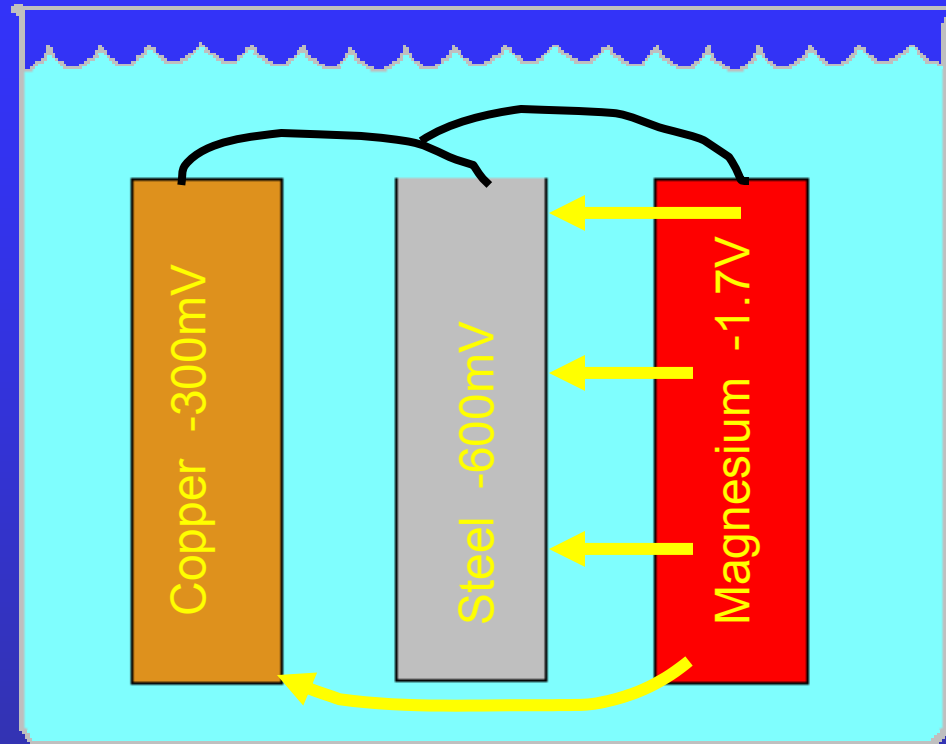
3) ELECTROLYTE

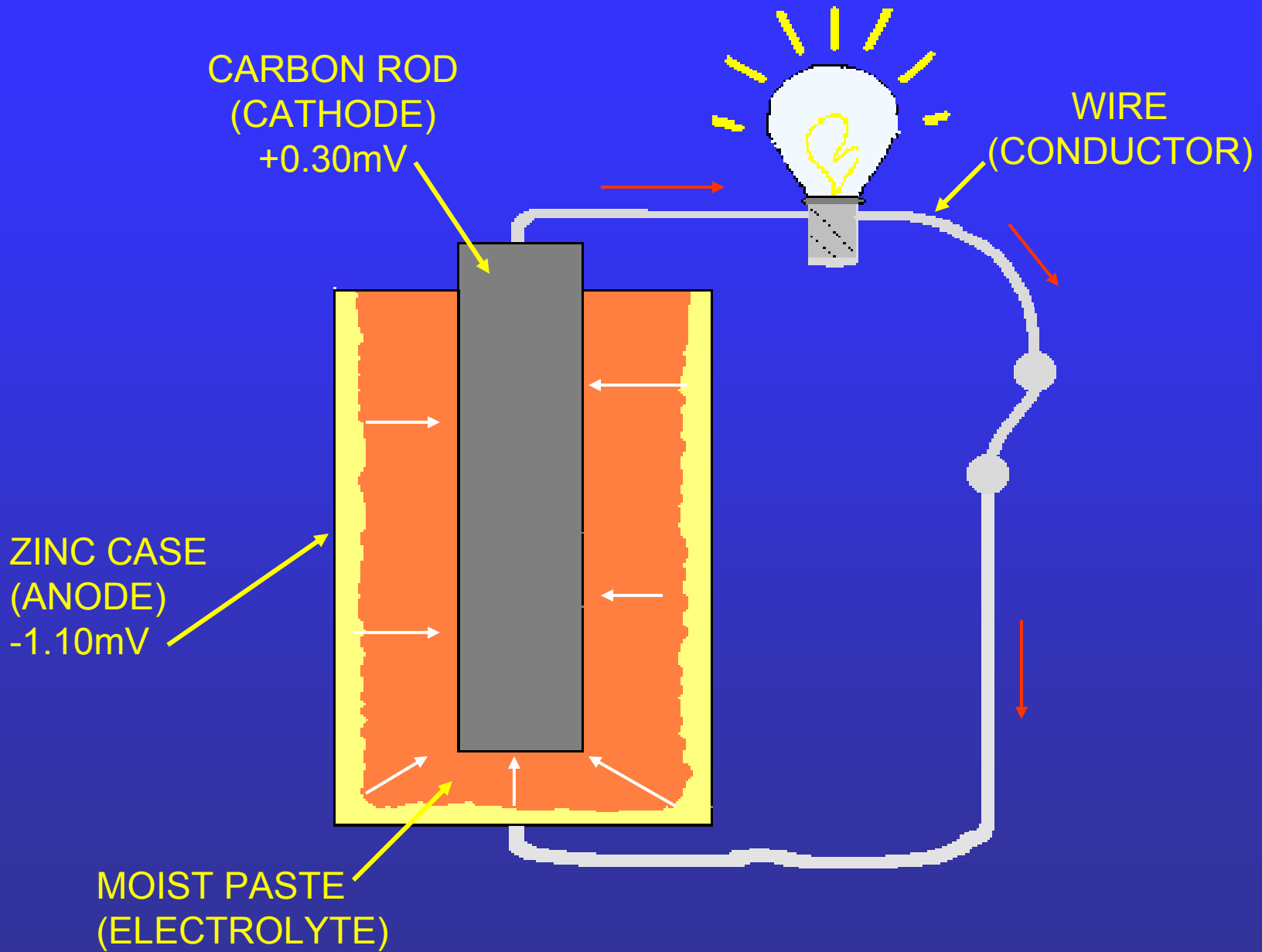
4) ELECTRICAL  
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- 1) ANODE
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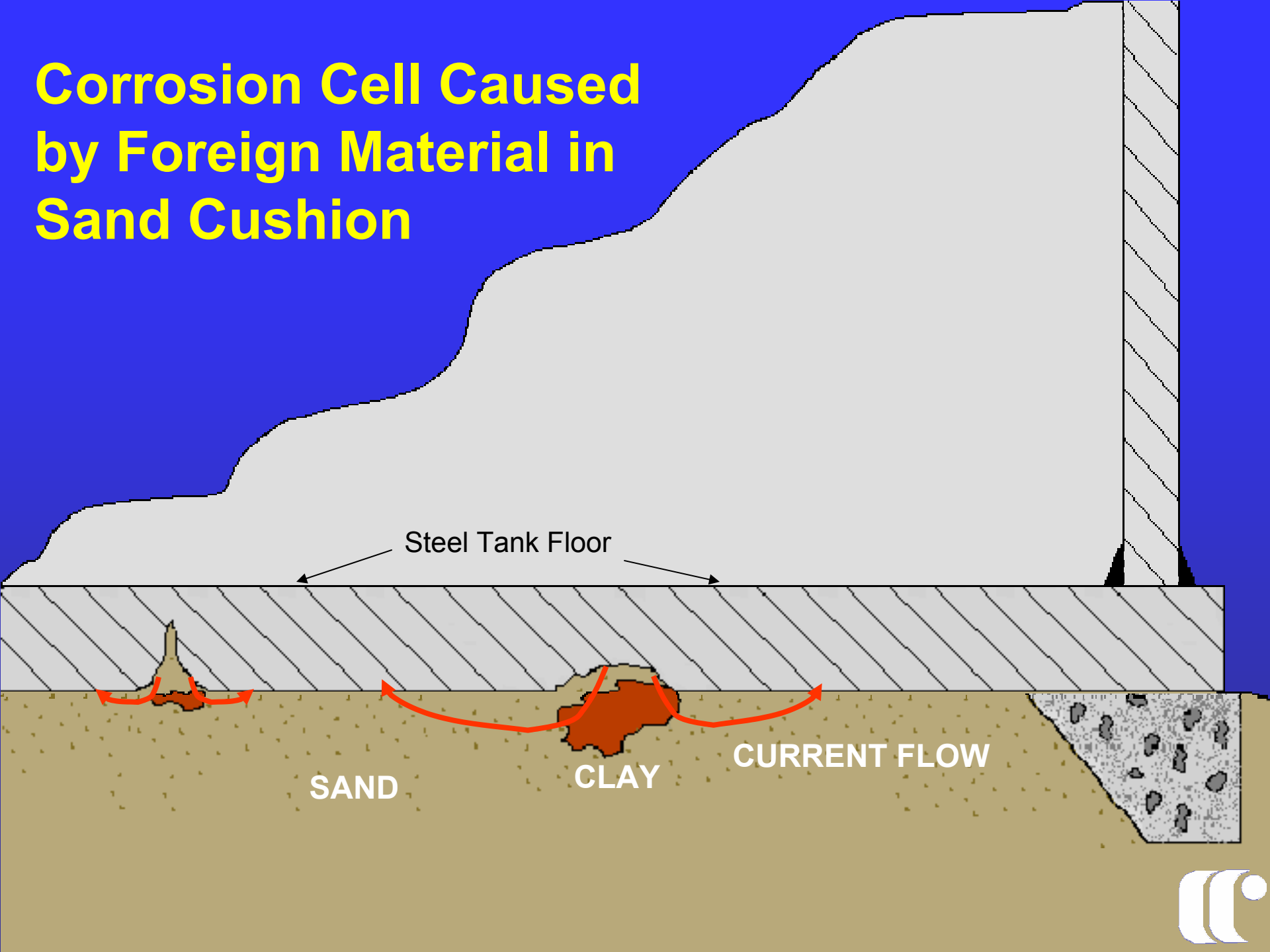


# Piping Installation





# Corrosion Cell Caused by Foreign Material in Sand Cushion



Steel Tank Floor

SAND

CLAY

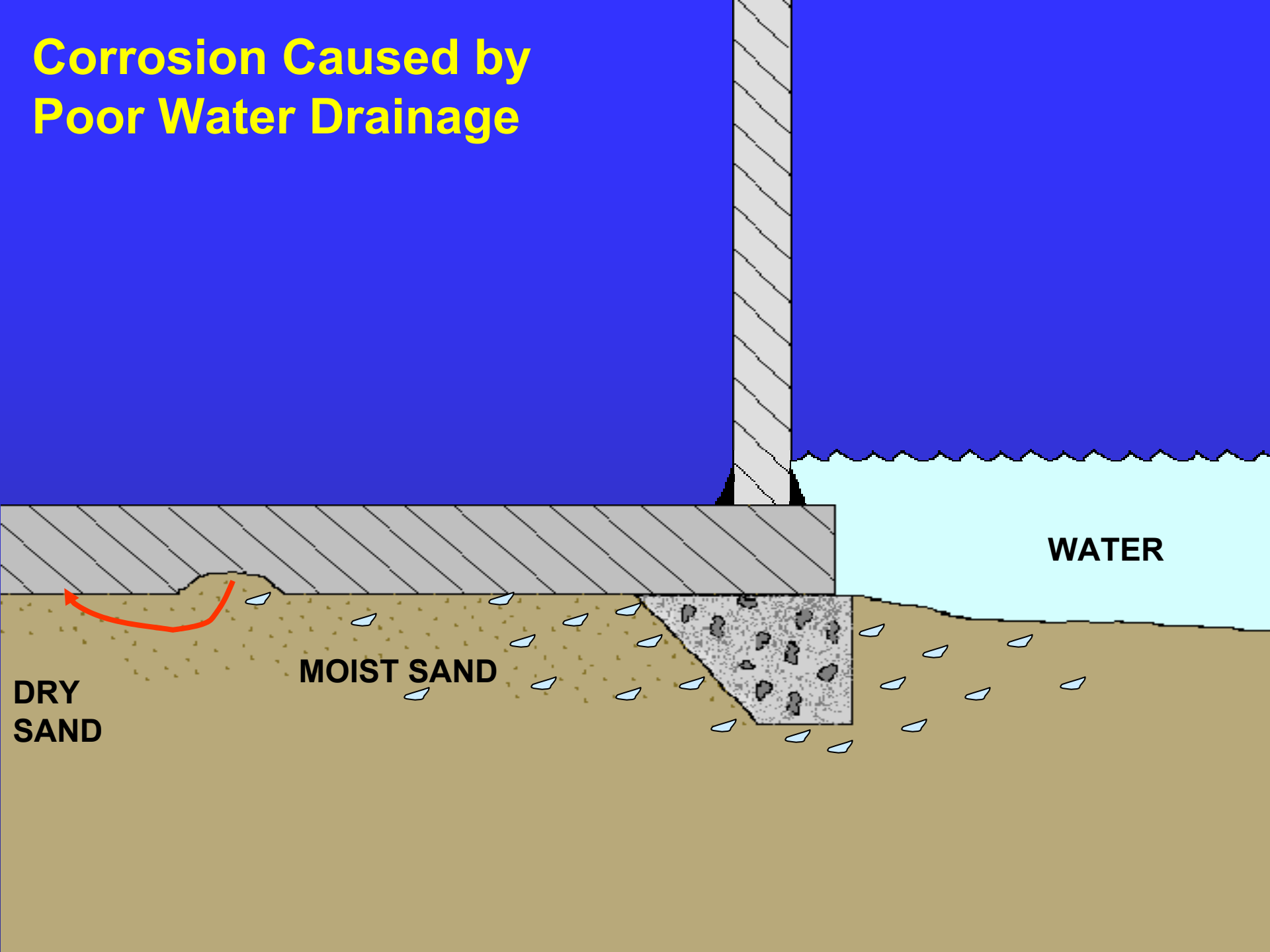
CURRENT FLOW







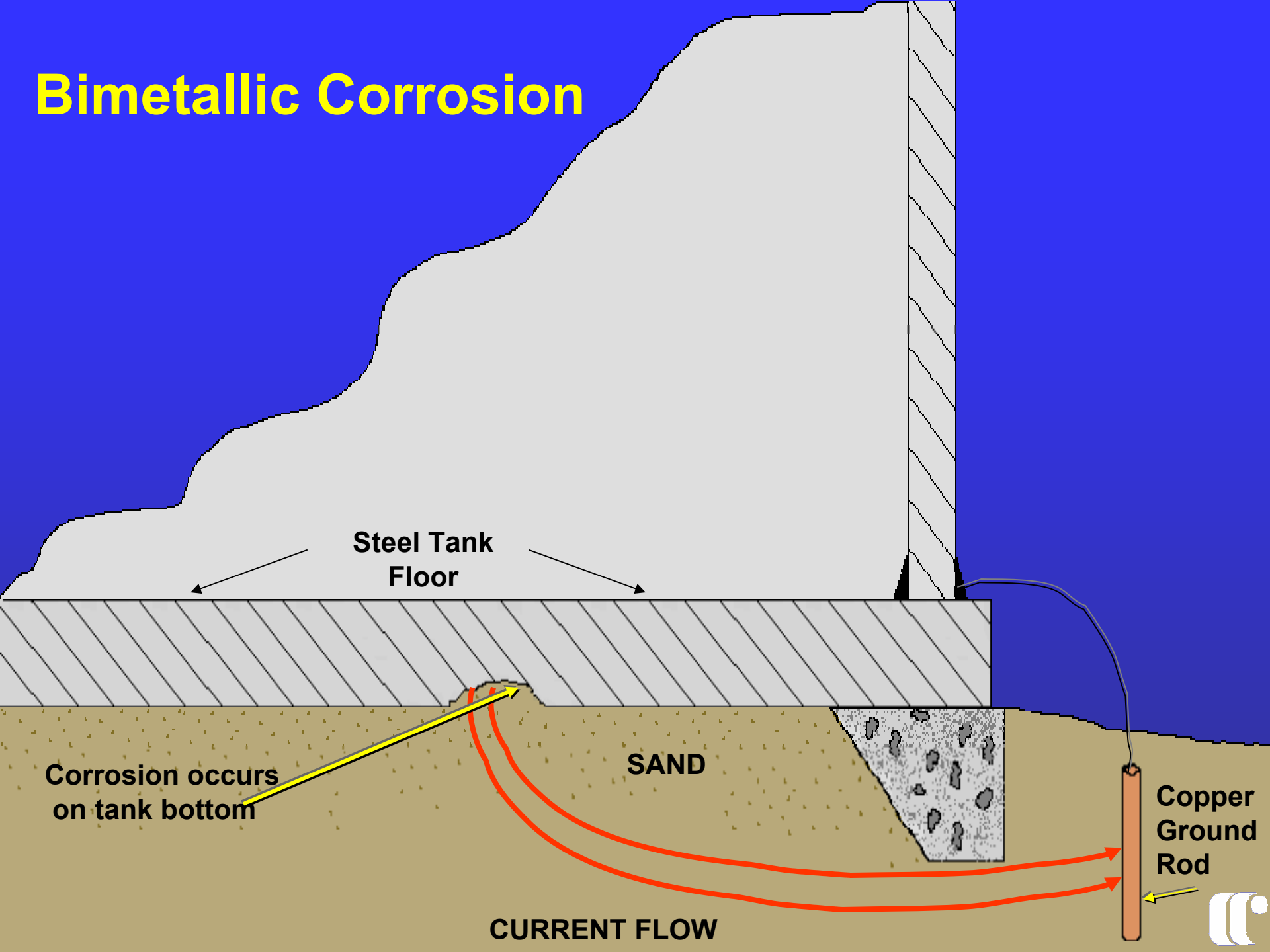
# Corrosion Caused by Poor Water Drainage







# Bimetallic Corrosion



Steel Tank Floor

Corrosion occurs on tank bottom

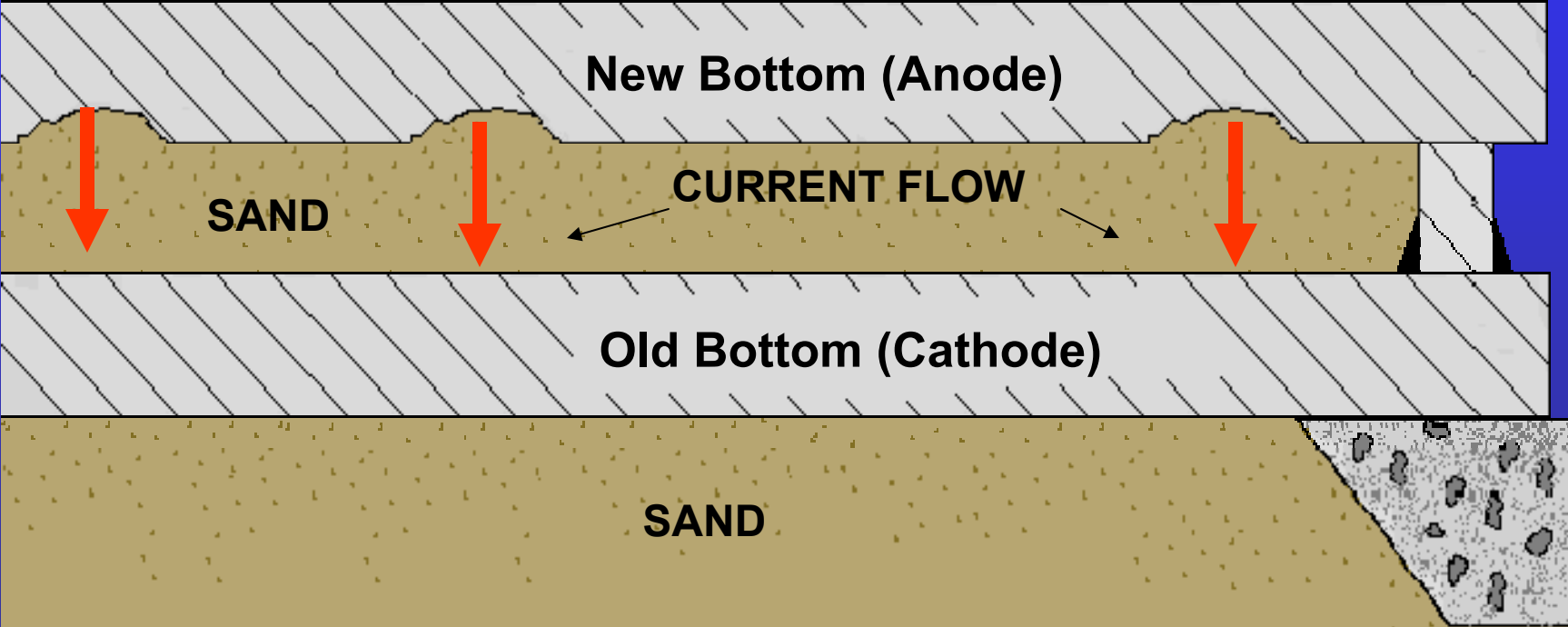
SAND

CURRENT FLOW

Copper Ground Rod



# New Steel Coupled to Old Steel



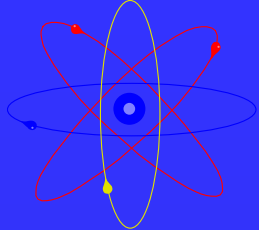
# Types of Cathodic Protection

*Galvanic*: *Current obtained from a metal with a higher energy level.*

*Impressed Current*: *Requires external power source (transformer rectifier).*

# Galvanic Anode Cathodic Protection

- ▶ Current is obtained from a metal of a higher energy level



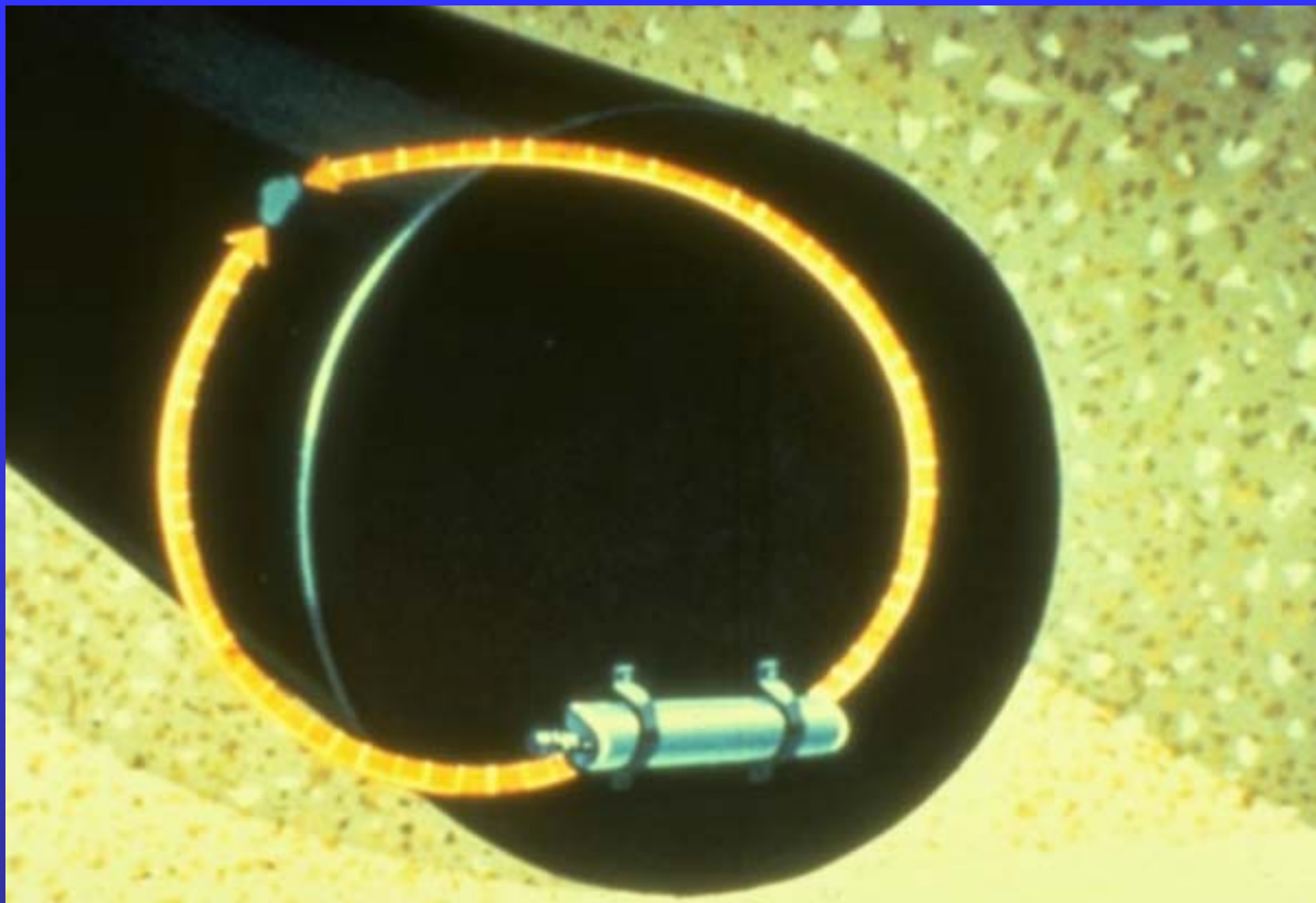
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Stainless Steel	-0.50 to + 0.10
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\* Potentials With Respect to Saturated Cu-CuSO<sub>4</sub> Electrode

