Corrosion Prevention and Maintenance for Water & Wastewater Facilities

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Outline

- *What is corrosion?*
  - *Galvanic corrosion and Galvanic Series*
  - *H_2S & MIC corrosion*
- *How do we prevent corrosion in water and wastewater facilities?*
  - *Coatings*
    - *Elements of Paints and Coatings*
    - *How coatings work*
    - *Types of coatings and coating systems*
    - *Discussion of lead based coatings and current regulations.*
    - *Surface preparation*
  - *Cathodic Protection*

Outline (Cont'd)

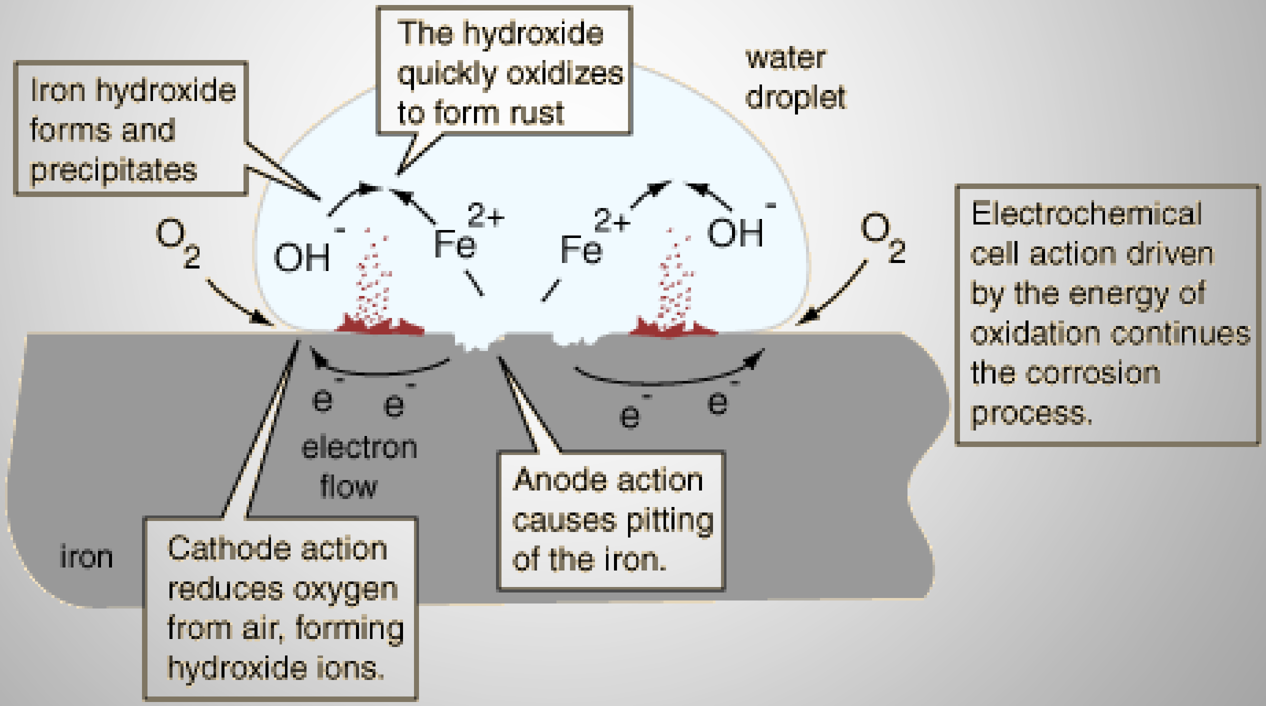
- *Coating inspection*
- *Questions*

What is corrosion?

