



Industrial Coatings Polyurea Elastomer Technology



Dudley J Primeaux II, PCS
Primeaux Associates LLC
June 2006



Polyurea Technology

Outline:

- I. What is *Polyurea*?
 - Chemistry
 - History of the technology
 - Characteristics
- II. Types of *Polyurea* systems
 - performance issues
- III. Polyurea system processing
- IV. Technology application
- V. Conclusion / Questions

What is a “Polyurea”?

“Polyurea” is a description of a technology and it in itself is not a coating / lining material.



Polyurea Technology

- Introduced in 1987
- Volume usage in 1990, < 1,000 gallons
- 2005 Volume, 18 – 20 million gallons
 - Worldwide
 - 30+ System Suppliers



From Polyurea Development Association (2003), Skeist Report (2004)

What is a “Polyurea”?

Common Comments as to What “*Polyurea*” is!

- Fast reacting system
- Must be processed using plural component equipment
- Can spray / apply it over water / ice
- Contains 70% amine

Polyurea Definition

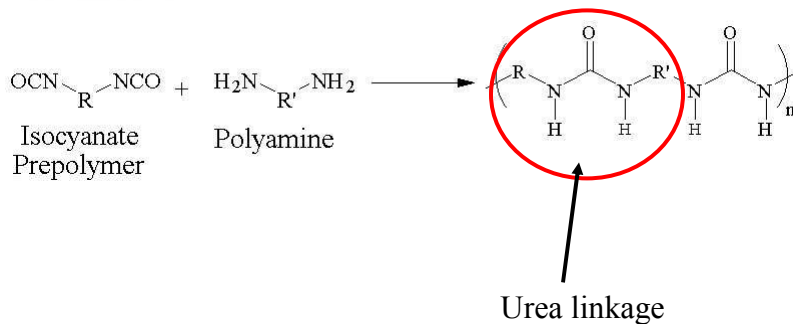
- A polyurea coating / elastomer is that derived from the reaction product of an isocyanate component and a resin blend component. The isocyanate can be aromatic or aliphatic in nature. It can be monomer, polymer, or any variant reaction of isocyanates, quasi-prepolymer or a prepolymer. The prepolymer, or quasi-prepolymer, can be made of an amine-terminated polymer resin, or a hydroxyl-terminated polymer resin.
- The resin blend must be made up of amine-terminated polymer resins, and/or amine-terminated chain extenders. The amine-terminated polymer resins will not have any intentional hydroxyl moieties. Any hydroxyls are the result of incomplete conversion to the amine-terminated polymer resins. The resin blend may also contain additives, or non-primary components. These additives may contain hydroxyls, such as pre-dispersed pigments in a polyol carrier. Normally, the resin blend will not contain a catalyst(s).

Polyurea Definition

From the PDA Definition:

- Two-part system
- One part is Isocyanate component
 - reactive isocyanate groups (-NCO)
- Other part is a Resin blend component
 - reactive group is amine (primary or secondary)
 - (-NH₂ or -NH-)
- Reaction of the two components yields a urea linkage

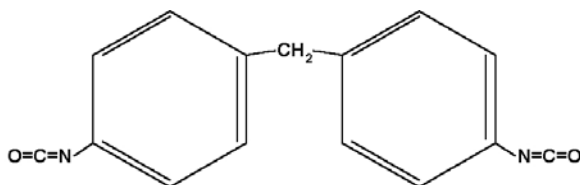
Polyurea Reaction



Chemistry - Isocyanates

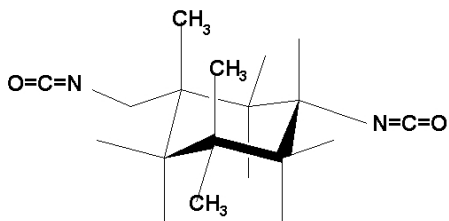
MDI - aromatic

- some TDI based

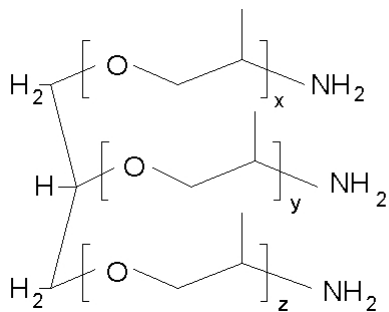
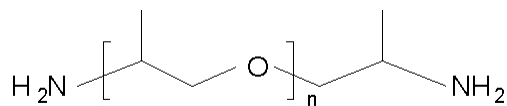