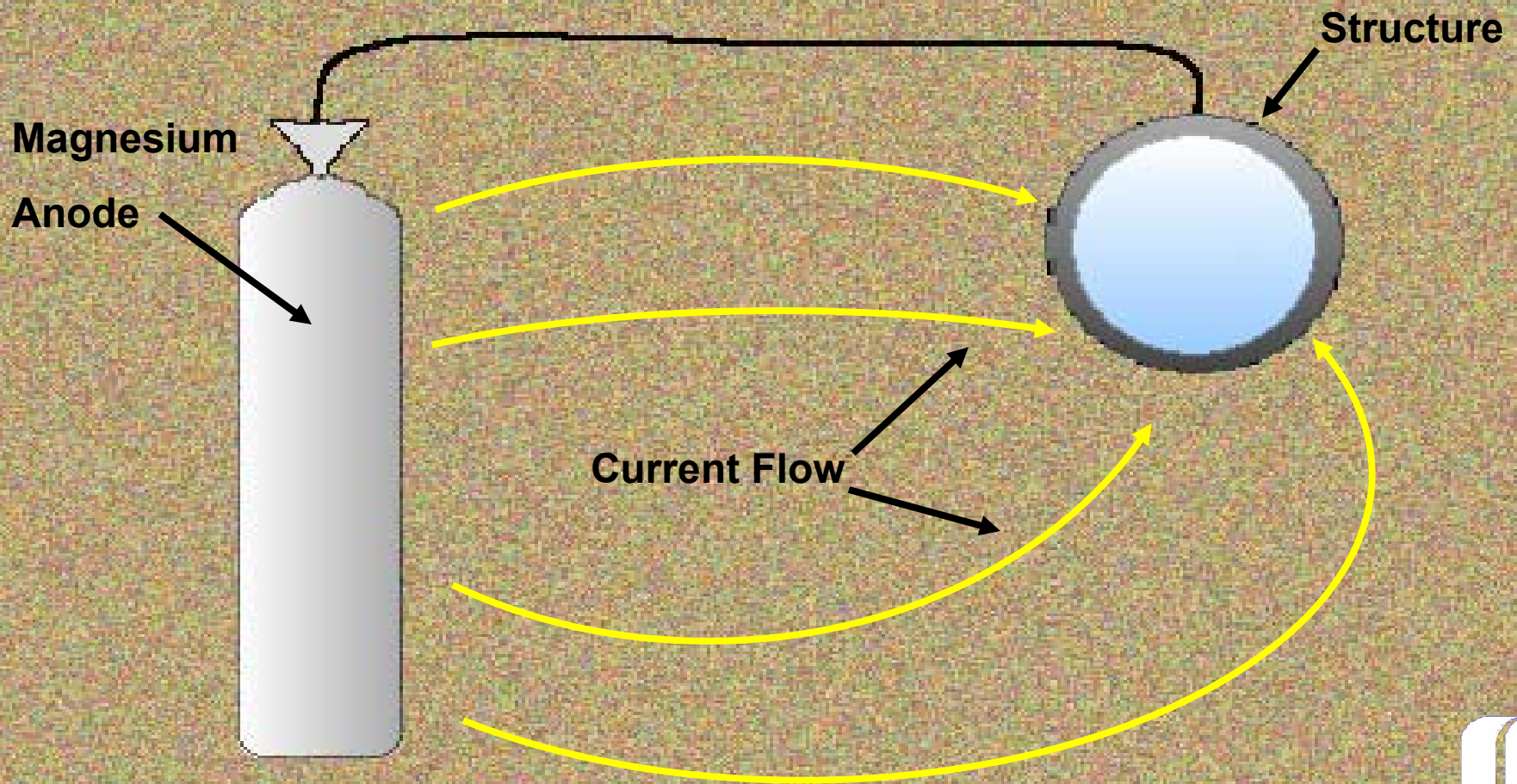




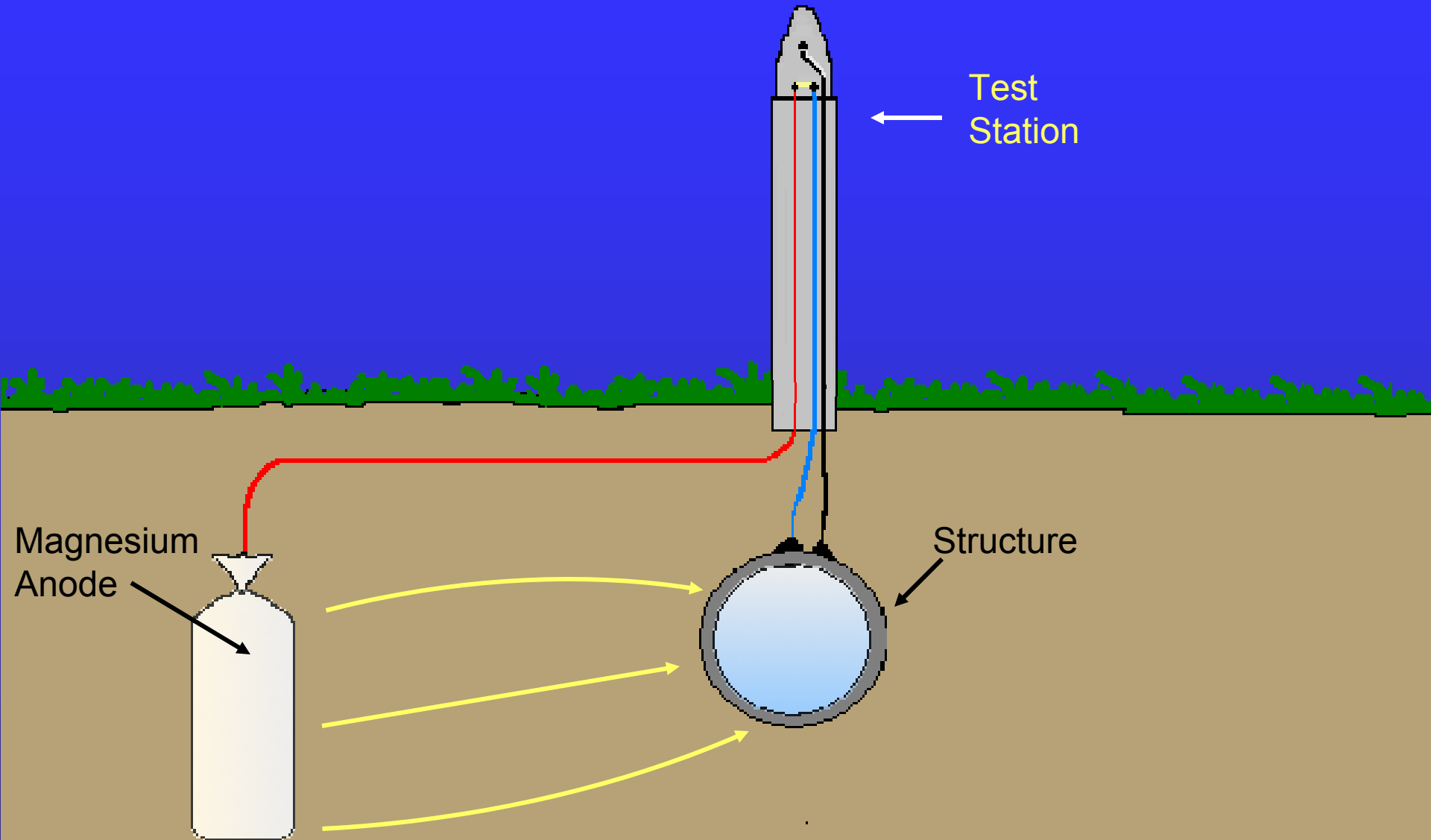




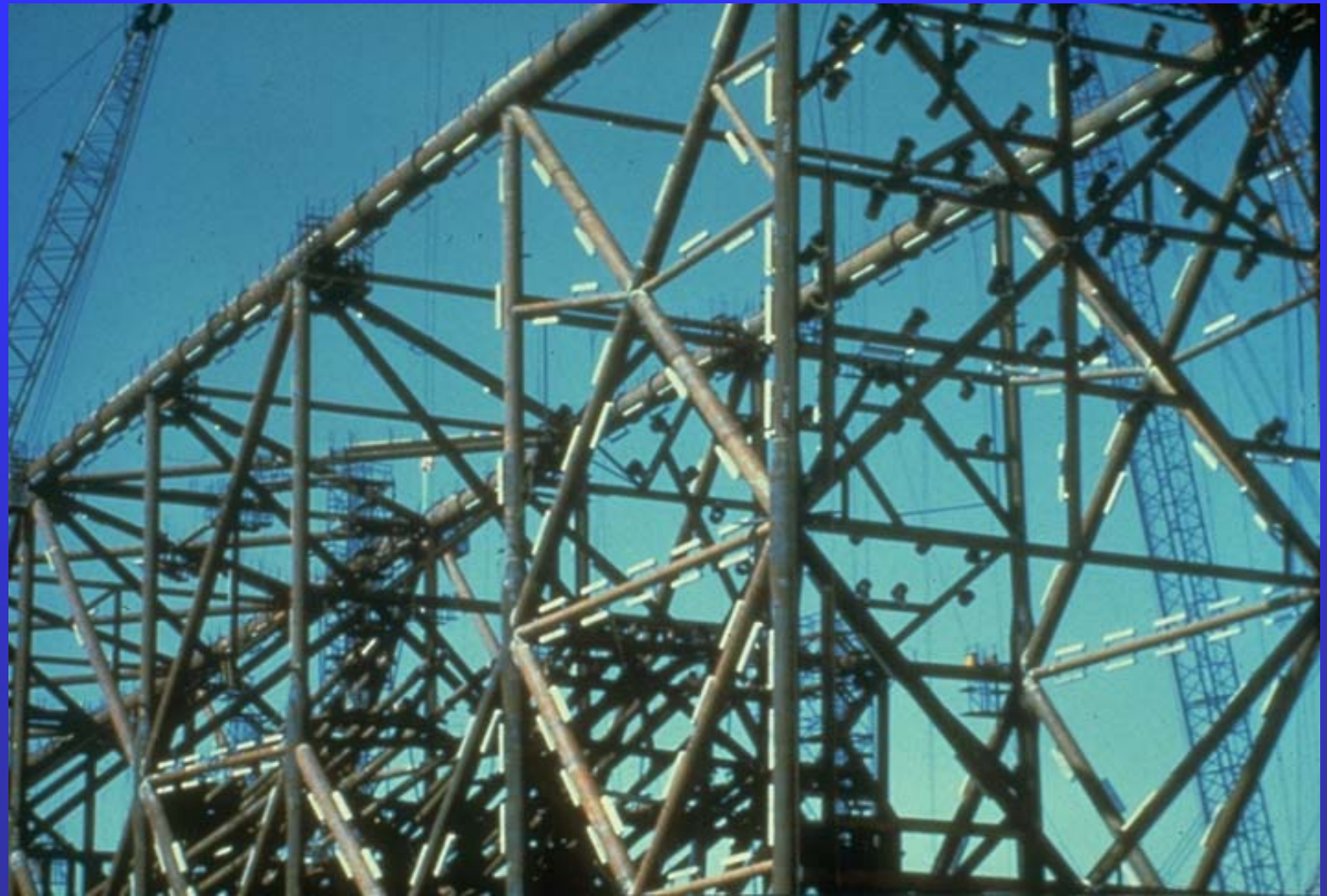
# Galvanic Cathodic Protection



# Cathodic Protection Test Station







# ✓ KENMORE Gas Water Heaters

It's their performance and dependability that keep you in hot water...  
check their features, check the facts!

- ✓ **Warranty...**our 5 to 10-year limited warranties convey our confidence in Kenmore quality and longevity
- ✓ **Polyurethane foam or fiber glass insulation** resists heat loss and helps save energy. Polyurethane insulation provides 175% greater heating insulation than fiber glass
- ✓ **Anode rods help protect water tank from internal corrosion and premature tank failure**
- ✓ **Energy cut-off automatically shuts off power supply** if thermostat fails; prevents overheating
- ✓ **Adjustable thermostat keeps your hot water at pre-selected levels.** "low" setting lets you save energy while you're away
- ✓ **Porcelain glass lining in our steel tanks helps prevent rust to extend tank life and helps maintain hot water supply**



## Power Miser 10 High Performance

- ✓ Tank has limited 10-year warranty against leaks
- ✓ Roto-Swirl™ cold water inlet tube swirls water to help prevent mineral build-up at bottom of tank... extends tank life
- ✓ Porcelain glass lining and 2 anode rods help fight rust and corrosion
- ✓ Fastest hot water recovery rate of any gas unit we sell
- ✓ Natural gas only

**\$349<sup>99</sup>** and up  
\$14 MONTHLY



## Power Miser 8

- ✓ Tank has limited 8-year warranty against leaks
- ✓ 1-inch polyurethane foam insulation (R-value 8.33)
- ✓ Roto-Swirl™ cold water inlet tube swirls water to help prevent mineral build-up at bottom of tank... extends tank life
- ✓ Natural or LP gas

**\$239<sup>99</sup>** and up  
\$11 MONTHLY

Money-saving coupon  
See us to clip  
and show our  
coupon on p. 35A

† Treat it high gas bills? Fight back with our finest gas water heater. It has a recovery efficiency of over 80% thanks to its unique combustion chamber and air intake design. The polyurethane foam insulation retains heat 2½ times longer than standard fiberglass insulation plus heat trap applied on cold and hot water inlet connections help to lower fuel bills. Adjustable gas control automatically maintains temperature you select. High temperature safety shut-off. Drain valve. Requires 3 or 4-inch vent. Design certified by the American Gas Association. 10-year limited warranty against tank leaks. Warranted by Sears. Write for free copy. See page 325A. Not for mobile homes.

Tank No.	Capacity in gals.	Height in inches	Width in inches	Blow-in insulation (R-value)	Recovery in gals. per hr. at 107°F. rise	Category Number	Shipping wt. lbs.	Price
31107-36	36	48	18	11.5	175	31107-36	100	\$210
31147-48	48	54	24	11.5	225	31147-48	120	\$240
31217-36	36	48	18	11.5	175	31217-36	100	\$210
31247-48	48	54	24	11.5	225	31247-48	120	\$240
31267-36	36	48	18	11.5	175	31267-36	100	\$210
31267-48	48	54	24	11.5	225	31267-48	120	\$240
31267-60	60	60	30	11.5	270	31267-60	150	\$270
31267-72	72	72	36	11.5	324	31267-72	180	\$324
31267-84	84	84	42	11.5	378	31267-84	210	\$378
31267-96	96	96	48	11.5	432	31267-96	240	\$432
31267-108	108	108	54	11.5	486	31267-108	270	\$486
31267-120	120	120	60	11.5	540	31267-120	300	\$540
31267-132	132	132	66	11.5	594	31267-132	330	\$594
31267-144	144	144	72	11.5	648	31267-144	360	\$648
31267-156	156	156	78	11.5	702	31267-156	390	\$702
31267-168	168	168	84	11.5	756	31267-168	420	\$756
31267-180	180	180	90	11.5	810	31267-180	450	\$810
31267-192	192	192	96	11.5	864	31267-192	480	\$864
31267-204	204	204	102	11.5	918	31267-204	510	\$918
31267-216	216	216	108	11.5	972	31267-216	540	\$972
31267-228	228	228	114	11.5	1026	31267-228	570	\$1026
31267-240	240	240	120	11.5	1080	31267-240	600	\$1080
31267-252	252	252	126	11.5	1134	31267-252	630	\$1134
31267-264	264	264	132	11.5	1188	31267-264	660	\$1188
31267-276	276	276	138	11.5	1242	31267-276	690	\$1242
31267-288	288	288	144	11.5	1296	31267-288	720	\$1296
31267-300	300	300	150	11.5	1350	31267-300	750	\$1350
31267-312	312	312	156	11.5	1404	31267-312	780	\$1404
31267-324	324	324	162	11.5	1458	31267-324	810	\$1458
31267-336	336	336	168	11.5	1512	31267-336	840	\$1512
31267-348	348	348	174	11.5	1566	31267-348	870	\$1566
31267-360	360	360	180	11.5	1620	31267-360	900	\$1620
31267-372	372	372	186	11.5	1674	31267-372	930	\$1674
31267-384	384	384	192	11.5	1728	31267-384	960	\$1728
31267-396	396	396	198	11.5	1782	31267-396	990	\$1782
31267-408	408	408	204	11.5	1836	31267-408	1020	\$1836
31267-420	420	420	210	11.5	1890	31267-420	1050	\$1890
31267-432	432	432	216	11.5	1944	31267-432	1080	\$1944
31267-444	444	444	222	11.5	1998	31267-444	1110	\$1998
31267-456	456	456	228	11.5	2052	31267-456	1140	\$2052
31267-468	468	468	234	11.5	2106	31267-468	1170	\$2106
31267-480	480	480	240	11.5	2160	31267-480	1200	\$2160
31267-492	492	492	246	11.5	2214	31267-492	1230	\$2214
31267-504	504	504	252	11.5	2268	31267-504	1260	\$2268
31267-516	516	516	258	11.5	2322	31267-516	1290	\$2322
31267-528	528	528	264	11.5	2376	31267-528	1320	\$2376
31267-540	540	540	270	11.5	2430	31267-540	1350	\$2430
31267-552	552	552	276	11.5	2484	31267-552	1380	\$2484
31267-564	564	564	282	11.5	2538	31267-564	1410	\$2538
31267-576	576	576	288	11.5	2592	31267-576	1440	\$2592
31267-588	588	588	294	11.5	2646	31267-588	1470	\$2646
31267-600	600	600	300	11.5	2700	31267-600	1500	\$2700

Order water valve at \$ 384. For all except Greenhouse area and North Carolina points.  
 † Allow about 18 inches for clearance. Storage cabinet and venting clearance.  
 ‡ Maximum run should slope up 1/8 inch per foot.

Estimated annual energy costs based on U.S. Dept. of Energy test procedures and 1983 national average utility rates.

Category Number	Capacity in gals.	Height in inches	Width in inches	Blow-in insulation (R-value)	Recovery in gals. per hr. at 107°F. rise	Category Number	Capacity in gals.	Height in inches	Width in inches	Blow-in insulation (R-value)	Recovery in gals. per hr. at 107°F. rise
31107-36	36	48	18	11.5	175	31217-36	36	48	18	11.5	175
31147-48	48	54	24	11.5	225	31247-48	48	54	24	11.5	225
31217-36	36	48	18	11.5	175	31267-36	36	48	18	11.5	175
31247-48	48	54	24	11.5	225	31267-48	48	54	24	11.5	225
31267-36	36	48	18	11.5	175	31267-36	36	48	18	11.5	175
31267-48	48	54	24	11.5	225	31267-48	48	54	24	11.5	225
31267-60	60	60	30	11.5	270	31267-60	60	60	30	11.5	270
31267-72	72	72	36	11.5	324	31267-72	72	72	36	11.5	324
31267-84	84	84	42	11.5	378	31267-84	84	84	42	11.5	378
31267-96	96	96	48	11.5	432	31267-96	96	96	48	11.5	432
31267-108	108	108	54	11.5	486	31267-108	108	108	54	11.5	486
31267-120	120	120	60	11.5	540	31267-120	120	120	60	11.5	540
31267-132	132	132	66	11.5	594	31267-132	132	132	66	11.5	594
31267-144	144	144	72	11.5	648	31267-144	144	144	72	11.5	648
31267-156	156	156	78	11.5	702	31267-156	156	156	78	11.5	702
31267-168	168	168	84	11.5	756	31267-168	168	168	84	11.5	756
31267-180	180	180	90	11.5	810	31267-180	180	180	90	11.5	810
31267-192	192	192	96	11.5	864	31267-192	192	192	96	11.5	864
31267-204	204	204	102	11.5	918	31267-204	204	204	102	11.5	918
31267-216	216	216	108	11.5	972	31267-216	216	216	108	11.5	972
31267-228	228	228	114	11.5	1026	31267-228	228	228	114	11.5	1026
31267-240	240	240	120	11.5	1080	31267-240	240	240	120	11.5	1080
31267-252	252	252	126	11.5	1134	31267-252	252	252	126	11.5	1134
31267-264	264	264	132	11.5	1188	31267-264	264	264	132	11.5	1188
31267-276	276	276	138	11.5	1242	31267-276	276	276	138	11.5	1242
31267-288	288	288	144	11.5	1296	31267-288	288	288	144	11.5	1296
31267-300	300	300	150	11.5	1350	31267-300	300	300	150	11.5	1350
31267-312	312	312	156	11.5	1404	31267-312	312	312	156	11.5	1404
31267-324	324	324	162	11.5	1458	31267-324	324	324	162	11.5	1458
31267-336	336	336	168	11.5	1512	31267-336	336	336	168	11.5	1512
31267-348	348	348	174	11.5	1566	31267-348	348	348	174	11.5	1566
31267-360	360	360	180	11.5	1620	31267-360	360	360	180	11.5	1620
31267-372	372	372	186	11.5	1674	31267-372	372	372	186	11.5	1674
31267-384	384	384	192	11.5	1728	31267-384	384	384	192	11.5	1728
31267-396	396	396	198	11.5	1782	31267-396	396	396	198	11.5	1782
31267-408	408	408	204	11.5	1836	31267-408	408	408	204	11.5	1836
31267-420	420	420	210	11.5	1890	31267-420	420	420	210	11.5	1890
31267-432	432	432	216	11.5	1944	31267-432	432	432	216	11.5	1944
31267-444	444	444	222	11.5	1998	31267-444	444	444	222	11.5	1998
31267-456	456	456	228	11.5	2052	31267-456	456	456	228	11.5	2052
31267-468	468	468	234	11.5	2106	31267-468	468	468	234	11.5	2106
31267-480	480	480	240	11.5	2160	31267-480	480	480	240	11.5	2160
312											





**INSULATING UNIONS**



**FLANGE INSULATION KIT**



# ✓ KENMORE Gas Water Heaters

It's their performance and dependability that keep you in hot water...  
check their features, check the facts!