- ***Definition of corrosion***
  - (Chemistry) a process in which a solid, especially a metal, is eaten away and changed by a chemical action, as in the oxidation of iron in the presence of water by an electrolytic process (Webster)
  - Slow deterioration by being eaten or worn away (Webster)
  - Deterioration of a material, usually a metal, because of a reaction with its environment (NACE International)

- ***Galvanic corrosion***
  - The Galvanic Series (or electropotential series) determines the nobility of metals and semi-metals. When two metals are submerged in an electrolyte, while electrically connected, the less noble (base) will experience galvanic corrosion. The rate of corrosion is determined by the electrolyte and the difference in nobility. The difference can be measured as a difference in voltage potential.
  - Galvanic series developed by Luigi Galvani in late 1700’s
  - Galvani’s principles were used by Alessandro Volta to invent the first battery in 1800.

- ***Galvanic corrosion***
  - ***How it works***



- ***Partial galvanic series (most noble at top)***
  - *Graphite*
  - *Platinum*
  - *Gold*
  - *Silver*
  - *Stainless steel*
  - *Copper (often found in water)*
  - *Cast iron*
  - *Steel*
  - *Lead*
  - *Aluminum*
  - *Zinc (used in galvanization and cathodic protection)*

- ***H_2S and MIC Corrosion***

  - The list of hazardous elements a wastewater facility has to endure has always been a long one. By deteriorating concrete and completely destroying it over time, Hydrogen Sulfide gas permeation, Sulfuric acid, industrial waste residue and abrasion have always been major contributors to corrosion.

  - However, due to legislation passed over the last 30 years, corrosion has risen to extreme levels within wastewater facilities

- **The Clean Air Act of 1970**
  - Sanctioned the sealing of open wastewater tanks.

- **The Clean Water Act of 1980**
  - Demanded industrial pretreatments to abolish harmful heavy metals from wastewater discharges.

Unforeseen Consequences

- While beneficial for health purposes, the legislation caused an unexpected side effect within wastewater facilities:
  - The sealing of tanks has trapped H_2S within and increased the quantities of sulfuric acid.
  - Removing metals from the wastewater system has allowed bacteria to flourish and also caused H_2S levels to dramatically increase.

Unforeseen Consequences

- Due to the drastic rise in H_2S levels and the absence of heavy metals to inhibit bacteria, Hydrogen sulfide gas condenses on the surface where it is metabolized by sulfur oxidizing bacteria, thus creating sulfuric acid and advancing the process commonly known as Microbiologically Induced Corrosion (**MIC**).

Microbiologically Induced Corrosion

Microbiologically Induced Corrosion

- Today, wastewater facilities are struggling with **MIC** more than ever.

- Many cities and metropolitan areas are diverting their wastes to larger regional treatment plants to control costs. This, in turn, is resulting in waste being retained longer within collection systems, increasing sulfide and H_2S concentrations.

- With the boom of regionalization in today's industry, H_2S levels in large domestic wastewater plants have skyrocketed, resulting in massive concrete deterioration.

Examples of H_2S Corrosion

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How do we prevent corrosion in water and wastewater facilities?

- **Why prevent corrosion? It costs money!!**

- **Annual cost of corrosion in U.S is expected to exceed $1 Trillion dollars in 2013 (G2MT Labs).**

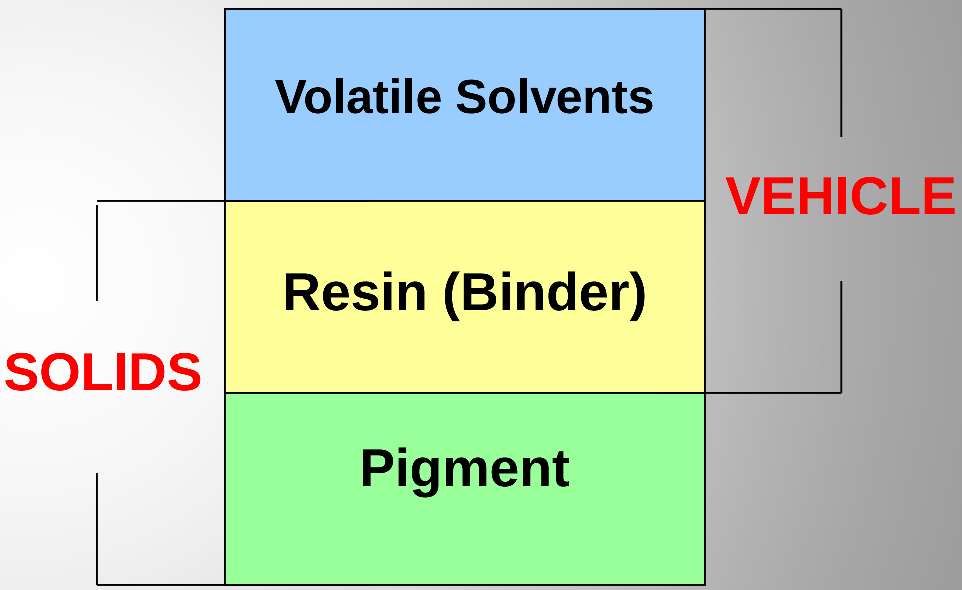
- **Two broad categories of corrosion protection used**

