NISTM

National Institute for Storage Tank Management

Vapor Corrosion Inhibitors (VCIs) for Storage Tanks
Corrosion Controlled Cost Controlled

Presented by Kelly Baker, Zerust Oil & Gas
Efim Lyublinski, Monique Posner, Terry Natale,
Yefim Vaks, Ronnie Singh
Northern Technologies International Corporation, USA

Marcelo Schultz
Petrobras, Brazil

NTI

ZERUST OIL & GAS

Topics For Discussion

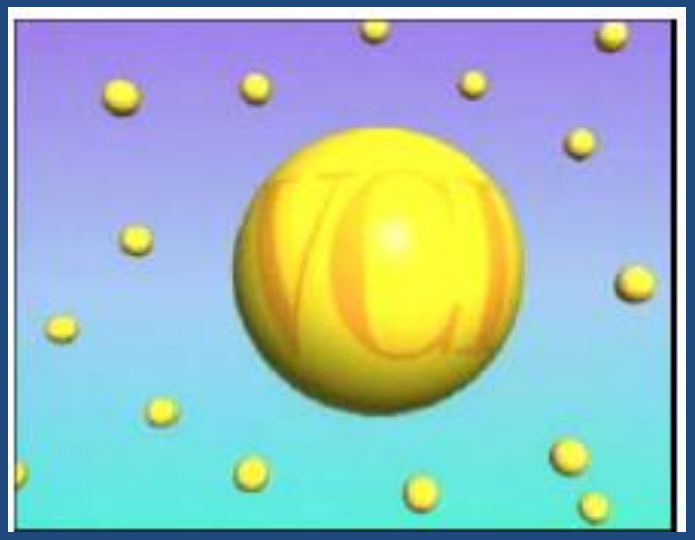
1. VCI Background
2. Problem definition
3. Corrosion protection of storage tanks soil side bottom (SSB)
4. Corrosion protection of oil storage tank roofs
5. Conclusions

Definition - VCI

Vapor Corrosion Inhibitors

Also referred to as Volatile Corrosion Inhibitors

- A class of corrosion inhibiting compounds which have vapor pressures higher than that of air.
- This results in the release of vapor molecules of inhibitor into the air.
- These molecules will adsorb to the surface of steel and block other molecules from coming in contact with the steel.



Many forms of VCI

What's the difference?

1. Self-fogging Flash Corrosion Inhibitor (FCI™) technology
   - High vapor pressure, low vapor density
   - Fast acting flash corrosion inhibitor
   - Fills vapor spaces immediately
   - Highest volume of protection per weight of active ingredient
   - Navigates complex systems
2. Long-term Vapor Corrosion Inhibitor (VCI) protection
   - Slower evolving, long-term vapor corrosion inhibitor
3. Long-term Soluble Corrosion Inhibitor (SCI) protection
   - Contact corrosion inhibitors activated when water present
   - Chloride "neutralizer"

Automotive industry – 30+ years

Not "NEW" Technology

- Thousands of machined parts must remain pristine during transport and storage.
- Clean, environmentally friendly, requires no cleaning prior to assembly.

VCIs have been sold through major retailers for years

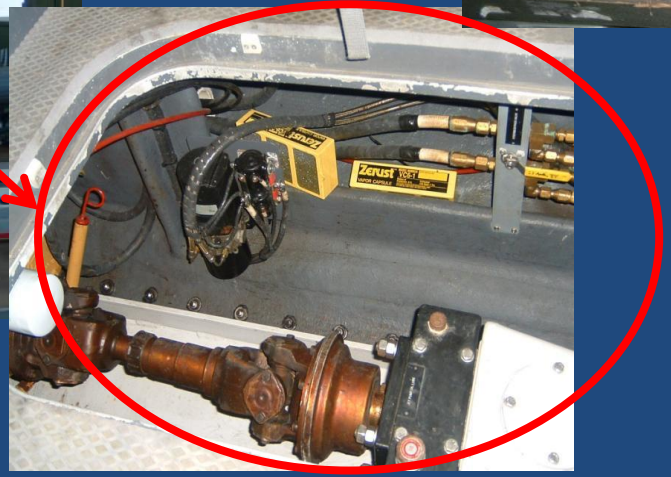
Several 'consumer market' products you can try

- Lowes
- Cabellas
- Flambeau
- Kobalt
- …others

Some consumers are more demanding than others …

The Navy SEALS

VCI capsules in the engine housing



The Marines in Iraq

VCI gun sleeves

Long Term Corrosion Protection

Shipping, Storage, Mothballing

Retarding Corrosion

Corrosion cannot be eliminated, it's mechanism can only be retarded

Applications!

How can VCI be used in AST's?

Problem Definition

Corrosion Is One Of The Biggest Problems In The Oil And Gas Industry Worldwide

Risks

- Critical risks from corrosion of storage tanks are:
  - ✓ Loss of product
  - ✓ Contamination of environment
  - ✓ Critical component down time
  - ✓ Risk of fire and explosion

Costs

- Estimated corrosion costs: ~ $0.40 per barrel of oil produced
- Maintenance Costs: ~ 60% of all are related to corrosion
- Loss of oil production: ~ 10%
- Production Industries ~ $12.8B annually in 2002

Existing Solutions

Existing Corrosion Protection Methods (CPM)