IPDI - aliphatic

- also HDI and H₁₂MDI derivatives



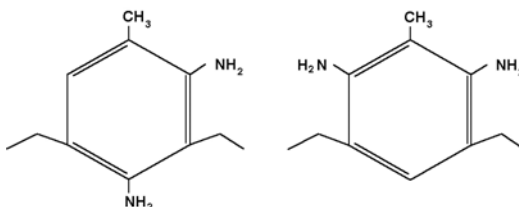
Chemistry - Resins in Blend



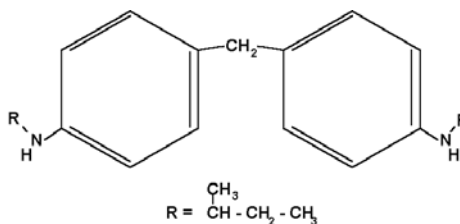
Chemistry - Chain Extenders

Primary Amines

- DETDA

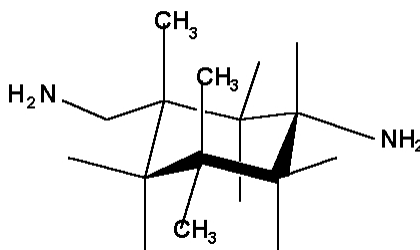


- Secondary Amines



Also some hindered primary amines

Chemistry - Chain Extenders

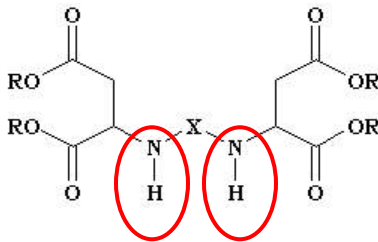


Cycloaliphatic Primary Amines

- IPDA, cyclohexane diamine, hydrogenated MDA's

Polyaspartic Polyurea Systems

Polyaspartic Ester resin



X = primarily cycloaliphatic, but can be linear

Polyaspartic Polyurea Systems

Polyaspartic Ester Characteristics

- Can be processed without plural component equipment
 - roller, brush or squeegee
- System can be pre-mixed and applied using airless spray
- System can be applied using plural component equipment
- Designed mainly for thin film application
- Are polyaspartic systems “polyurea”?

Chemistry - Isocyanates

New Isocyanate Technology

- based on polyester or poly BD resin backbones
 - improved chemical resistances
- based on fluorinated backbone
 - for anti-graffiti or foul release markets

Chemistry - Resins in Blend

New Resin Technology

- based on polyester or poly BD resin backbones
 - improved chemical resistances
- slower reacting amine resins / chain extenders
 - improved adhesion / surface appearance

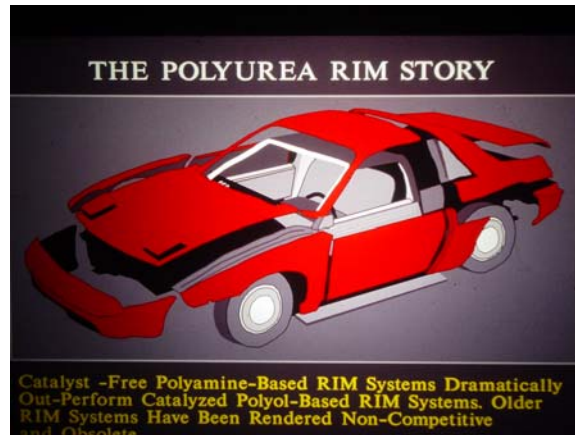
Chemistry Overview

- From a chemistry perspective, polyurea is that system where the reaction is with isocyanate and amine terminated resin - no polyols / hydroxyls
- Does not always require plural component equipment for application
- Can be fast or slow setting
- Growing technology

History of the Technology

- **1981 - Developed for Automotive RIM**
- **1986 - Polyurea Spray Systems
Developed**
- **1987 - Polyurea Spray Technology
Introduced to Industry**
- **1988 - First Commercial Use**