- ✓ Warranty... our 5 to 10-year limited warranties convey our confidence in Kenmore quality and longevity
- ✓ Polyurethane foam or fiber glass insulation resists heat loss and helps save energy. Polyurethane insulation provides 175% greater heating insulation than fiber glass
- ✓ Anode rods help protect water tank from internal corrosion and premature tank failure
- ✓ Energy cut-off automatically shuts off power supply if thermostat fails, prevents overheating
- ✓ Adjustable thermostat keeps your hot water at pre-selected levels, "low" setting lets you save energy while you're away
- ✓ Porcelain glass lining in our steel tanks helps prevent rust to extend tank life and helps maintain hot water supply



### Power Miser 10 High Performance

- ✓ Tank has limited 10-year warranty against leaks
- ✓ Roto-Swirl™ cold water inlet tube swirls water to help prevent mineral build-up at bottom of tank... extends tank life
- ✓ Porcelain glass lining and 2 anode rods help fight rust and corrosion
- ✓ Fastest hot water recovery rate of any gas unit we sell
- ✓ Natural gas only

**\$349<sup>99</sup> and up**  
\$14 MONTHLY



### Power Miser 8

- ✓ Tank has limited 8-year warranty against leaks
- ✓ 1-inch polyurethane foam insulation (R-value 8.33)
- ✓ Roto-Swirl™ cold water inlet tube swirls water to help prevent mineral build-up at bottom of tank... extends tank life
- ✓ Natural or LP gas

**\$239<sup>99</sup> and up**  
\$11 MONTHLY

Mineral buildup on tank is sure to cut and waste our coupon value. \*EPA

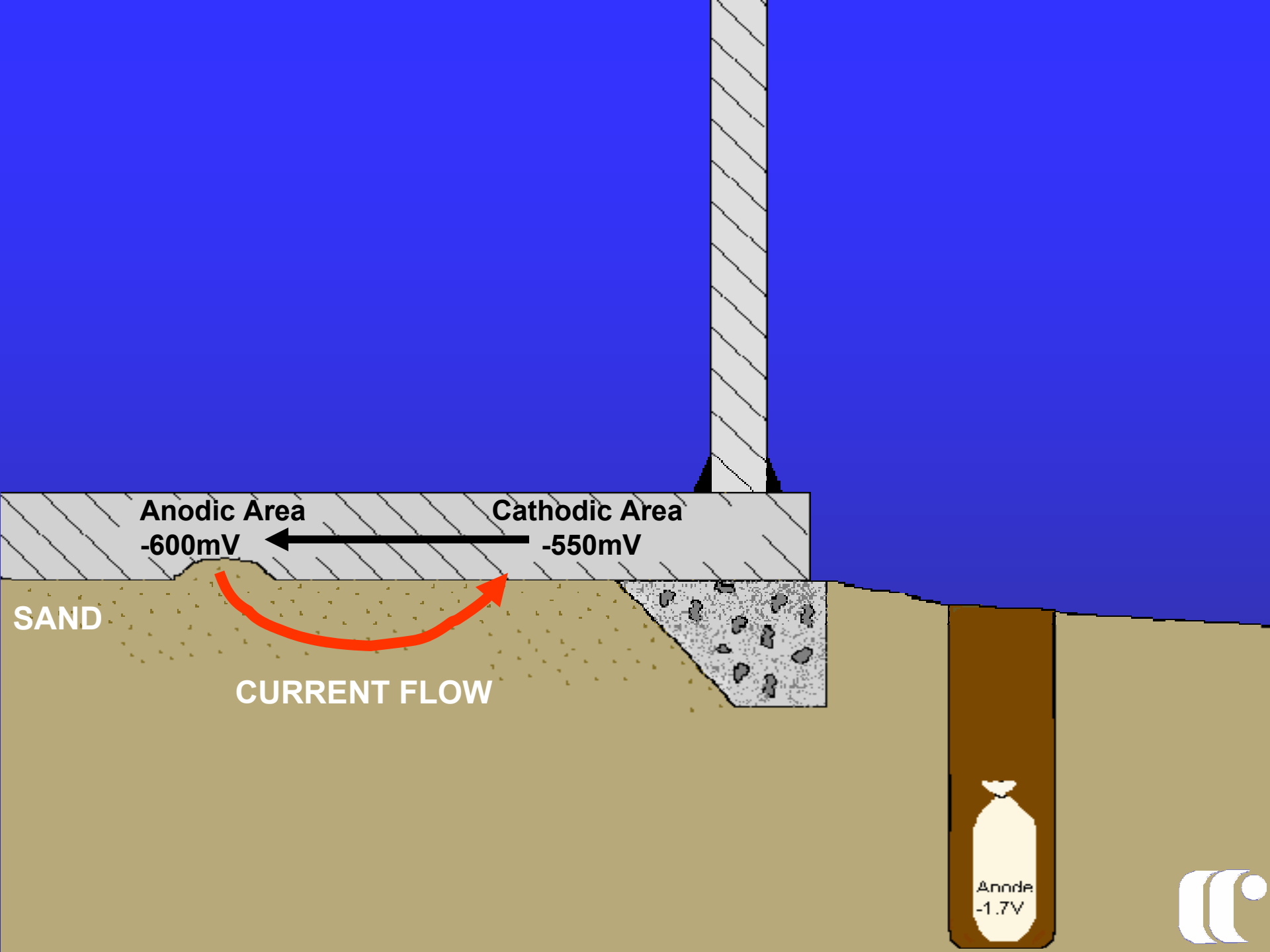
✓ Tired of high gas bills? Fight back with our finest gas water heater. It has a recovery efficiency of over 80% thanks to its unique combustion chamber and air intake design. The polyurethane foam insulation retains heat 2 1/2 times longer than standard fiberglass insulation plus heat trap nipples on cold and hot water inlet connections help to lower fuel bills. Adjustable gas control automatically maintains temperature you select. High temperature safety cut-off. Drain valve. Requires 3 or 4 inch vent. Design certified by the American Gas Association. 10-year limited warranty against tank leaks. Warranted for 5 years, write for free copy, see page 325A. Not for mobile homes.

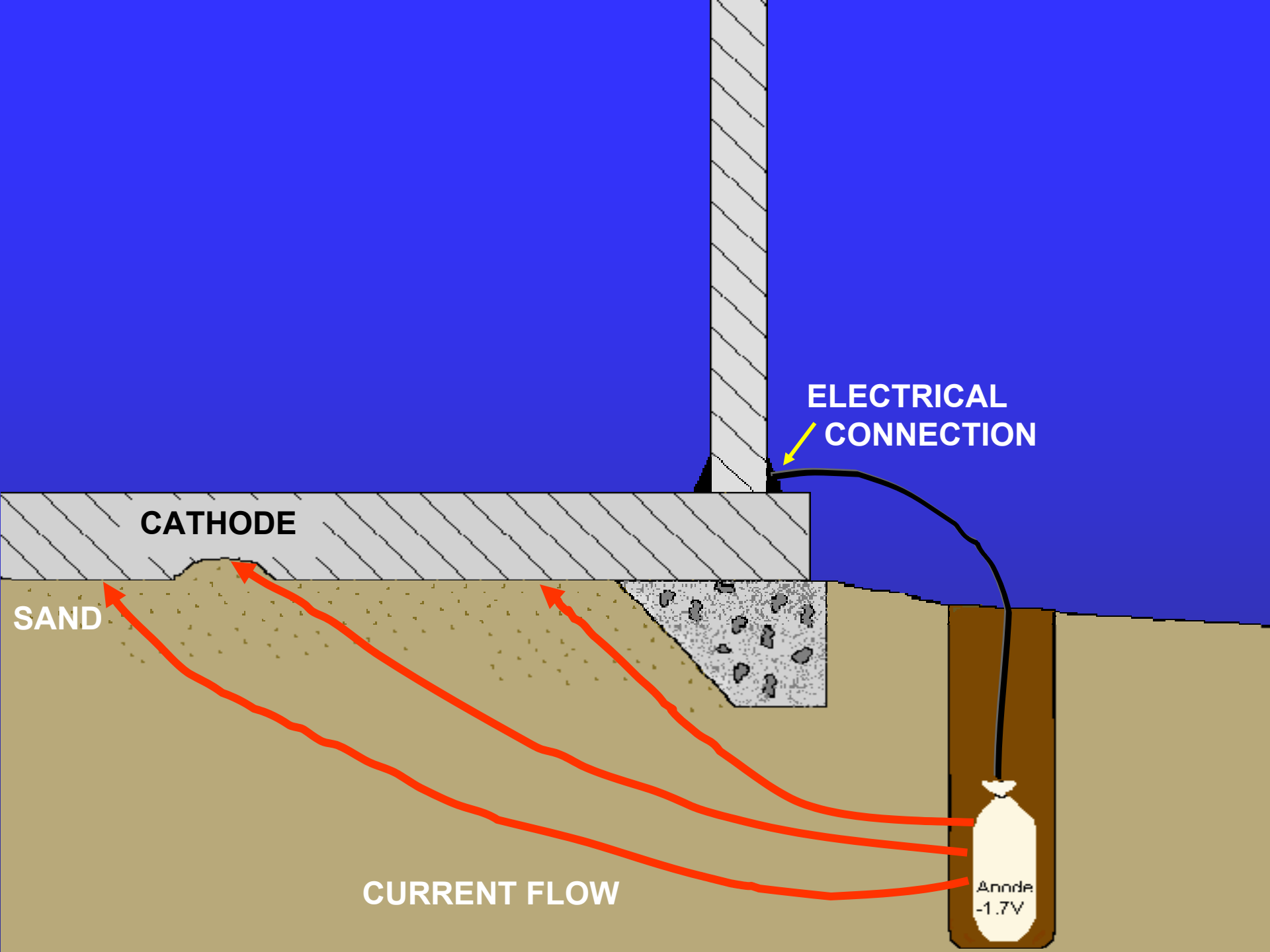
Tank size gal.	Capacity in gal. per hr.	Recovery in gal. per hr. at 80% rate	Control Number	Wing wt. lbs.	Price
40	30	45.0	325A	170	\$249.99
50	40.0	60.0	325B	175	\$279.99
60	50.0	75.0	325C	180	\$309.99
70	60.0	90.0	325D	185	\$339.99
80	70.0	105.0	325E	190	\$369.99

\*Minimum vent 1/2" diameter for standard. See page yellow and ceiling clearance. Recommended vent should range up to 3" high per foot.

Estimated annual energy costs based on U.S. Dept. of Energy test procedures and 1983 national average utility rates

Control Number	Capacity	Recovery	Annual energy cost range for all brands for fixed base 1983 range	Control Number	Capacity	Recovery	Annual energy cost range for all brands for fixed base 1983 range
325A	40	45.0	\$176 to \$246	325E	80	105.0	\$310 to \$343
325B	50	60.0	\$188 to \$266	325F	100	140.0	\$329 to \$401
325C	60	75.0	\$198 to \$286	325G	120	170.0	\$349 to \$426
325D	70	90.0	\$208 to \$298	325H	140	200.0	\$369 to \$451
325E	80	105.0	\$218 to \$308	325I	160	230.0	\$389 to \$471
325F	100	140.0	\$238 to \$328	325J	180	260.0	\$409 to \$491
325G	120	170.0	\$258 to \$348	325K	200	290.0	\$429 to \$511
325H	140	200.0	\$278 to \$368	325L	220	320.0	\$449 to \$531
325I	160	230.0	\$298 to \$388	325M	240	350.0	\$469 to \$551
325J	180	260.0	\$318 to \$408	325N	260	380.0	\$489 to \$571
325K	200	290.0	\$338 to \$428	325O	280	410.0	\$509 to \$591
325L	220	320.0	\$358 to \$448	325P	300	440.0	\$529 to \$611
325M	240	350.0	\$378 to \$468	325Q	320	470.0	\$549 to \$631
325N	260	380.0	\$398 to \$488	325R	340	500.0	\$569 to \$651
325O	280	410.0	\$418 to \$508	325S	360	530.0	\$589 to \$671
325P	300	440.0	\$438 to \$528	325T	380	560.0	\$609 to \$691
325Q	320	470.0	\$458 to \$548	325U	400	590.0	\$629 to \$711
325R	340	500.0	\$478 to \$568	325V	420	620.0	\$649 to \$731
325S	360	530.0	\$498 to \$588	325W	440	650.0	\$669 to \$751
325T	380	560.0	\$518 to \$608	325X	460	680.0	\$689 to \$771
325U	400	690.0	\$538 to \$628	325Y	480	710.0	\$709 to \$791
325V	420	720.0	\$558 to \$648	325Z	500	740.0	\$729 to \$811
325W	440	750.0	\$578 to \$668	325AA	520	770.0	\$749 to \$831
325X	460	780.0	\$598 to \$688	325AB	540	800.0	\$769 to \$851
325Y	480	810.0	\$618 to \$708	325AC	560	830.0	\$789 to \$871
325Z	500	840.0	\$638 to \$728	325AD	580	860.0	\$809 to \$891
325AA	520	870.0	\$658 to \$748	325AE	600	890.0	\$829 to \$911
325AB	540	900.0	\$678 to \$768	325AF	620	920.0	\$849 to \$931
325AC	560	930.0	\$698 to \$788	325AG	640	950.0	\$869 to \$951
325AD	580	960.0	\$718 to \$808	325AH	660	980.0	\$889 to \$971
325AE	600	990.0	\$738 to \$828	325AI	680	1010.0	\$909 to \$991
325AF	620	1020.0	\$758 to \$848	325AJ	700	1040.0	\$929 to \$1011
325AG	640	1050.0	\$778 to \$868	325AK	720	1070.0	\$949 to \$1031
325AH	660	1080.0	\$798 to \$888	325AL	740	1100.0	\$969 to \$1051
325AI	680	1110.0	\$818 to \$908	325AM	760	1130.0	\$989 to \$1071
325AJ	700	1140.0	\$838 to \$928	325AN	780	1160.0	\$1009 to \$1091
325AK	720	1170.0	\$858 to \$948	325AO	800	1190.0	\$1029 to \$1111
325AL	740	1200.0	\$878 to \$968	325AP	820	1220.0	\$1049 to \$1131
325AM	760	1230.0	\$898 to \$988	325AQ	840	1250.0	\$1069 to \$1151
325AN	780	1260.0	\$918 to \$1008	325AR	860	1280.0	\$1089 to \$1171
325AO	800	1290.0	\$938 to \$1028	325AS	880	1310.0	\$1109 to \$1191
325AP	820	1320.0	\$958 to \$1048	325AT	900	1340.0	\$1129 to \$1211
325AQ	840	1350.0	\$978 to \$1068	325AU	920	1370.0	\$1149 to \$1231
325AR	860	1380.0	\$998 to \$1088	325AV	940	1400.0	\$1169 to \$1251
325AS	880	1410.0	\$1018 to \$1108	325AW	960	1430.0	\$1189 to \$1271
325AT	900	1440.0	\$1038 to \$1128	325AX	980	1460.0	\$1209 to \$1291
325AU	920	1470.0	\$1058 to \$1148	325AY	1000	1490.0	\$1229 to \$1311
325AV	940	1500.0	\$1078 to \$1168	325AZ	1020	1520.0	\$1249 to \$1331
325AW	960	1530.0	\$1098 to \$1188	325BA	1040	1550.0	\$1269 to \$1351
325AX	980	1560.0	\$1118 to \$1208	325BB	1060	1580.0	\$1289 to \$1371
325AY	1000	1590.0	\$1138 to \$1228	325BC	1080	1610.0	\$1309 to \$1391
325AZ	1020	1620.0	\$1158 to \$1248	325BD	1100	1640.0	\$1329 to \$1411
325BA	1040	1650.0	\$1178 to \$1268	325BE	1120	1670.0	\$1349 to \$1431
325BB	1060	1680.0	\$1198 to \$1288	325BF	1140	1700.0	\$1369 to \$1451
325BC	1080	1710.0	\$1218 to \$1308	325BG	1160	1730.0	\$1389 to \$1471
325BD	1100	1740.0	\$1238 to \$1328	325BH	1180	1760.0	\$1409 to \$1491
325BE	1120	1770.0	\$1258 to \$1348	325BI	1200	1790.0	\$1429 to \$1511
325BF	1140	1800.0	\$1278 to \$1368	325BJ	1220	1820.0	\$1449 to \$1531
325BG	1160	1830.0	\$1298 to \$1388	325BK	1240	1850.0	\$1469 to \$1551
325BH	1180	1860.0	\$1318 to \$1408	325BL	1260	1880.0	\$1489 to \$1571
325BI	1200	1890.0	\$1338 to \$1428	325BM	1280	1910.0	\$1509 to \$1591
325BJ	1220	1920.0	\$1358 to \$1448	325BN	1300	1940.0	\$1529 to \$1611
325BK	1240	1950.0	\$1378 to \$1468	325BO	1320	1970.0	\$1549 to \$1631
325BL	1260	1980.0	\$1398 to \$1488	325BP	1340	2000.0	\$1569 to \$1651
325BM	1280	2010.0	\$1418 to \$1508	325BQ	1360	2030.0	\$1589 to \$1671
325BN	1300	2040.0	\$1438 to \$1528	325BR	1380	2060.0	\$1609 to \$1691
325BO	1320	2070.0	\$1458 to \$1548	325BS	1400	2090.0	\$1629 to \$1711
325BP	1340	2100.0	\$1478 to \$1568	325BT	1420	2120.0	\$1649 to \$1731
325BQ	1360	2130.0	\$1498 to \$1588	325BU	1440	2150.0	\$1669 to \$1751
325BR	1380	2160.0	\$1518 to \$1608	325BV	1460	2180.0	\$1689 to \$1771
325BS	1400	2190.0	\$1538 to \$1628	325BW	1480	2210.0	\$1709 to \$1791
325BT	1420	2220.0	\$1558 to \$1648	325BX	1500	2240.0	\$1729 to \$1811
325BU	1440	2250.0	\$1578 to \$1668	325BY	1520	2270.0	\$1749 to \$1831
325BV	1460	2280.0	\$1598 to \$1688	325BZ	1540	2300.0	\$1769 to \$1851
325BW	1480	2310.0	\$1618 to \$1708	325C1	1560	2330.0	\$1789 to \$1871
325BX	1500	2340.0	\$1638 to \$1728	325C2	1580	2360.0	\$1809 to \$1891
325BY	1520	2370.0	\$1658 to \$1748	325C3	1600	2390.0	\$1829 to \$1911
325BZ	1540	2400.0	\$1678 to \$1768	325C4	1620	2420.0	\$1849 to \$1931
325C1	1560	2430.0	\$1698 to \$1788	325C5	1640	2450.0	\$1869 to \$1951
325C2	1580	2460.0	\$1718 to \$1808	325C6	1660	2480.0	\$1889 to \$1971
325C3	1600	2490.0	\$1738 to \$1828	325C7	1680	2510.0	\$1909 to \$1991
325C4	1620	2520.0	\$1758 to \$1848	325C8	1700	2540.0	\$1929 to \$2011
325C5	1640	2550.0	\$1778 to \$1868	325C9	1720	2570.0	\$1949 to \$2031
325C6	1660	2580.0	\$1798 to \$1888	325CA	1740	2600.0	\$1969 to \$2051
325C7	1680	2610.0	\$1818 to \$1908	325CB	1760	2630.0	\$1989 to \$2071
325C8	1700	2640.0	\$1838 to \$1928	325CC	1780	2660.0	\$2009 to \$2091
325C9	1720	2670.0	\$1858 to \$1948	325CD	1800	2690.0	\$2029 to \$2111
325CA	1740	2700.0	\$1878 to \$1968	325CE	1820	2720.0	\$2049 to \$2131
325CB	1760	2730.0	\$1898 to \$1988	325CF	1840	2750.0	\$2069 to \$2151
325CC	1800	2760.0	\$1918 to \$2008	325CG	1860	2780.0	\$2089 to \$2171
325CD	1820	2790.0	\$1938 to \$2028	325CH	1880	2810.0	\$2109 to \$2191
325CE	1840	2820.0	\$1958 to \$2048	325CI	1900	2840.0	\$2129 to \$2211
325CF	1860	2850.0	\$1978 to \$2068	325CJ	1920	2870.0	\$2149 to \$2231
325CG	1880	2880.0	\$1998 to \$2088	325CK	1940	2900.0	\$2169 to \$2251
325CH	1900	2910.0	\$2018 to \$2108	325CL	1960	2930.0	\$2189 to \$2271
325CI	1920	2940.0	\$2038 to \$2128	325CM	1980	2960.0	\$2209 to \$2291
325CJ	1940	2970.0	\$2058 to \$2148	325CN	2000	2990.0	\$2229 to \$2311
325CK	1960	3000.0	\$2078 to \$2168	325CO	2020	3020.0	\$2249 to \$2331
325CL	1980	3030.0	\$2098 to \$2188	325CP	2040	3050.0	\$2269 to \$2351
325CM	2000	3060.0	\$2118 to \$2208	325CQ	2060	3080.0	\$2289 to \$2371
325CN	2020	3090.0	\$2138 to \$2228	325CR	2080	3110.0	\$2309 to \$2391
325CO	2040	3120.0	\$2158 to \$2248	325CS	2100	3140.0	\$2329 to \$2411
325CP	2060	3150.0	\$2178 to \$2268	325CT	2120	3170.0	\$2349 to \$2431
325CQ	2080	3180.0	\$2198 to \$2288	325CU	2140	3200.0	\$2369 to \$2451
325CR	2100	3210.0	\$2218 to \$2308	325CV	2160	3	





# Recommended Practices

## API-651 - Cathodic Protection of Aboveground Petroleum Storage Tanks:

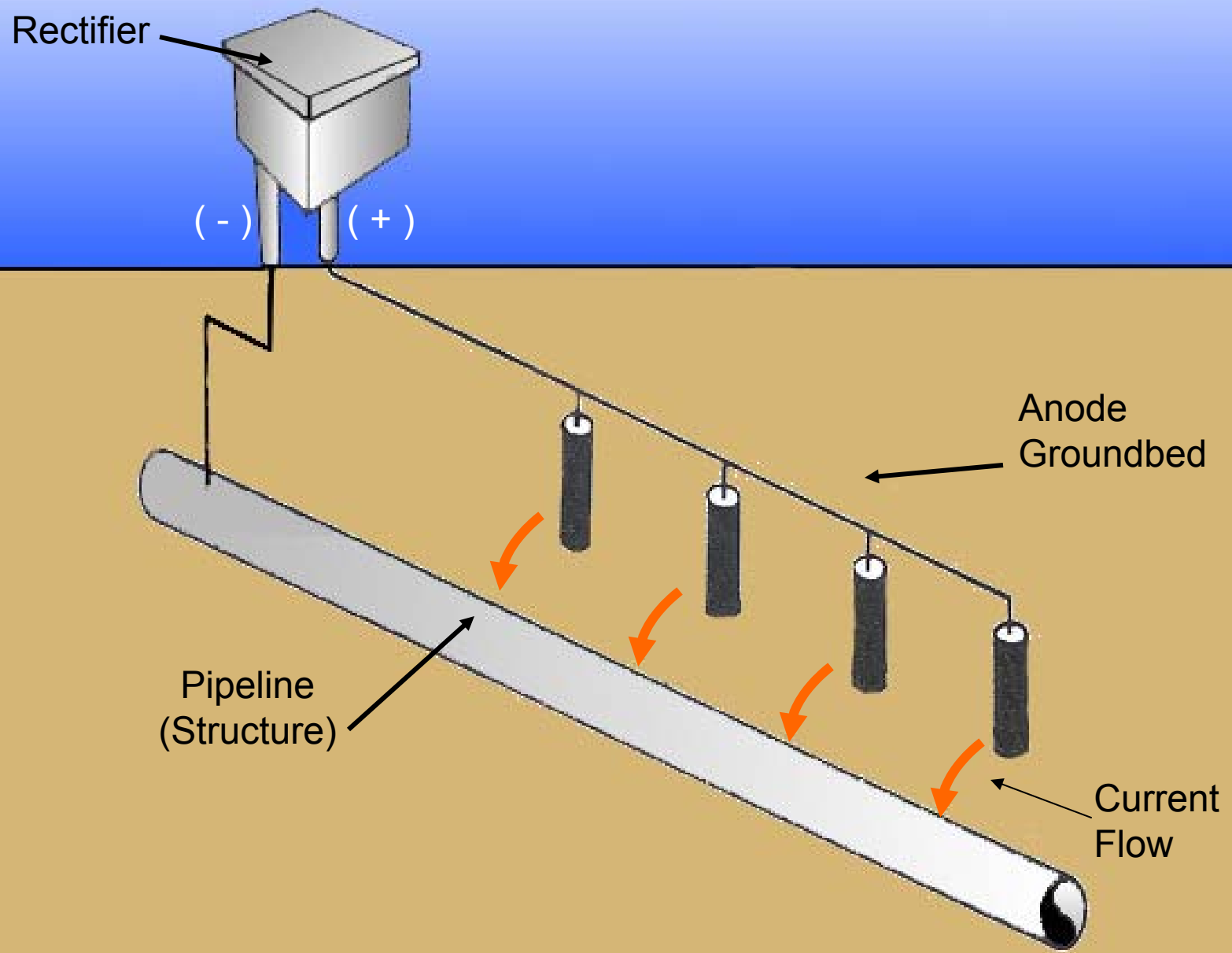
*“Galvanic anodes method is not practical for protection of large bare structures.”*