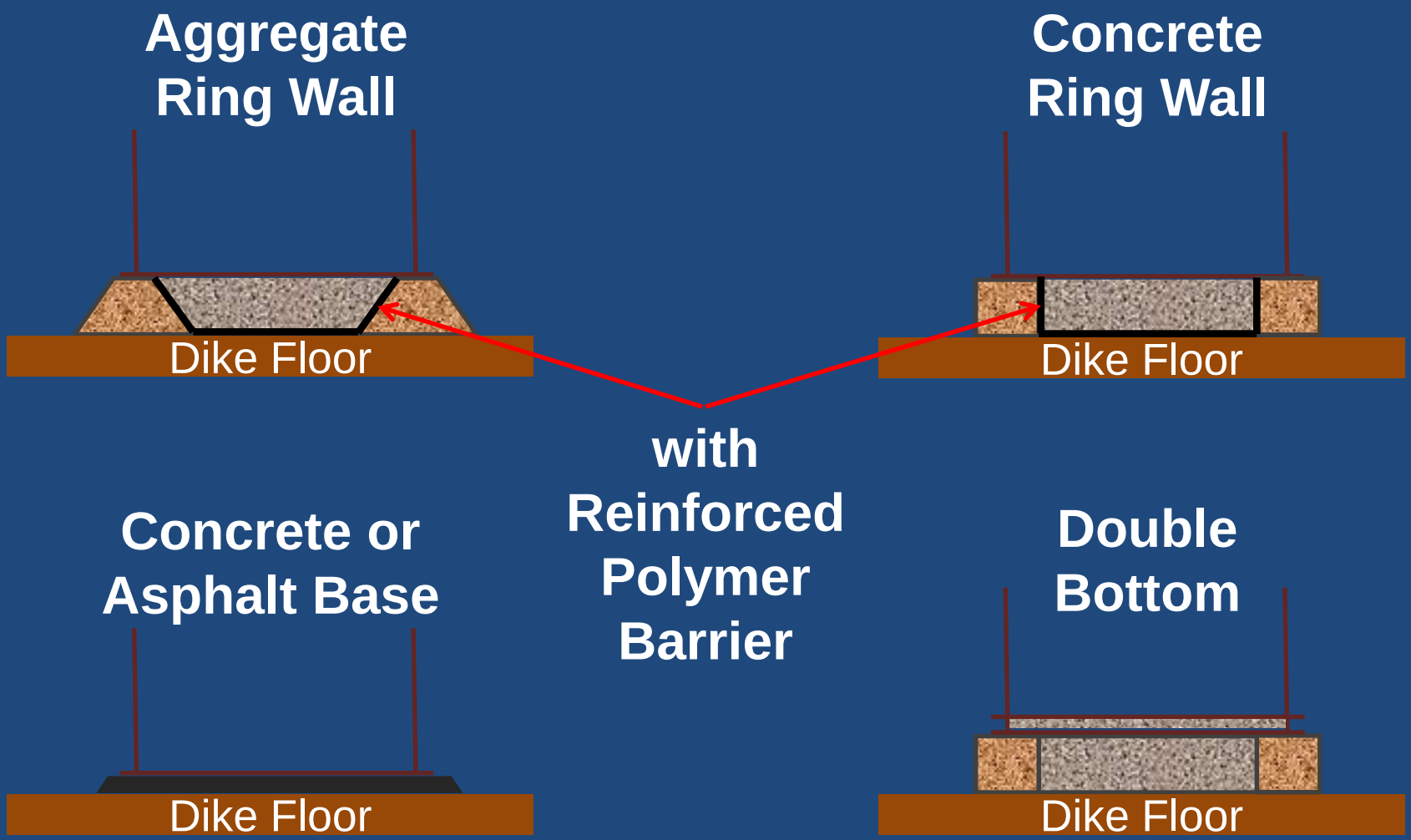
Some CPM may not be appropriate or are not efficient when used alone:

- **Cathodic Protection Systems (CPS)**
- **Coatings / Linings**
- **Volatile or Vapor Corrosion Inhibitors (VCI)**

Discussion focus:

- **Crude oil storage tanks soil side bottoms (SSB)**
- **Tank roofs**
- **Case Studies of these VCI solutions**