Polyurea RIM Technology



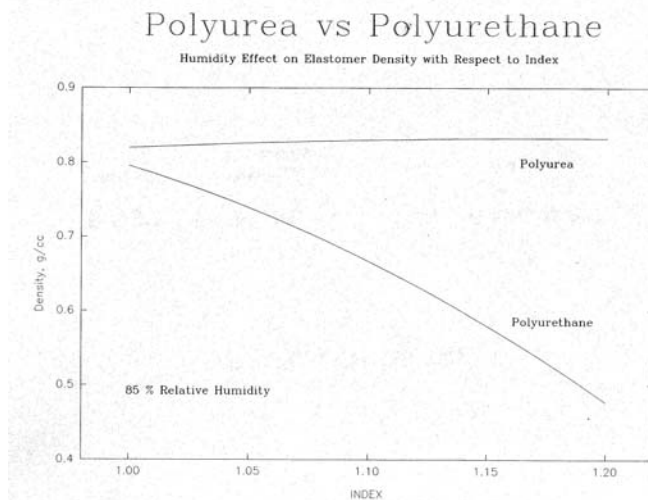
Polyurea Advantage

- **Isocyanate component**
- **Resin blend component**
 - **Amine terminated resins / no polyols**
 - **No catalysts**
- **Very fast reaction, < 10 sec gel time**
- **Usually processed using impingement mix**

Characteristics

- **Fast, consistent reactivity / no catalysts**
- **Relative environmental processing insensitivity**
- **Excellent mechanical properties**
- **Good adhesion to a variety of substrates**
- **100% solids formulations**

Performance - Moisture Affect



Practical Advantages

- **Fast cure: minimal downtime**
- **Extended working season**
- **Flexible: bridges cracks**
- **Resistant to many chemicals**
- **Seamless & Waterproof**
- **Accepts heavy traffic**
- **No solvents, No VOC's, No odor**

Systems Available

- **Aromatic Based Spray Formulations**
 - limited color stability in outdoor applications
- **Aliphatic Based Spray Formulations**
 - excellent color stability in outdoor applications
 - more costly than aromatic based systems
- **ANSI/NSF 61 Potable Water Approved**
- **Polyaspartic Ester Polyurea (thin film)**
- **Slow Cure Joint Sealants**
- **Brush Grade Systems for Repair**

Performance Issues

- **UV Stability - Aromatic Based Systems**



250 hours



3000 hours



3250 hours



3000 hours

QUV Weatherometer testing, ASTM G-53 , UVB-313 bulbs

Typical Physical Properties

Tensile strength, psi	up to 4000
Shore Hardness	A 30 to D 65
Elongation, %	up to 1000
Tear strength, pli	250 to 600
100% Modulus, psi	500 to 2000
Burst strength, psi	250 to 500
Flex/Crack Bridging	> 1/8 inch

-26° C / -15° F

Property Testing

Flexibility, Gardner Impact ASTM-D2794

Tests the impact resistance of the coating on a thin metal panel. A steel rod is dropped from varying heights.



Flexibility, Mandrel Bend ASTM D-522 (D-1737)

The same metal panel is coated and bent around a 1/4" steel rod and demonstrates the flexibility of the coating. This test is sometimes performed at various temperatures.



Property Testing

Flexibility and Crack Bridging: ASTM C-836

Measure of a coating / lining material's ability to bridge a crack that may develop in the substrate. Commonly used for concrete flooring type applications.

Many fast set polyurea elastomer systems note the following result:

> 1/8 of an inch (3.2 mm) at -20°C

- Need to be cautious of "memory" in the polymer system.

Property Testing

Flexibility and Crack Bridging: ASTM C-836



- PCS 320 / PCS 350; Polyurea Coating Systems, Inc.

Primeaux
Associates Inc.

Adhesion Characteristics

<u>Substrate</u>	<u>Elcometer Adhesion, psi</u>
Concrete, dry	400, SF
Concrete, primed	> 400, SF
Steel, 2-mil blast profile	> 2000
Aluminum, cleaned	> 2000
Wood	250, SF
Polyurea, cleaned	= cohesive strength

SF = Substrate Failure

Adhesion Characteristics



- over concrete, note level of substrate failure.



