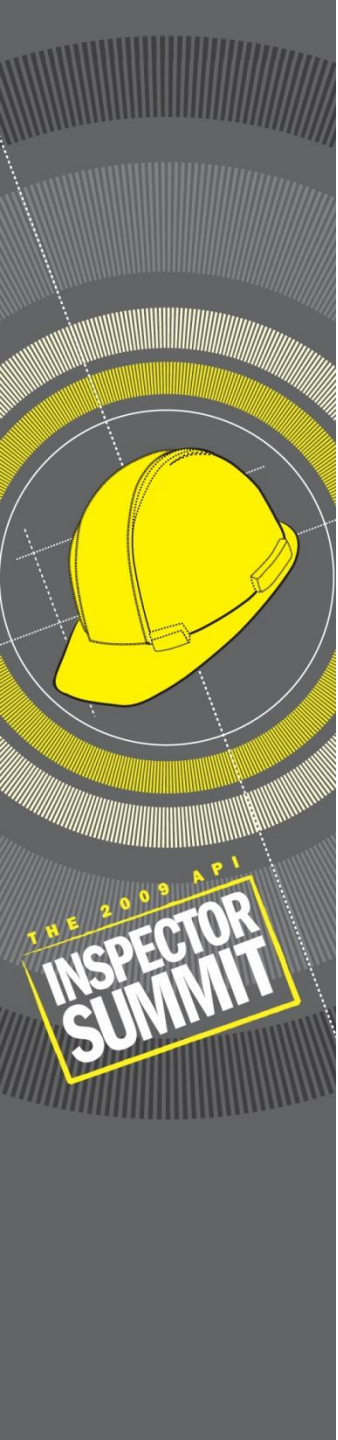


# **An Introduction to Coatings and Linings**

**by Billy G. Musgraves**



# Billy G. Musgraves

- 15 Years Coating Installation and Inspection experience in a variety of industrial settings
  - NACE certified coating inspector
  - API certifications: 510, 570, 653, 936, 571
  - CWI

## Current job

- Technical services manager responsible for project development and field supervision of industrial inspection projects
- Active in curriculum development for the Non Destructive Testing program at Louisiana State Technical College (T.H. Harris Campus)



# Coatings and Linings

Objectives: This presentation will provide an overview of the types of coatings and linings commonly utilized in the petrochemical industry. Their compatibility with various process conditions and application requirements will also be discussed. The role of the inspector in a coatings program will be discussed

## References:

*Principles and Prevention of Corrosion, Second Edition*, Denny A. Jones.

*The Protective Coating User's Handbook*, Dr. Louis D. Vincent.

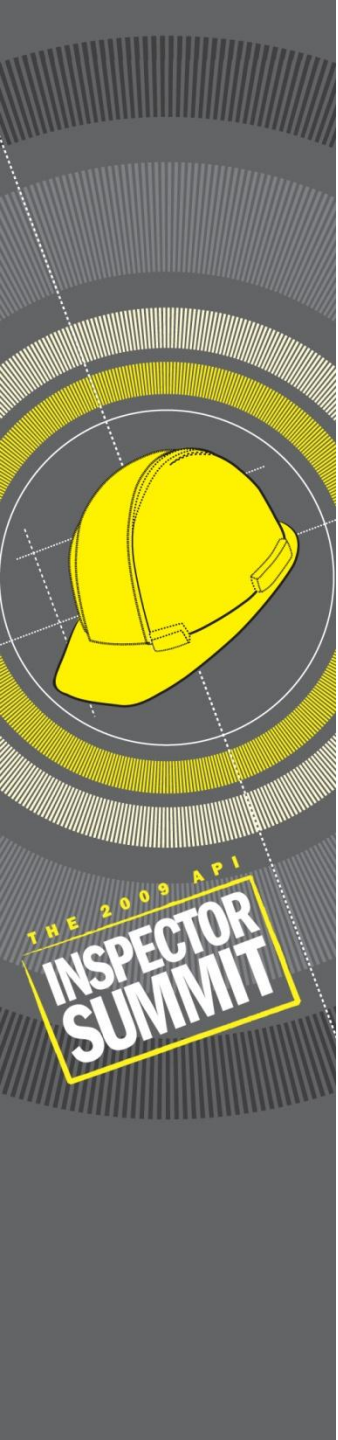
*Paint and Coatings: Application and Corrosion Resistance*, Phillip A. Schweitzer, P.E.

*Coatings and Linings for Immersion Service, Revised Edition*, NACE International



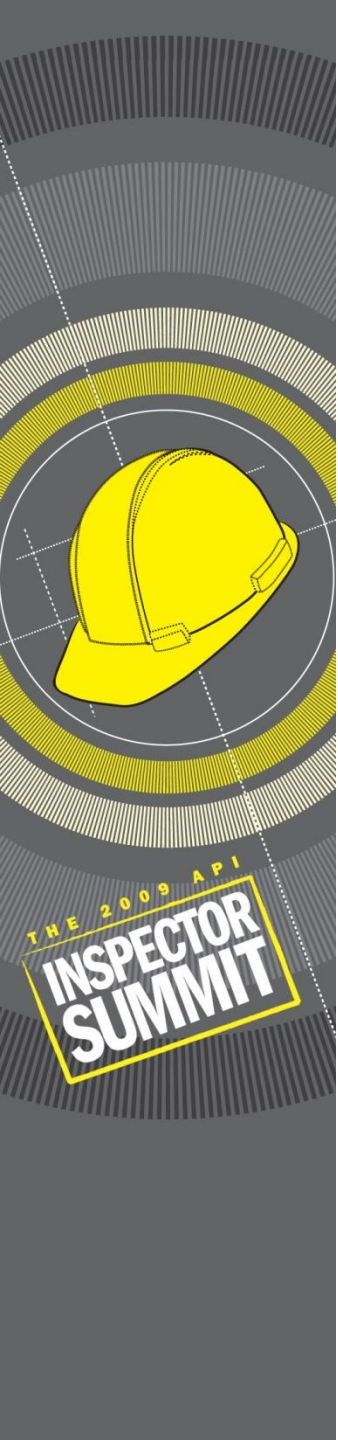
# References Continued:

*Good Painting Practice, SSPC Painting Manual, Volume 1, 4<sup>th</sup> Edition, The Society for Protective Coatings*



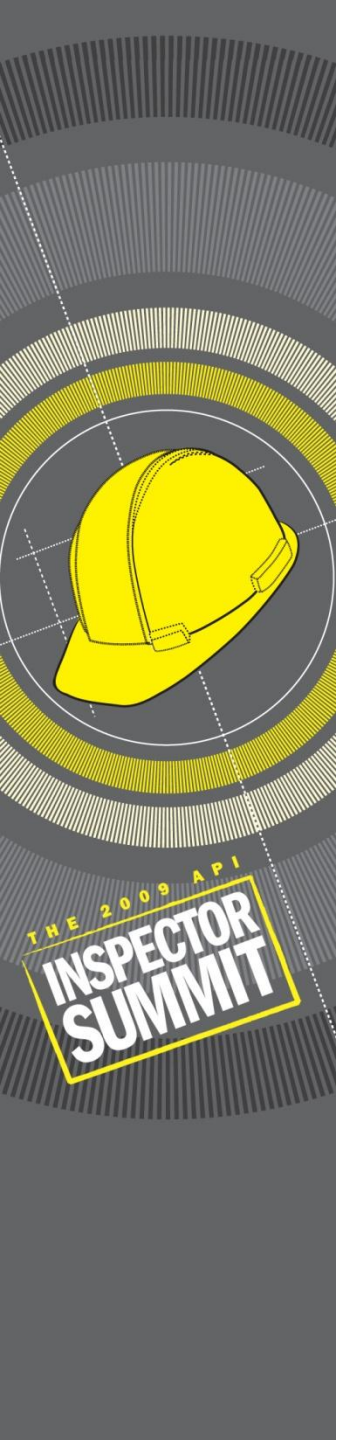
# Why Coatings and Linings?

- The proper utilization of coatings and linings can provide the most cost effective means to retard corrosion affecting piping and equipment.
- A properly designed coating/lining system can increase equipment longevity by a factor of 10+.
- Conversely, an improperly designed or applied coating/lining system can accelerate corrosion and immediately degrade equipment.