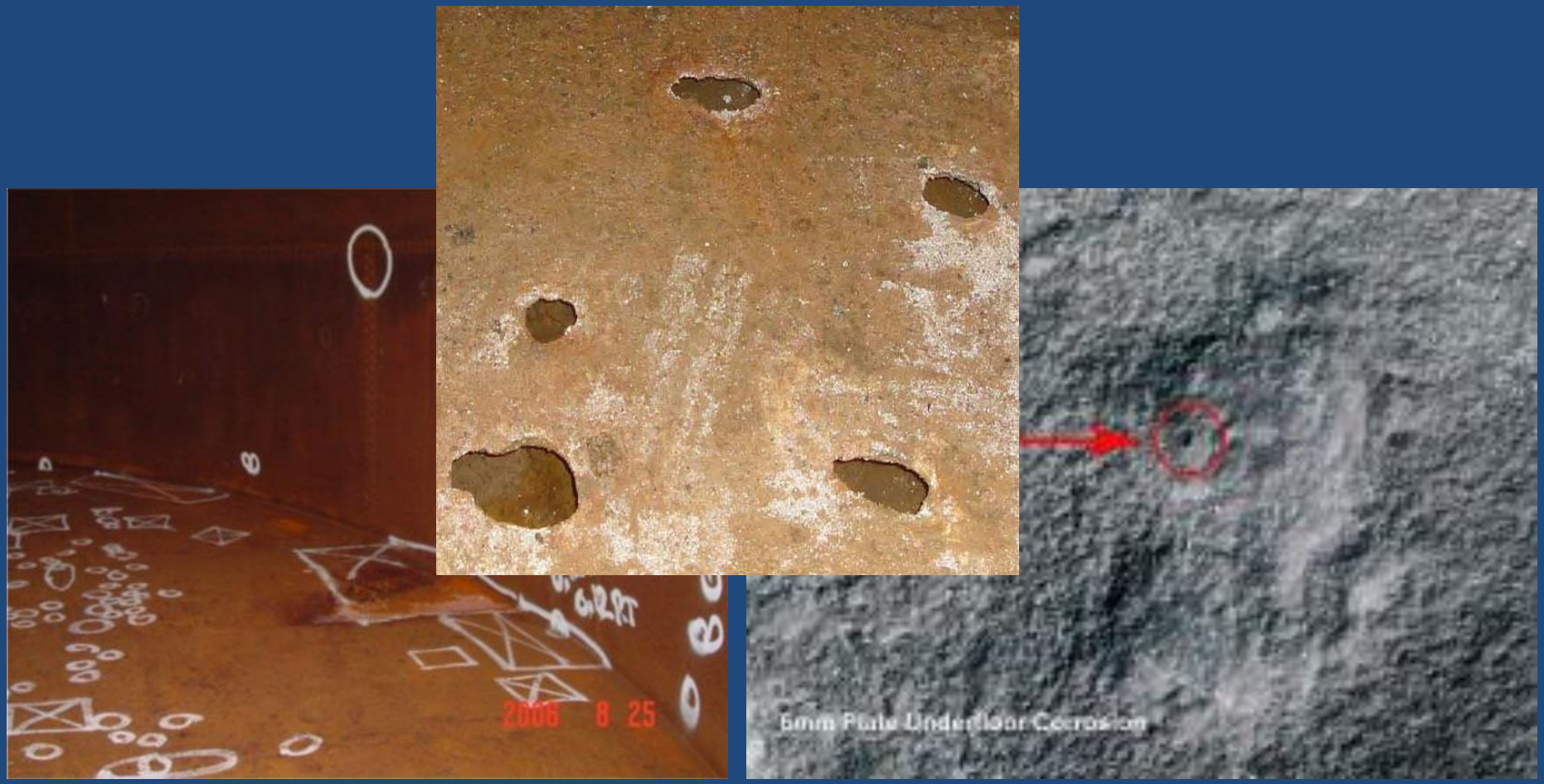
Tank Bottom Geometries



Cone Up - Flat - Cone Down

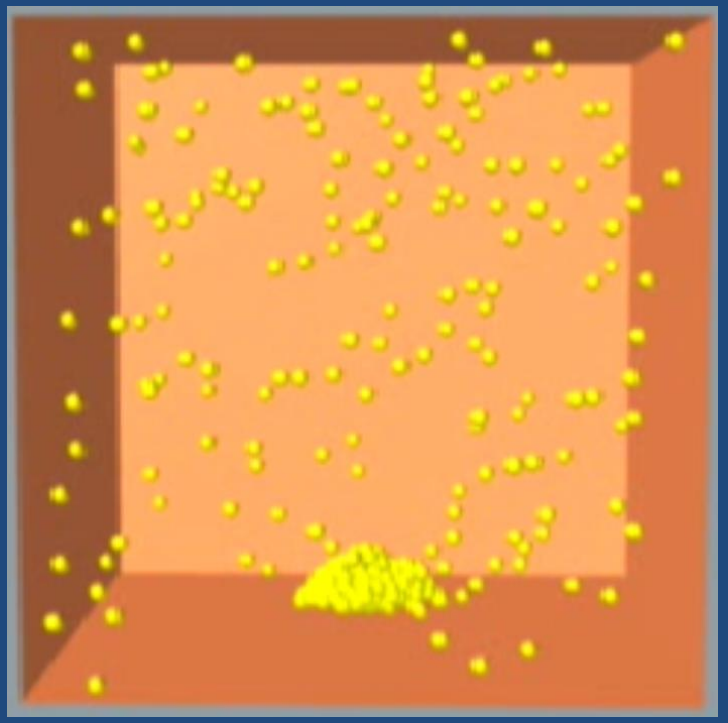
Examples of Problems

Penetrations due to tank bottom corrosion



What are VCIs?

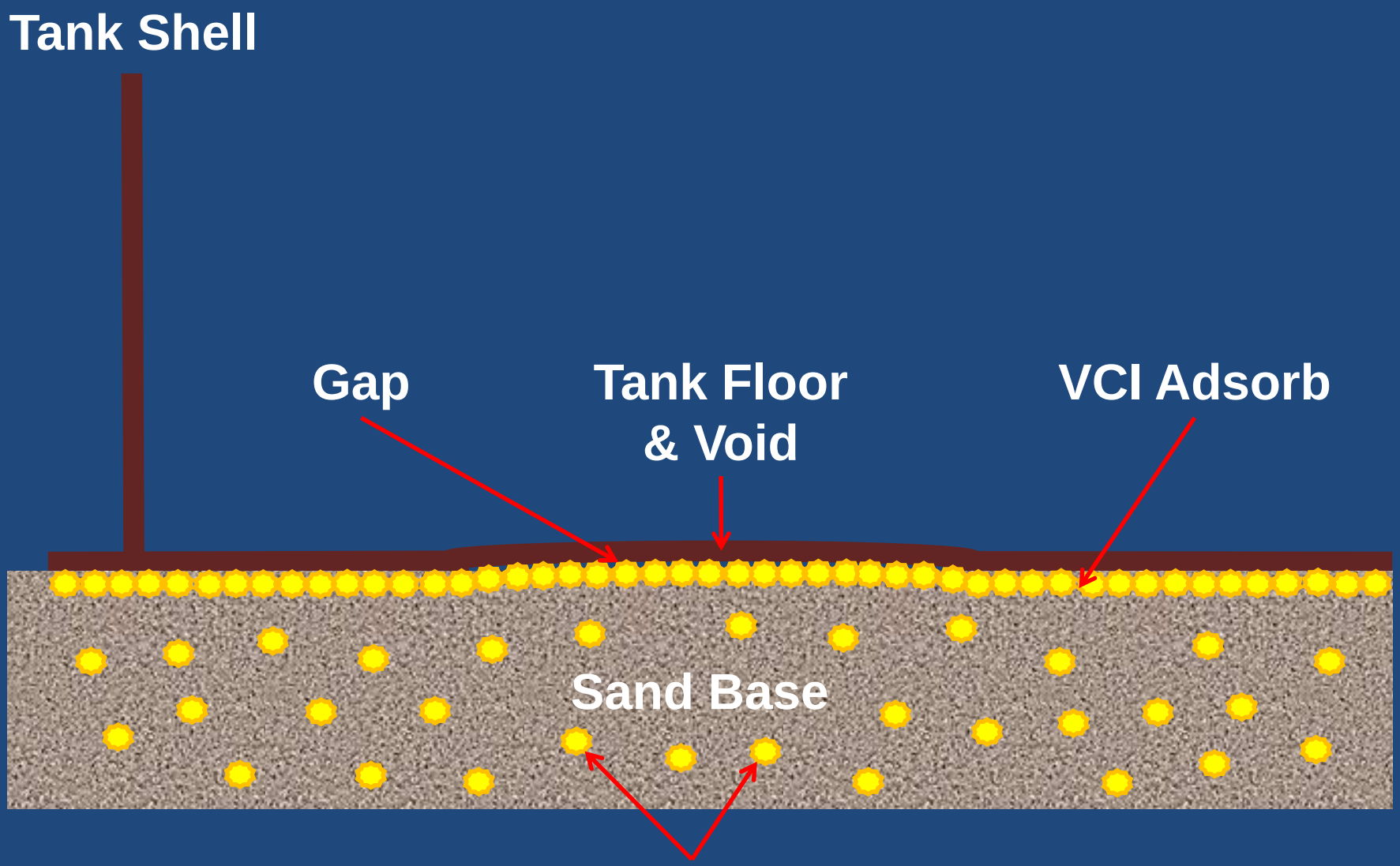
- A class of corrosion inhibiting compounds which have vapor pressures higher than that of air.
- This results in the release of vapor molecules of inhibitor into the air.
- These molecules will adsorb to the surface of steel and block other molecules from coming in contact with the steel.



