Plastic Pellet Hopper Car Lining Issues

by

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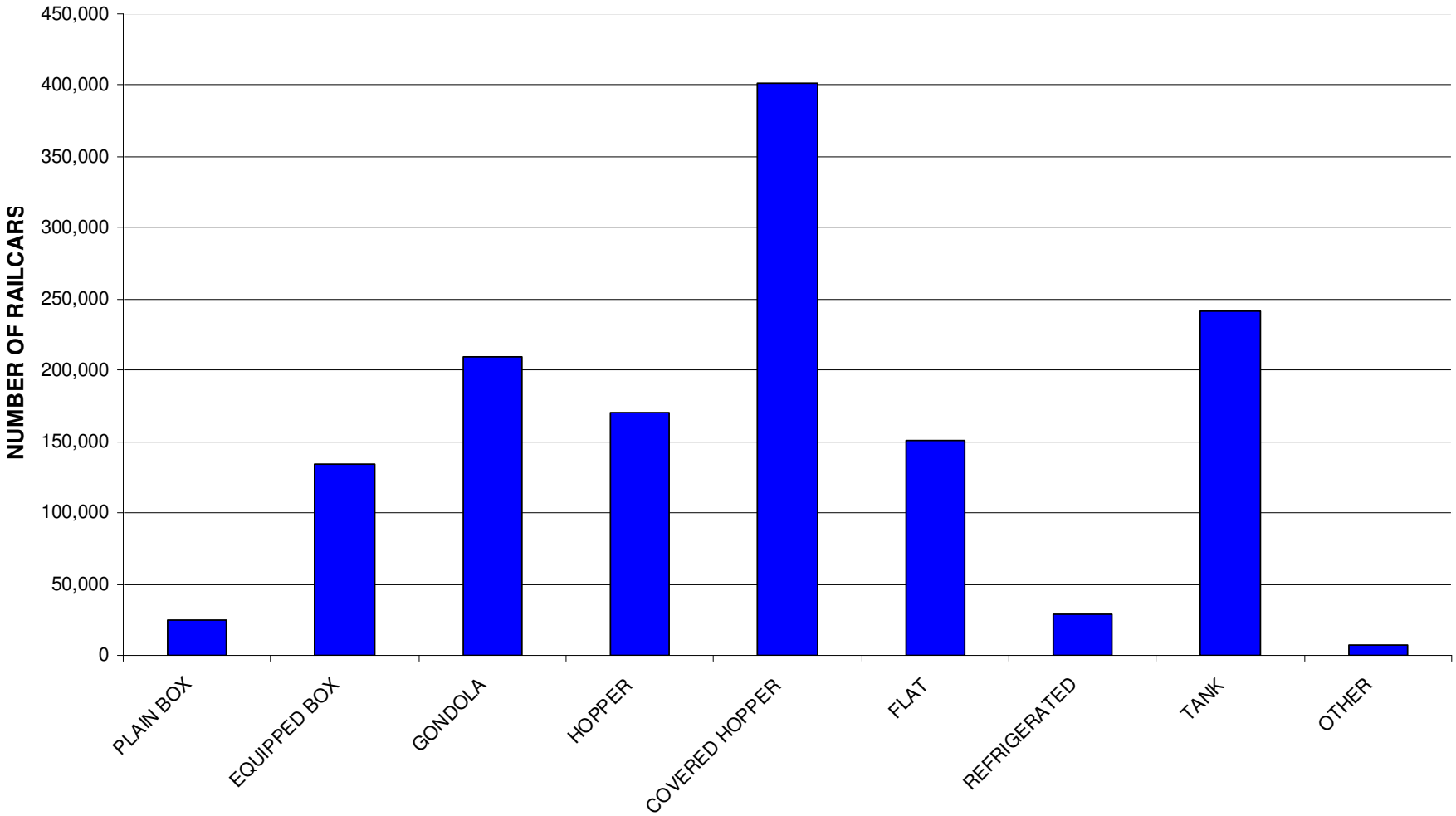
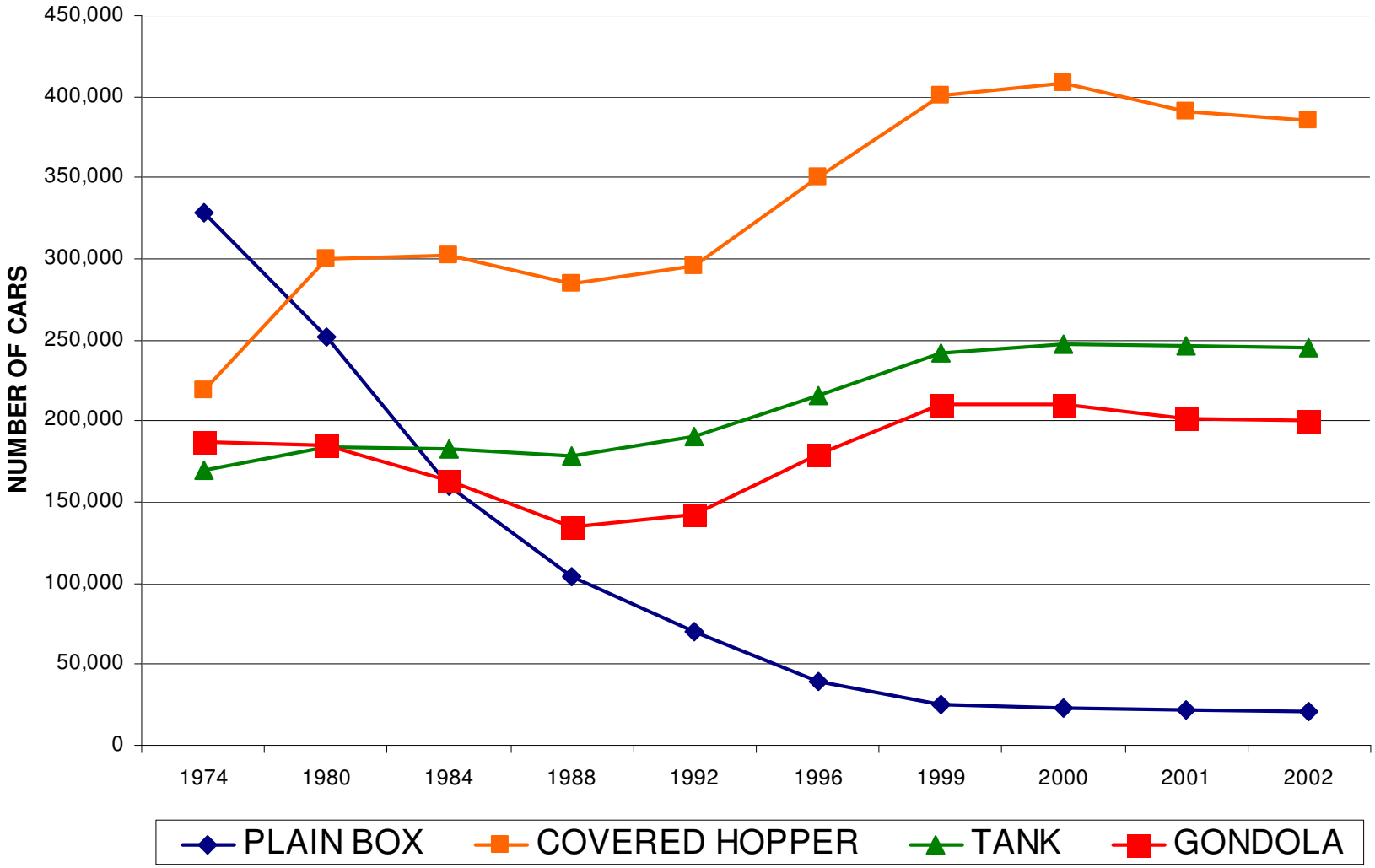
September 20, 2005