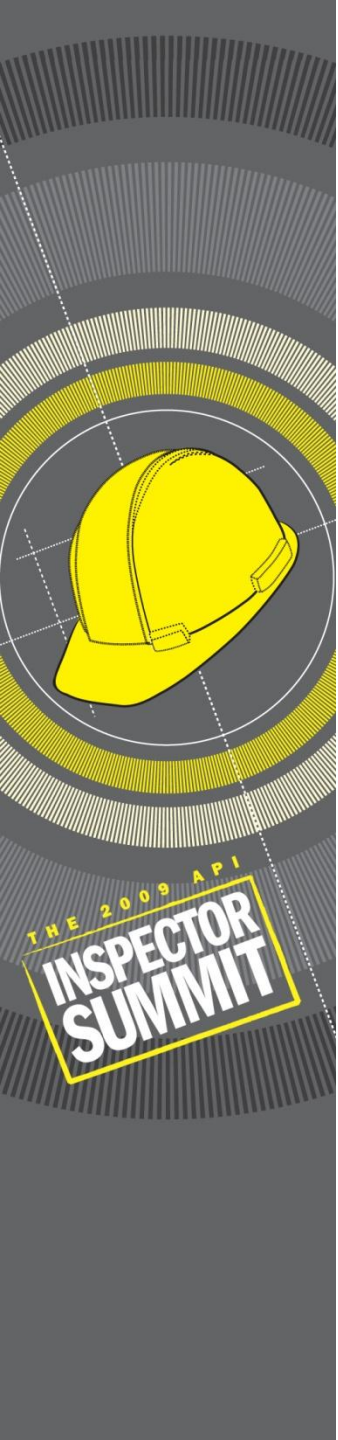
# Corrosion

- The direct costs of corrosion on the US economy is staggering. It is estimated that the direct cost of corrosion on the United States is approximately 276 Billion dollars annually. Approximately, 3-4% of our gross domestic product is lost annually due to the effects of corrosion.
- Corrosion is defined as “ the deterioration of a material, usually a metal, because of a reaction with its environment.”
- In the context of the above statistics it is easy to see the need for coating/lining systems.



# Definitions

- Coating: a paint, varnish, lacquer, or other finish used to create a protective and/or decorative layer. Generally used to refer to paints and coatings applied in an industrial setting.
- Lining: a coating designed for immersion service.
- Paint: a generally opaque coating that contains resin, solvents, additives, and pigment.



# Classes of Coatings

## Organic

Coal tars  
Phenolics  
Vinyls  
Acrylics  
Epoxy  
Alkyds  
Urethanes

## Inorganic

Silicates  
Ceramics  
Glass

## Conversion

Anodizing  
Phosphating  
Chromate

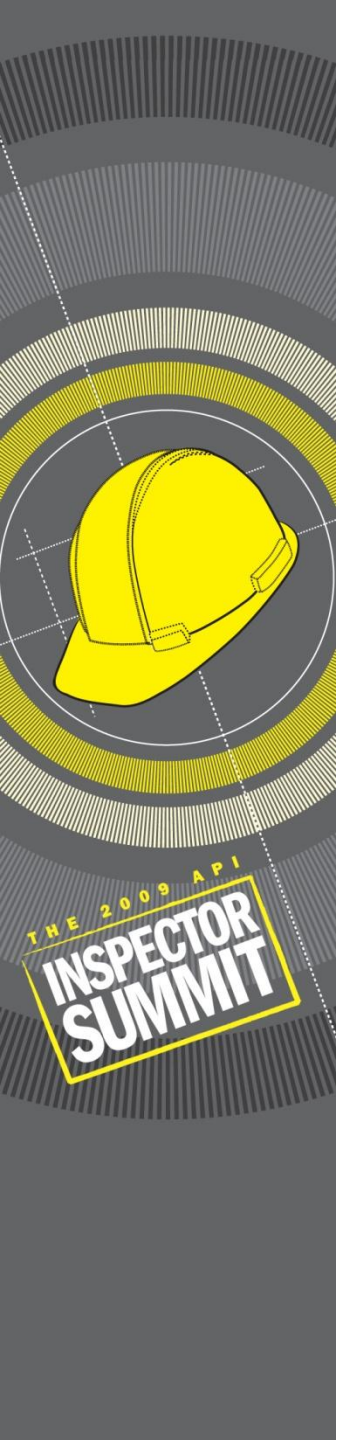
## Metallic

Galvanizing  
Vacuum vapor  
deposition  
Electroplating  
Weld Overlay



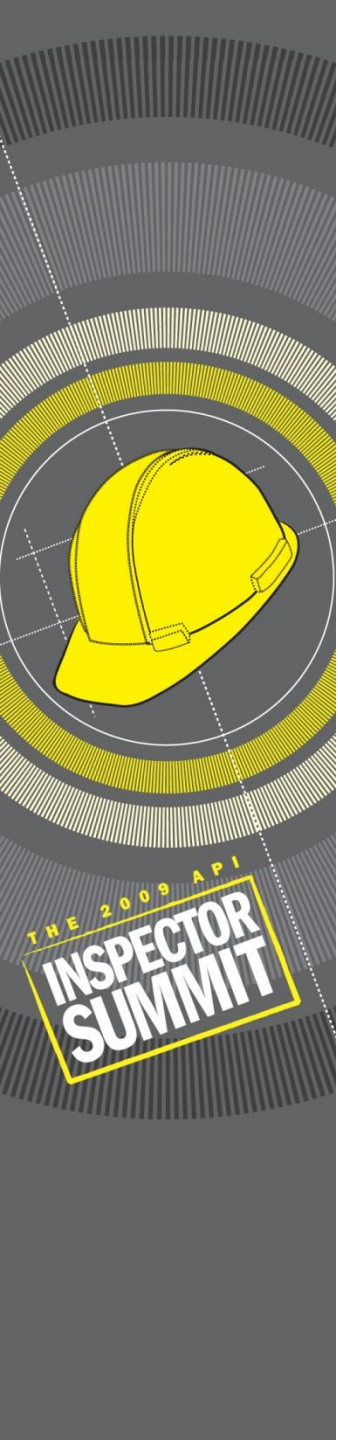
# Organic Coatings

- Organic Coatings provide protection by a barrier action from the coating layer or from active corrosion inhibition provided by the pigments in the coating.
- All organic coating are permeable to water to varying degrees.



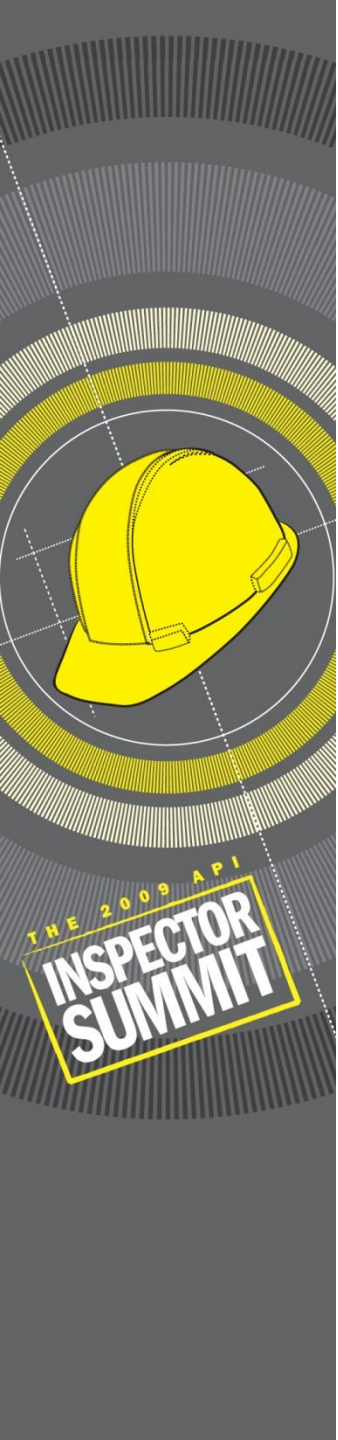
# Organic Coatings: Coal Tars

- Advantages: exhibits excellent water resistance. Good resistance to acids, alkalis, minerals, animal/vegetable oils, and salts.
- Disadvantages: Unless cross linked with another resin it will become viscous and flow at temperatures of 100F or less. It also hardens and becomes brittle in cold weather. Due to volatile organic compound emissions, coal tar is limited in some jurisdictions



# Organic Coatings: Phenolics

- Advantages: Synthetic resin that cures fast with good adhesion to many substrates. Phenolics have excellent heat resistance, chemical resistance and electrical properties. Common applications for phenolic based coatings include tank linings used for alcohol storage and fermentation, food products, and hot water immersion services.
- Disadvantages: Poor UV resistance, requires baking to cure (450F to 150F depending on composition), and poor resistance to alkaline environments. Additionally, condensation during curing limits film thickness to 3mil.



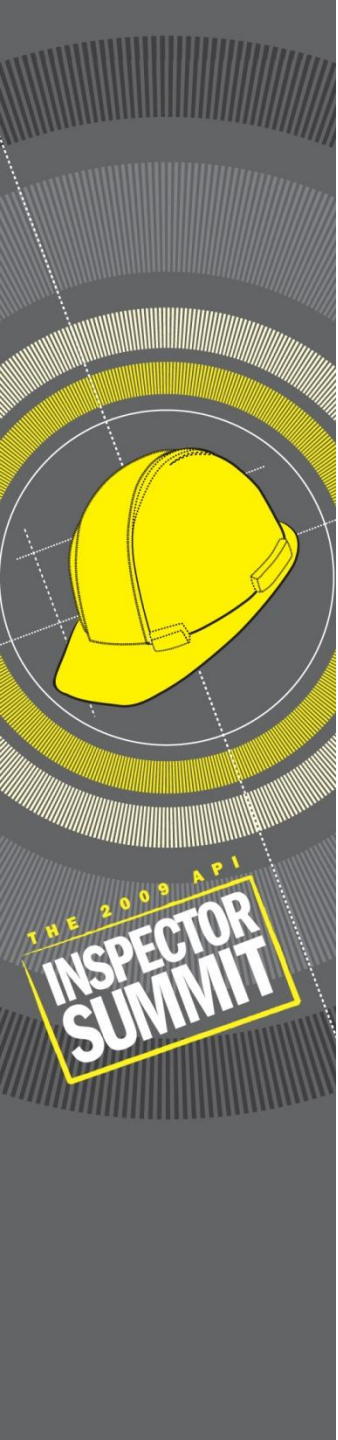
# Organic Coatings: Vinyls

- Advantages: Vinyl based coatings have good resistance to oils, greases, aliphatic hydrocarbons, and alcohols. Vinyl based coatings are temperature resistant to 180F. This family of coatings are tasteless and odorless. Applications for vinyl coatings are utilized on surfaces exposed to potable water and sanitary immersion equipment.
- Disadvantages: Requires a high amount of solvents in solution to dissolve the vinyl co-polymers. This prevents high volumes of solids in solution and allows only thin coats to be applied(1 to 1.5 mils). The high percentage of solvents in solution prevent application in areas where VOC emissions are regulated.