  - **Coatings**
    - Interior Linings
    - Exterior Coatings

  - **Cathodic Protection**

Elements of Paints & Coatings

- **Resins:** the framework on which the coating's performance is built
- **Pigments:** Color, hide & anti-corrosion
- **Solvents:** workability and wetting



- **How Coatings Provide Corrosion Protection**
  - **Coatings work via three types of protection mechanisms**
    - Barrier Protection
    - Sacrificial Protection
    - Inhibitive Protection

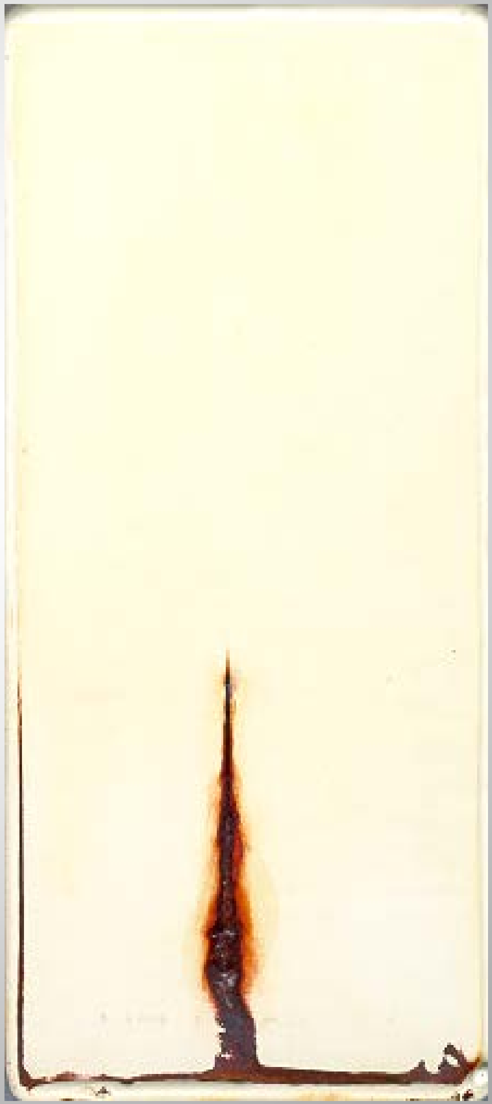
- ***Barrier Protection***
  - Keeps electrolyte, H_2S, etc. away from the substrate
  - Provides a physical barrier
  - Thickness measured in mils (1/1000 of an inch)
    - DFT = Dry Film Thickness
    - WFT = Wet Film Thickness
    - DFT/WFT is a function of the % solids in the coating.

- ***Sacrificial Protection***
  - Examples include zinc-rich primers and hot-dipped galvanized coatings for bolted-steel tanks.
  - Zinc acts as a sacrificial anode and corrodes to protect the steel surface in the event of coating damage or holidays.
  - Galvanizing may be attacked by copper in the water resulting in reduced service life.

- ***Galvanized tank failure***
  - ***Galvanized coating sacrificed itself to copper in the water.***

- ***Benefits of zinc-rich primer***

Three Coats Polyamide Epoxy



One Coat Zinc-Rich Primer

Two Coats Polyamide Epoxy

Levels of Corrosion Protection

Unprimed
32 hrs.