Composition of North America Railcar Fleet



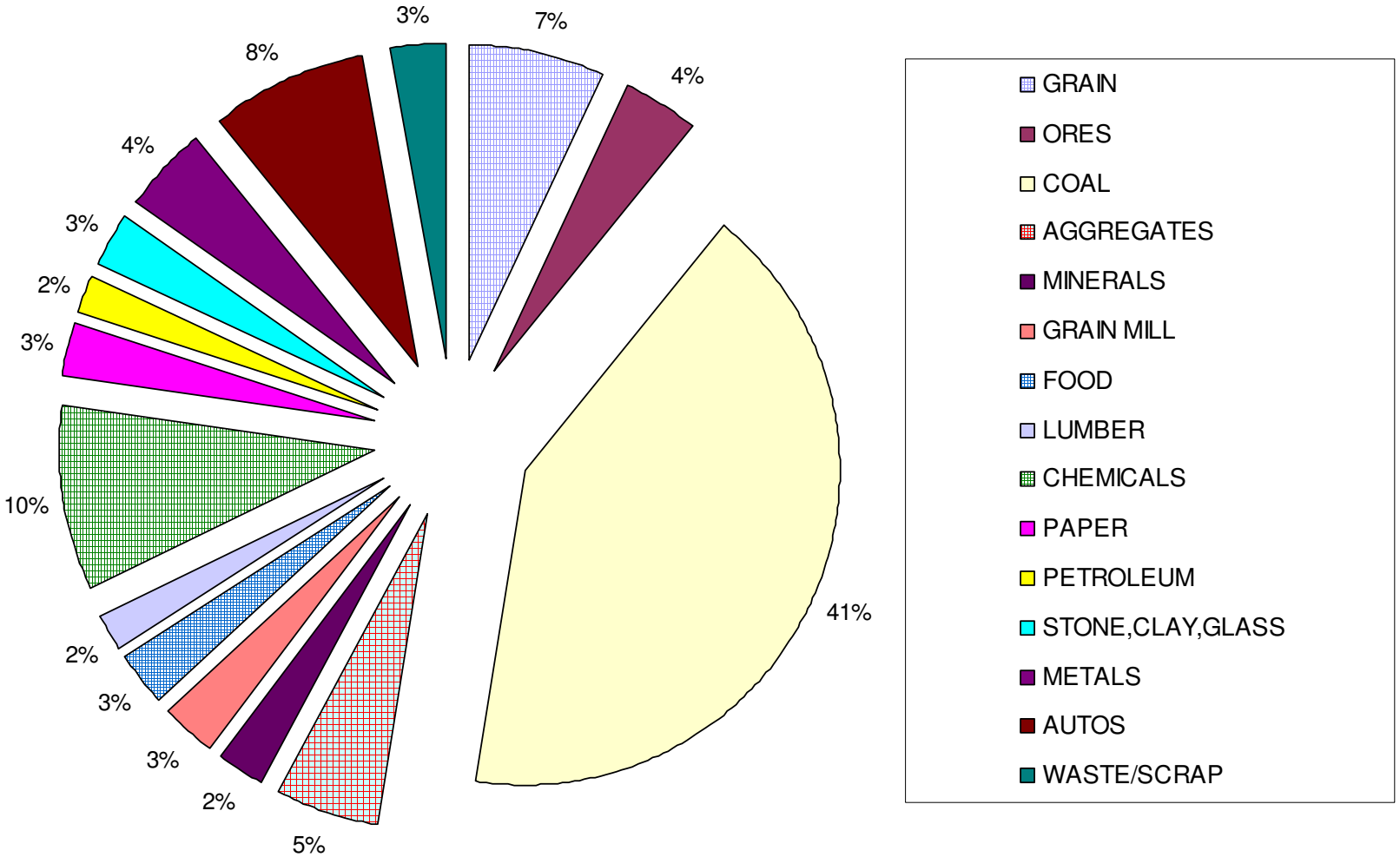
Source: Progressive Railroading's *Car & Locomotive Yearbook*