- Can protect immersed surfaces
- Not a ‘coating’
- Does not change metallurgy
- Not permanent

- Can be painted/welded
- Non-toxic
- Can be designed for specific service exposure

How Do VCIs Work Under Tanks?

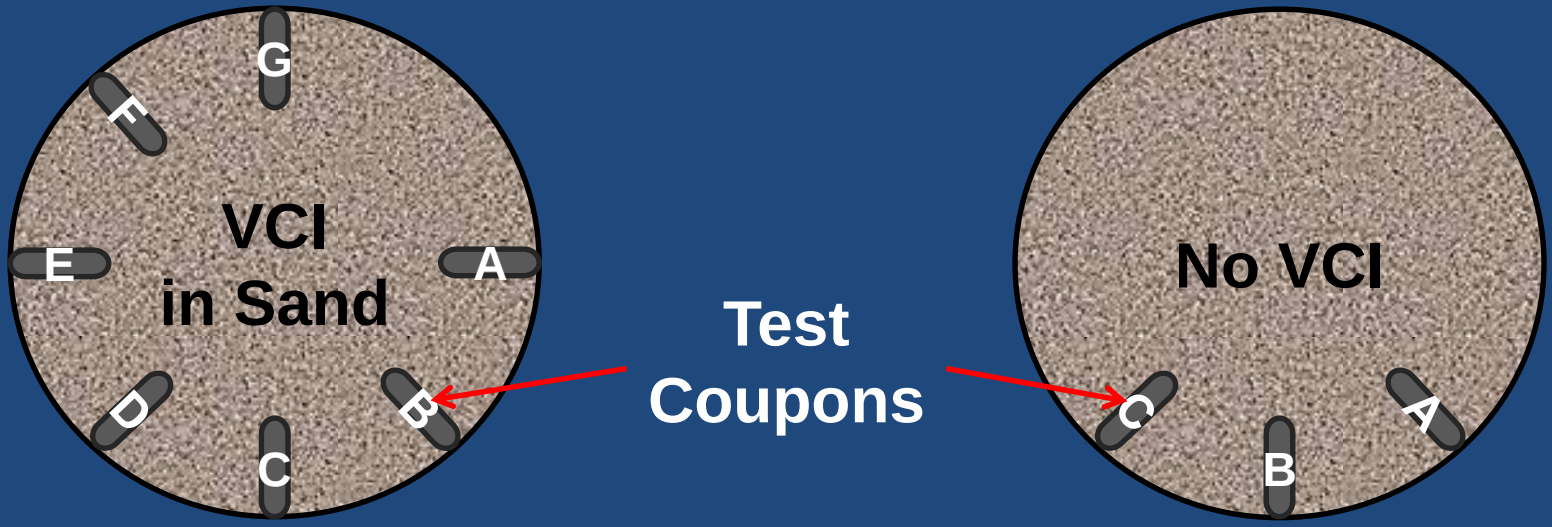


Case Study – Double Bottom

Soil Side Bottom (SSB) Protection

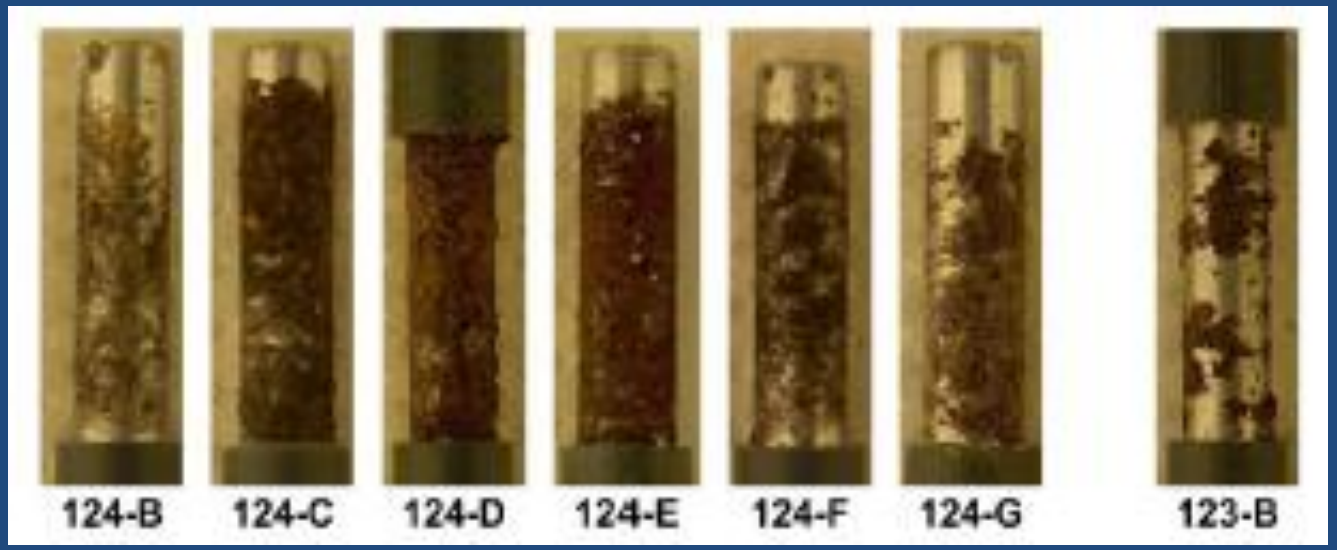
Test

Control



Coupon Tests

Coupons were removed in 2007 and 2011 for corrosion rate evaluation according to ASTM G1-03



1018 Carbon Steel

Surface Area Results

Surface Area Affected by Corrosion - 2007 Specimens

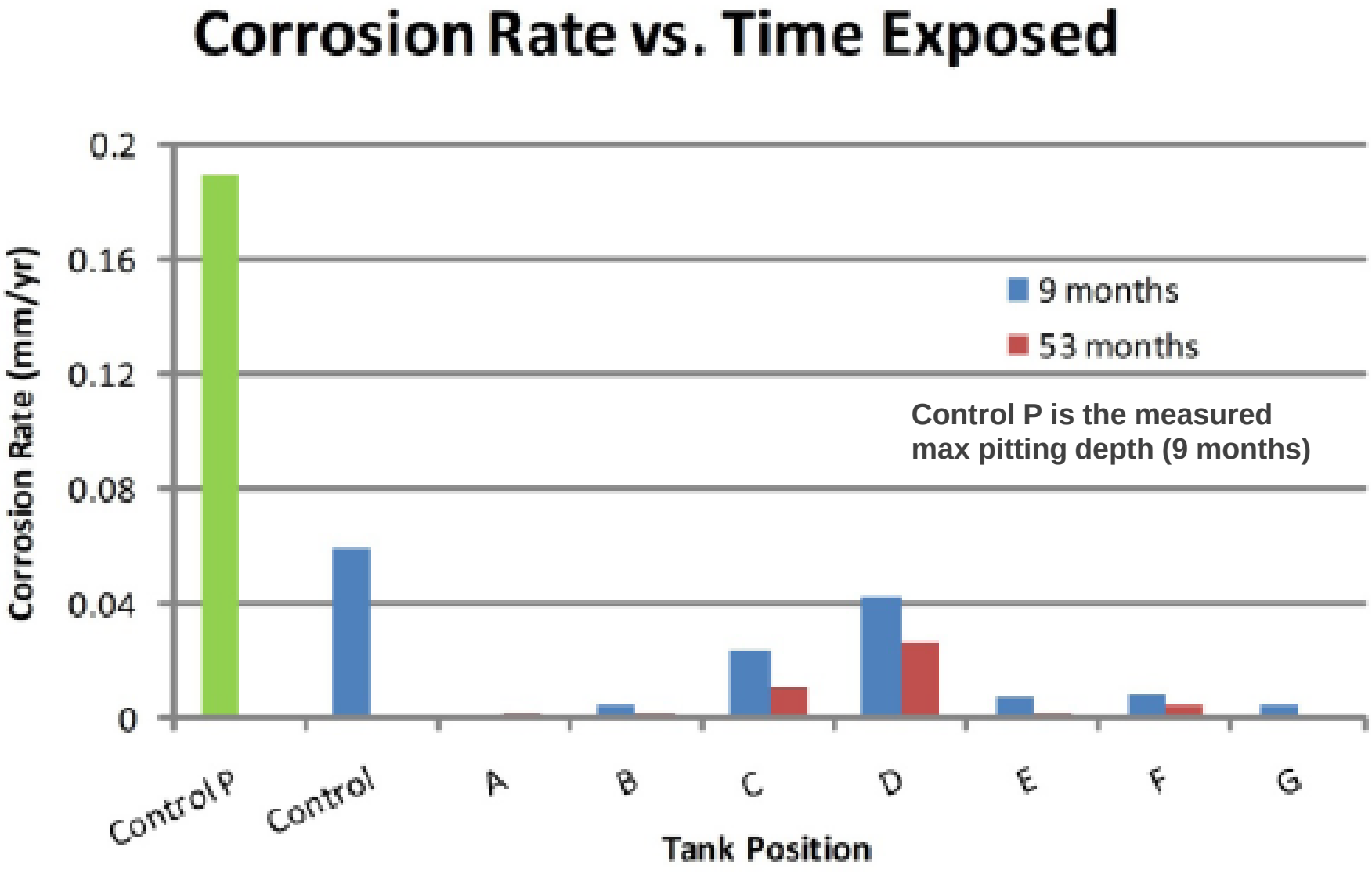
Specimen Type	Specimen ID	% Corroded Surface Area	Predominant Type of Corrosion
Test Tank	B	86	Uniform / General
	C	81	
	D	85	
	E	57	
	F	61	
	G	43	
Control Tank	Control	22	Pitting