## NACE RP0193-2001 - External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms:

*“Galvanic protection systems can be applied to tank bottoms where the metallic surface area exposed to the electrolyte can be minimized through the application of a dielectric coating or the area is small due to the tank size or configuration.”*



# Impressed Current System





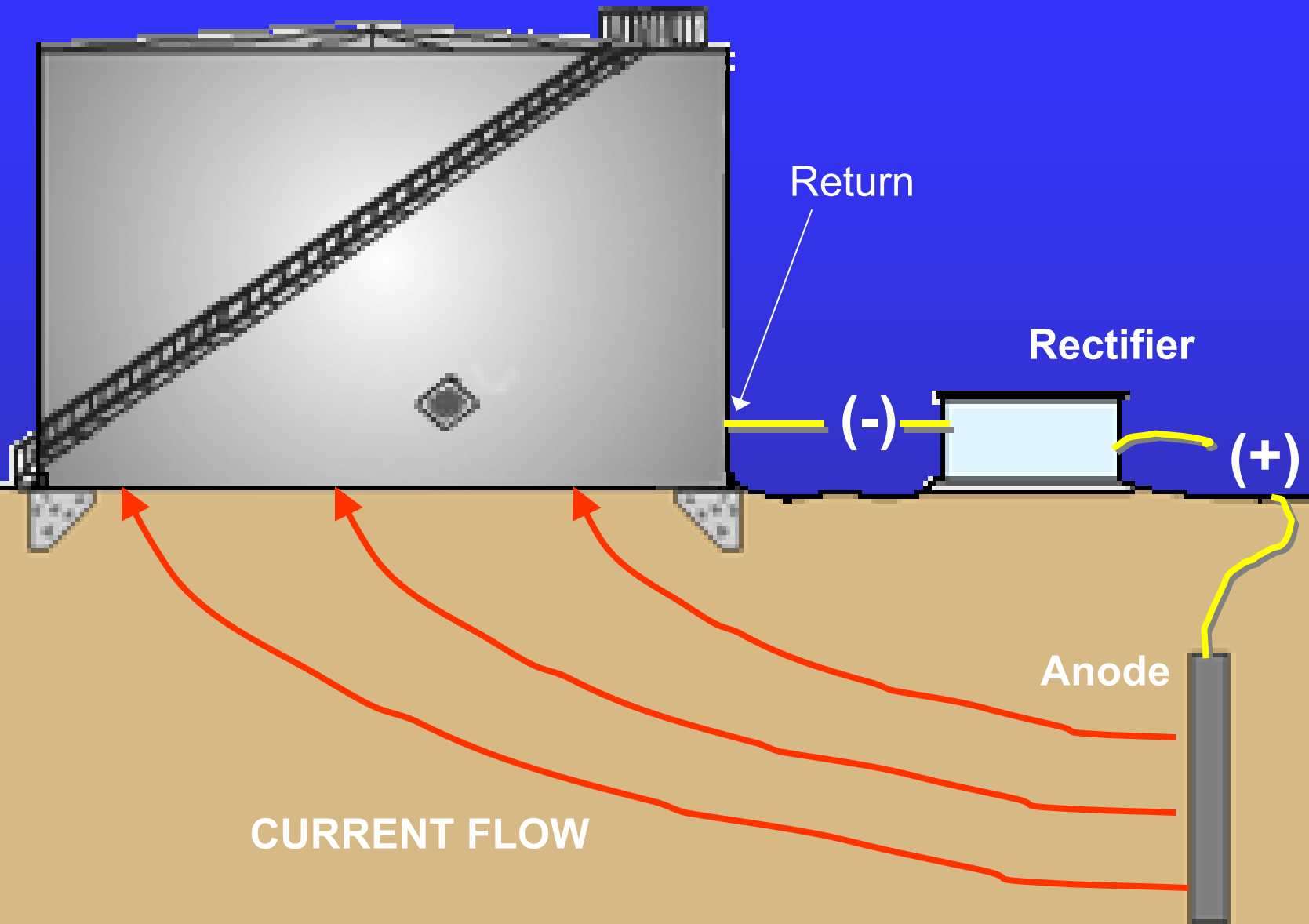


# Impressed Current Cathodic Protection System

- ▶ Anodes
- ▶ Rectifier
- ▶ Wiring

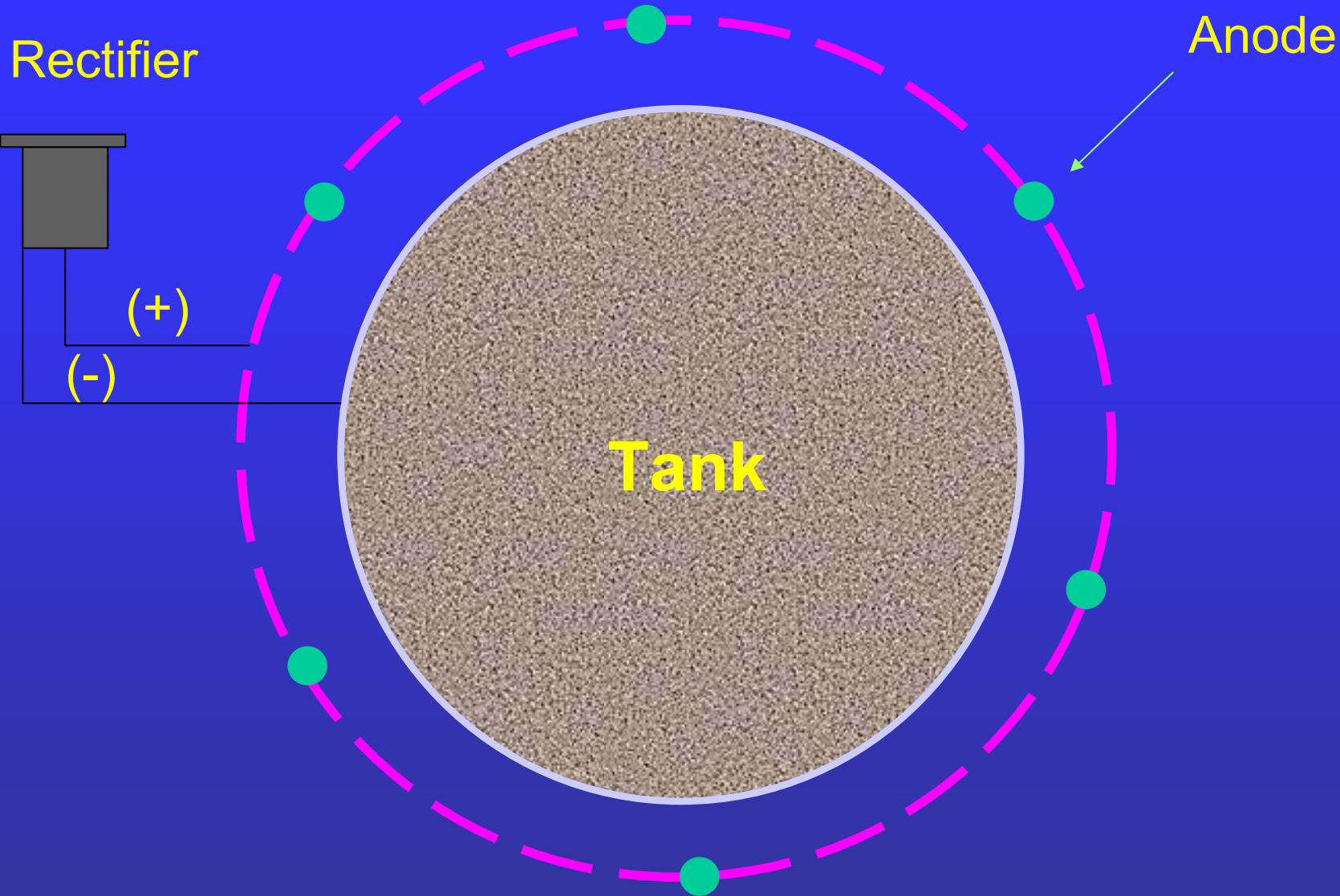


# Impressed Current Cathodic Protection





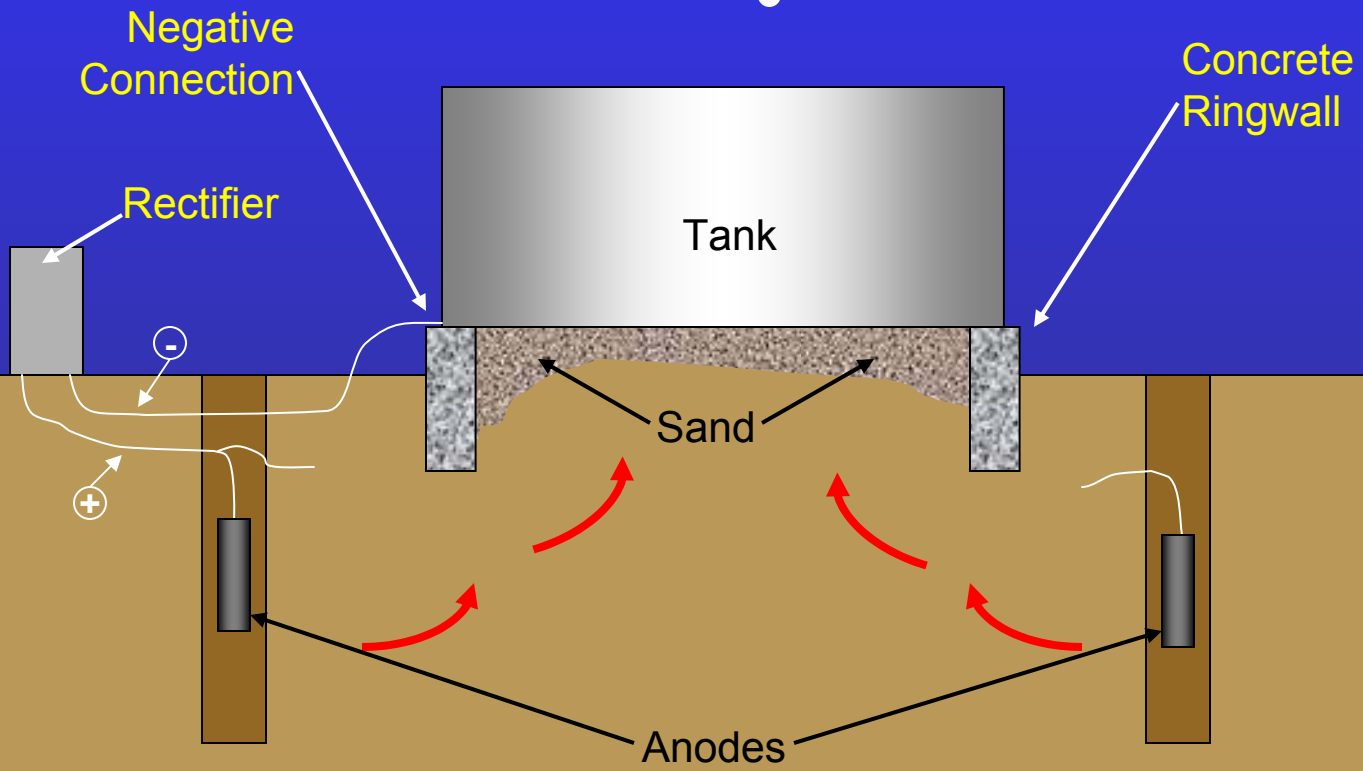
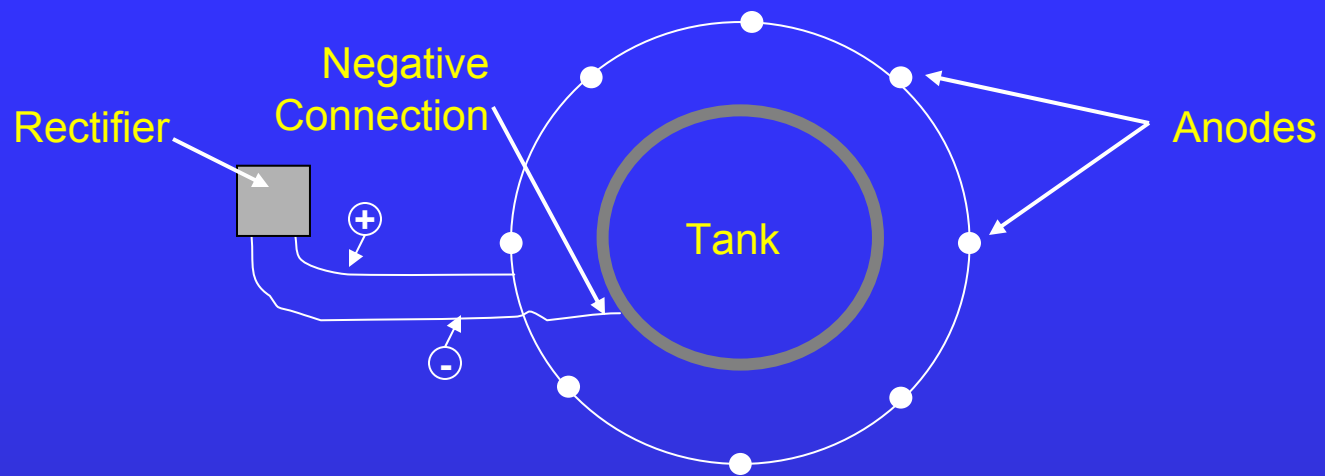




# Shallow Anodes



# Above Ground Storage Tank Vertical Impressed Current Anodes - Existing Tanks



**RECTIFIER**



**ANODE  
JUNCTION BOX**



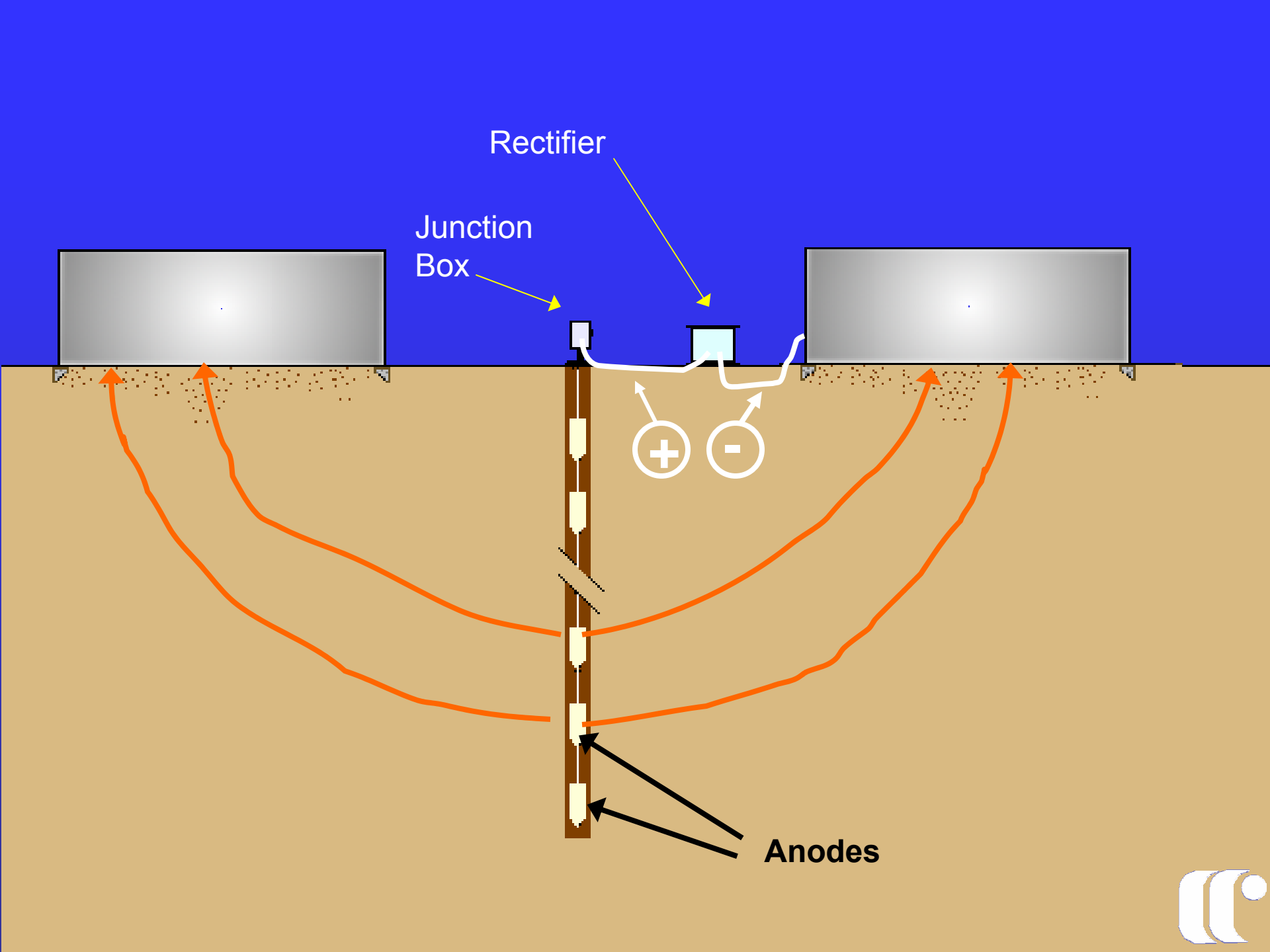
# Deep Anode System

**“One or more anodes installed vertically at a depth of 50 feet or more below grade, in a drilled hole, for the purpose of supplying cathodic protection...”**

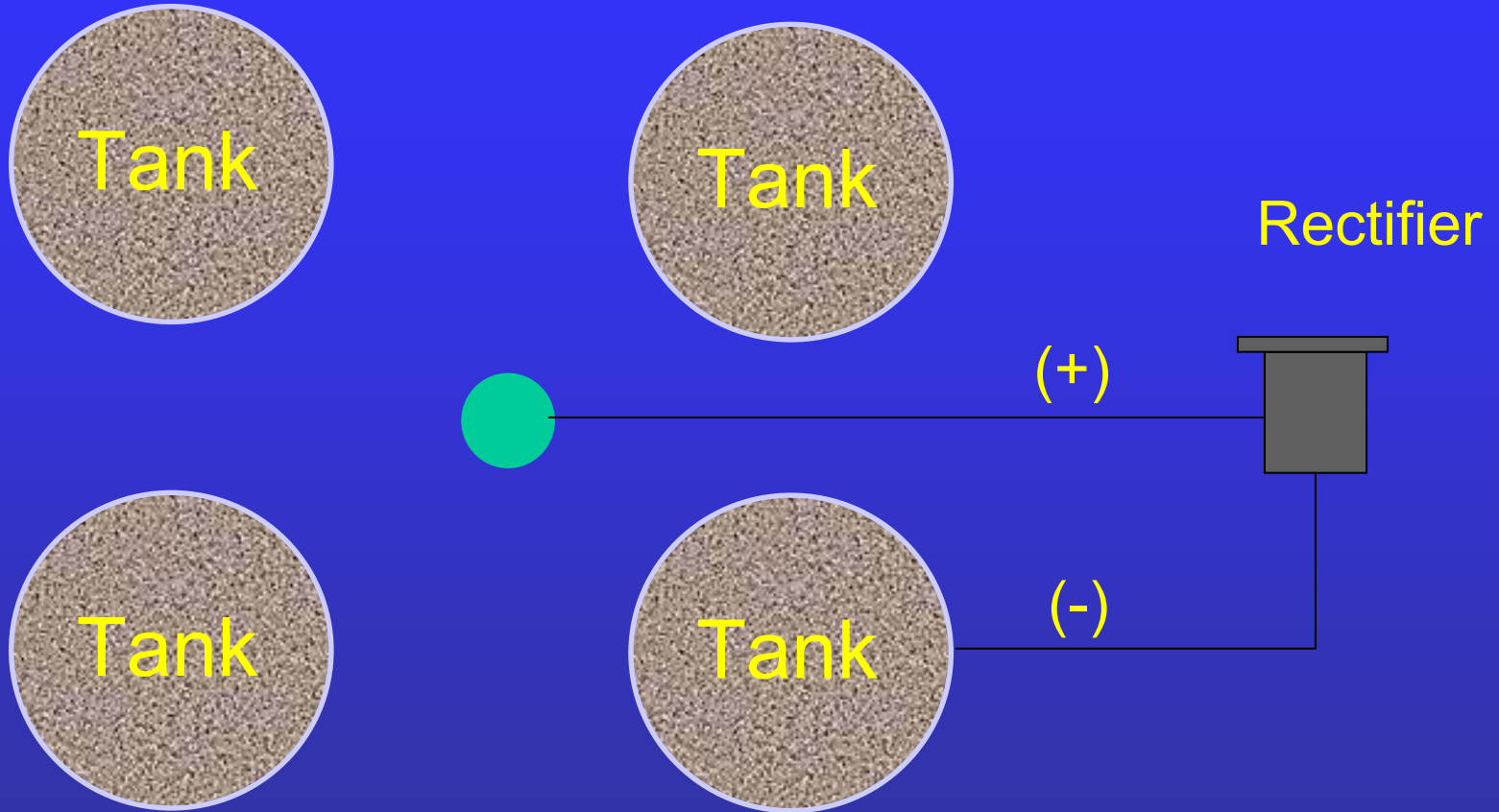
**NACE International Definition**











Deep Anode

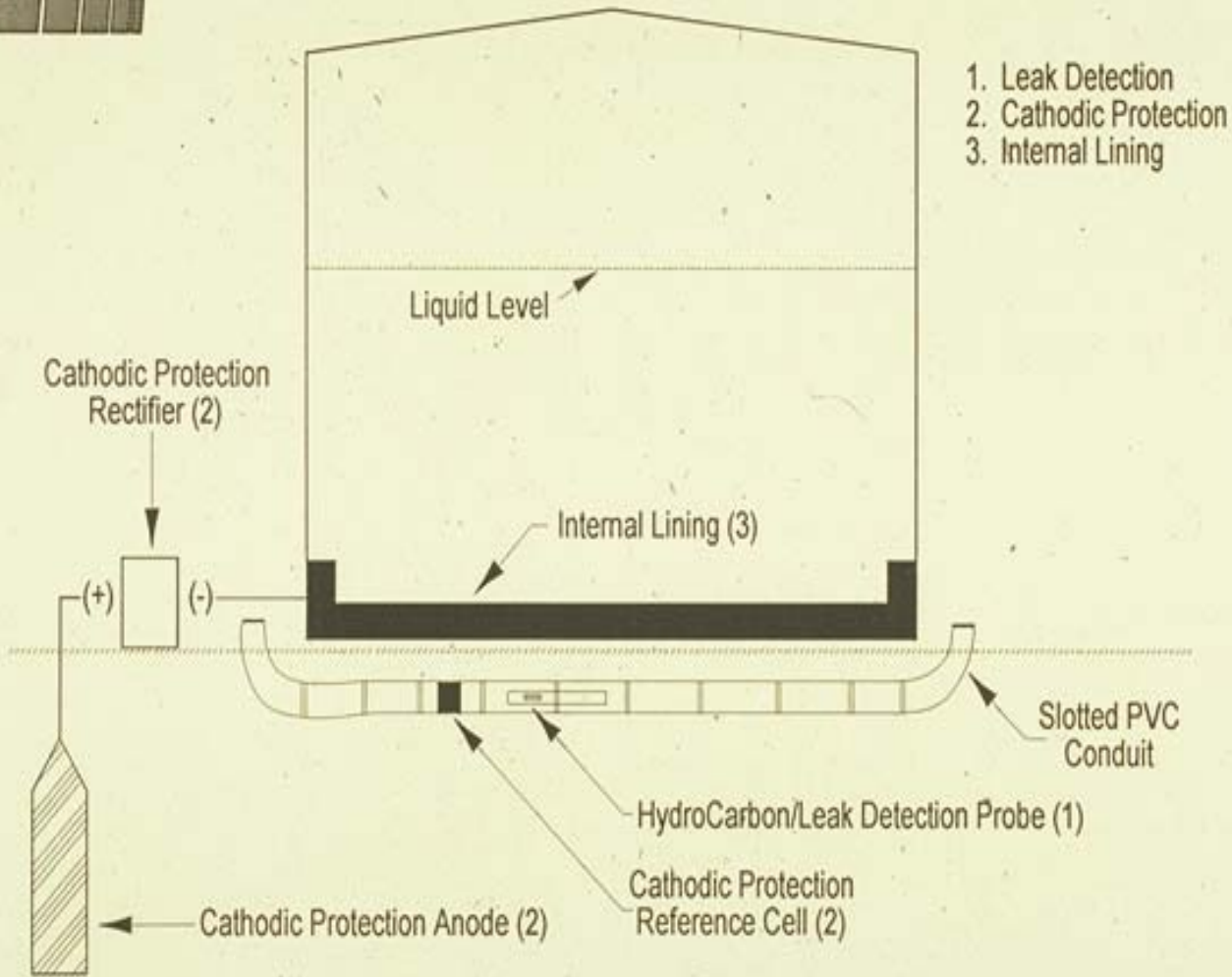
# Deep Anode System Advantages

- ▶ Better distribution of protective current
- ▶ Smaller right-of-way requirements
- ▶ Easily installed in congested areas