Change in North America Fleet



Source: Progressive Railroading's *Car & Locomotive Yearbook*

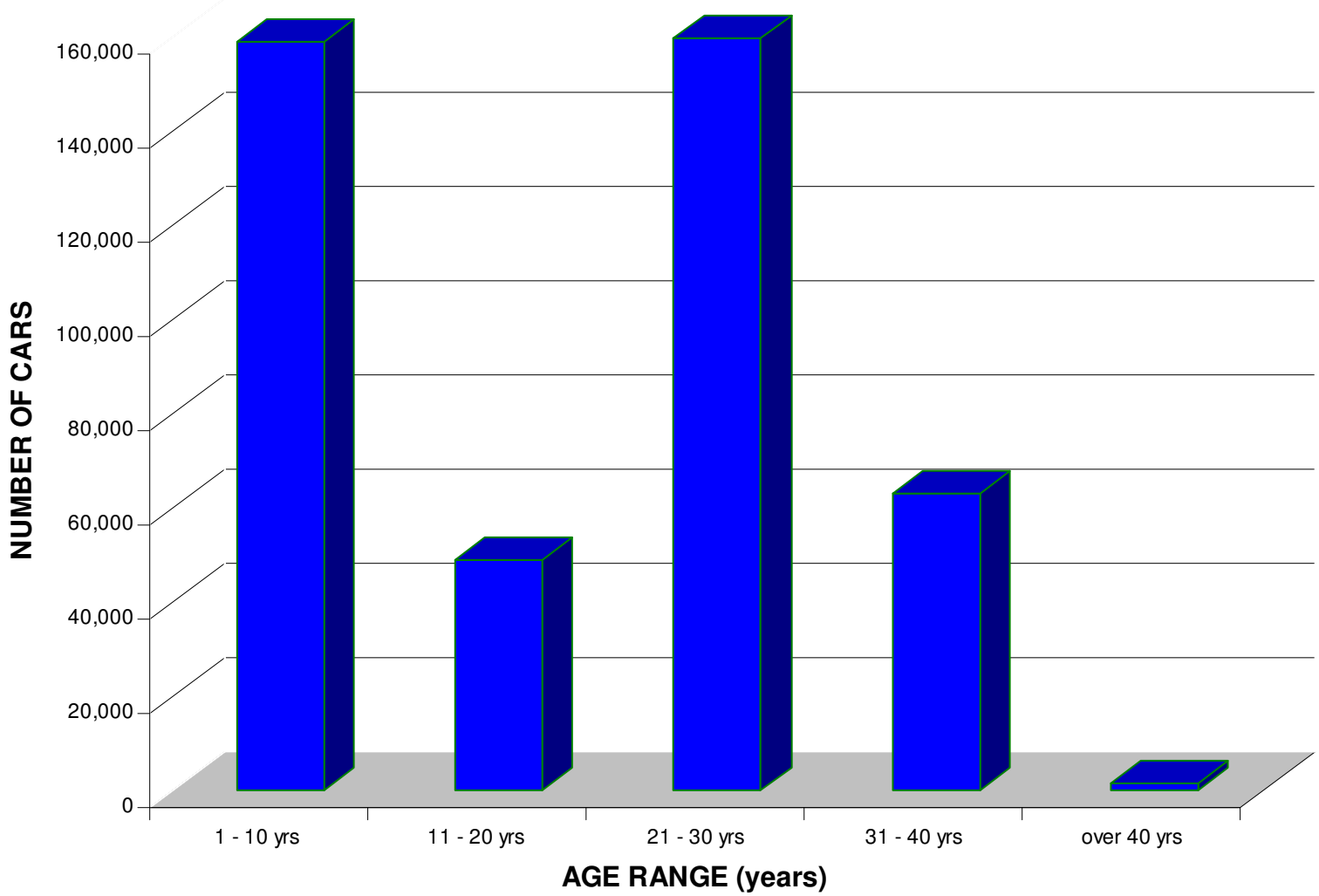
Railcar Loads by Commodity



Source: Progressive Railroading's *Car & Locomotive Yearbook*

Age of Covered Hopper Cars

New car order booms in 1974 and 1992



Source: Progressive Railroading's *Car & Locomotive Yearbook*

Plastic Pellet Hopper Cars

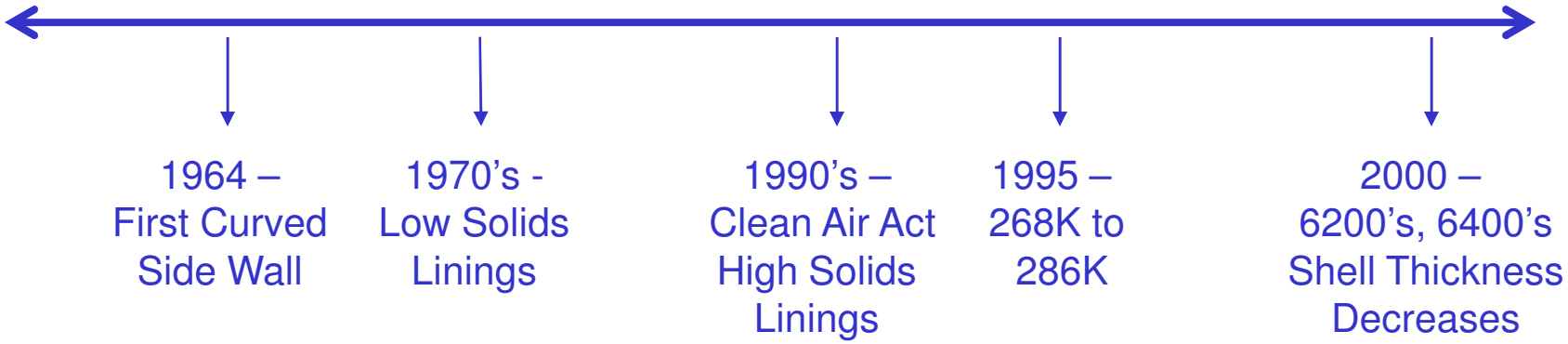
- AAR Field Manual Job Codes (Private Rail Car Standard Job Codes)
  - 8025 – Air Cure
  - 8026 – Force Cure

- Car Type Description
  - 5250 cu.ft. pneumatic hopper (purified terephthallic acid, polyvinyl chloride, polystryene, polypropylene, polyethylene, polybutylene terephthalate, polyester)
  - 5700 cu.ft. pneumatic hopper (polyvinyl chloride, polypropylene, acrylates, polyethylene, Bis phenol-A)
  - 5800 cu.ft. ACF pneumatic hopper (polyethylene, polypropylene, polystyrene)
  - 5820 cu.ft. Pullman Standard pneumatic hopper (polyethylene, polypropylene, polycarbonate, polyvinyl chloride)
  - 5850 cu.ft. Pullman Standard pneumatic hopper (polyethylene, polypropylene, polyvinyl chloride, polyvinyl alcohol, acrylonitrile-butadiene-styrene, polycarbonate)