Corrosion Rate Results

Specimen Type	Specimen ID	Corrosion Rate (mm/year)	
		2007 Specimens	2011 Specimens
Test Tank	A	--	0.0014
	B	0.0041	0.0013
	C	0.023	0.010
	D	0.042	0.026
	E	0.0075	0.0017
	F	0.0085	0.0041
	G	0.0050	--
	ALL (Avg)	0.015	0.0075
Control Tank	Control	0.059	--
	Control P*	0.19	--

* Control P is the measured maximum pitting depth

Results Continued



Soil Side Bottom - Conclusions

1. **VCIs can work in conjunction with other forms of corrosion protection or stand-alone.**

2. **Can be installed under almost any tank pad design.**

3. **Tank pad design determines whether the original VCI installation can be accomplished while the tank is in service, or if it needs to be out-of-service.**

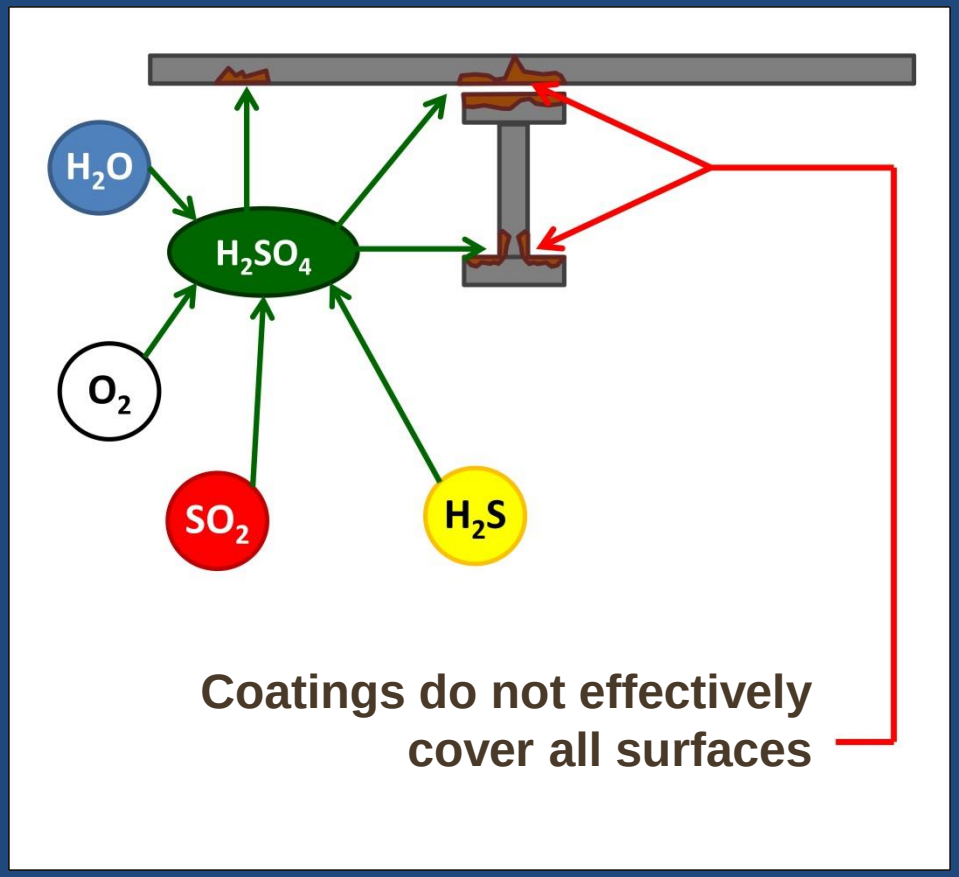
4. **VCI can be replenished as needed over time without taking the tank out-of-service, in any of the scenarios mentioned above.**

5. **Testing indicates that VCIs have a significant impact on reducing pitting corrosion.**