# Conventional Deep Anode System Disadvantages

- ▶ Premature system failure
- ▶ Costly re-drilling at failure
- ▶ Potential for cross mixing of subsurface aquifers
- ▶ Creates conduit for surface spills

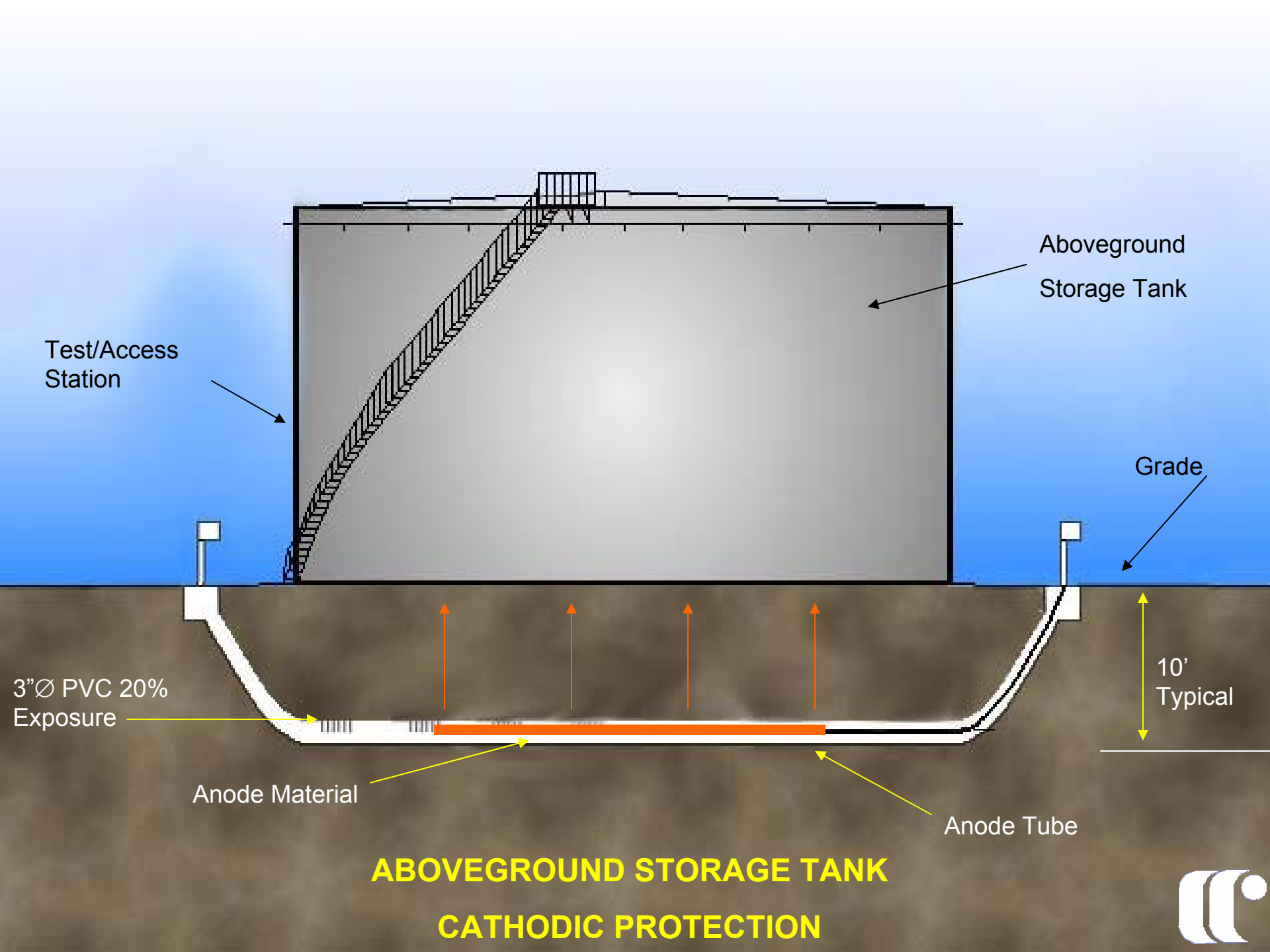
# 1999 REQUIREMENTS FOR ASTs





## Directional Boring Under Existing AST





**ABOVEGROUND STORAGE TANK  
CATHODIC PROTECTION**

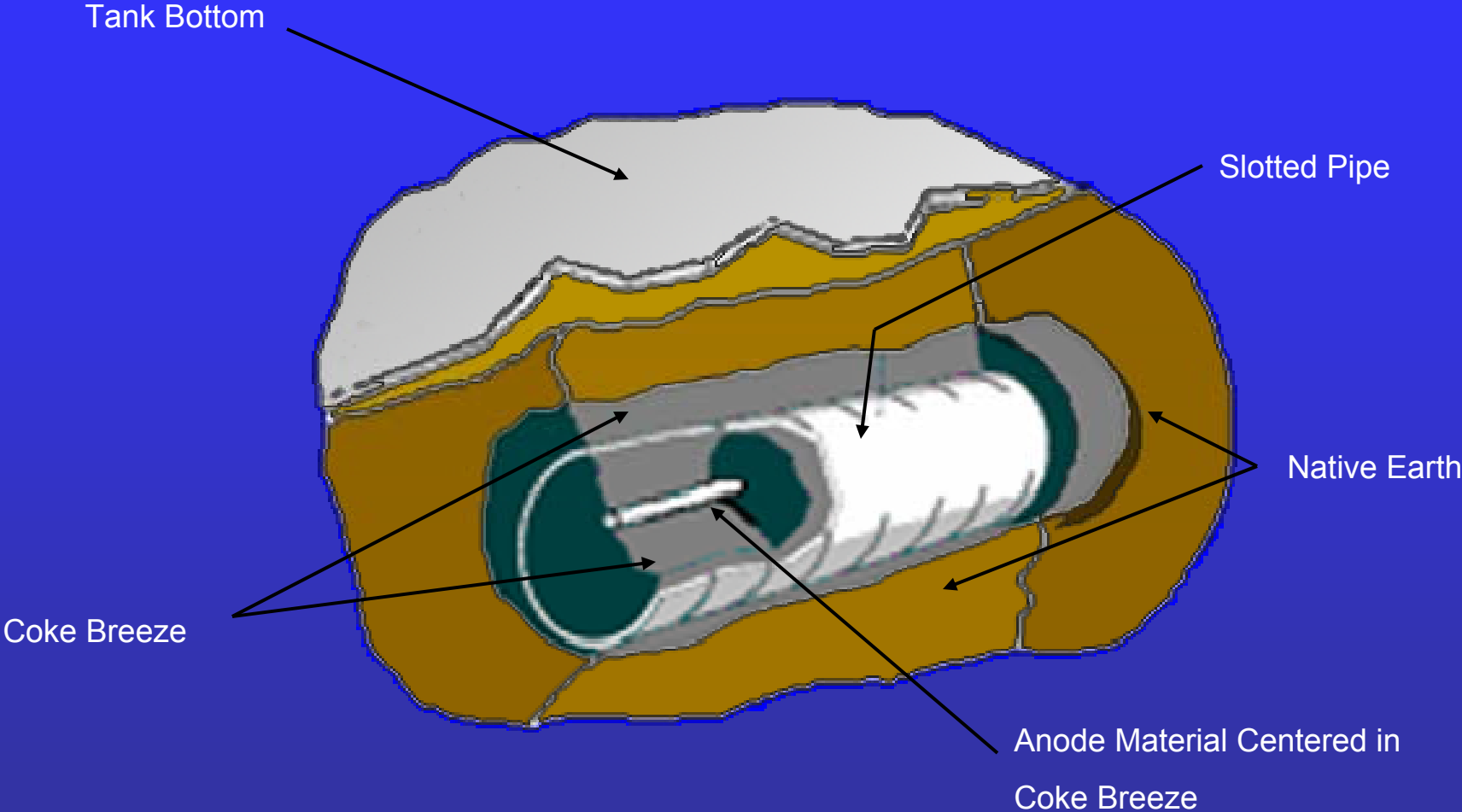








# TYPICAL ANODE INSTALLATION

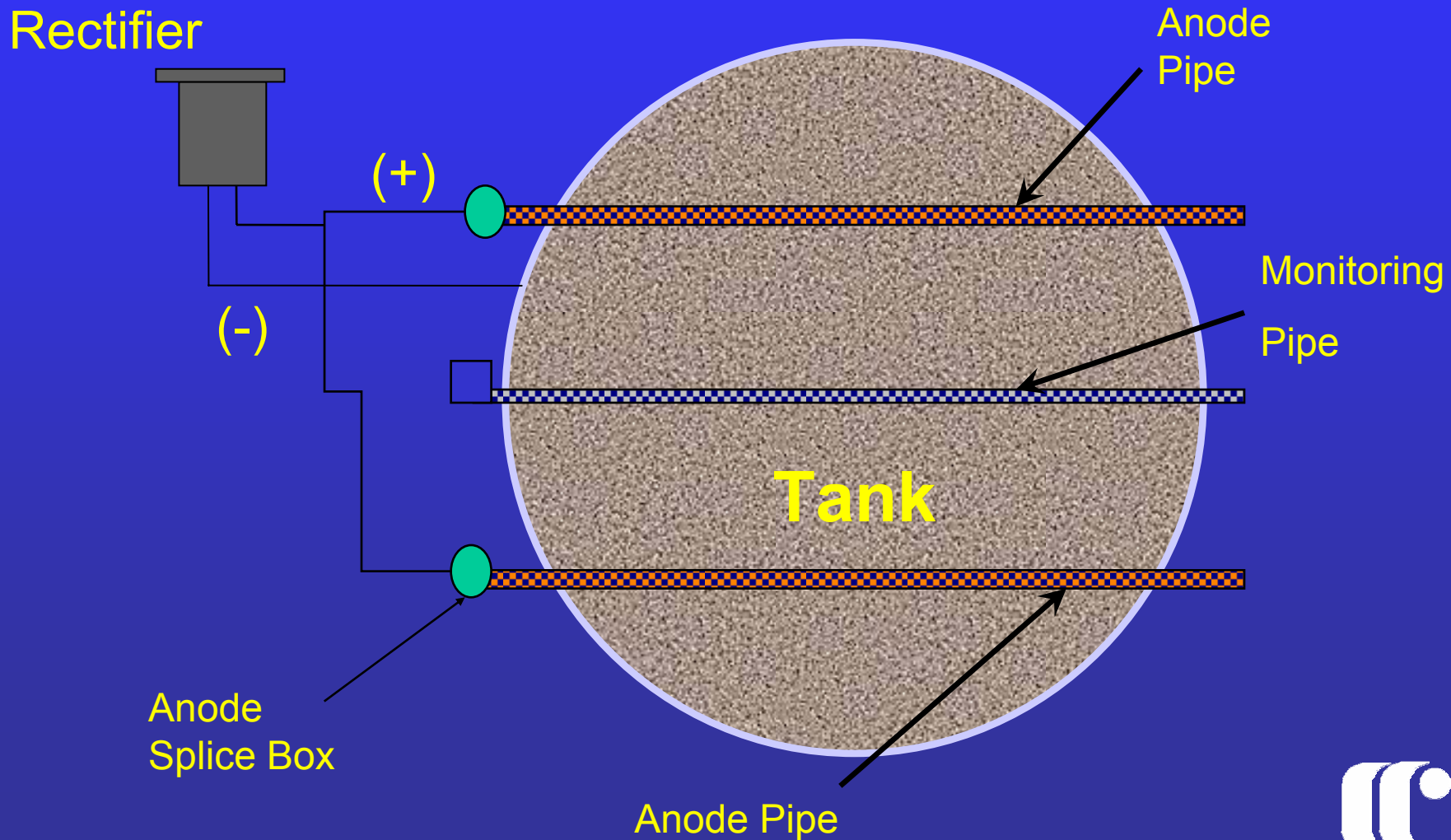




**Cathodic Protection Monitoring**



# Computer Guided Horizontally Bored Anode System



# Leak Detection Monitoring Station





# CP Applications for Re-bottomed or New Tanks

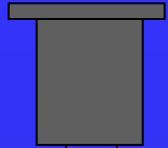




**New Floor Installation on Existing AST**



Rectifier



(-)

(+)

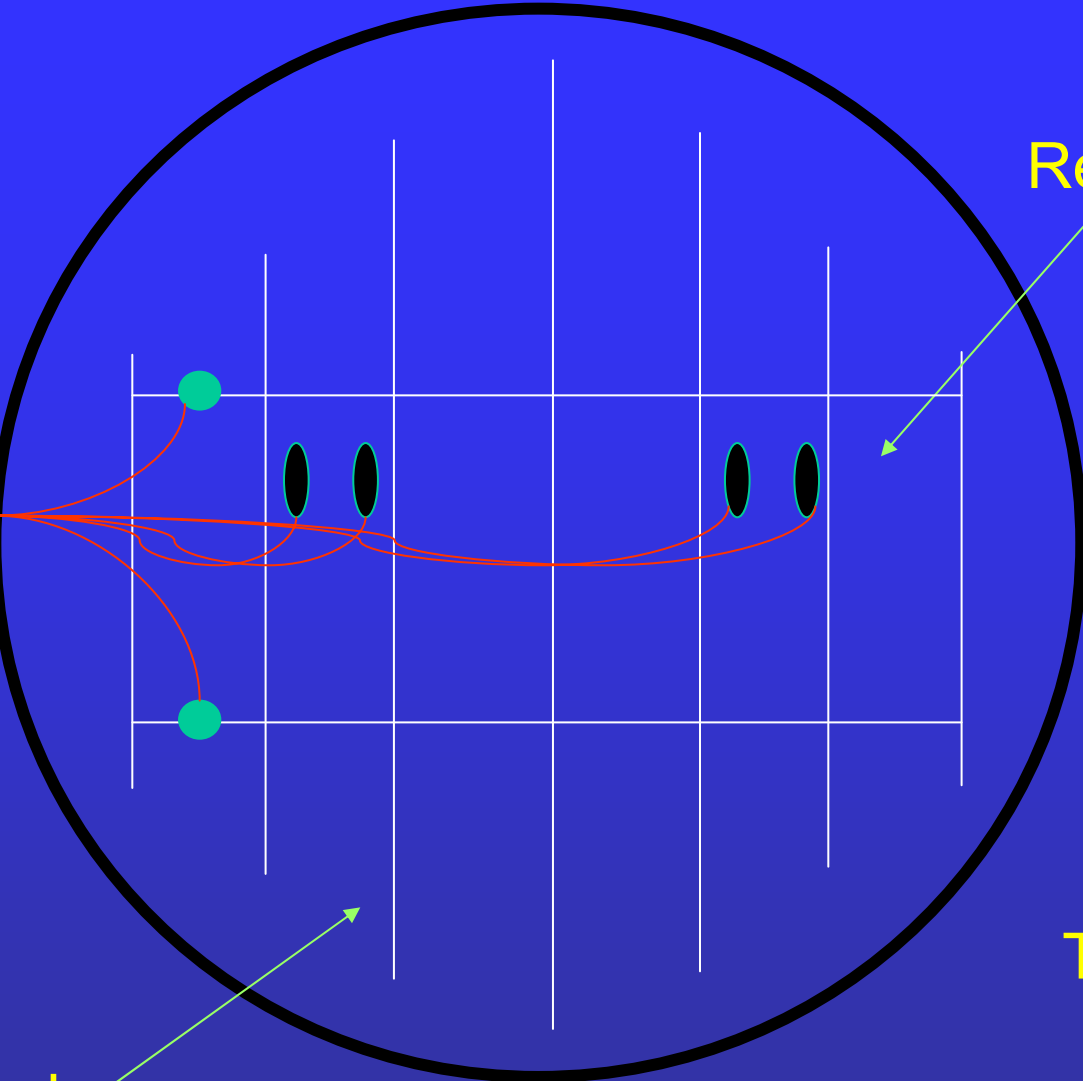
Junction  
Box

Anode

Reference  
Cells

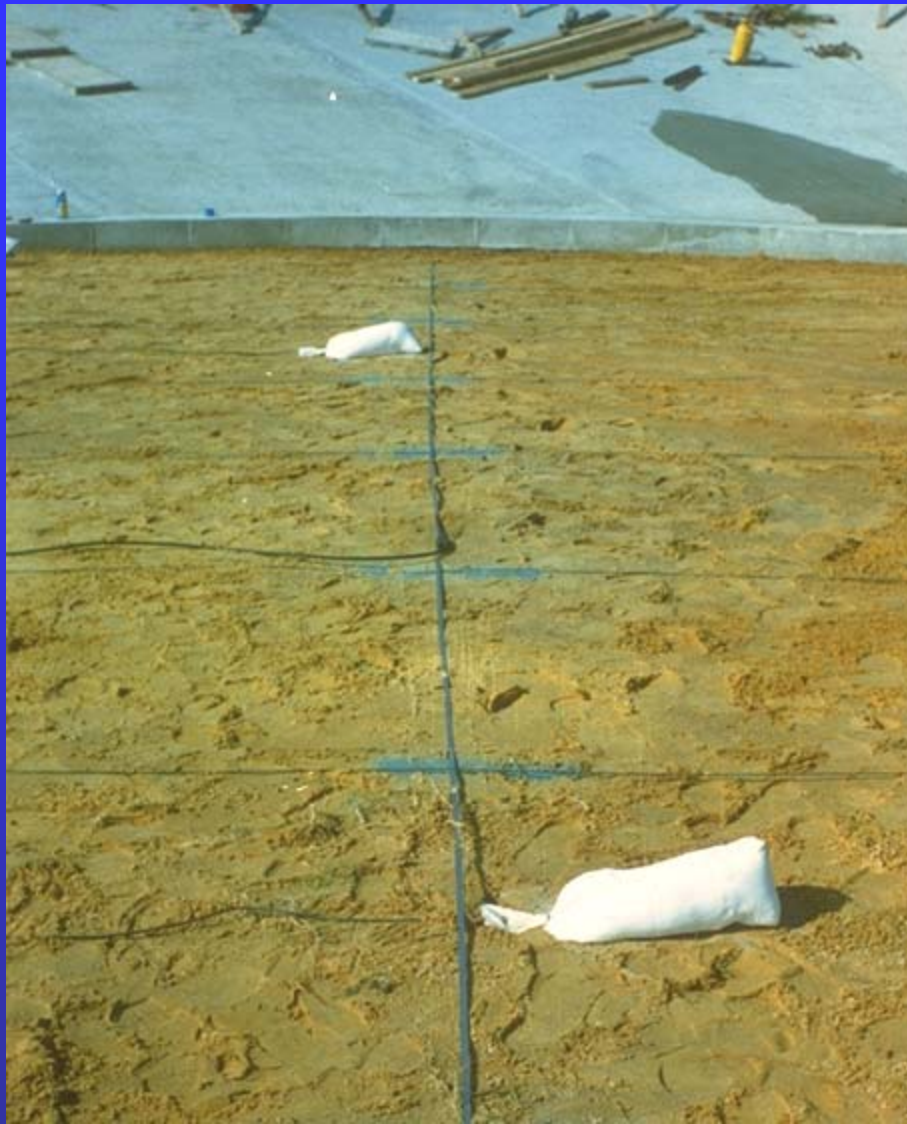
Tank

Impressed Current





**CP Installation on Rebottomed Tank**



**Titanium Anode Ribbon and Reference Cells**

**Above Ground**

**Storage Tank Bottoms**

**with Secondary Containment**



# Secondary Containment

- ▶ **Environmental Protection**
- ▶ **Minimize Liability**
- ▶ **State and Local Regulations**

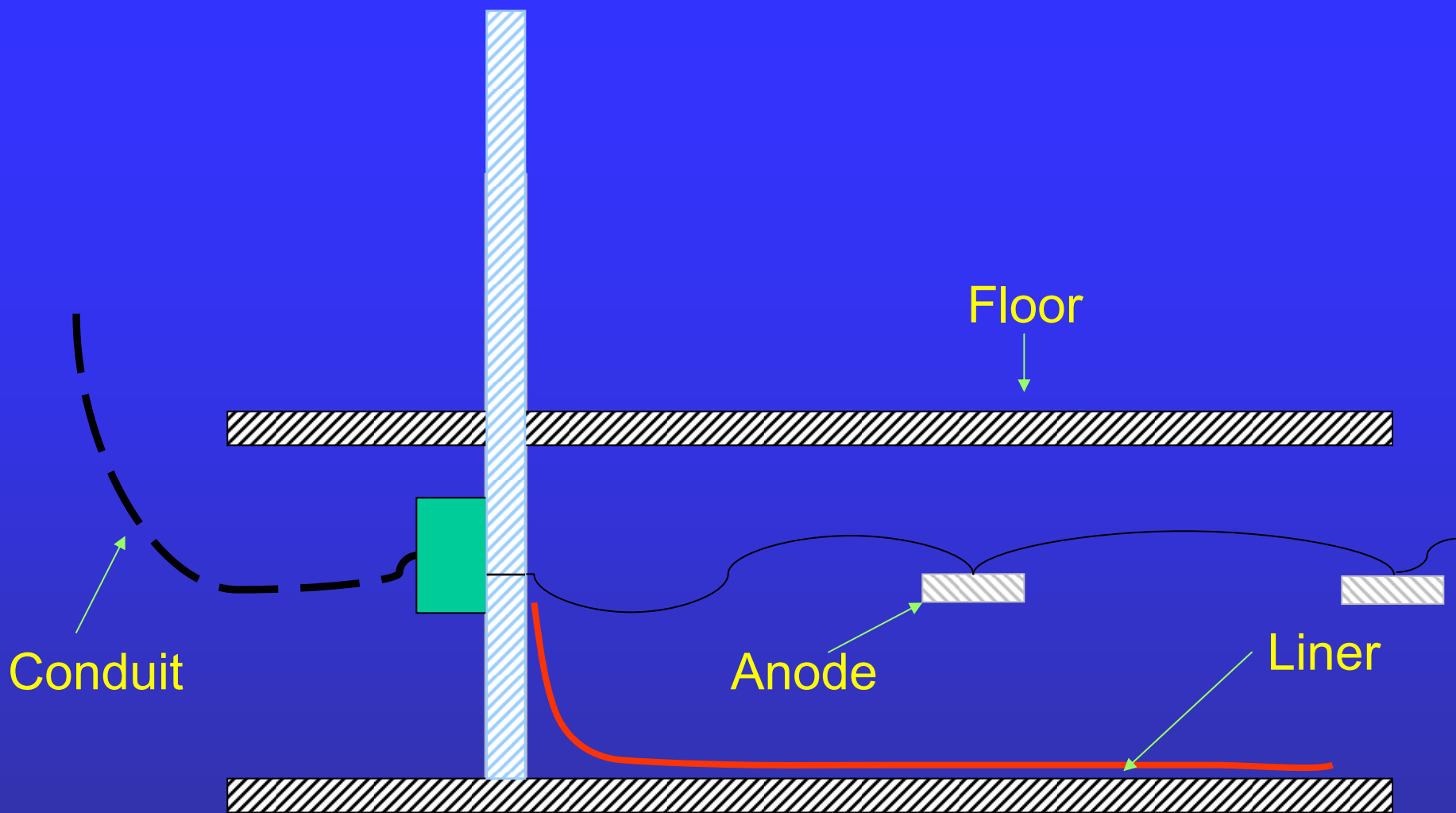






**New Tank Construction with Liner**





## CP Installation on Double Bottom Tank







**Anode & Reference Cell Placement  
in High Resistance Sand**









## **Ringwall Conduit for CP Wiring**







## Floor Plate Installation





**Air Bag Lift**





# Existing Sand Bed





# Install Containment Liner





# Installation of CP System on Lifted AST



# Cathodic Protection Monitoring

- Read rectifiers every 60 days.
- Conduct annual inspection (obtain potentials) by NACE certified individuals.