Plastic Pellet Commodities

- Non-corrosive
  - Polyethylene (PE)
  - Polypropylene (PP)
  - Polystryene (PS)
  - Acrylonitrile-butadiene-styrene (ABS)
  - Polybutylene terephthalate (PET)
  - Poly[imino(1-oxo-1,6-hexanediyl)]) (Nylon 6)
  - Polybisphenol-A-carbonate (PC)
- Corrosive
  - Terephthallic Acid (TPA)
  - Ethylene Vinyl Acetate Copolymer (EVA)
  - Isophthallic Acid (IPA)
  - Polyvinyl Alcohol (PVA)
  - Adipic Acid
  - Purified Terephthallic Acid (PTA)
  - Polyvinyl Chloride (PVC)

Hopper Car Sizes Increase



- High solids linings in 1990's have reduced flexibility
- AAR increase rail load limits
  - 1995 from 268,000 lbs. to 286,000 lbs.
  - Larger cubes
    - 5250, 5800, 6200, 6400
  - Sprayer access more difficult
- Fabricators reduce wall thickness to reduce weight
  - More stress on linings
    - Weld seam stresses

Weld Seam Repair

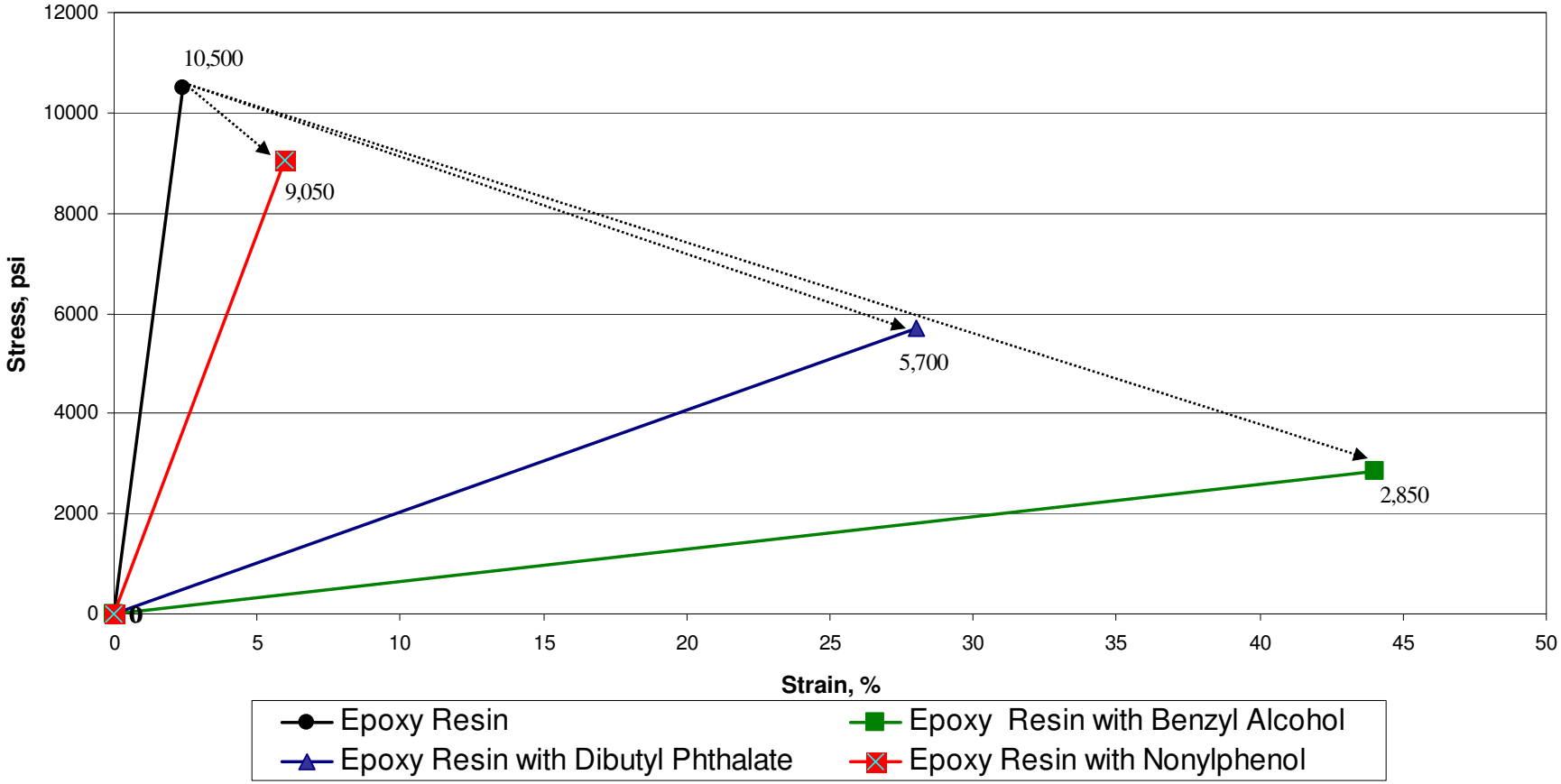
Pre-1990 Clean Air Act Amendments

- Epoxy linings with low volume solids
  - Solid flake epoxy resins
    - Dissolved with solvents
    - 40 – 50% solvents to attain sprayable viscosity – 60 to 70 KU
      - High VOC's (3.3 – 3.5 lbs/gal) and HAPs
  - High EEW (500), Shell Epon 1001F
  - Fast dry from solvent evaporation, leaving solid resin
  - Built-in flexibility, resistant to cracking
  - Lower cross-link density, less chemical resistance
  - Solvent improves wetting of substrate
    - Surface tension of xylene – 29 dynes/cm