Alkyd
500 hrs.

Epoxy
4,000 hrs.

Zinc Rich Urethane
10,000 hrs.

ASTM B117 Salt Fog

- **Inhibitive Protection**
  - Use of pigments that react with the absorbed moisture in the coating and then react with the substrate to passivate it and thus decrease corrosion.
  - Examples include red lead and zinc phosphate.
  - Will discuss hazards of lead based paint later in this presentation.

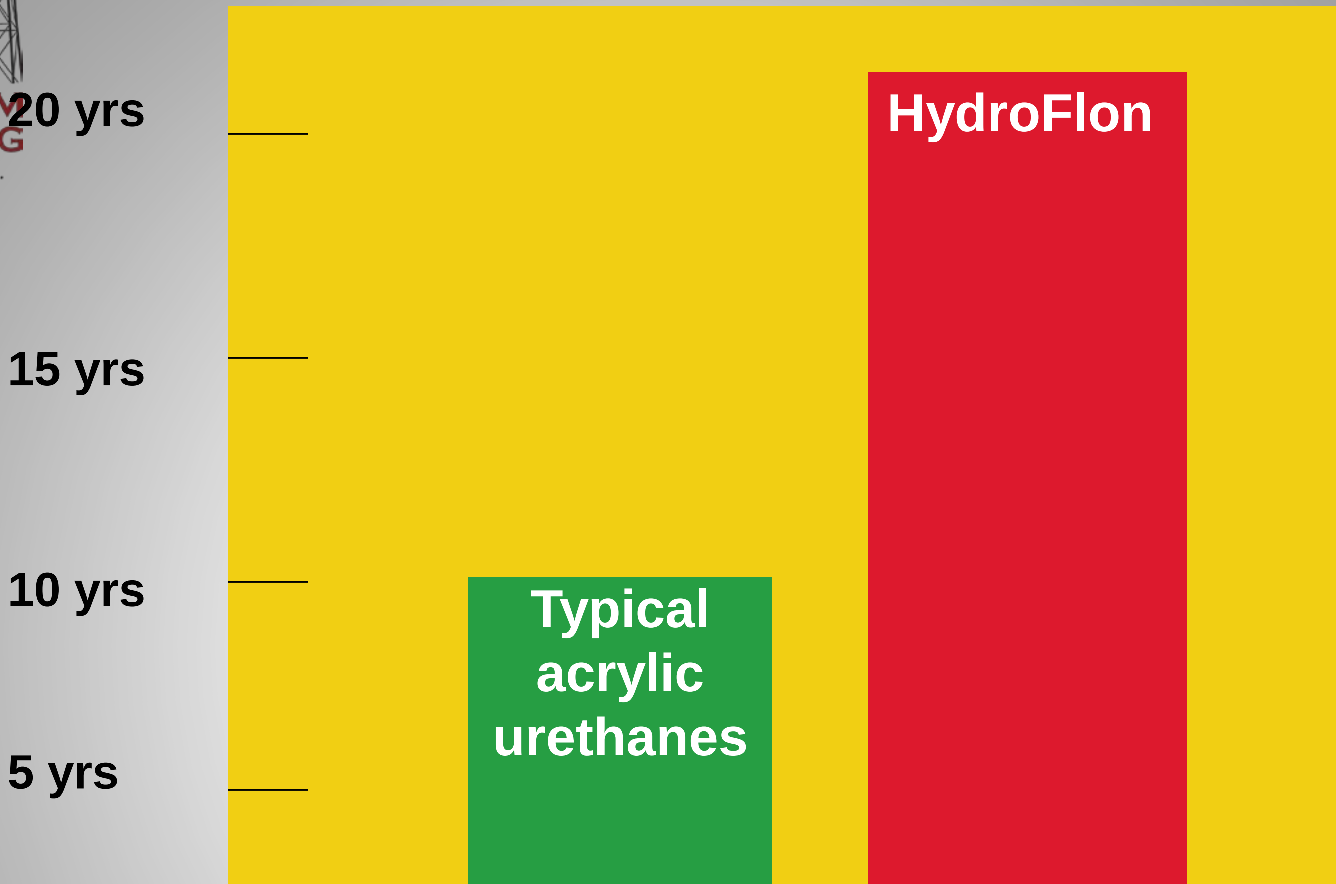
- **Types of coatings and coating systems for concrete and steel structures.**
  - Interior liners for potable water storage tanks
  - Interior liners for wastewater facilities
  - Exterior coating systems