# Inspection of CP System







- Record Volts/Amps
- Compare values to target settings





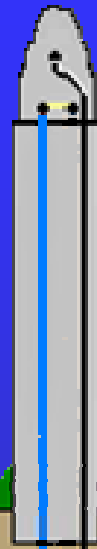
# Qualifications of the corrosion engineer

- Certified by N.A.C.E.  
(National Association of Corrosion Engineers)
- Experienced in Cathodic Protection
- Experienced in Cathodic Protection of Fuel Storage Systems

# Remote Monitoring of CP



# Test Station



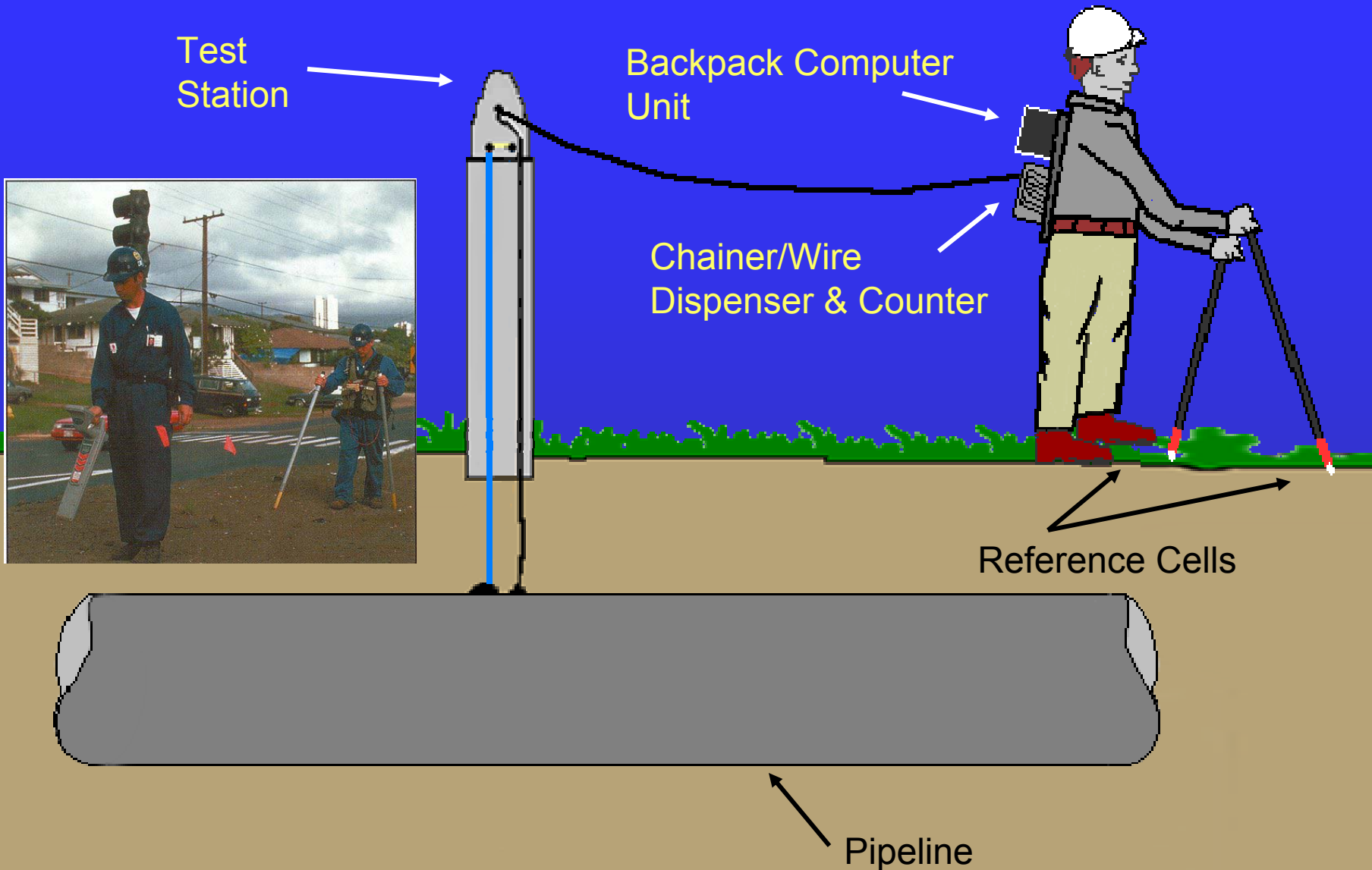
Test Station



Structure

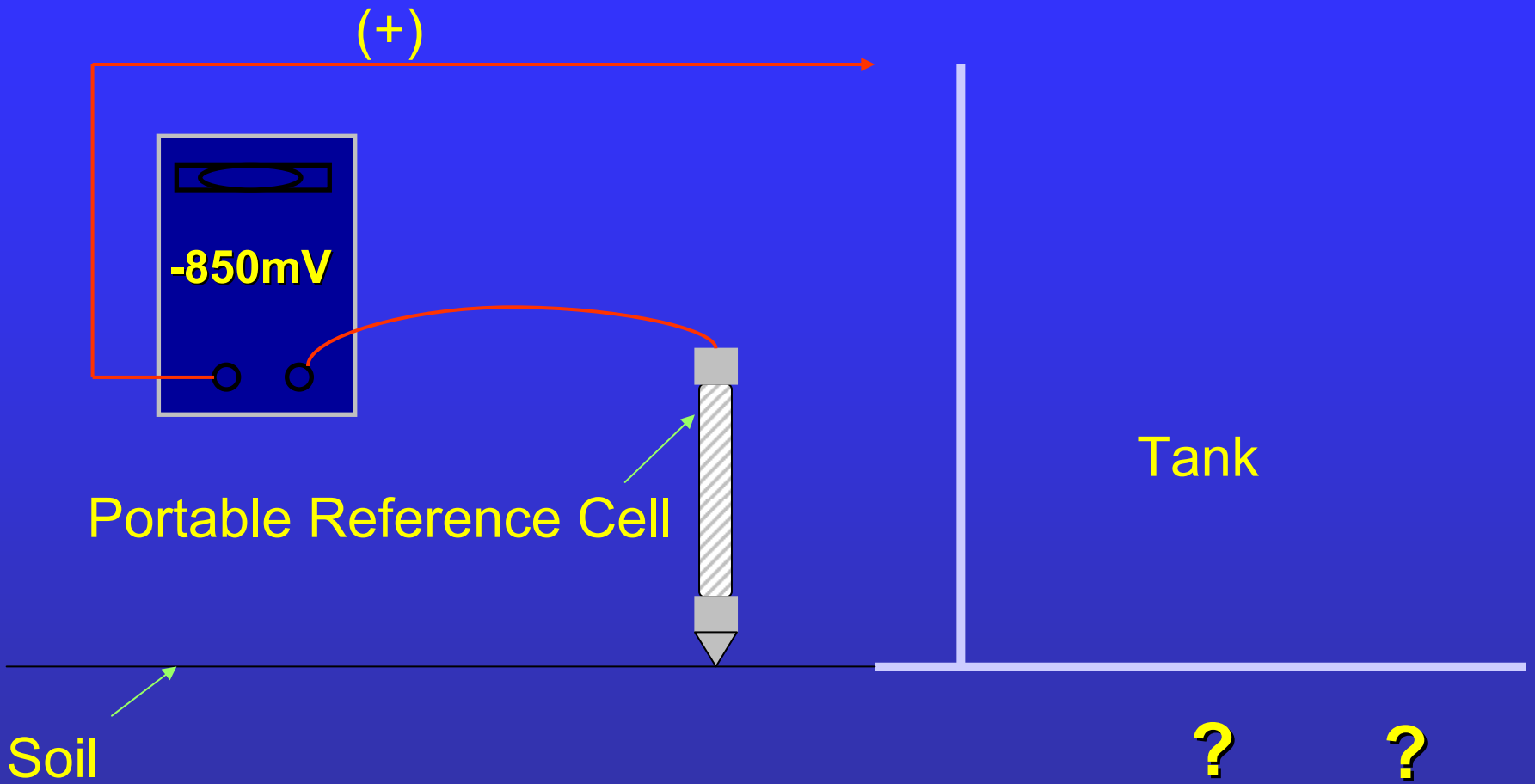


# Computerized Potential Logging Survey





# MFL Floor Inspection



# Rim Potential Measurements







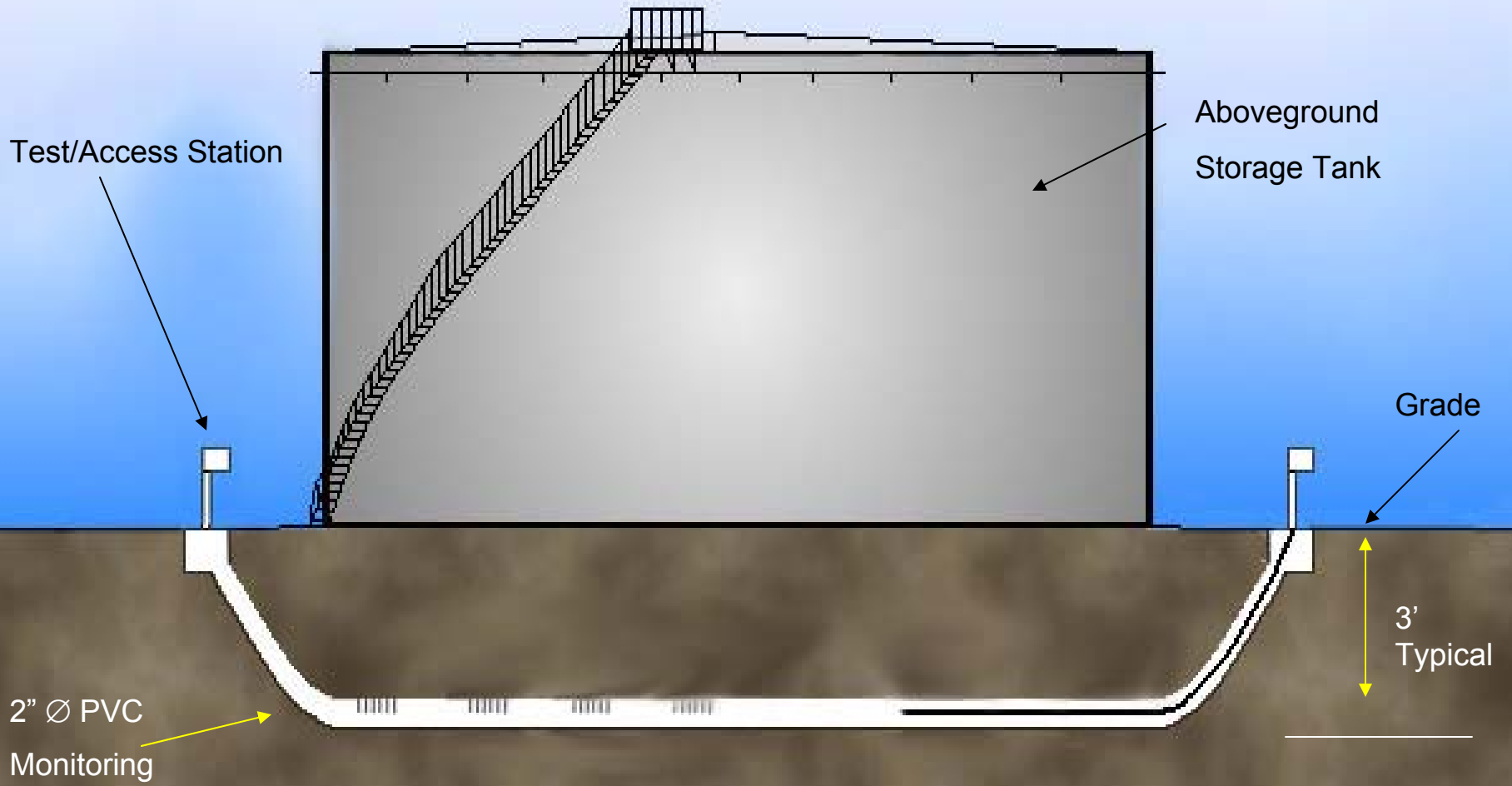
**Tank to Soil Potential Measurements**





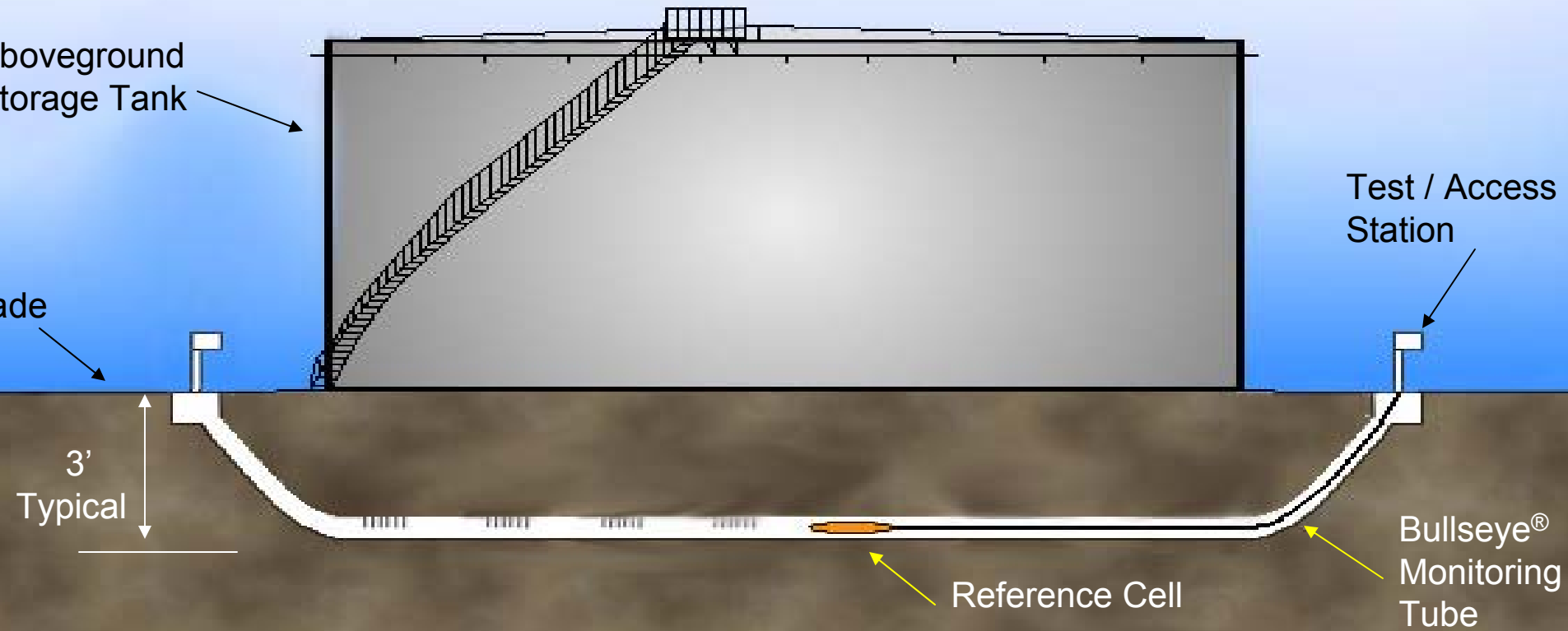
**Annual Cathodic Protection Survey**





# REFERENCE CELL MONITORING TUBE



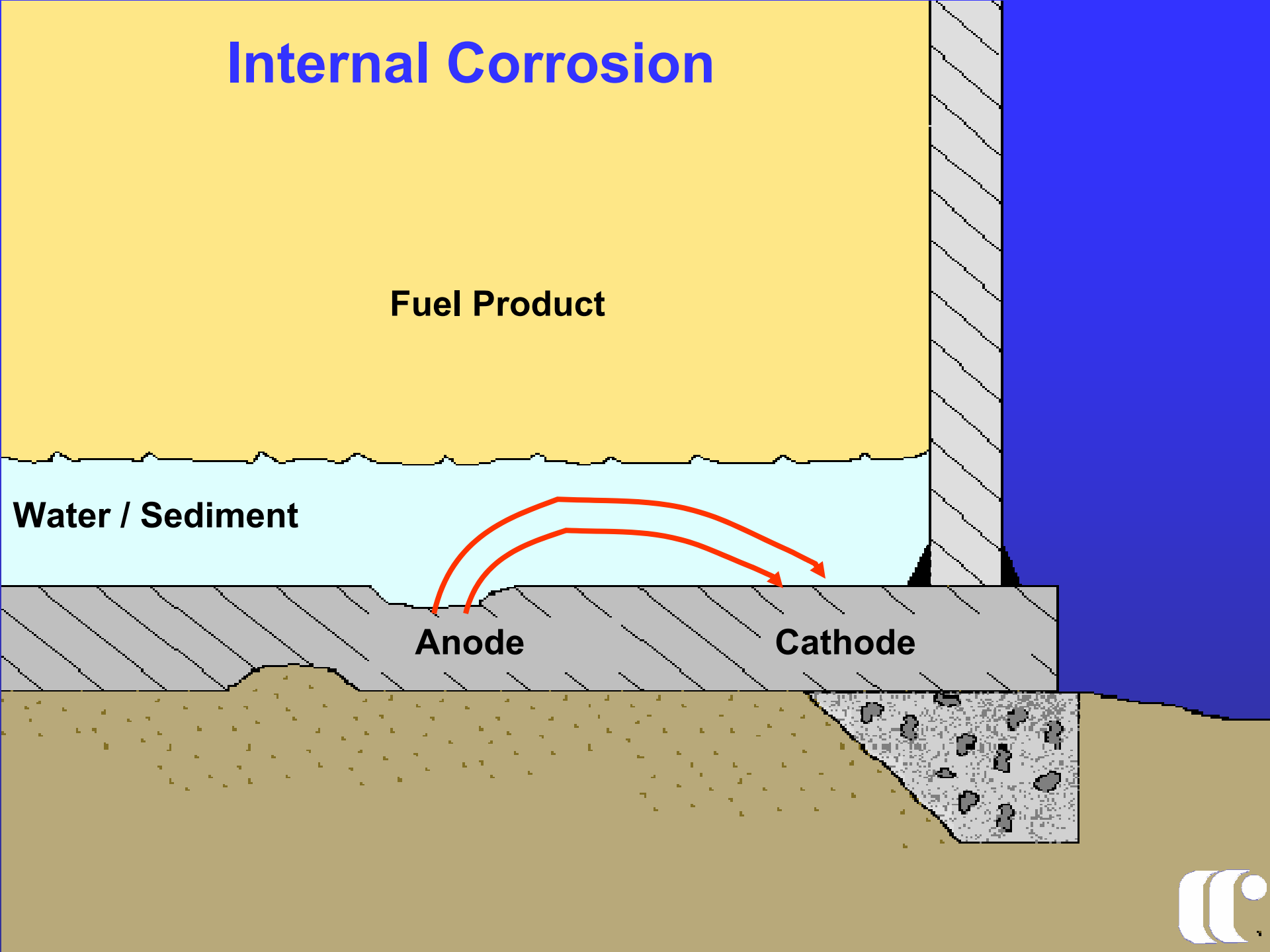


	Rim	25'	Center	55'	Rim
On	-1411	-698	-404	-601	-1455
Off	-902	-664	-402	-578	-911

Potentials (mV)



# Internal Corrosion



Fuel Product

Water / Sediment

Anode

Cathode







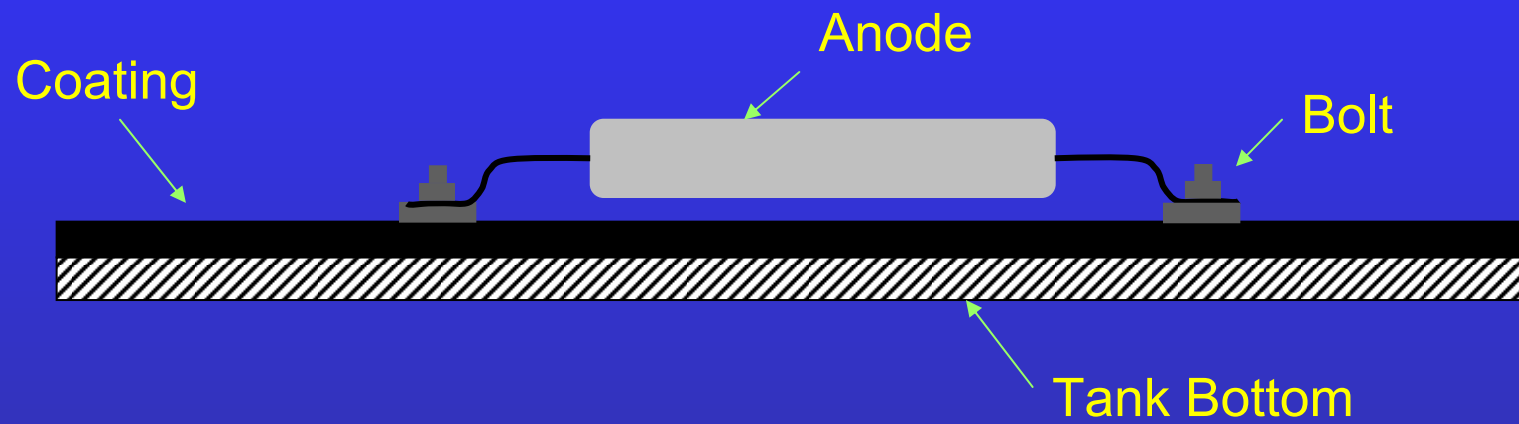
## Internal Corrosion











# 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

# Cathodic Protection Design Considerations

- ▶ Safety
- ▶ Codes
- ▶ Economics
- ▶ Performance
- ▶ System Life
- ▶ Interference
- ▶ Monitoring &  
maintenance
- ▶ Governmental Regulations





**Hot Asphalt Tank Bottoms**

- **Linings**

- **Must be compatible with with product stored**
- **Must maintain properties at operating temperatures**
- **Must be applied to properly prepared surface**
- **Must be applied with strict inspection**



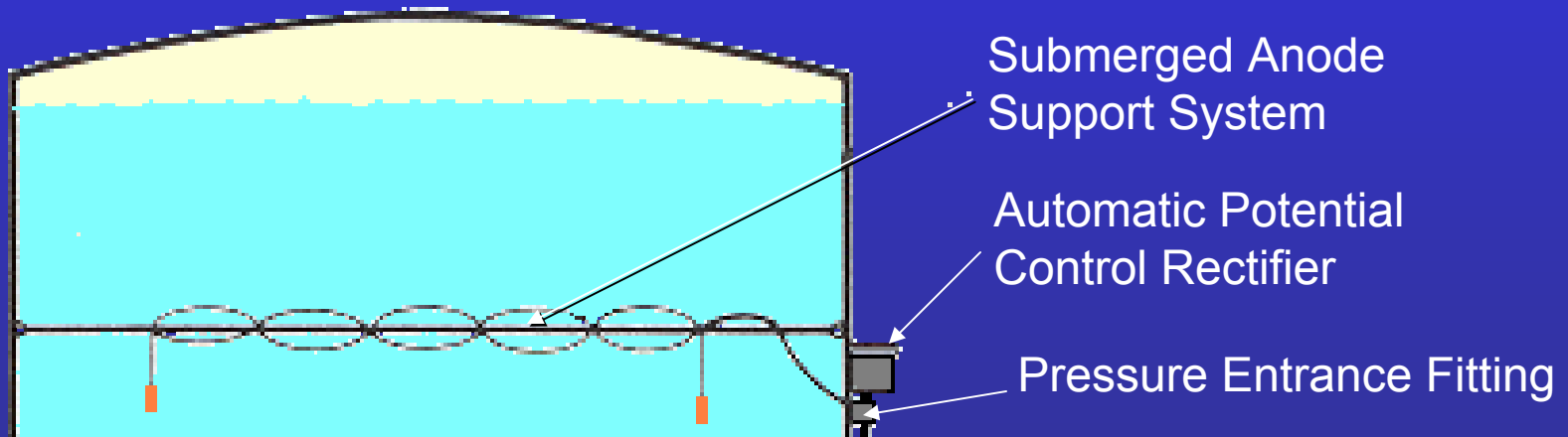
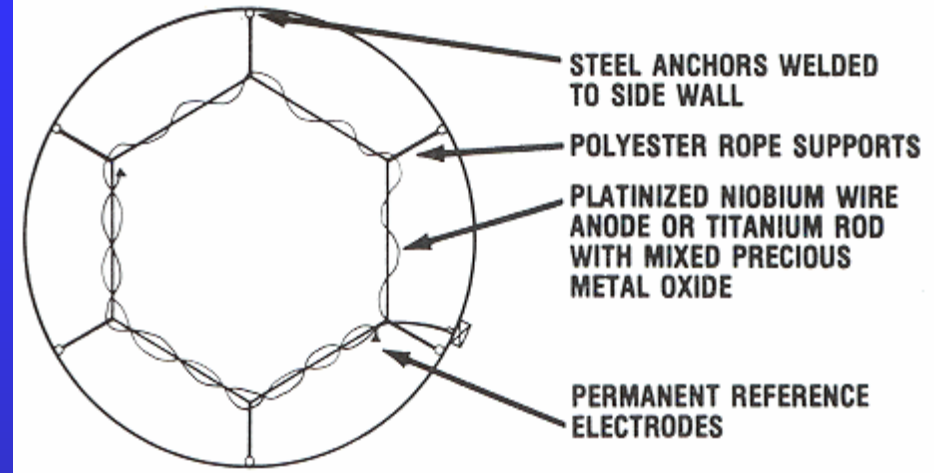
# Ductile Iron Water Piping



Pitting (concentrated) corrosion attack on ductile iron pipe.