Post 1990 Clean Air Act Amendments

- Epoxy linings with high volume solids
  - Liquid epoxy resins
    - Low EEW = 192, Shell Epon 828
  - Little or no thinning, heat used to reduce to spray viscosity
    - Surface wetting reduced
  - Longer dry times
    - Less dependent on solvent evaporation
    - Accelerators added to formulation
  - Substantial decrease in flexibility and surface wetting
    - Plasticizers/leveling agents and silicone surface additives required
  - Substantial decrease in impact resistance
    - Greater cross-link density
      - More brittle
  - Improvement in chemical and corrosion resistance
  - Internal (residual) stresses during cross-linking due to volumetric contraction

Effect of Equal phr of Modifiers to EEW 200 Epoxy Cured with Cycloaliphatic Amine



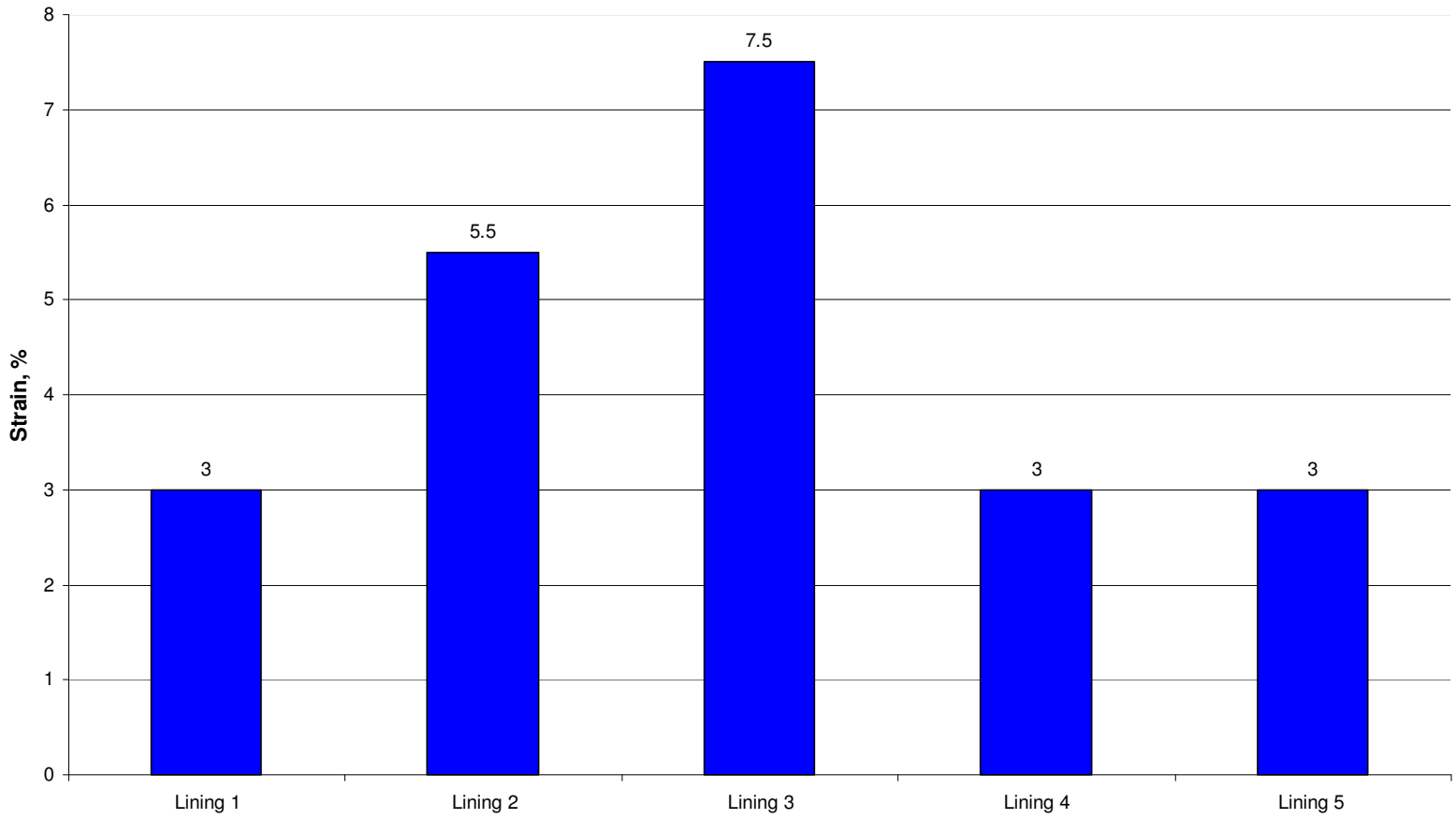
Mechanical Properties

- Traditional Flexibility / Crack Resistance Tests
  - ASTM D 522 *Mandrel Bend Test of Attached Organic Coatings*
    - Coated panel bend over conical mandrel
    - Length of crack gives % elongation

  - ASTM D 2794 *Effect of Rapid Deformation (Impact)*
    - Sledge hammer strikes

Empirical Tests Used for Ranking Selections, but Do Not Provide Prediction of Long-term Performance