Property Testing

Coefficient of Linear Thermal Expansion (CLTE): ASTM C-531

	$\mu\text{in} / \text{in} - ^\circ\text{F}$	$\mu\text{m} / \text{m} - ^\circ\text{C}$
Polyurea, typical	2 - 6	4 - 13
Steel	6 - 7	12 - 13
Concrete	5 - 6	9 - 11
Glass	4 - 5	8 - 10
Plywood	3 - 4	5 - 6
Vinyl Ester	10 - 11	18 - 20
FRP	15 - 16	27 - 29
Polyurethane, typical	53 - 85	100 - 150
Epoxy	20 - 25	35 - 55

Property Testing

Coefficient of Linear Thermal Expansion (CLTE): ASTM C-531

	$\mu\text{in} / \text{in} - ^\circ\text{F}$	$\mu\text{m} / \text{m} - ^\circ\text{C}$
Polyurea, typical	2 - 6	4 - 13
Steel	6 - 7	12 - 13
Concrete	5 - 6	9 - 11
LDPE	~ 3	~ 5
HDPE	~ 6	~ 12
UHMW PE	~ 11	~ 20
Polypropylene	~ 5	~ 9

© 2005 Primeaux Associates LLC, all rights reserved

Coefficient of Friction

ASTM D 1894, stainless steel platen

Smooth finish	0.14 - 0.15
Orange peel	0.25 - 0.40
Textured	0.40 - 0.75
Polyethylene (reference)	0.20

ASTM D 2047, dry & wet leather

	<u>Dry</u>	<u>Wet</u>
Smooth	0.85	0.64
Medium texture	0.93	> 1.20
Heavy texture	0.94	> 1.20

Manning Coefficient of Roughness 0.009 - 0.011

Coefficient of Friction

The Coefficient of Friction can be enhanced by the addition of aggregate, **NOT Sand**, onto the polyurea elastomer during installation. This can be light, or broadcast to rejection. This is then topcoated with a light coat of polyurea or other suitable system (polyurethane).

For broadcast to rejection, use 1/2 lbs aggregate / ft².



Light addition



Broadcast to Rejection

Burn Characteristics

ASTM E 1354, Cone Calorimeter

Flame Spread	~ 7	Smoke	275
Class I			

ASTM E 84, Tunnel Test

Flame Spread	~ 10	Smoke	35
Class I			

ASTM D 1929, Ignition Temperature

Flash ignition: 515 °C	Spontaneous Ignition: 530 °C
------------------------	------------------------------

Ref: EnviroLastic® AR 425, PolyShield® SS-100, InstaCote ML-2, Perma-Tech UX-397FR

Performance Issues

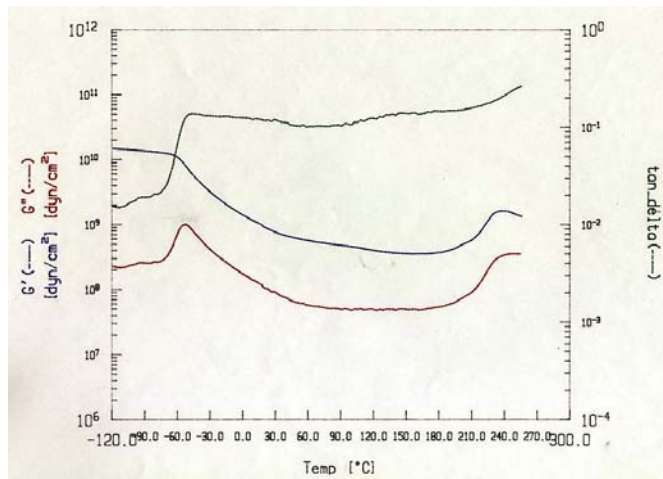
Performance Type	Polyurea	Polyurethane	Polyester	Epoxy	Vinyl Ester	Acrylic	Polysulfide
Physical strength	Low-High	Low-Mid	High	High	High	Mid-High	Low-Mid
Elongation	High	High	Low	Low	Low	Low-Mid	High
Impact resistance	High	Mid-High	Mid	Mid	Mid	Mid-High	Mid-High
Abrasion resistance	High	Mid-High	Mid-High	Mid-High	Mid-High	Mid-High	Mid
Adhesion to concrete	Low-High	Low-Mid	Mid	High	Mid	Low-Mid	Low-Mid
Cure shrinkage	Low	Low	High	Low	High	High	Low
Permeability	Low	Mid-High	Low	Low	Low	Low-Mid	Mid-High
UV Resistance	Mid-High	Low-High	Mid-High	Low	Mid	High	High
Creep	Low	High	Low-Mid	Low-Mid	Low-Mid	Low-Mid	High
Temperature limit	Low-High	Mid	Low-Mid	Mid-High	Mid-High	Mid	Low-Mid
Chemical Resistance							
Mineral acids	Low-Mid	Low-Mid	Mid-High	Mid-High	Mid-High	Mid	Low-Mid
Organic acids	Mid	Low-Mid	High	Mid	High	Mid	Low-Mid
Alkalies	Mid-High	Low-Mid	Mid	High	High	High	Low-Mid
Chlorinated solvents	Low-Mid	Low-Mid	Low-High	Low-High	Mid-High	Low-Mid	Low-Mid
Oxygenated solvents	Low-Mid	Low-Mid	Low-High	Low-High	Mid-High	Low-Mid	Low-Mid
Hydrocarbon solvents	Low-Mid	Low-Mid	Mid-High	Mid-High	Mid-High	Low-High	Low-Mid
Salts	High	Mid-High	High	High	High	High	Mid-High
Water	High	Low-High	Mid-High	Mid-High	Mid-High	Mid-High	Low-High