- **Interior liners of potable water storage tanks**
  - Must be NSF/ANSI 61 approved
  - Generally epoxy based systems (ex. SW Macropoxy, Tnemec Series 20, etc.).
  - May have a zinc-rich primer for improved protection
  - Typically thin mil systems (10-15 mils DFT)
  - New 100% solids coatings available (ex. Carboline Poly-brid)
    - Reduces VOC content
    - Requires costly plural-component spray equipment
    - Cures almost instantly
    - Lasts longer on average, more expensive to apply and re move.
    - Instant cure can entrap moisture resulting in blistering.
  - Interior of concrete tanks is generally not coated.

- ***Interior liners for wastewater facilities***
  - Generally two-component modified epoxy based coating systems
    - Modified for high H_2S, chemical and abrasion resistance
    - Most modern systems are 100% solids, require plural-component spray equipment. Provide very hard, durable, tile-like finish.
    - Ex. Tnemec Series 435 Perma-Glaze
    - Must use care and proper primers to prevent failure due to moisture entrapment and efflorescence
  - Used to use Vinyl coating systems, but these have been discontinued due to VOC regulations.
  - Used to use coal-tar epoxies. These have fallen out of favor due to workability & environmental issues, but are still used today. Less resistant to abrasion.

- ***Interior liners for wastewater facilities (Cont'd)***
  - Thick mil coating systems
    - 15-50 mils DFT on steel
    - 30-150 mils DFT on concrete

- ***Exterior coating systems (steel tanks)***
  - Must provide good UV protection
    - Epoxies will chalk when exposed to UV rays
  - State of the art finish coat is Fluoropolymer (ex. Tnemec Hydroflon, SW Fluorokem).
    - Provides excellent color and gloss retention
    - Adds Approx. $1 per square foot to cost of project



HydroFlon’s color & gloss retention surpasses typical high quality polyurethanes by 2-3 times!

It also has higher volume solids (nearly 60%!) with lower VOC’s (under 3.01 lbs./gallon)

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- ***Exterior coating systems (Cont'd)***
  - Until recently, high performance polyurethanes were the state of the art and are still used widely today.
  - Clear-coats are rarely used in industrial painting today due to difficulty of ensuring complete coverage.
  - Most systems use a zinc-rich primer and an epoxy intermediate coat to provide sacrificial and barrier protection.
  - Exterior of concrete may be coated with a variety of coating types (ex. acrylic, elastomeric) to prevent water penetration and improve aesthetics.

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- ***Lead based coatings and current regulations***
  - Since 1992 TCEQ has mandated lead abatement procedures for removing coatings from water tanks having greater than 1% lead by weight
    - Equivalent to 10,000 ppm or mg/kg
  - This is separate and apart from the HUD rule pertaining to residences with lead paint. Threshold for abatement under that rule is 0.5%
  - Must notify TCEQ prior to starting work
  - Abatement includes containment, wet blasting, air monitoring and proper disposal of waste.
  - Can add 20%-50% to cost of job depending on location

- ***Lead based coatings and current regulations (Cont'd)***
  - Coating sample should be collected by trained technician and analyzed for Pb content by a certified laboratory.
    - Qualitative tests that utilize Sulfide ion (S^{2-}) or Rhodizonate ion ($C_6O_6^{2-}$) that change color in the presence of lead are not reliable.
  - OWNER and Contractor are considered co-generators and are BOTH responsible for proper abatement and disposal.
    - Always obtain and save receipt from disposal facility to show proper disposal of waste
  - Collect soil samples before and after project to ensure soil was not contaminated.
    - Texas Risk Reduction Program states soils with <500 ppm lead are safe.