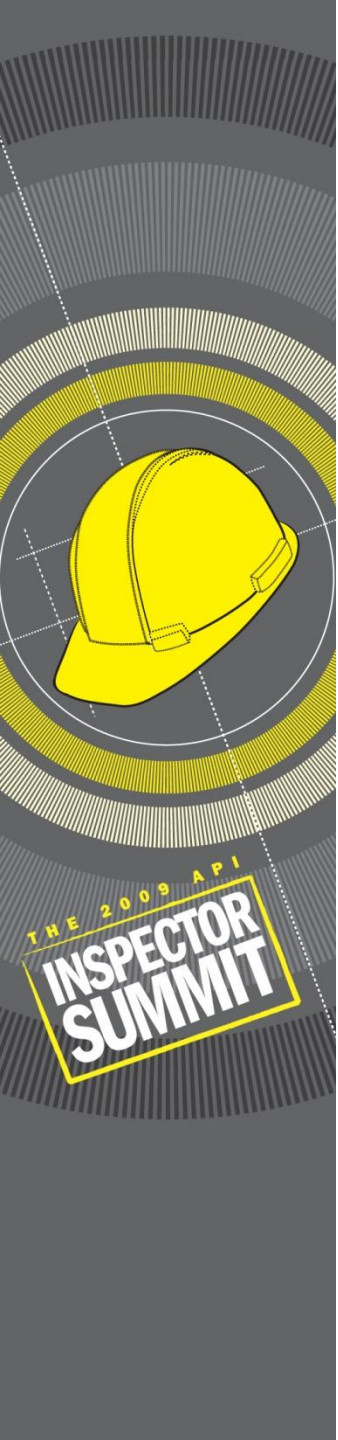
## Organic Coatings: Acrylics

- Advantages: Acrylic based coatings exhibit excellent light and ultraviolet stability, high gloss and color retention, good chemical resistance, and excellent weathering resistance. Acrylic coatings are primarily used as topcoats in atmospheric service.
- Disadvantages: Acrylic coatings have low impact resistance and are generally not suitable for immersion service. Additionally, acrylic coatings are not suitable for acid or alkaline chemical exposure.



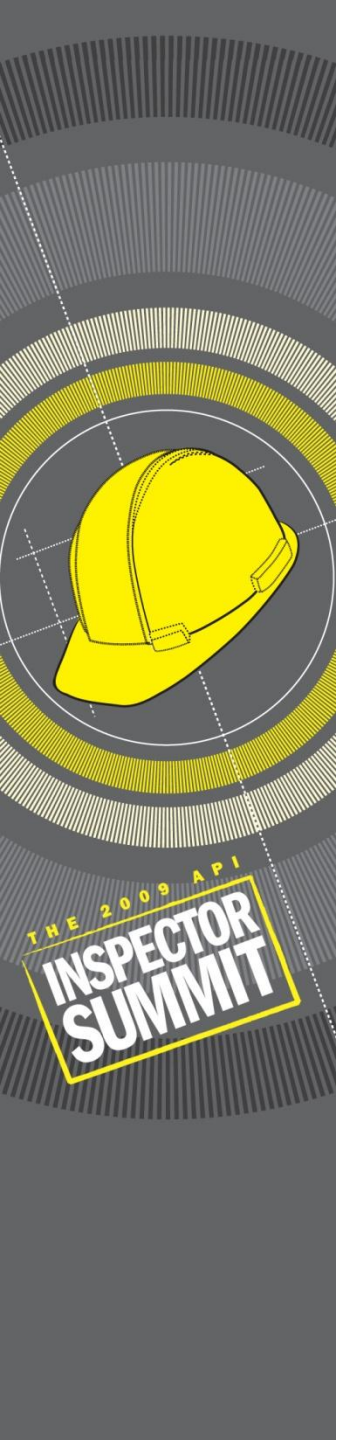
# Organic Coatings: Epoxy

- Advantages: Epoxy based coatings comprise the largest generic family of coatings. Endless combinations with other resins allow the formulation of a coating system for most applications. Epoxy coatings are often utilized in tank linings. Epoxy linings provide excellent chemical and corrosion resistance to temperatures to 500F.
- Disadvantages: Epoxy resins must be cured with cross-linking agents (hardeners) or catalyst to develop the desired properties. Patching and repair of damaged areas can be difficult due the curing requirements of epoxy coatings.



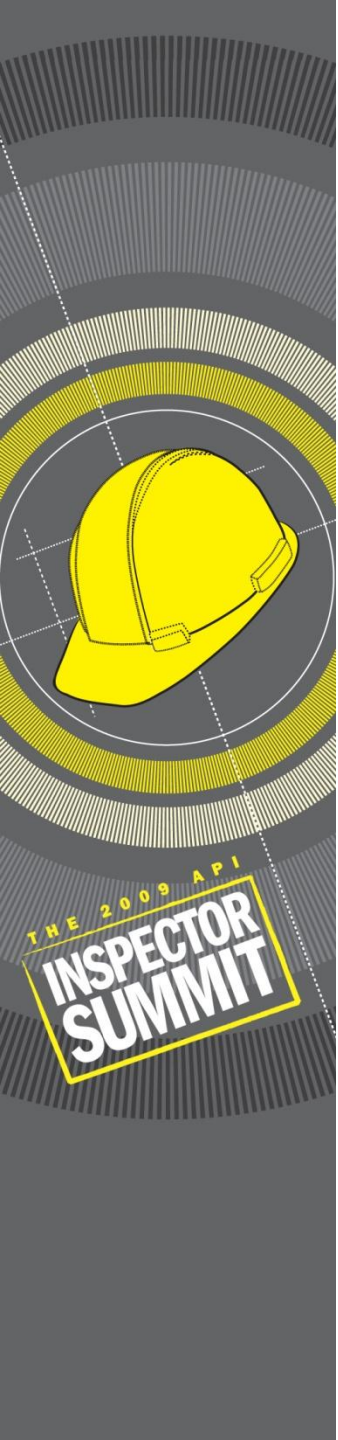
# Organic Coatings: Alkyds

- Advantages: Alkyd based coatings have good durability at relatively low cost. These coating have good penetrating ability. They have good weathering resistance and good adhesion to substrates. Alkyd based coatings are primarily used on external wood and metal surfaces as primers.
- Disadvantages: Alkyd based coatings have poor resistance to chemical attack. Additionally, they have a maximum temperature resistance of 225F.



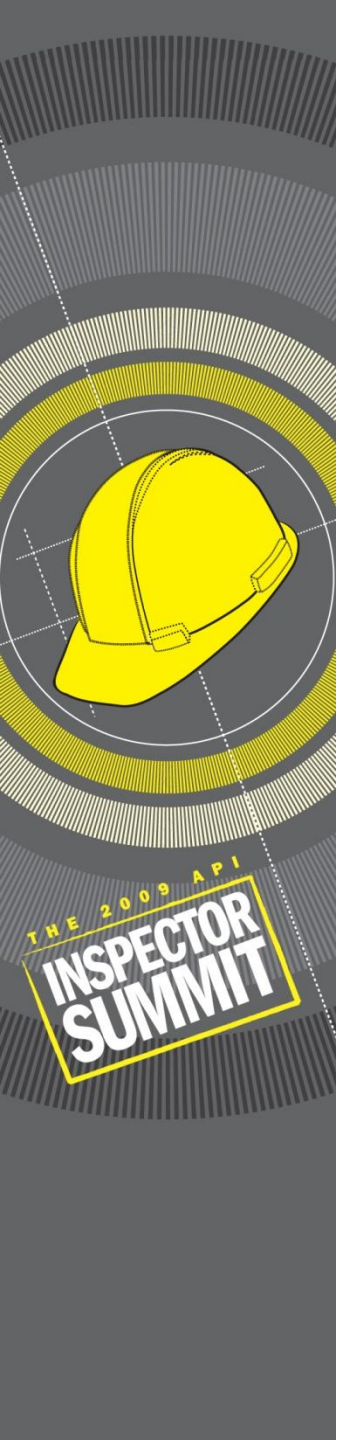
# Organic Coatings: Urethanes

- Advantages: Urethane component coatings are extremely versatile. They are resistant to most mineral and vegetable oils, greases, and fuels. These coatings are often applied to the interior of tanks and pipes.
- Disadvantages: Exposure to high humidity can cause gassing or bubbling in the coating. Urethane has limited ability to resist acid solutions. They are not resistant to steam or caustics. The maximum effective temperature is 250F.