Performance - Chemical Resistance

- Similar to polyurethanes - polyether backbone
- More resistant to hydrolysis (urea linkage)
- Better alkali resistance (high pH)
- Exposure temperature significantly affects performance
- Some formulation subject to oxidation
- “Modified” systems showing improved performance

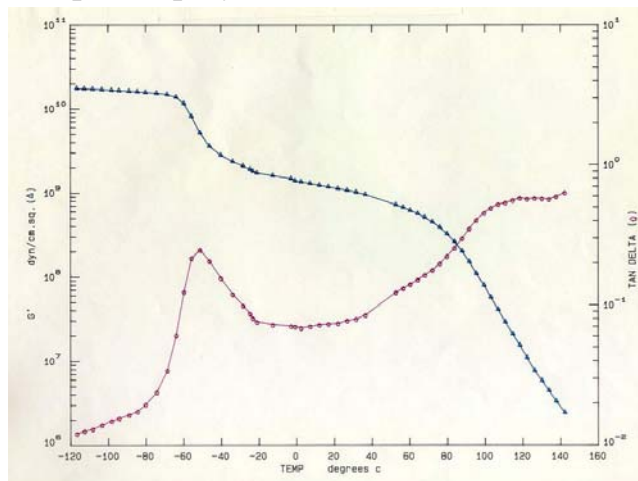
Performance - Thermal Properties

Fast set aromatic polyurea



Performance - Thermal Properties

Fast set aliphatic polyurea



Performance - Shrinkage

- **Polyurea is a thermoset material, not a thermoplastic**
- **As with all thermoset materials, there is some “shrinkage” associated with cure**

Polyurea Spray Elastomer Approvals

AREMA Manual for Engineering Ballast Impact Test

Canadian General Standards Board #76002, Standards Council of Canada #1; railway bridge deck approval. Used #4 Canada Pacific Railway Ballast, ran 2 million cycles.

CCME PN1326 "Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum and Allied Petroleum Products", Section 3.9 Secondary Containment Requirements

ULC/ORD-C58.9-1997 “Secondary Containment Liners For Underground And Aboveground Flammable And Combustible Liquid Tanks”

Florida Department of Environmental Protection, Rule 62-761.850, F.A.C.

Relates to Bureau of Petroleum Storage, use of polyurea spray as a secondary containment liner system, and complies with Rule 62-761.500 (1) (e) 3.b., F.A.C (Florida Administrative Code)

Florida Department of Environmental Protection, API 652 Requirements

Relates to API requirements and approval of the use of a polyurea spray elastomer system for lining above ground storage tanks, Rule 62-761.210 (2) (b) 9., F. A. C.

Polyurea Spray Elastomer Approvals

Wisconsin COMM 10 Material Approval

Approves the use of a polyurea spray elastomer system for dike lining applications, according to COMM 10.345 (l) (e) of the Wisconsin Administrative Flammable and Combustible Liquid Code.