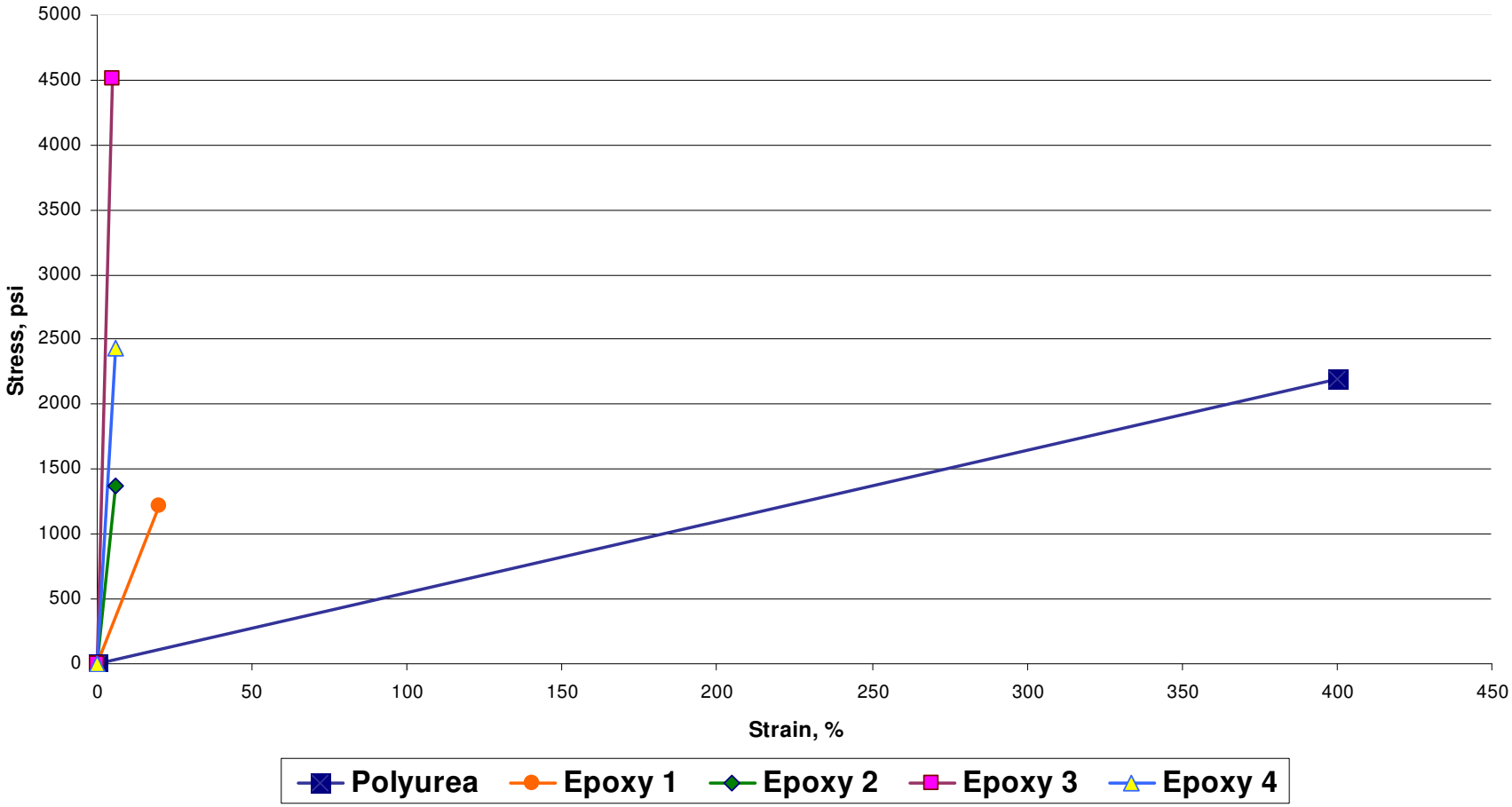
ASTM D 522 - % Elongation for Epoxy Hopper Car Linings



Mechanical Properties

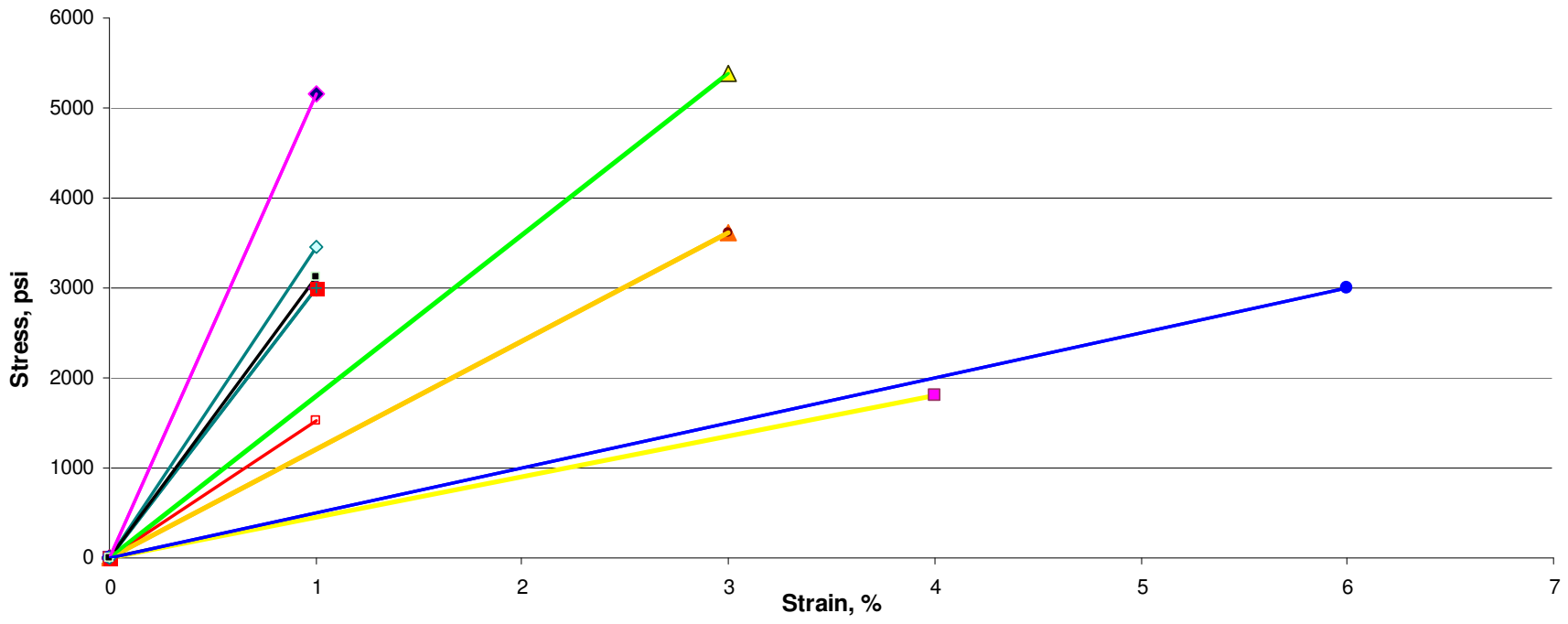
- Traditional Flexibility / Crack Resistance Tests
  - ASTM D 2370 *Tensile Properties of Organic Coatings*
    - Free film pull on tensile tester, ie Instron
      - Ultimate Tensile Strength and Elongation at break