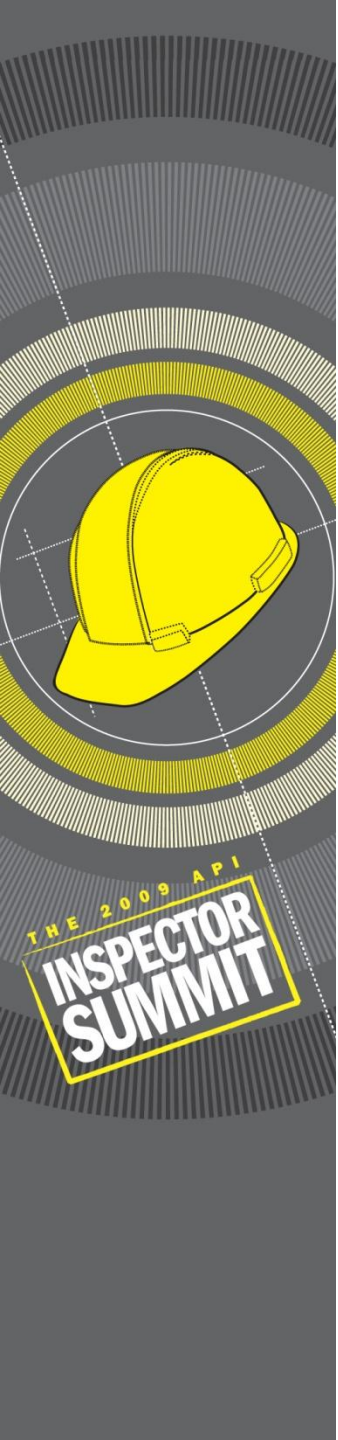
# Inorganic Coatings

- Inorganic coatings are used describe coatings that are not based on carbon components. These coatings are characterized by a high solid volumes. They are often used to provide corrosion/erosion protection at high temperatures.



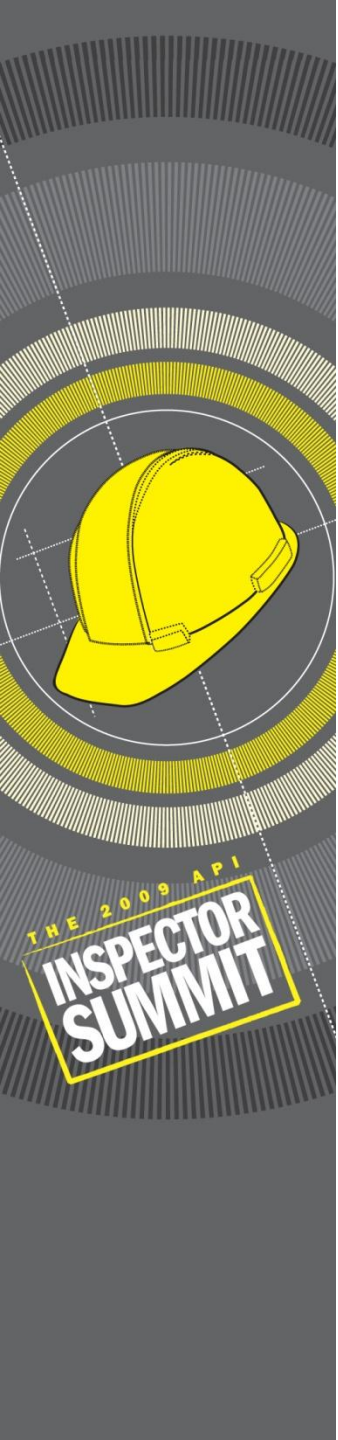
# Inorganic Coatings: Silicates

- Advantages: Silicates are a form of cementitious coatings. They provide excellent resistance to concentrated acids except for hydrofluoric. Can be applied in thicknesses to .5". Can be applied by troweling or gunning.
- Disadvantages: Following manufacturer's mixing instructions is extremely important. The proper water ratio must be maintained or porosity is likely to develop. Silicate coatings will fail when exposed to mild alkaline environments.



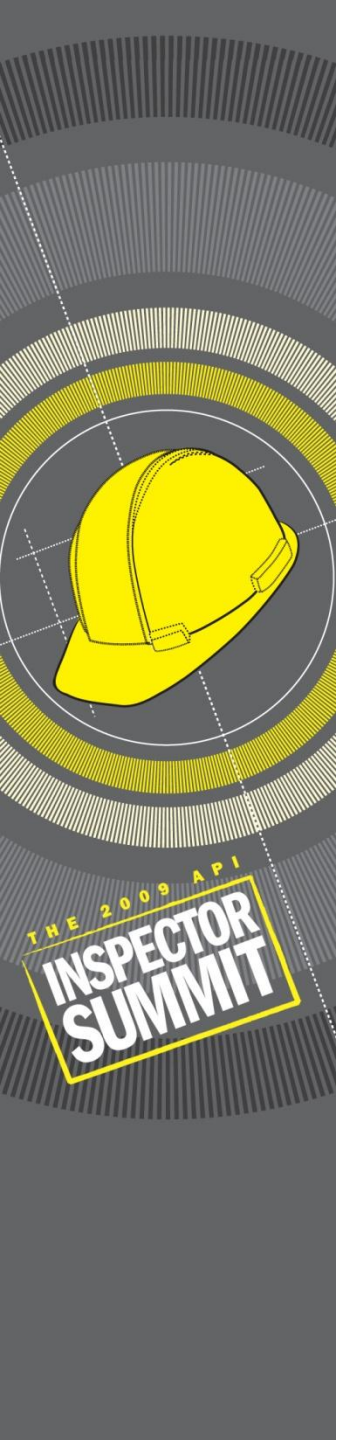
# Inorganic Coatings: Ceramics

- Advantages: Ceramic coatings have widespread applications in furnaces, heaters, and boiler fireboxes. Ceramic coatings can provide protection against high temperatures and a wide range of chemicals.
- Disadvantages: Ceramic coatings require a high degree of skill to install. Ceramic coatings are very process specific; therefore, consultation with a qualified ceramic engineer prior to the installation of ceramic coatings



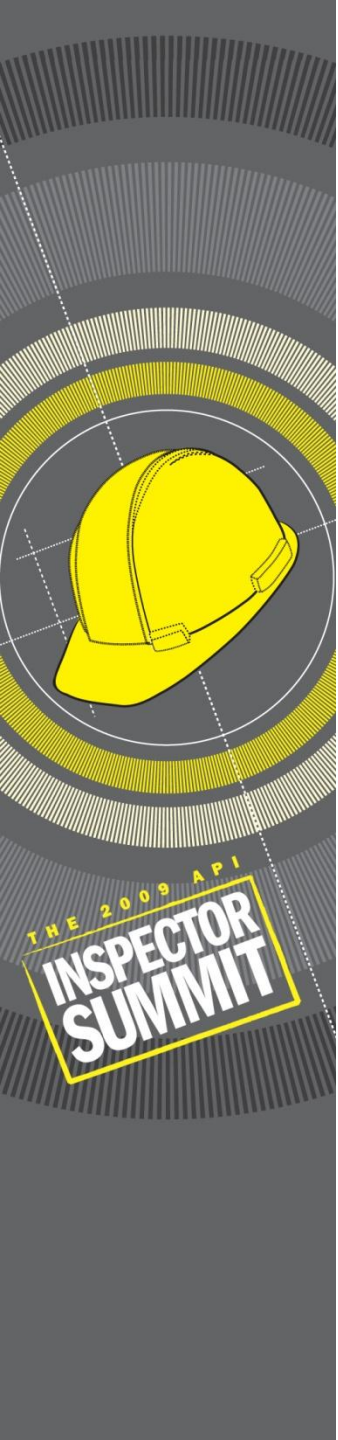
## Inorganic Coatings: Glass

- Advantages: Glass coatings are often utilized to provide a impermeable barrier for a wide variety of chemicals. Glass coatings are often utilized for low temperature specialized chemical storage. Additional, applications involve potable water storage.
- Disadvantages: Glass coatings have low impact resistance. Installation is often difficult and expensive. Finally, glass coatings will degrade in the presence of hydrofluoric acid or in contact with high pH substances (9pH)



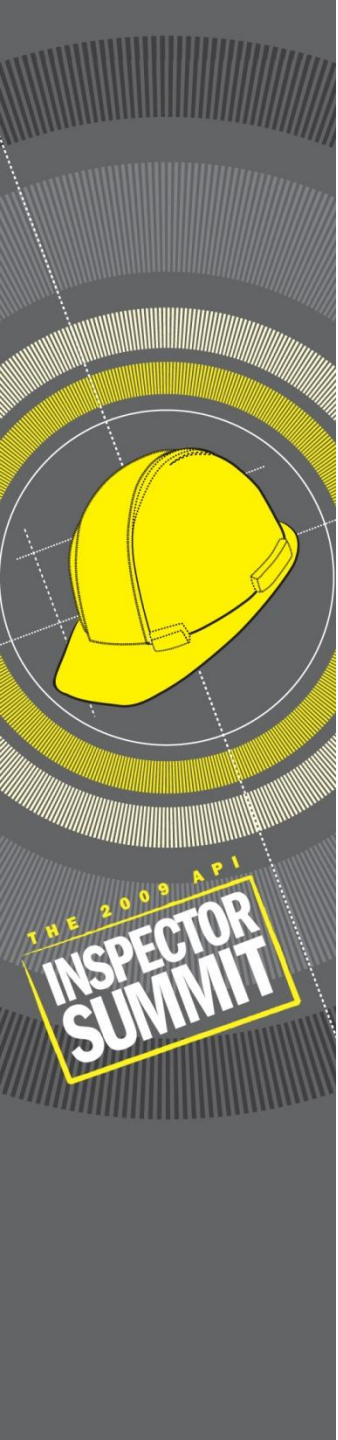
# Conversion Coatings

- Conversion coatings are those in which the substrate metal provides ions that become part of the protective coating. Conversion coatings are utilized to: improve the adherence of the organic layer; to obtain electrically insulating barrier layers; and to promote active corrosion inhibition by passivating the metallic substrate.