Michigan Department of Environmental Quality (MDEQ)

Use of a polyurea elastomer system for landfill lining and repair work. Company actually received an engineering award for the repair work at Carleton Farms Landfill.

40CFR761.61 CAPS, EPA Region 5 Approval, Membrane Liner/Capping System

This relates to the approval by the EPA for the use of a polyurea spray elastomer system over a geotextile fabric as a liner / capping system for earthen / gravel dike areas at a refinery contaminated with PCB's.

Nassau County, State of New York, Department of Health

Relates to the use of a polyurea spray system to line the bottom and 30 inches up the wall of above ground Fuel Oil Storage tanks, Article XI.

SUFFOLK County, State of New York, Office of Pollution Control

Approval for the use of polyurea spray elastomer as a corrosion protection coating / lining system for concrete and steel tanks.



PROCESSING BASICS



Spray Applications

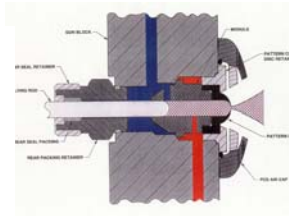
Three Basic Requirements:

- Develop high pressure
- High Temperature, lower mix viscosity
- Material volume flow, greater than the capacity of the spray gun setup

Plural Component Equipment



Plural Component Equipment



Primeaux
Associates Inc.

High Pressure Spray Guns

Must be impingement mix

- **Moving mixing chamber / purge air purge guns**
- **Fixed mixing chamber / moving valving rod; mechanical purge**

Material must enter chamber, mix and exit rapidly

Primeaux
Associates Inc.

TECHNOLOGY APPLICATIONS

What is a “Polyurea”?

“Polyurea” is not an excuse **NOT** to perform
the proper / required surface preparation.

Surface Preparation

Substrates:

Remember:

You are only as good as what you are sticking to!

Surface Preparation - Concrete

- Methods
 - SSPC SP-13 / NACE No. 6
 - ICRI Guideline No. 03732
 - replicate plaques



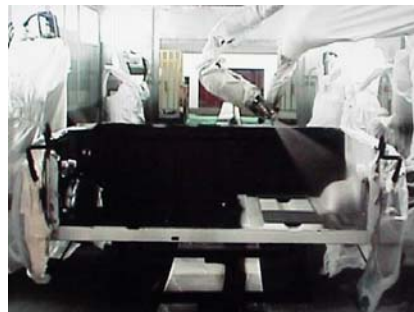
Surface Preparation - Concrete

- For high build coating / lining systems
 - 10 - 125 mils (100 μ m - 3 mm) applied polyurea

Suggested use of CSP 3 to CSP 6 for optimum performance in polyurea systems

OEM Application

- Today, we have the handles coated with polyurea spray for Sebring Convertible



NISSAN OEM Bedliner – Aliphatic Polyurea System

Hopper Car Lining



Primeaux
Associates Inc.

Hopper Car Lining



Primeaux
Associates Inc.

Concrete Coatings

- **Secondary containment**



Primeaux
Associates LLC

Concrete Coatings

- **Secondary containment**

-AUTEC



- primed



- sprayed same day (100 mils)

Primeaux
Associates LLC

Concrete Coatings

- Temporary Secondary Containment



Primeaux
Associates Inc.

Concrete Coatings

- Clean rooms / food processing



Primeaux
Associates Inc.

Concrete Coatings

- Clean room walls



Primeaux
Associates Inc.

Concrete Coatings

- Decorative Flooring



Primeaux
Associates Inc.

Concrete Coatings



Primeaux
Associates LLC

Concrete Coatings

- **Industrial Flooring**



Primeaux
Associates LLC

Concrete Coatings

- **Industrial Flooring**



Primeaux
Associates LLC

Concrete Coatings

- **Marine**

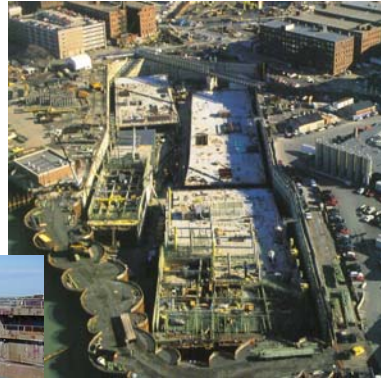


• Corpus Christi, TX Seawall, PCSI

Primeaux
Associates LLC

Concrete Coatings

- Boston CA/T Project
- Boston MBTA Project



Primeaux
Associates Inc.