# Suspended Horizontal Anode System

Top View Diagram



# Cathodic Protection Design Considerations

- ▶ Safety
- ▶ Codes
- ▶ Economics
- ▶ Performance
- ▶ System Life
- ▶ Monitoring &  
Maintenance
- ▶ Governmental Regulations



# Recommended Practices

API-651 - Cathodic Protection of Aboveground Petroleum Storage Tanks:

NACE RP0193-2001 - External Cathodic Protection of On-Grade Carbon Steel Tank Bottoms:





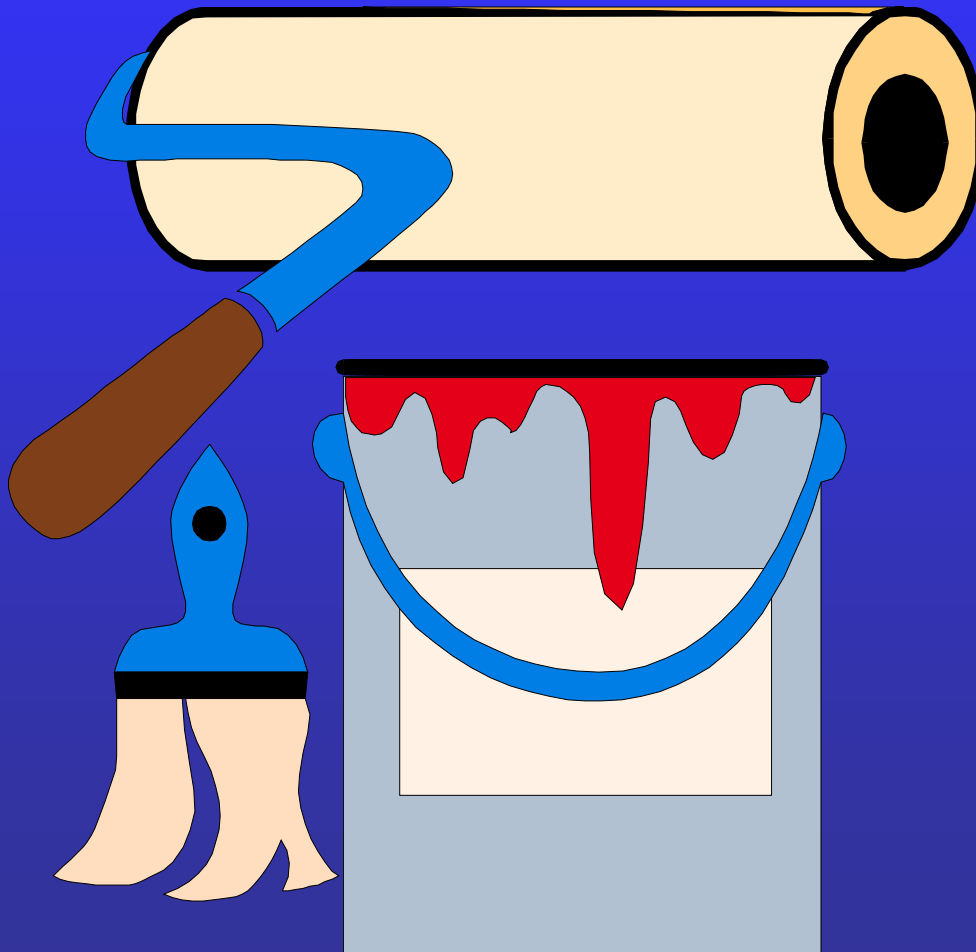
# Application Makes the Difference

Good Job

Poor Job



# Proper Application



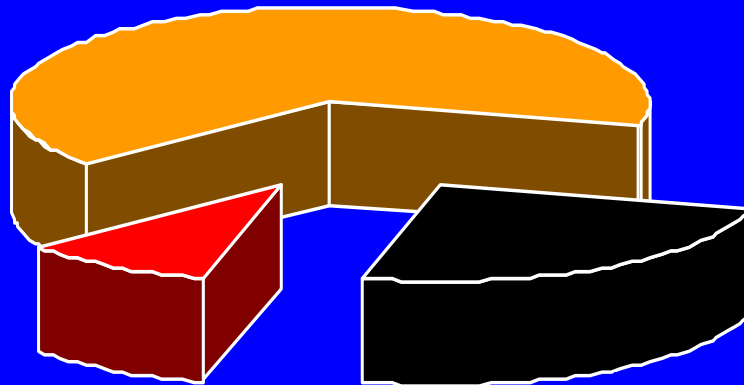
Application is the most expensive and most important part of the job...give it the attention it deserves!



# Cost Breakdown

## Typical Coating Project

Surface  
Preparation  
65%

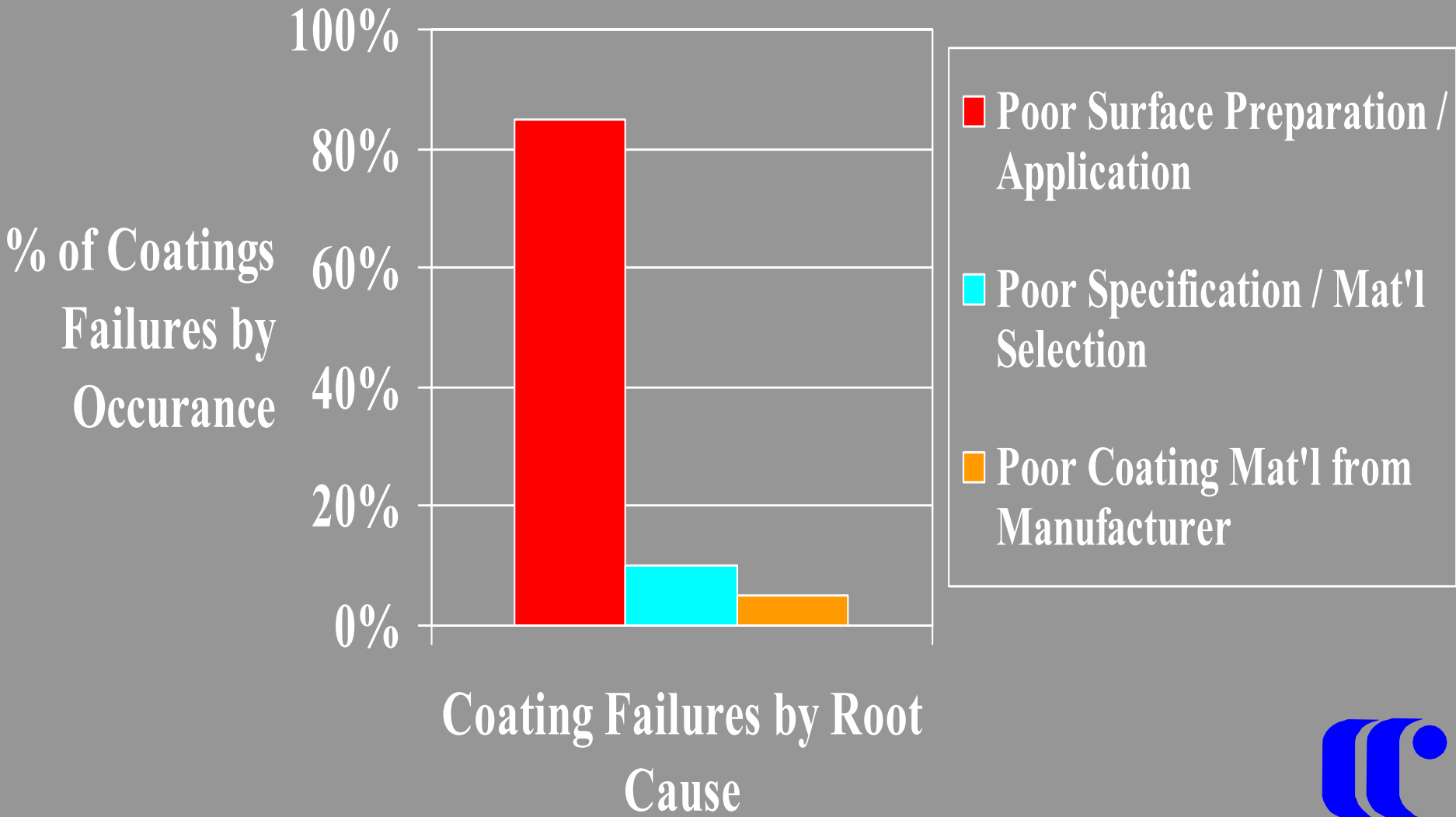


Material  
10%

Application  
25%



# Approximate Percentage of Coating Failure Occurrences, Grouped by Root Cause







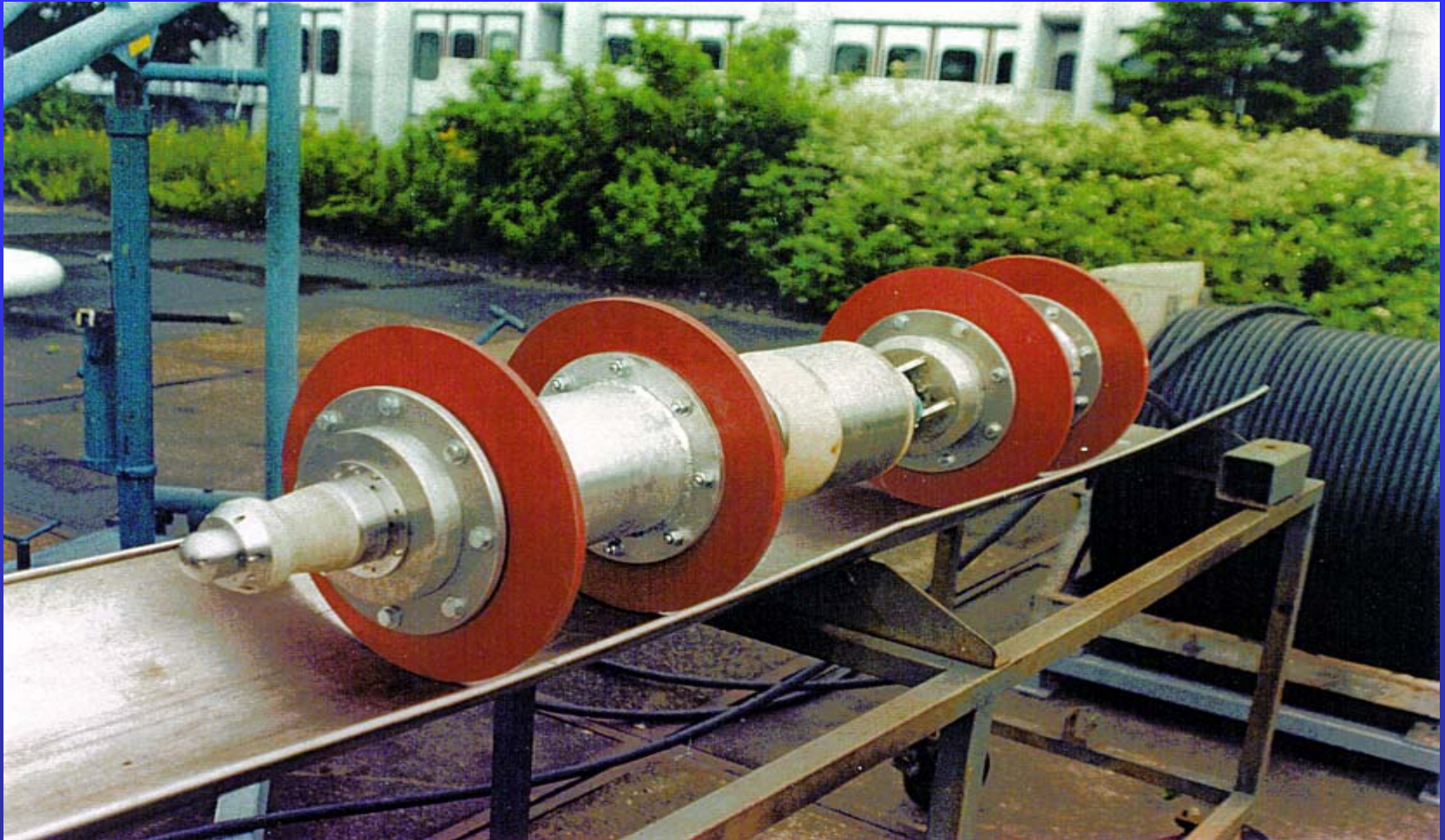
# Coating Inspection

# Pipeline Integrity Inspections

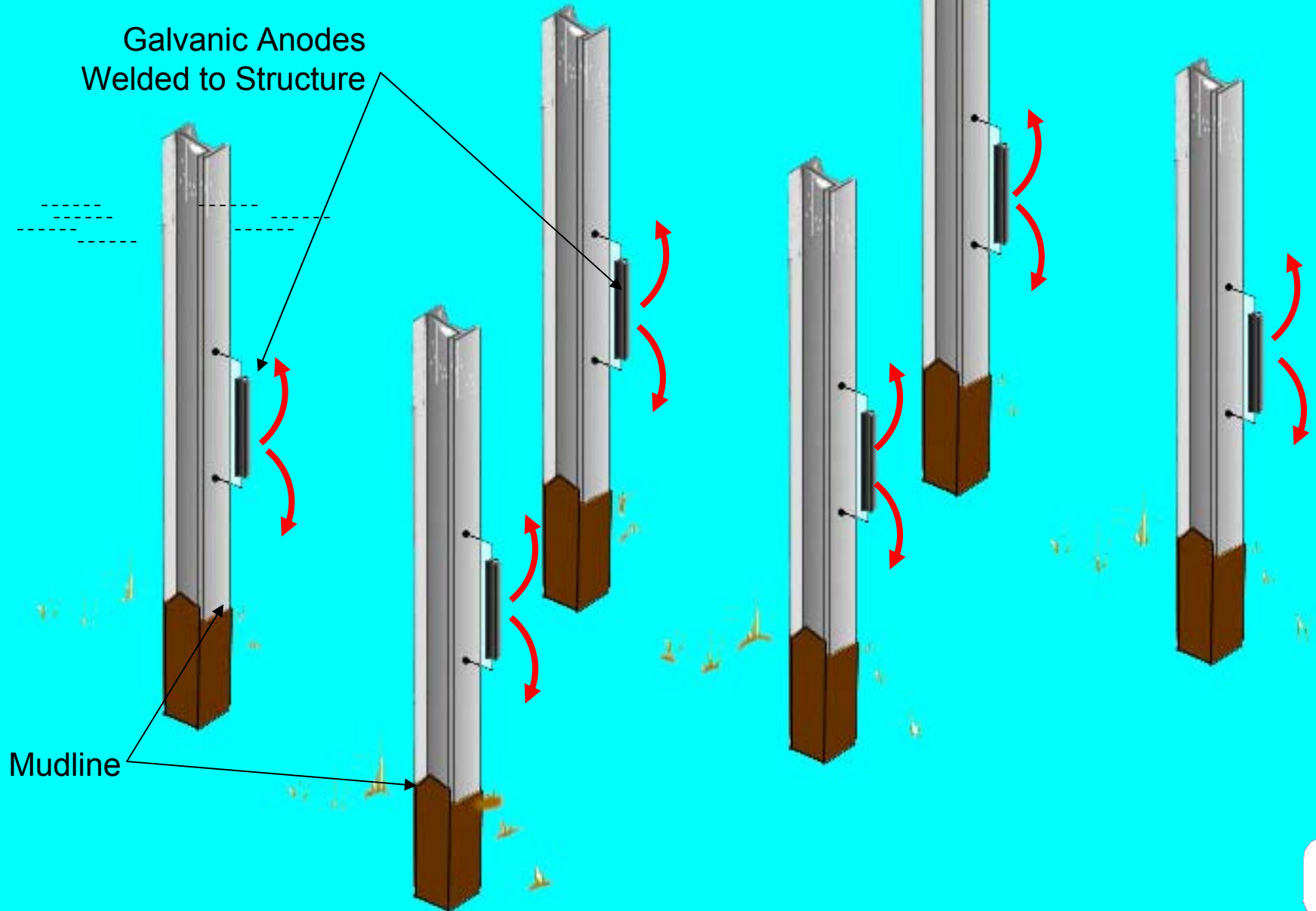




# Pipeline Inspection Tool

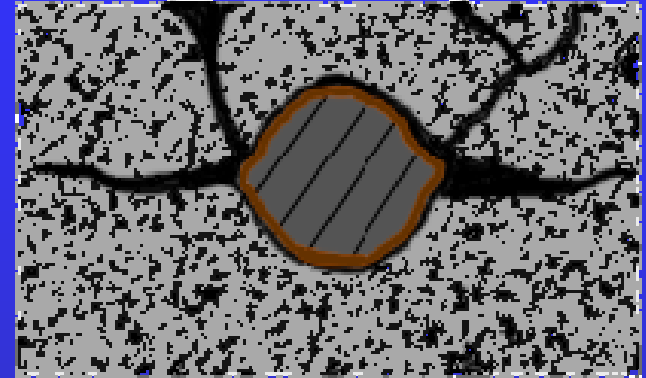
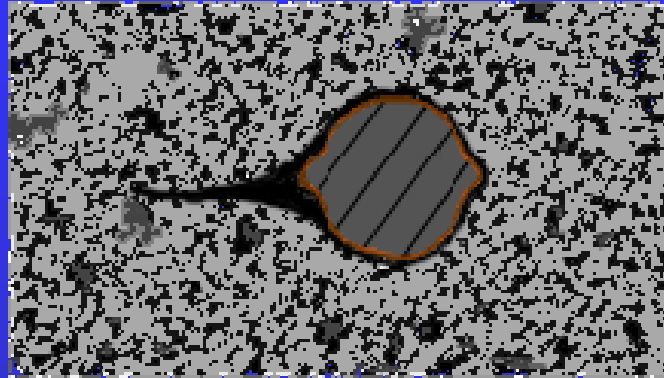
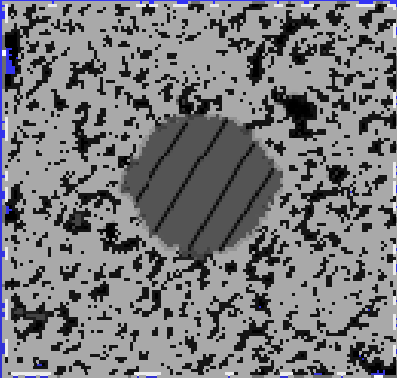


# Galvanic Cathodic Protection System Steel H-Piles or Pipe Piles





# Corrosion Induced Cracking of the Concrete



- Carbonation
- Chloride Contamination

# Summary

- **Be aware of all regulations that may pertain to your tanks and piping. When in doubt talk to the governing agencies.**
- **Engage NACE qualified & experienced personnel to engineer/maintain your cathodic protection system.**
- **Refer to NACE/API Standards for guidance.**

**Questions...**



***Thank You***

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Medina, Ohio 44256  
330-723-5082 (215)  
email [jlary@corrpro.com](mailto:jlary@corrpro.com)**



# Arc-Sprayed Al-Zn-In (Galvanic)

- Thermally sprayed onto concrete
- Al-20Zn-0.2In
- Applicable in marine & northern deicing salt environments
- Indium (In) used as activating agent