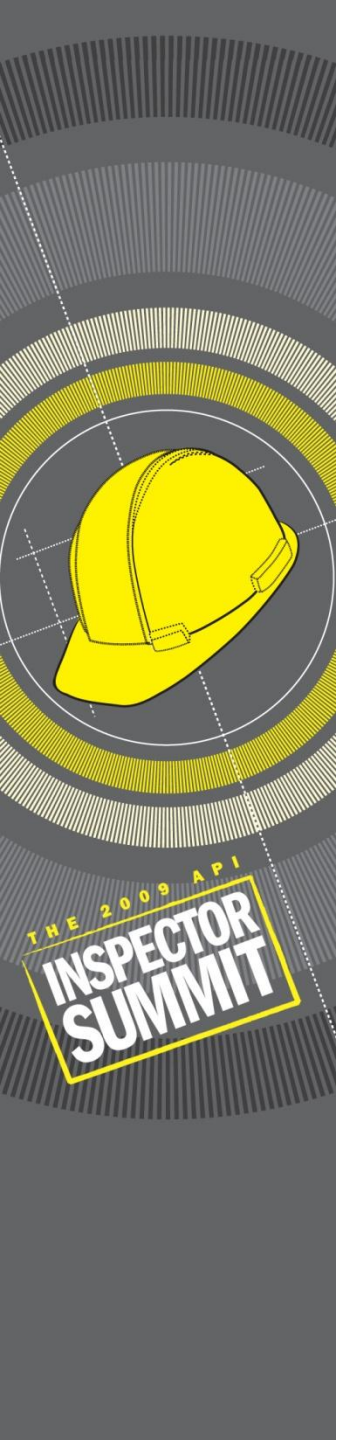
# Conversion Coatings: Anodizing

- Advantages: Anodizing is the establishment of protective coating barrier on the metallic substrate by use of an electrochemical treatment. Sulfuric acid is a commonly used chemical in the Anodizing process. Anodizing produces hard protective coatings that serve as a base for dyeing.
- Disadvantages: Anodizing can be difficult to obtain with complicated part geometry. Limited use in industrial settings.



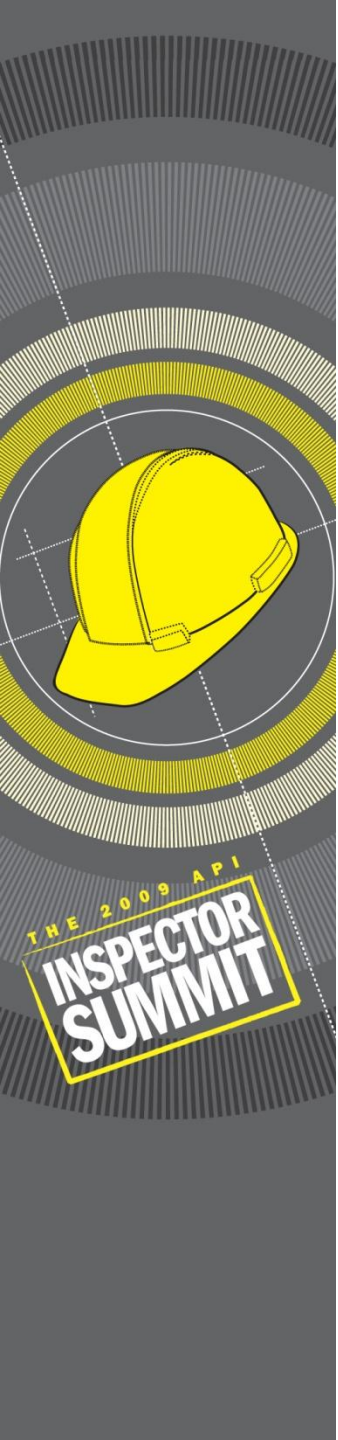
# Conversion Coatings: Phosphating

- Advantages: A phosphate coating is created when the metal surface is treated with a weak phosphoric acid solution. As a result of this treatment, the phosphate film provides a good base for paint, plastics, and rubber coatings.
- Disadvantages: Pinholes in the phosphate film can lead to accelerated corrosion on the metallic substrate. Not widely used in industrial settings.



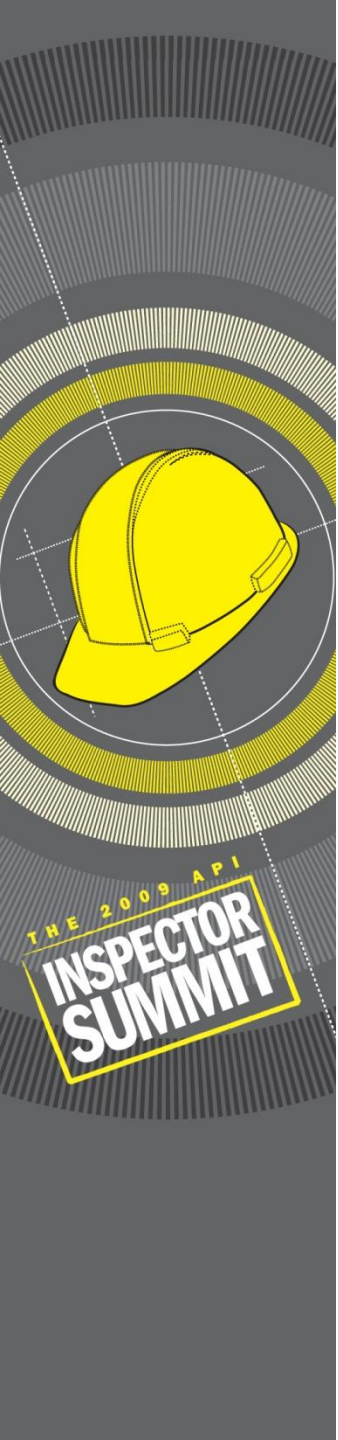
# Conversion Coatings: Chromate

- Advantages: Chromate conversion coatings are formed on aluminum, magnesium, zinc, and cadmium. Protection is provided by the leaching of hexavalent chromium compounds out of the chromate coating. Chromate coatings provide a good base for organic coatings.
- Disadvantages: Chromate coatings are subject to elevated corrosion attack if exposed to atmospheric pollution (chloride leaching)



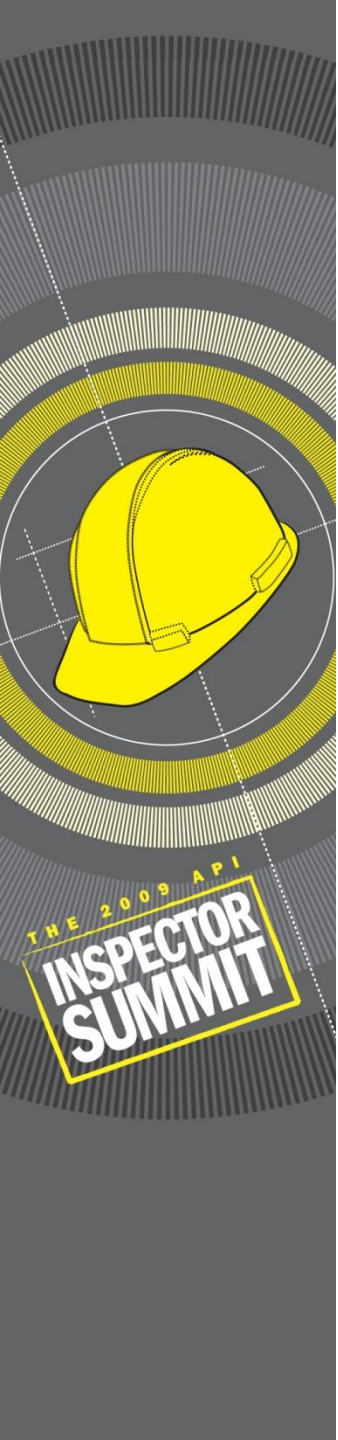
# Metallic Coatings

- Metallic coatings are applied to the substrate to provide corrosion and wear resistance. Metallic coatings provide protection by providing a barrier between the substrate and the environment or by cathodically protecting the substrate.