ASTM D 2370 – Stress / Strain Properties for Hopper Car Linings

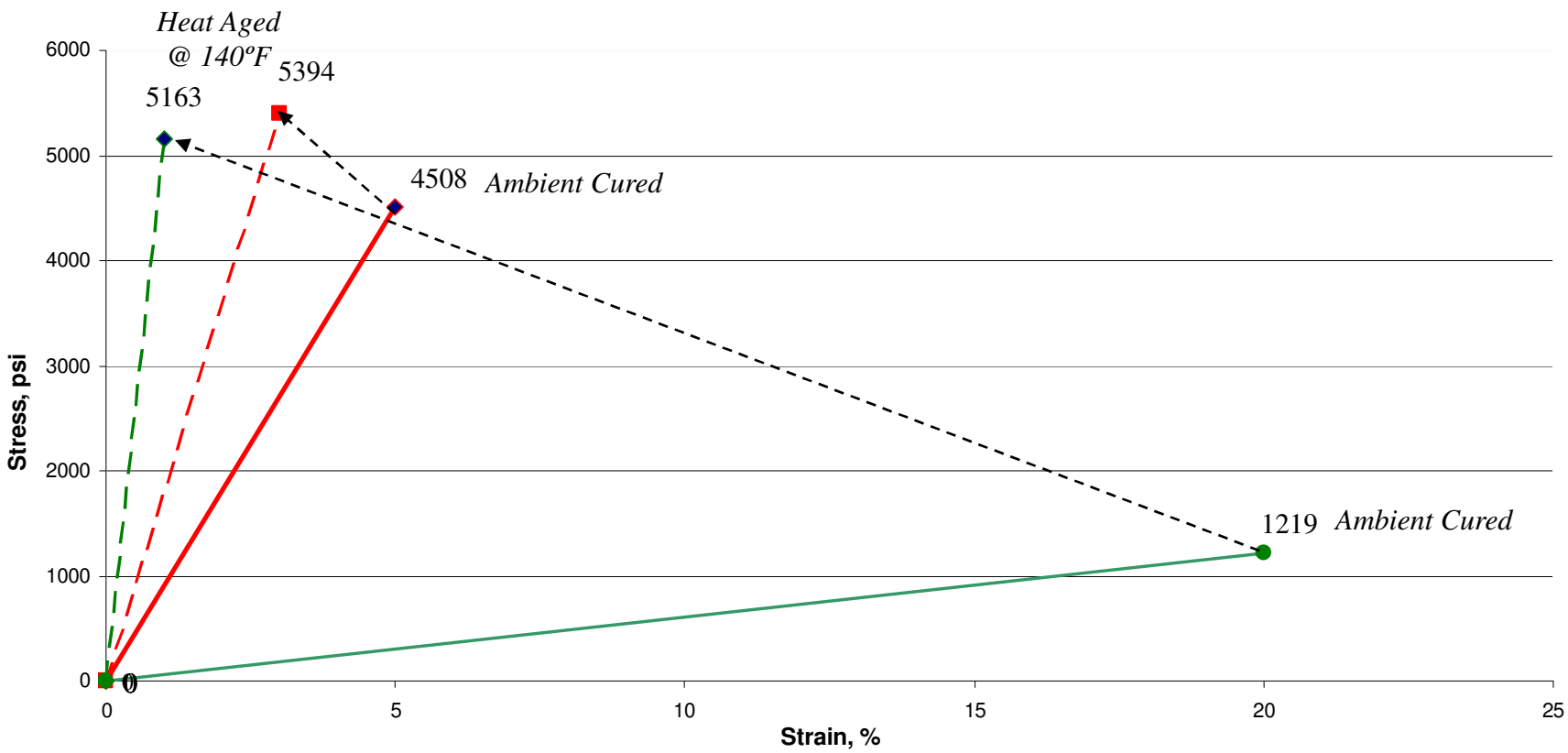


Mechanical Properties

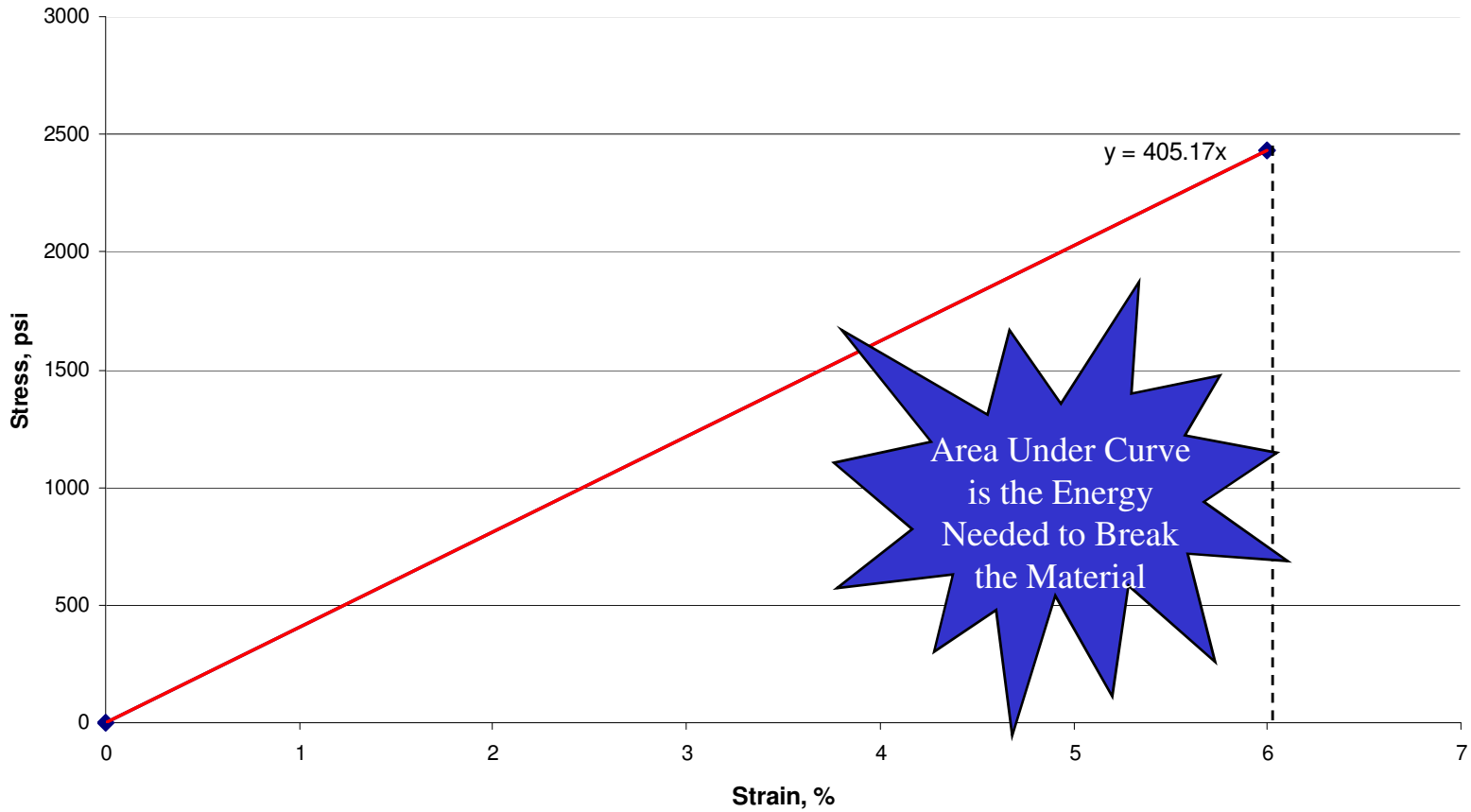
ASTM D 2370 – Stress / Strain Properties for Heat Aged Epoxy Hopper Car Linings