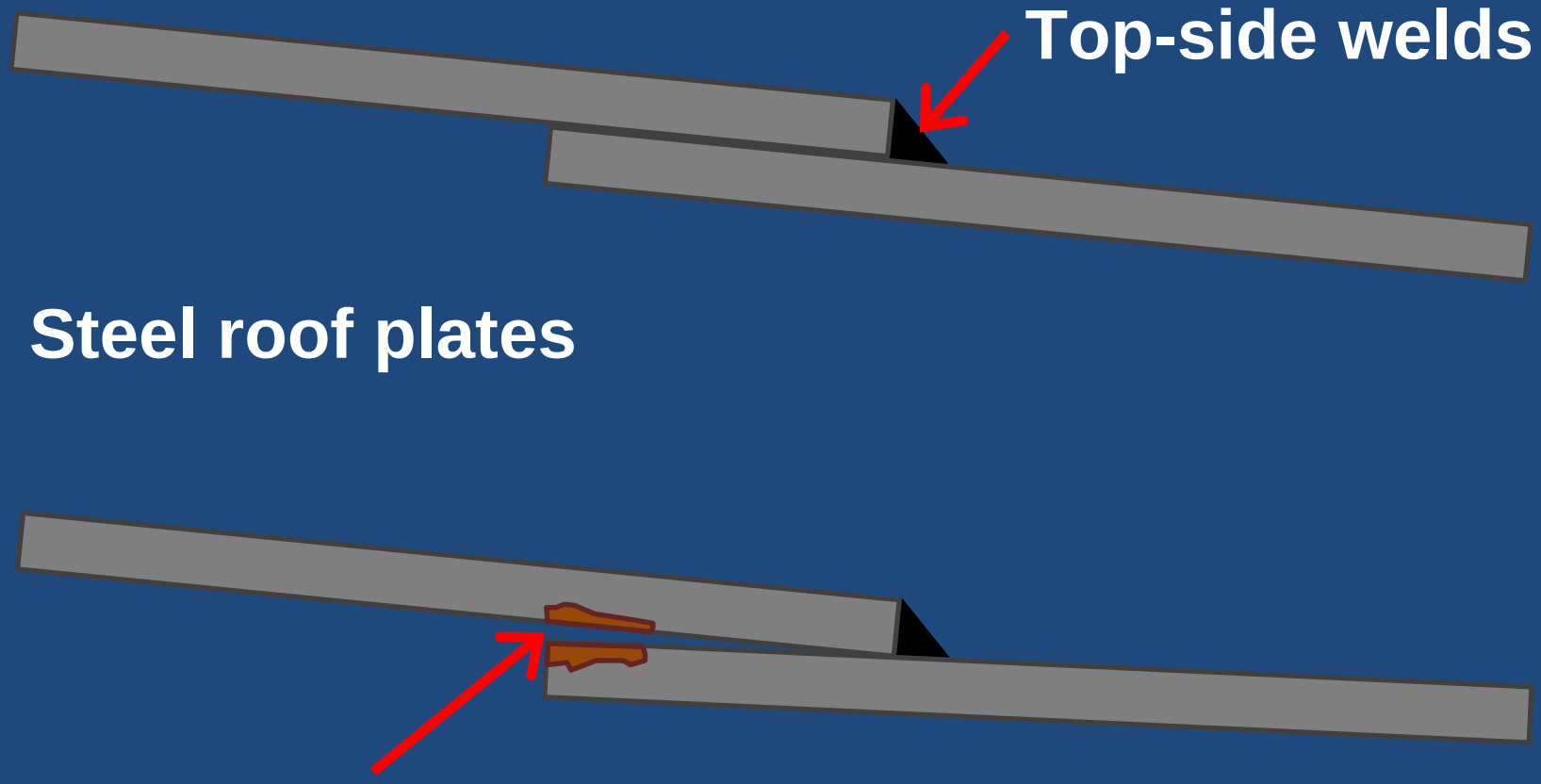
6. **Reduction in corrosion rates extend the life of the asset and the maintenance interval.**

Difficulty in Protection

Tank roof and support beam



Flexing of Plates



Flexing of roof plates allows for crevice corrosion

Vapor Space Environments and Corrosion Rates

Basic Composition Tank Top Vapor Space Atmospheres

Typical vapor space environment for a crude oil storage tank considered in developing the corrosion protection solution

Components	O_2	SO_2	H_2S	Cl^-	N_2	CO_2	H_2O
Contents, %	4.0	1.0	1.0	0.5	70.0	12.0	0.5

Relative humidity (RH): Close to 100% **Temperature: Ranges up to +80°C**

Corrosion environments are unpredictable.

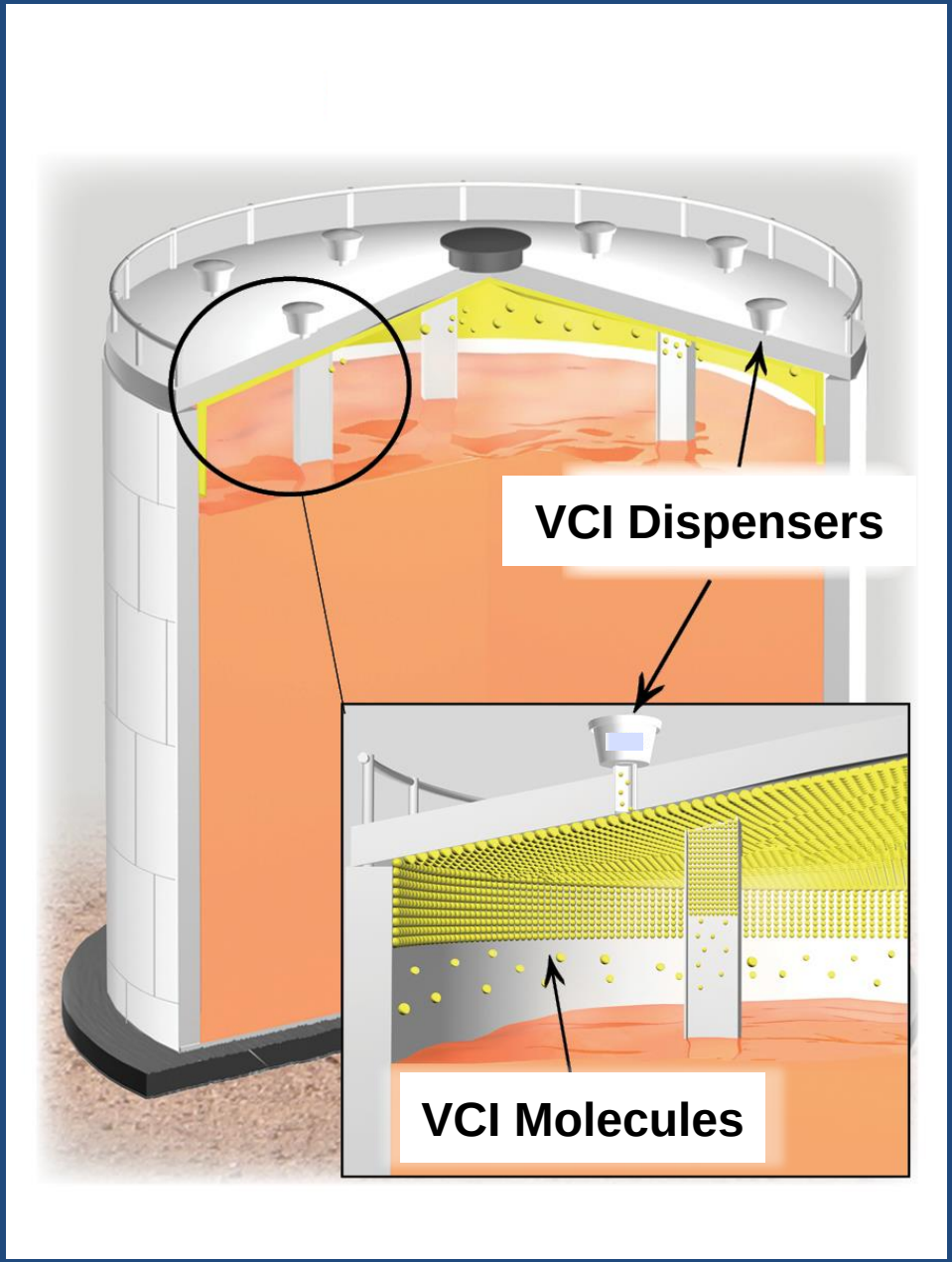
Corrosion occurs in the acidic condensed water layer (pH as low as 2-5) on the inner surface of the tank roofs