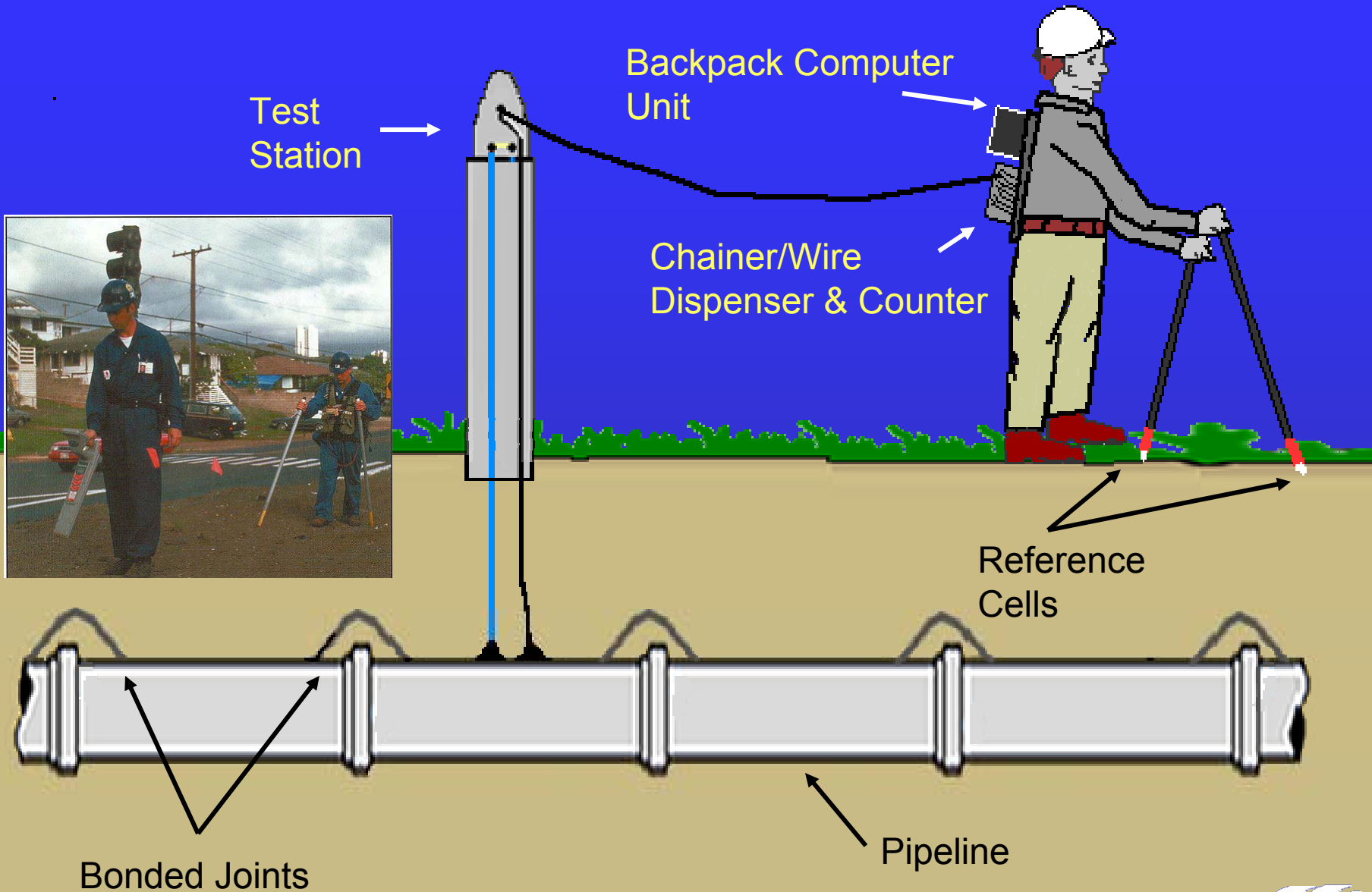


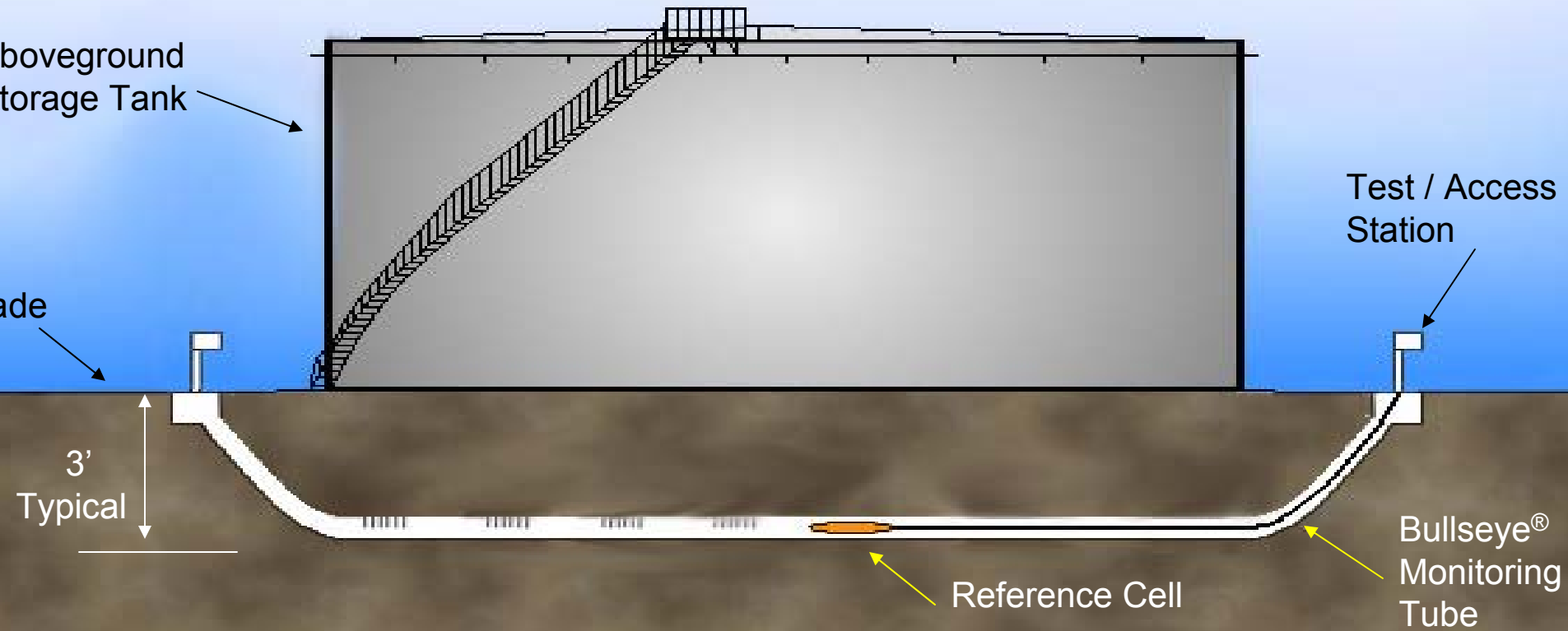
Presented by:

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# Computerized Potential Logging Survey



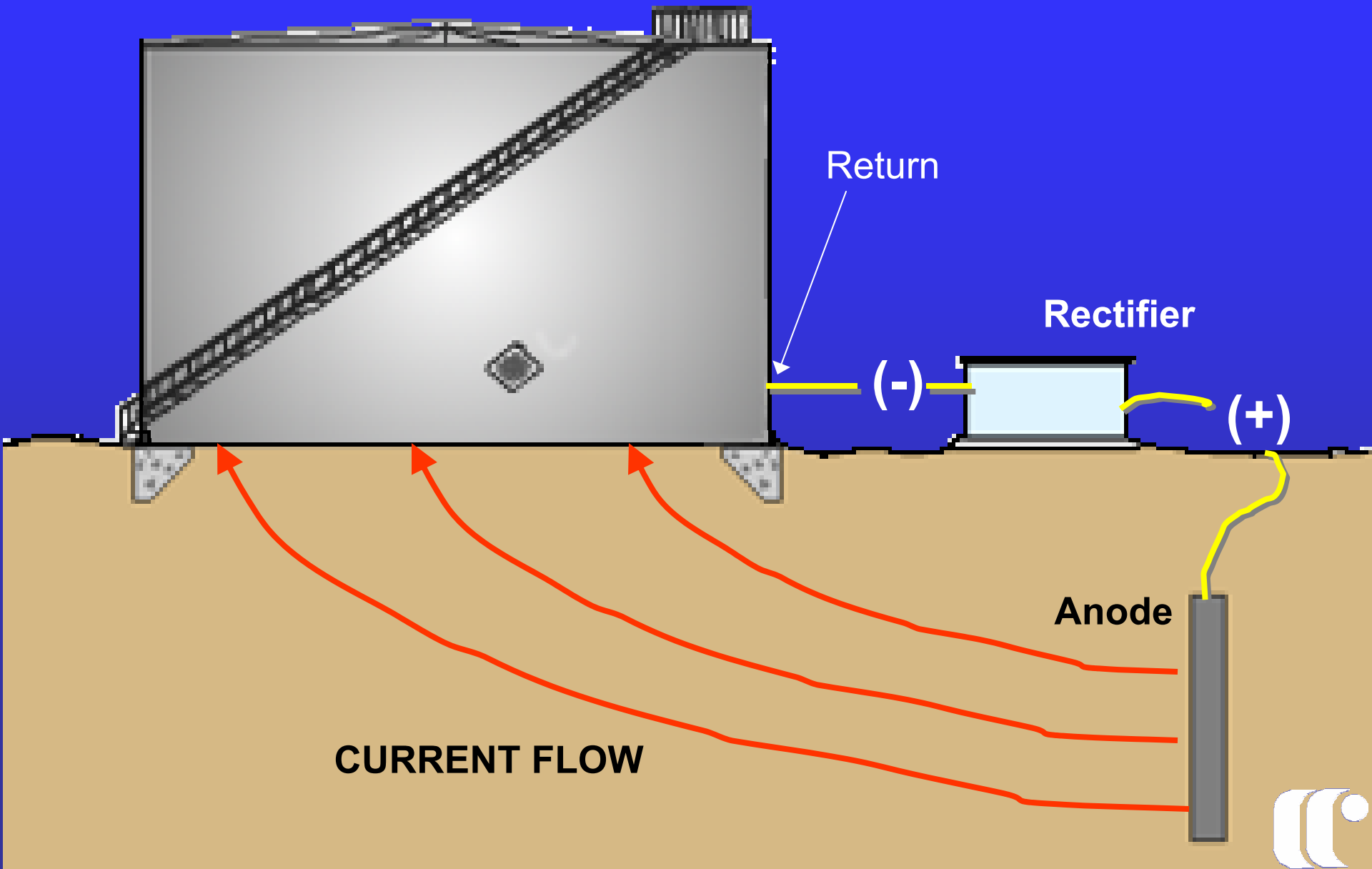


	Rim	25'	Center	55'	Rim
On	-1411	-698	-404	-601	-1455
Off	-902	-664	-402	-578	-911

Potentials (mV)



# Impressed Current Cathodic Protection





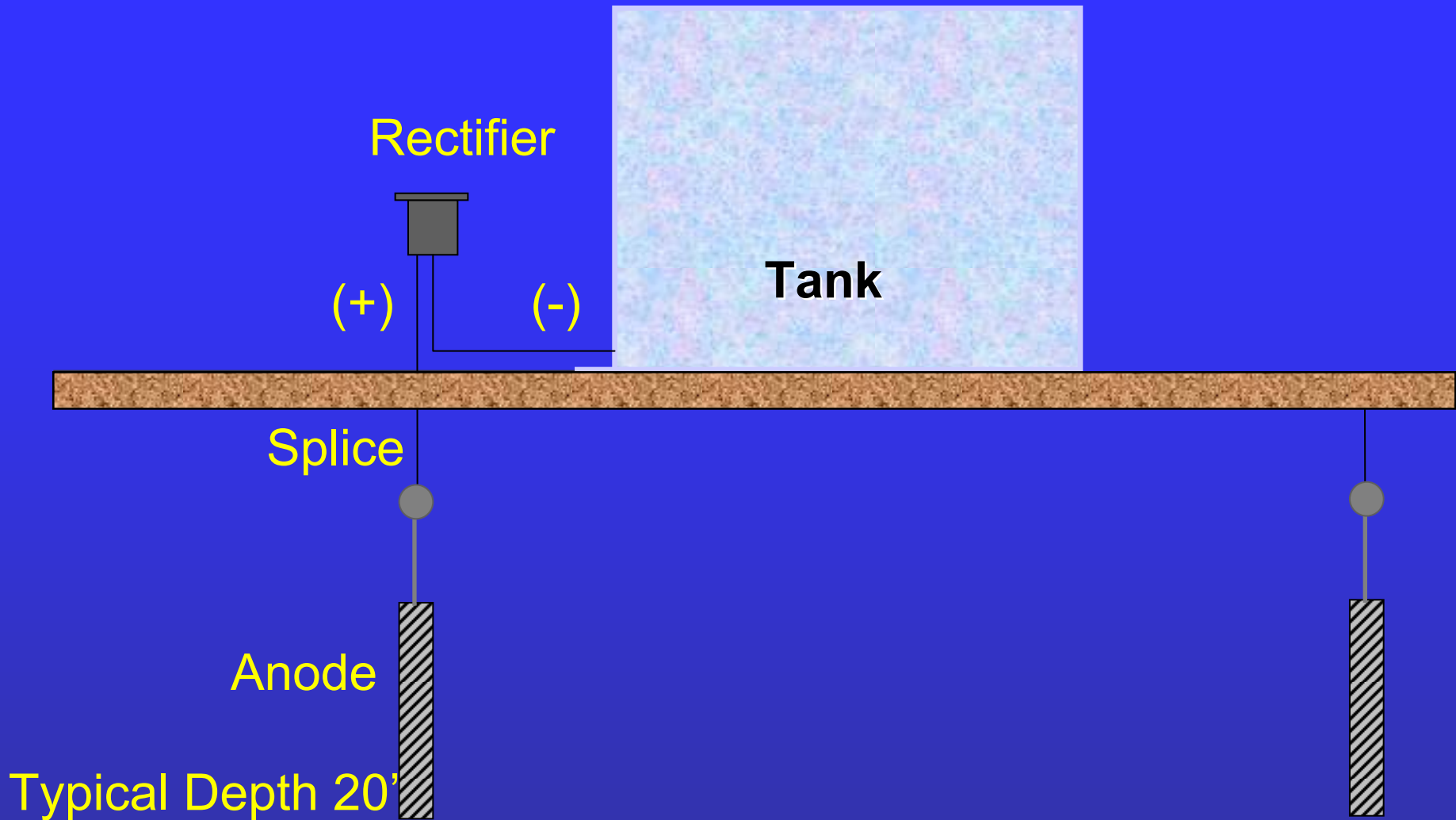






**Annual Cathodic Protection Survey**



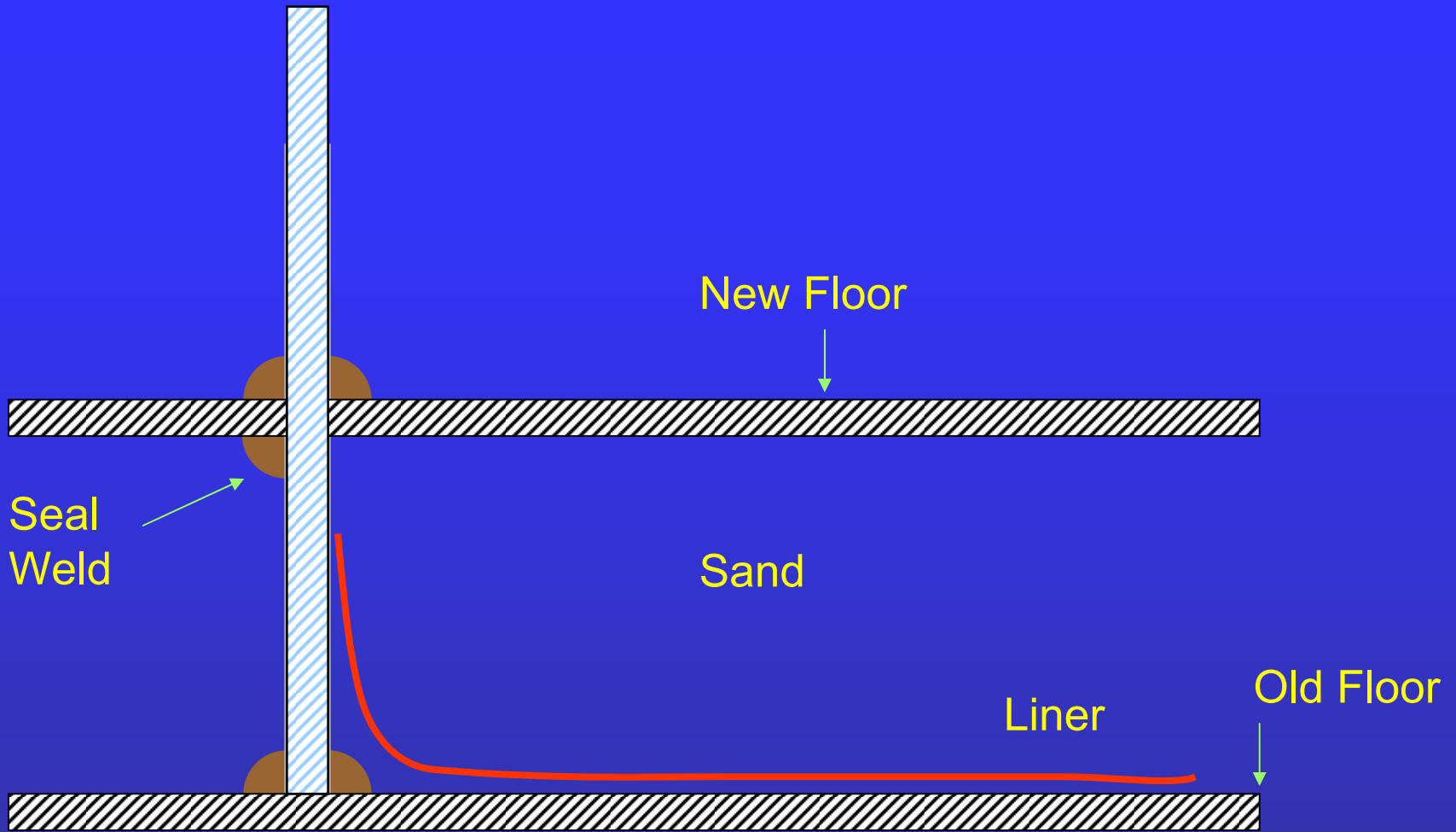


# Shallow Anodes









**Double Bottom Seal**



# **Pennsylvania DEP Summary of Technical Requirements for Aboveground Storage Tanks, Chapter 245, Subchapter F, Effective October 11, 1997...**

## **Cathodic Protection Systems (§245.532)**

- “When corrosion prevention is required on new, reconstructed or relocated tanks, or on tank bottom replacement, the cathodic protection system must be either: sacrificial anodes and dielectrical coating, or impressed current. (Another method s acceptable if it is recognized in a code of practice, such as API 651, or by a nationally-recognized association, such as NACE.)”



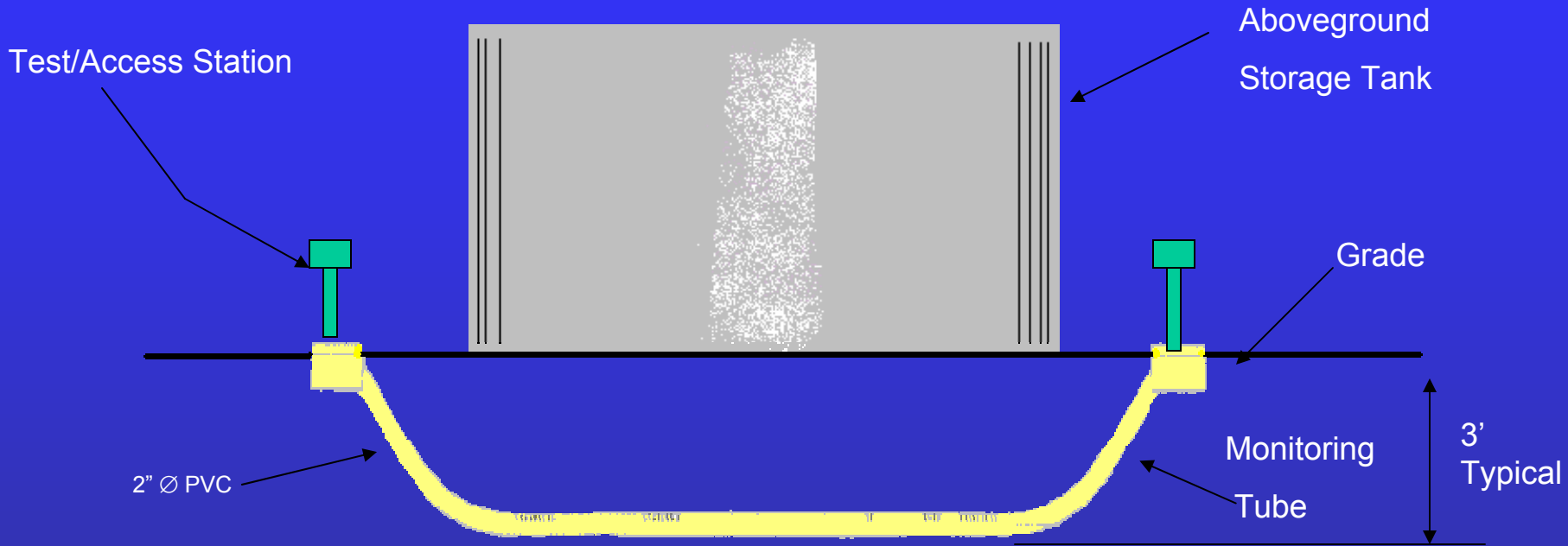
# Conventional Deep Anode System Disadvantages

- ▶ Premature system failure
- ▶ Costly re-drilling at failure
- ▶ Potential for cross mixing of subsurface aquifers
- ▶ Creates conduit for surface spills





**API 653 Floor Scan**



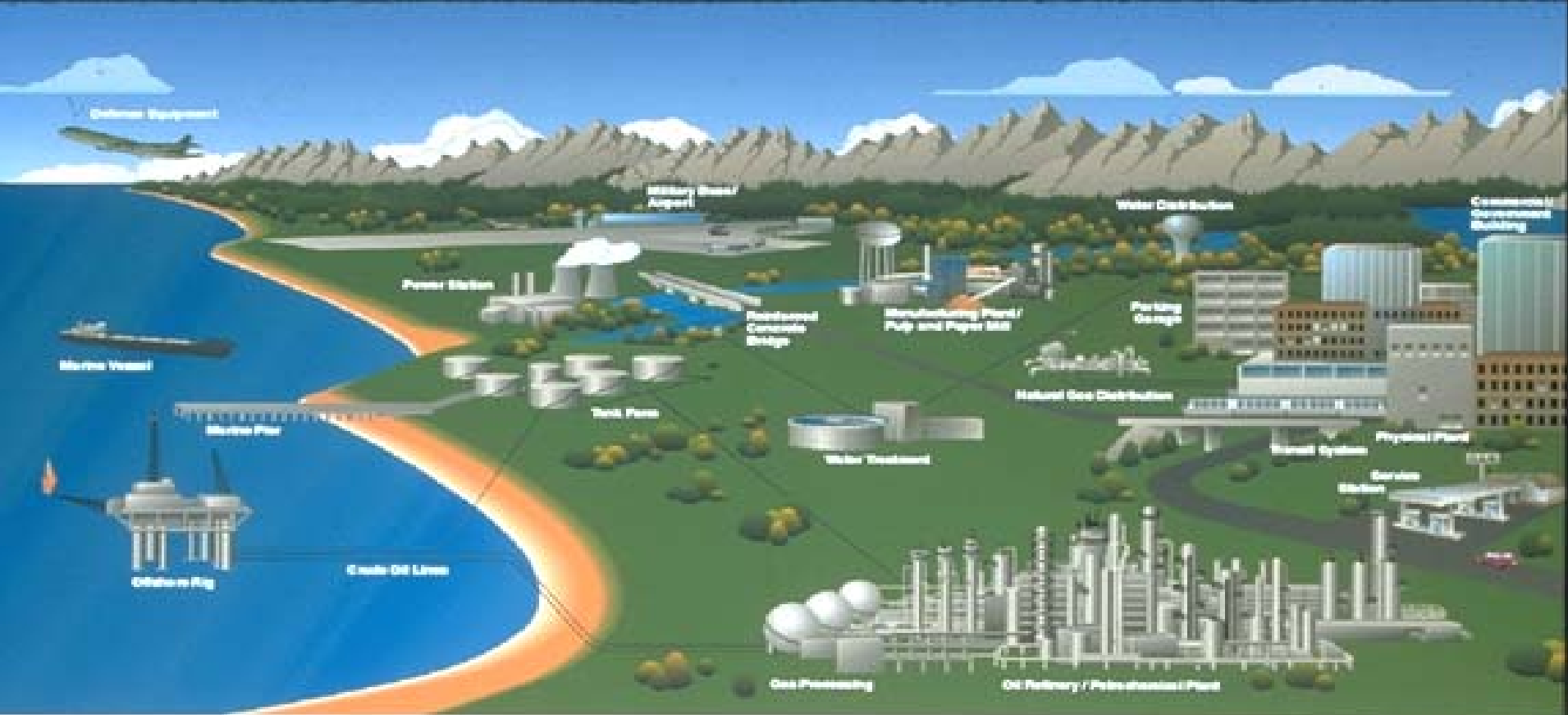
**CATHODIC PROTECTION / LEAK DETECTION  
MONITORING TUBE**

# Our Business

**Engineering Design, Application & Installation of:**

-  **Cathodic Protection**
-  **Corrosion Monitoring**
-  **Material Selection**
-  **Chemical Treatment Systems**
-  **Protective Coatings**
-  **Pipeline Integrity Assurance Programs**





# Worldwide Corrosion Control Source



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Companies  
Incorporated

*"A Commitment to Excellence"*



**GOOD-ALL ELECTRIC**  
A CORROSION CONTROL



**CPS**