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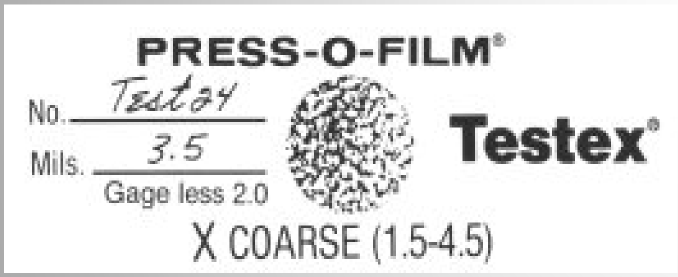
Surface Preparation

- **Note on surface preparation**
  - Proper surface Prep. is key to achieving the coating design life
  - Equally important on steel and concrete projects. Establishes the foundation of the coating system.
  - Surface Prep. is Approx. 70% of the cost of a steel coating project.
  - Specifying correct surface Prep. standard (ex. SSPC-SP10, SSPC SP-6, etc.) and surface profile is critical.
  - Concrete must be properly cleaned and bug holes filled prior to coating to prevent outgassing and interference of efflorescence.
  - Inspection of surface Prep. should be performed by a certified coating inspector prior to applying prime coat

Surface Profile (steel)

- ASTM D 4417, Method A and/or Method C “Field Measurement of Surface Profile of Blast Cleaned Steel”
- NACE Standard RP0287 “Field Measurement of Surface Profile of A brasive Blast Cleaned Steel Surfaces Using a Replica Tape”
- Anchor Profile Must Be **Angular**, Not Peened (i.e. Rounded)

Surface Profile (steel)



Bugholes (concrete)

Voids & Bugholes

Bughole Induced Failure

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- **Cathodic Protection Systems (steel water tanks)**
  - Types of systems
    - Impressed Current
      - Introduces current that helps to passivate the steel
      - Rectifiers must be inspected/calibrated
      - Care must be taken to prevent cathodic disbondment
    - Sacrificial
      - Utilizes zinc anodes that corrode instead of the steel substrate.
      - Anodes must be replaced periodically.
      - Anode access covers on roof must be inspected annually and re-sealed as needed.

- **Cathodic Protection Systems (Cont’d)**
  - Criteria for protection
    - Tank-to-water potential of
      -0.850V to -1.05V
    - AWWA D104

- **Cathodic Protection Systems (Cont’d)**

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- **Cathodic Protection Systems (Cont'd)**

Coating Inspection

- ***Coating Inspection***
  - Inspection is key to a successful coating project
  - Inspector should be properly trained and certified
    - NACE International CIP program
    - SSPC PCI program
  - Inspection can be performed on a hold-point or full-time basis
  - Coatings should be uniform in thickness and color, and free of runs, drips, sags and other defects.
  - Have warranty/anniversary inspections performed by certified inspector. Most defects can be detected and repaired at this time by the Contractor without additional cost to the Owner.

- ***Typical hold points***
    - Blast profile obtained and degree of blast completed
    - Prime coat completed.
    - Stripe coat completed.
    - Intermediate coat completed.
    - Finish coat completed.
    - Holiday detection test of interior completed.
    - Cure test of interior completed.

Dry Film Measurement

- DFT measurements and acceptance criteria should be in accordance with SSPC–PA2
- Measurements should be taken after each coat is applied and dry-to-touch.
- More paint is NOT always better!