Type of Corrosion:	General	Galvanic	Pitting	Crevice
Corrosion Rate, mm/year, up to:	0.5	3.0	5.0	8.0

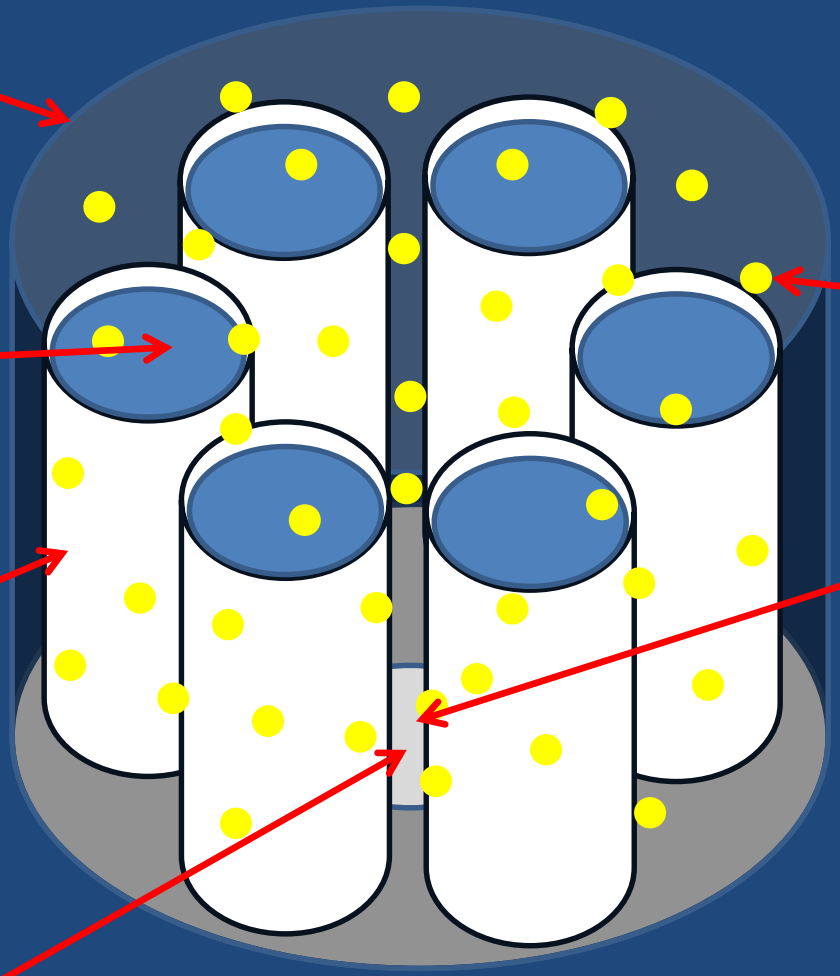
VCI Delivery System

- **Molecular vapor pressure disperses the inhibitor from canisters installed during a tank shutdown.**
- **Inhibitor levels can be monitored and replenished while the tank is “In-Service”.**

VCI in Vapor Space



Works on Vapor Pressure – No Moving Parts



1. Liquid VCI volatizes into a vapor.
2. Vapor pressure forces the VCI molecules down through the opening into the tank vapor space.

Field Trial and Results

Location: Petrobras refinery in Brazil
Setup: Two crude oil storage tanks - with and without VCI protection

Environment Conditions Of Tanks

Basic Parameters		Monitoring Results	
		Tank 1 (Control)	Tank 2 (With Inhibitor)
Temperature, ^oC		20 – 55	
RH %		40 - 100	
Concentration	O_2 (%)	18-18.9	10 - 21
	SO_2 (ppm)	1.0-7.0	> 20
	H_2S (ppm)	3.0-6.0	> 26

Test tank (with inhibitor) environment was more aggressive than that of the control tank

Trial Results

Average Roof Thickness Loss

Exposure Time (days)	Average Total Roof Thickness Loss (mm)	
	Tank 1 (Control)	Tank 2 (With Inhibitor)
90	0.17	0.03
185	0.25	0.06

Even with the more aggressive environment, a 4-fold reduction in thickness loss was achieved with applied VCI protection

Tank Roof - Conclusions

1. 4-fold reduction in thickness loss in trial with VCI application.
2. Reduction in thickness losses translates into increased tank service life.
3. Corrosion Protection System applicable to new and existing AST roofs.
4. Corrosion Protection System Advantages:

   - Reduces tank down time (for replacement of tops or coatings)
   - Eliminates need of more expensive construction materials (stainless steel, aluminum and plastic) instead of carbon steel
   - Reduces risks of environmental contamination, fire and explosion

Thank you for your attention!

Questions?

Kelly Baker
kbaker@ntic.com
832-465-5668