Concrete Coatings

- San Mateo Bridge



Primeaux
Associates Inc.

Concrete Coatings

- **Pentagon**

Remote Delivery
Facility Deckcoating



Concrete Coatings

- **De-Con Work**

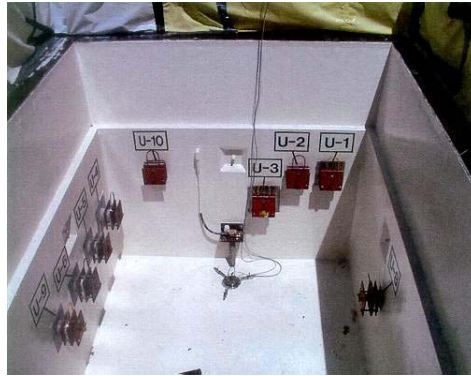
Flooring in nuclear application areas



Concrete Coatings

- **De-Con Work**

Pit lining for ease of decontamination of low level radioactive waste.



Primeaux
Associates Inc.

Concrete Coatings

- **De-Con Work**

PCB Containment / capping



Primeaux
Associates Inc.

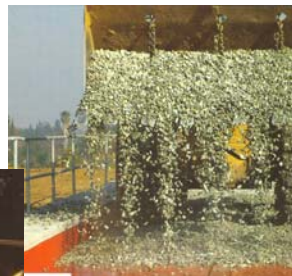
Concrete Coatings



- Acidic Environment
- Resistant Top Coat

Concrete Coatings

- Water Proofing
 - AREMA Bridge Deck



Concrete Coatings

- **Water Proofing**
 - Bridge Deck, Taiwan, 340 km



Primeaux
Associates Inc.

Concrete Coatings

- **Agricultural Flooring / Soft**
 - dairy barns



Primeaux
Associates Inc.

Tank Linings

- **Concrete tanks / waste-water**



Tank Linings

- **Concrete tanks / waste-water**
 - Duke Energy



Tank Linings

- **Concrete tanks / Manholes**



Tank Linings

- **Water storage**



Tank Linings

- **Sugar storage**



Primeaux
Associates Inc.

Corrosion Protection

- **Sand pump casing**



Primeaux
Associates Inc.

Industrial



- API Separator

Primeaux
Associates Inc.

Corrosion Protection



Primeaux
Associates Inc.

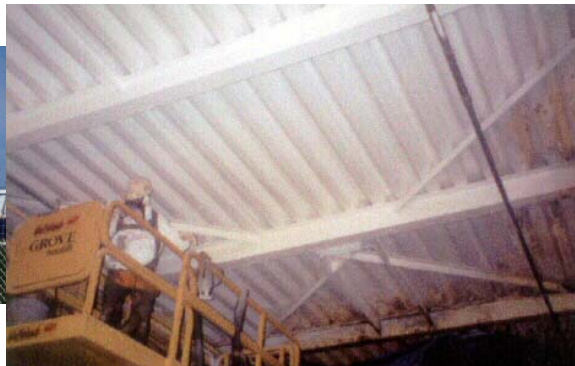
Interesting Application Work



Primeaux
Associates Inc.

Miscellaneous

- Encapsulation work



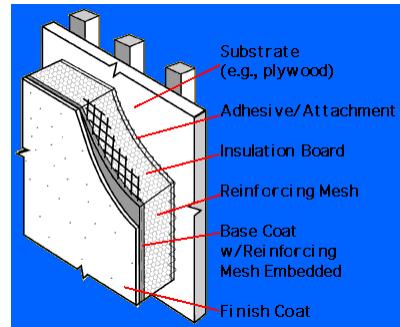
Primeaux
Associates Inc.

EIFS Work

- **Exterior Insulation & Finish System**
 - “polyurea” replaces Dryvit®



Hampton Inn



“polyurea” is base coat

Conclusion

- **Plural Component Technology**
 - no solvents, no VOC's
 - Isocyanate / amine terminated resins
- **Sound case history base exists**
- **New Technologies emerging**
- **NACE, SSPC and ICRI work**
- **Polyurea Development Association**