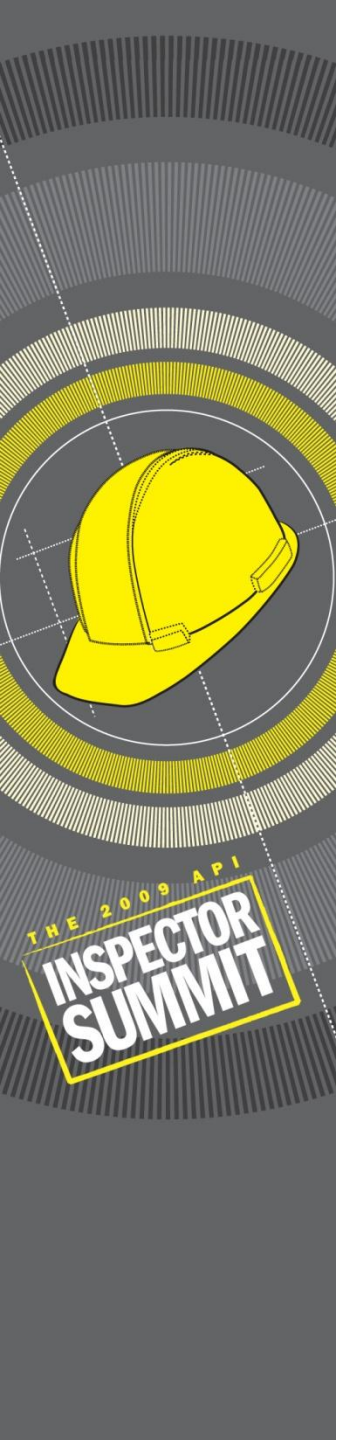
# Metallic Coatings: Galvanizing

- Advantages: Galvanizing is coating process in which steel is coated with a layer of Zinc. This is commonly accomplished by a hot dip process. Galvanizing is commonly used for structural steel components.
- Disadvantages: The corrosion protection afforded by galvanizing is only as good as the Zinc coating. Bare spots or thinly coated areas will result in elevated corrosion to the metallic substrate.



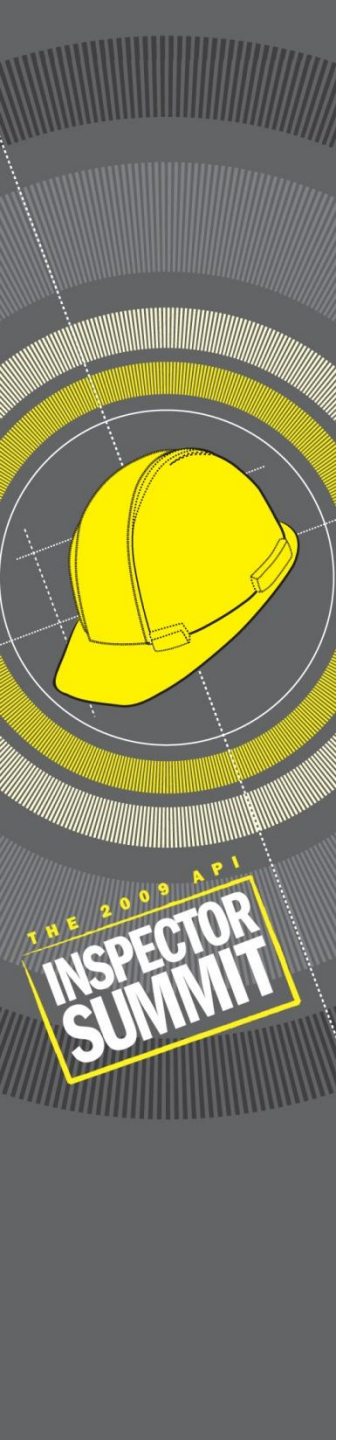
# Metallic Coatings: Vacuum Vapor Deposition

- Advantages: Vacuum vapor deposition is a method in which a metallic coating is deposited on the substrate in vapor form in vacuum chamber. The resultant coating is evenly dispersed and of uniform thickness
- Disadvantages: Vacuum vapor deposition is limited to the size of the vacuum chamber. Not widely utilized in industrial applications



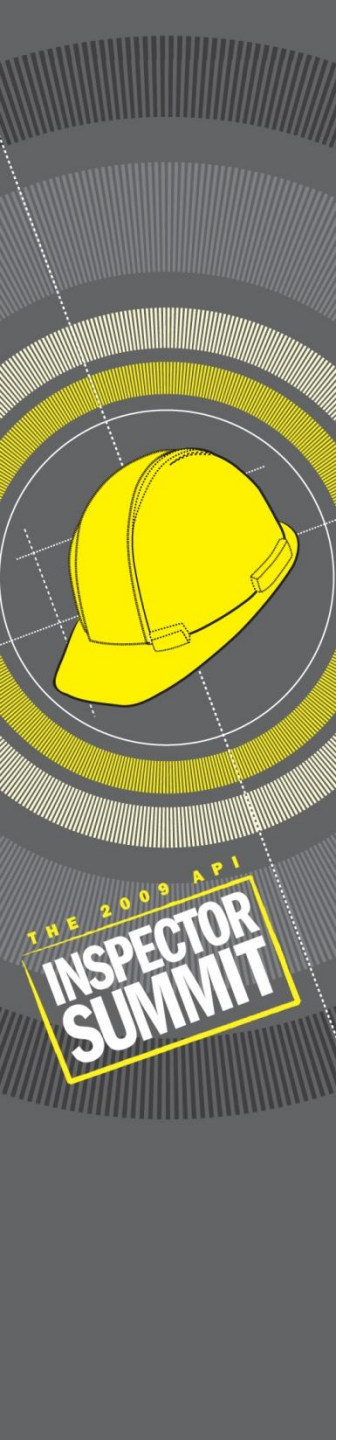
# Metallic Coatings: Electroplating

- Advantages: Electroplating is a versatile method in which a metallic coating is created on the substrate by means of cathodic deposition under a strong electrical current.
- Disadvantages: Electroplating requires access to a large power supply and is limited by part size.



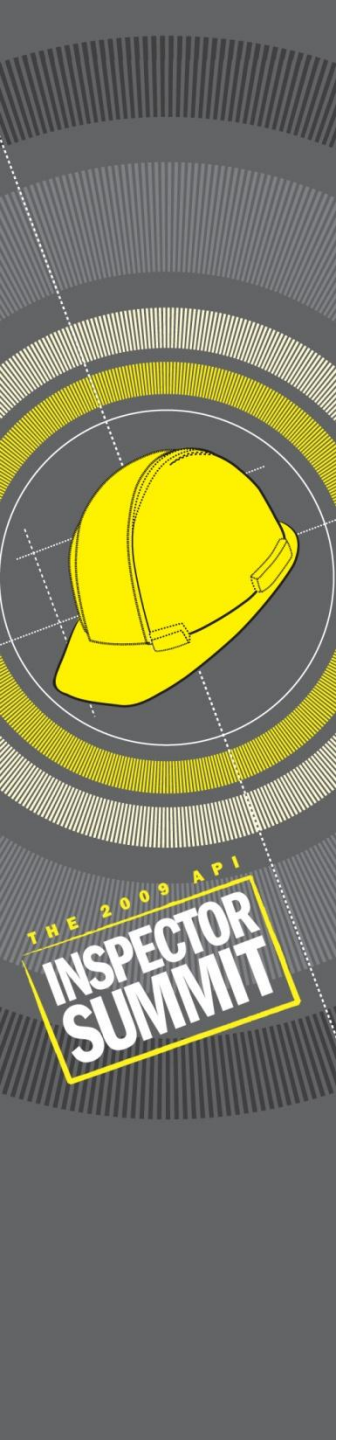
# Metallic Coatings: Weld Overlay

- Advantages: The deposition of weld filler metal to create a metallic coating is commonly utilized in the petrochemical industry. Weld overlay can provide a strong corrosion/erosion resistant coating.
- Disadvantages: Improperly crafted weld stringers can have voids which allow pockets of accelerated corrosion to develop. Can be cost prohibitive for large area coverage.