Holiday Detection

- All liners should be checked for holidays per NACE RP0188 prior to placing into service. This includes the roof and other surfaces above the high water level.
- Film thickness 20 mils and under requires use of low-voltage holiday detection.
- Film thickness over 20 mils requires use of high-voltage holiday equipment.
- High voltage equipment can be used on films of less than 20 mils within the recommendations of the coating manufacture

Low Voltage

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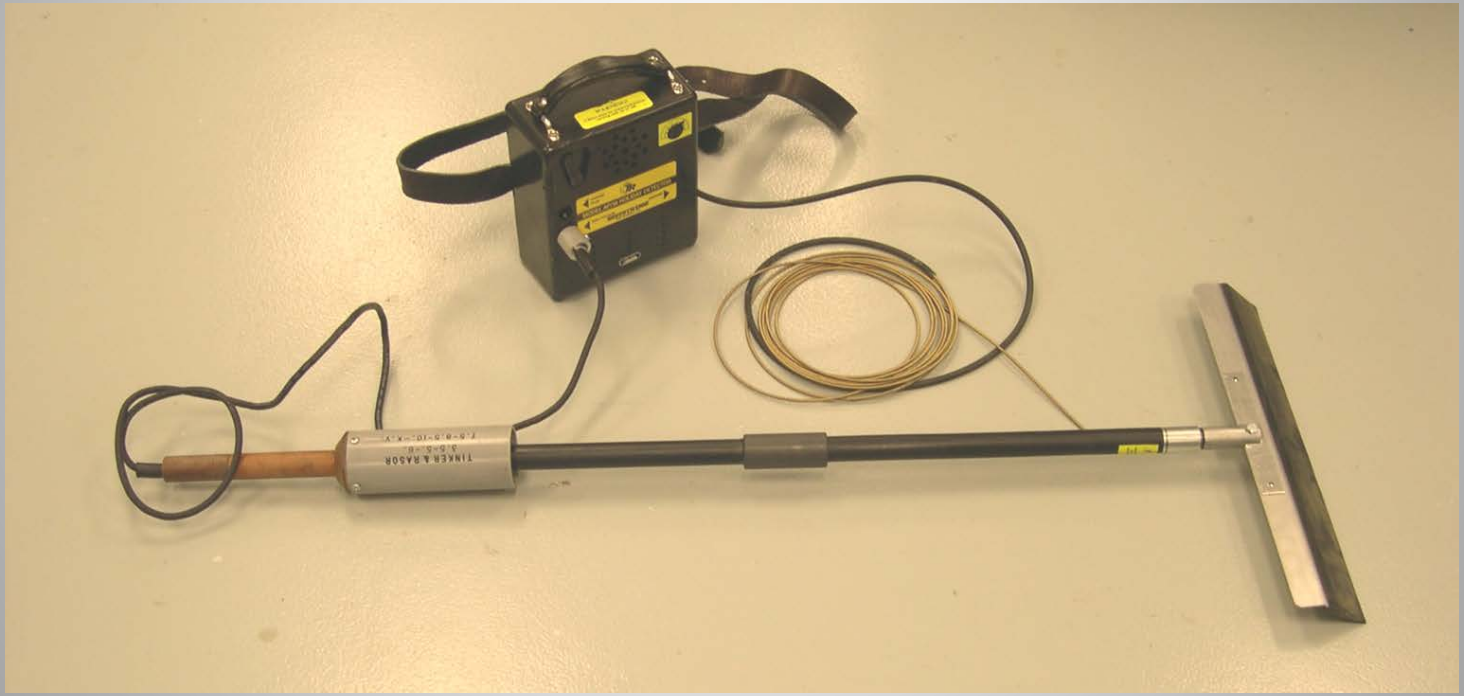
Low Voltage Holiday Testing

- Non-destructive test
- 1 ft/s back and forth motion
- Surfactant can be used to lower surface tension of water. Must be careful not to use between coats.

High-Voltage Holiday Testing

- Can be a destructive test!!
- Voltage set based upon measured DFT
- 1 ft/sec, single pass
- Generally 100-125 v/mil
- Consult coating manufacturer for voltage settings
- Tinker-Rasor is a common manufacturer

High-voltage Holiday Detection Equipment



- ***Cure test***
  - ASTM D5402
  - Solvent rub test, ensures coating for immersion surface is properly cured and ready for immersion.
  - If coating is not properly cured, solvent entrapment and osmotic blistering will occur.
  - Coatings with solvents must have forced air to cure

- ***Osmotic blistering***

Questions?