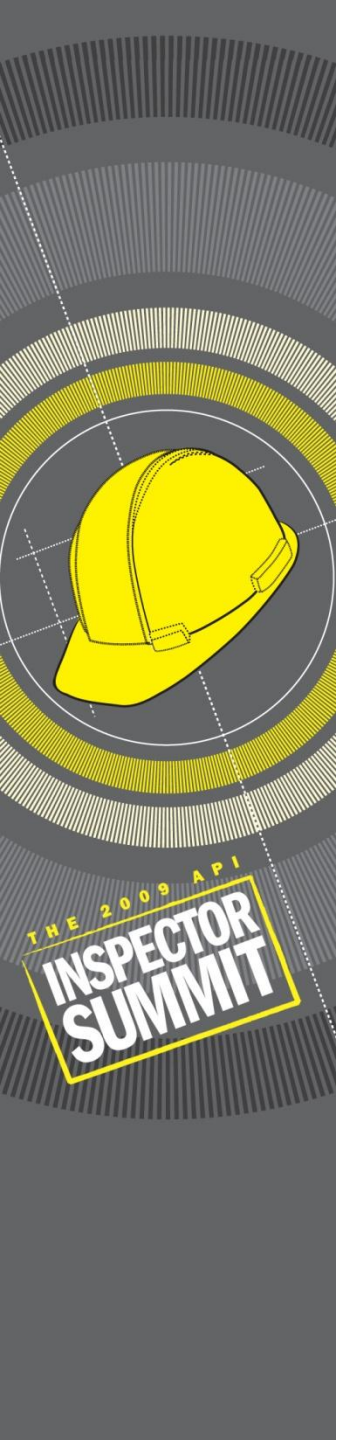
# Linings

- Many of the coatings listed on previous slides are utilized as linings in immersion services. The following slides will present common lining materials and their applications.



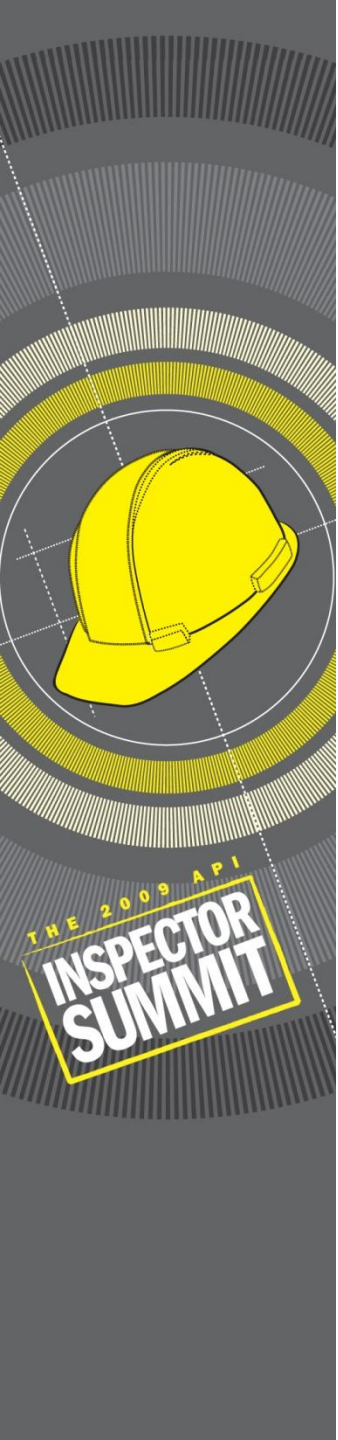
## **Linings: High-bake phenolic**

- High-bake phenolic linings provide excellent resistance to acids, solvents, food products, beverages and water. It is the most widely used lining material, but has poor flexibility.



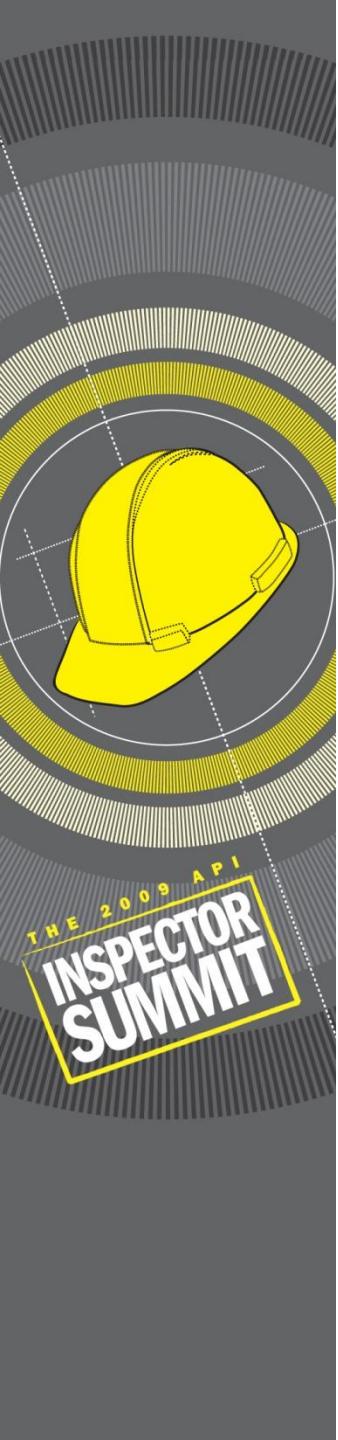
## **Linings: Modified PVC polyvinyl**

- Modified PVC polyvinyl coatings have excellent resistance to strong mineral acids and water. It is the most popular lining for water storage tanks.



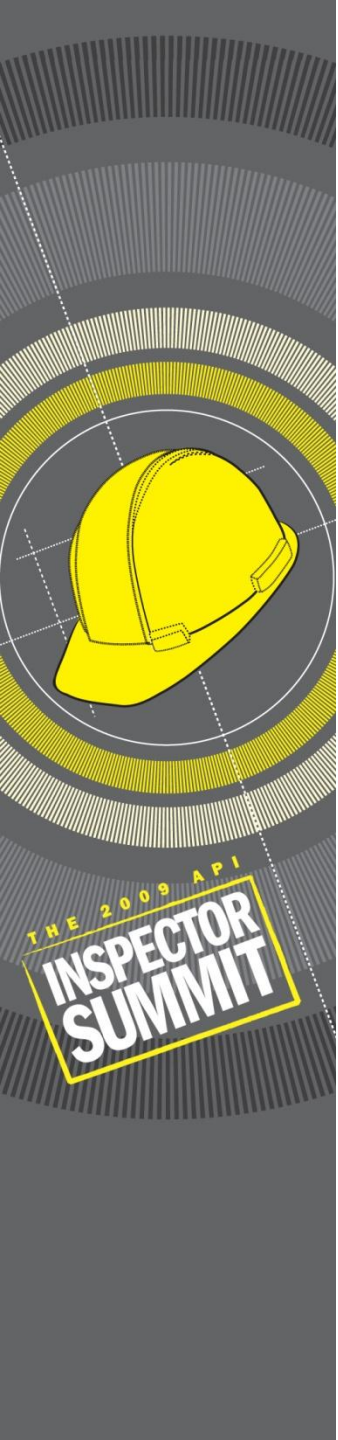
## Linings: PVC plastisols

- PVC plastisol linings are acid resistant, but require heat curing



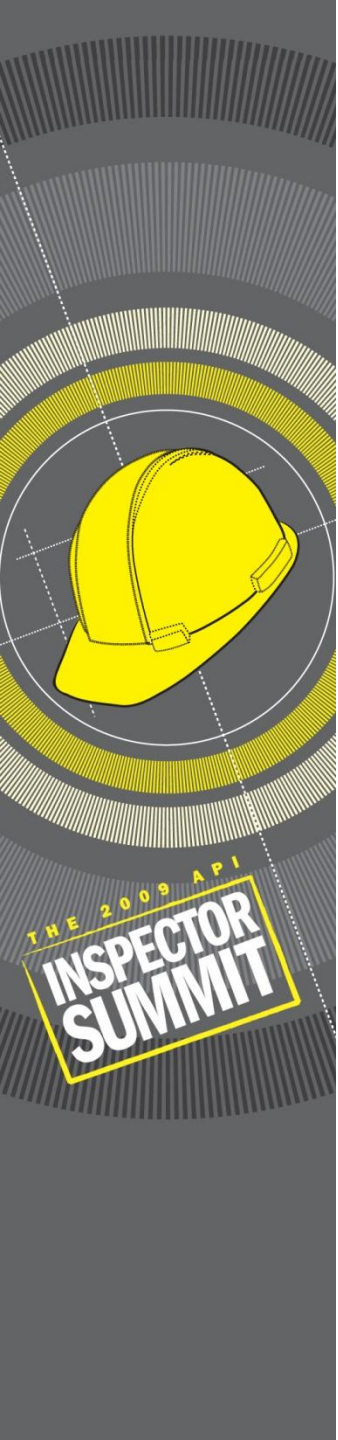
## **Linings: Epoxy (amine catalyst)**

- Epoxy linings have good alkali resistance. Fair to good resistance to solvents and mild acids. Applications include covered hopper-car linings and nuclear containment facilities.



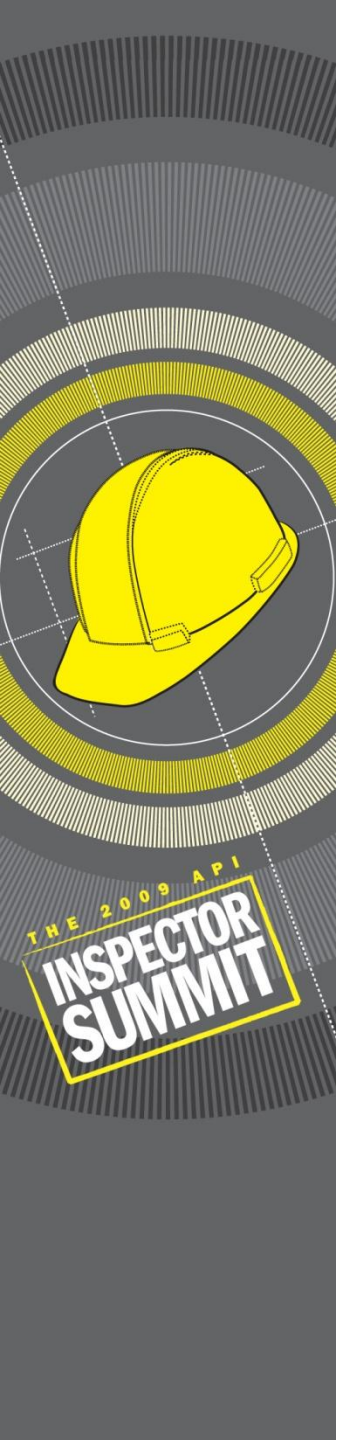
## Linings: Epoxy coal tar

- Epoxy coal tar linings have excellent resistance to mild acids, mild alkalies, salt water, and fresh water. Often used for crude oil storage tanks and sewage plants.



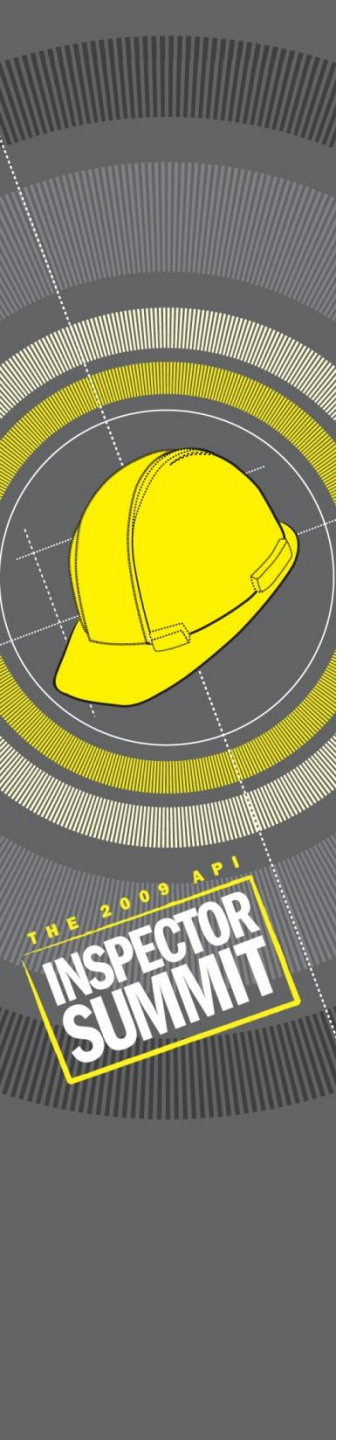
# **Linings: Rubber Latex**

- Rubber Latex linings have excellent alkali resistance and is often used in caustic tanks.



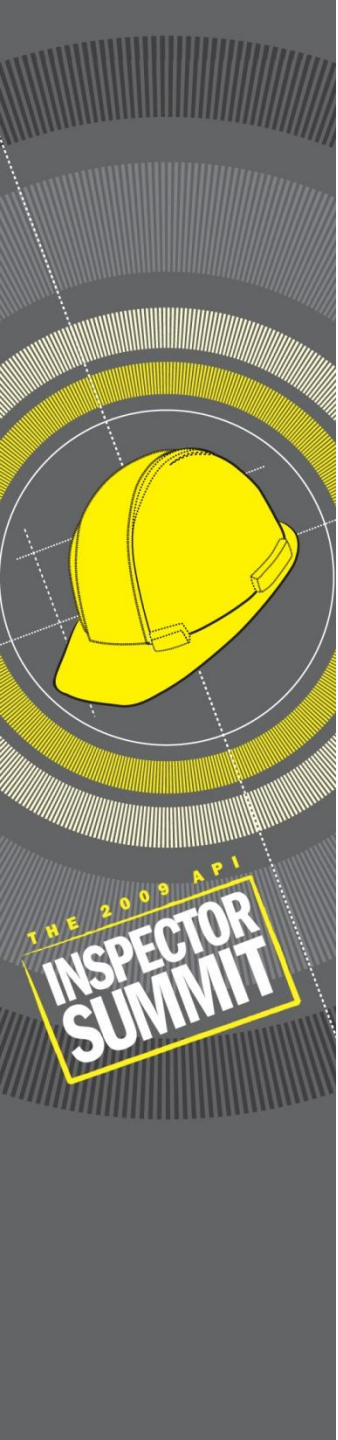
## **Linings: Vinyl ester**

- Vinyl ester linings have excellent resistance to strong acids up to 350F.



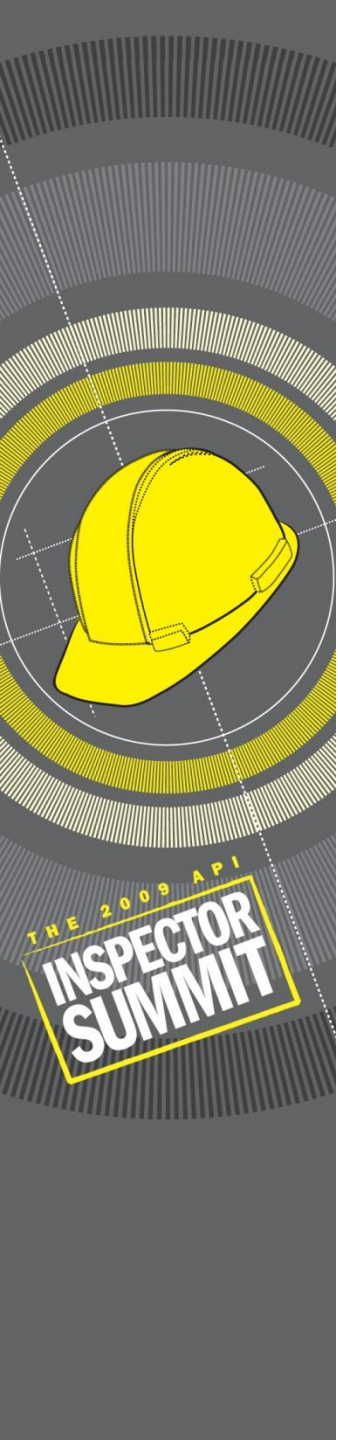
# Linings: Fluoropolymers

- Fluoropolymer linings have excellent chemical and fire resistance. Often used in SO<sub>2</sub> scrubbers.



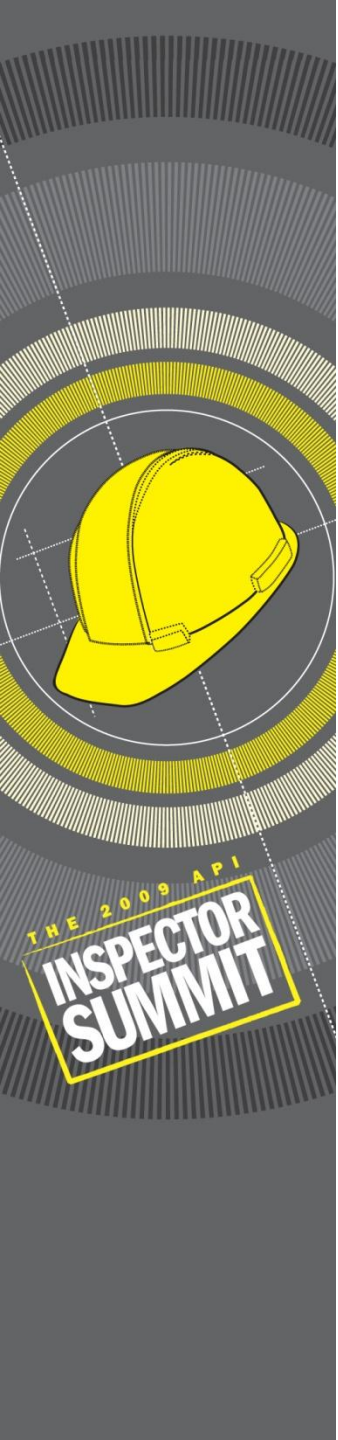
# Linings: Inorganic Zinc

- Inorganic Zinc linings have good resistance to petroleum products and are often used in jet fuel storage tanks.



# Linings: Furan

- Furan linings are the most acid resistant organic polymer. Often used for stack linings and chemical treatment tanks.



# Selection Criteria for Coatings and Linings

- In order to select the proper coating and lining for a particular piece of equipment it is **absolutely imperative** that the process conditions be known. Utilizing the wrong coatings for process conditions can cause accelerated corrosion and lead to catastrophic failure of equipment.
- The primary source of information regarding coating and lining selection should be the organization's coating engineer (if possible).
- If internal resources are not available, all of the major coatings manufacturers have extensive product support resources which can be utilized.



# Inspection's role in Successful Coating System Implementation

- Coating and Lining effectiveness is most often compromised during the installation phase. Poorly or improperly installed coatings often cause more damage than not coating at all. *The primary responsibility of inspection should be the assurance that the coating/lining is installed in accordance with the manufacturer's specification.*



# Questions ???

**Thank You!!**

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WHEN YOU NEED TO BE SURE