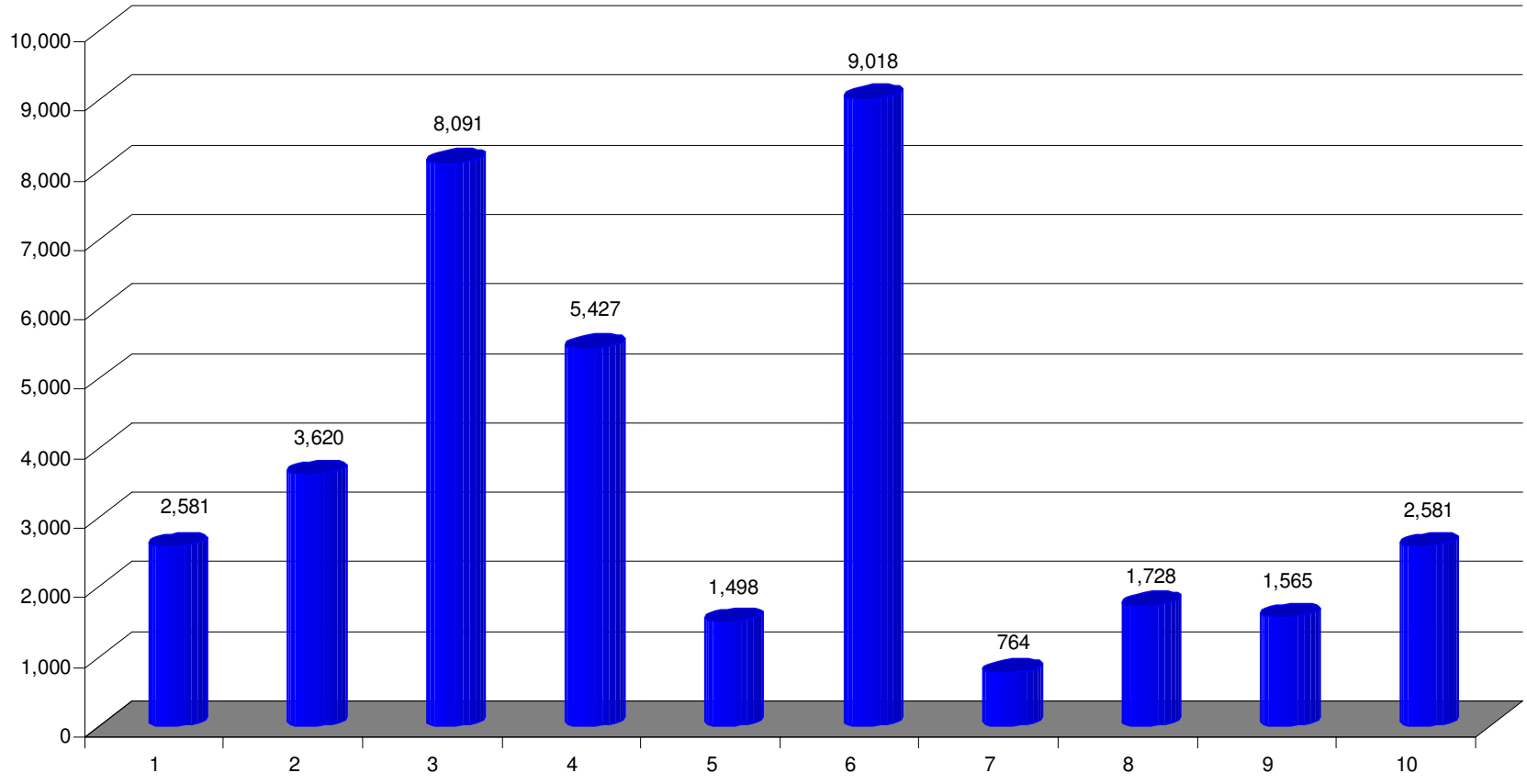
ASTM D 2370 - Stress / Strain Properties for Epoxy Hopper Car Linings



ASTM D 2370 – Stress / Strain Properties for Epoxy Hopper Car Lining



Toughness Values for Epoxy Hopper Car Linings



Mechanical Properties

Polymers Exhibiting High Degree of Cross-Linking Exhibit Very High Crack Growth Rates

High Strength and Modulus of Highly Cross-Linked Polymers Have Low Toughness And Account for Poor Fatigue Performance

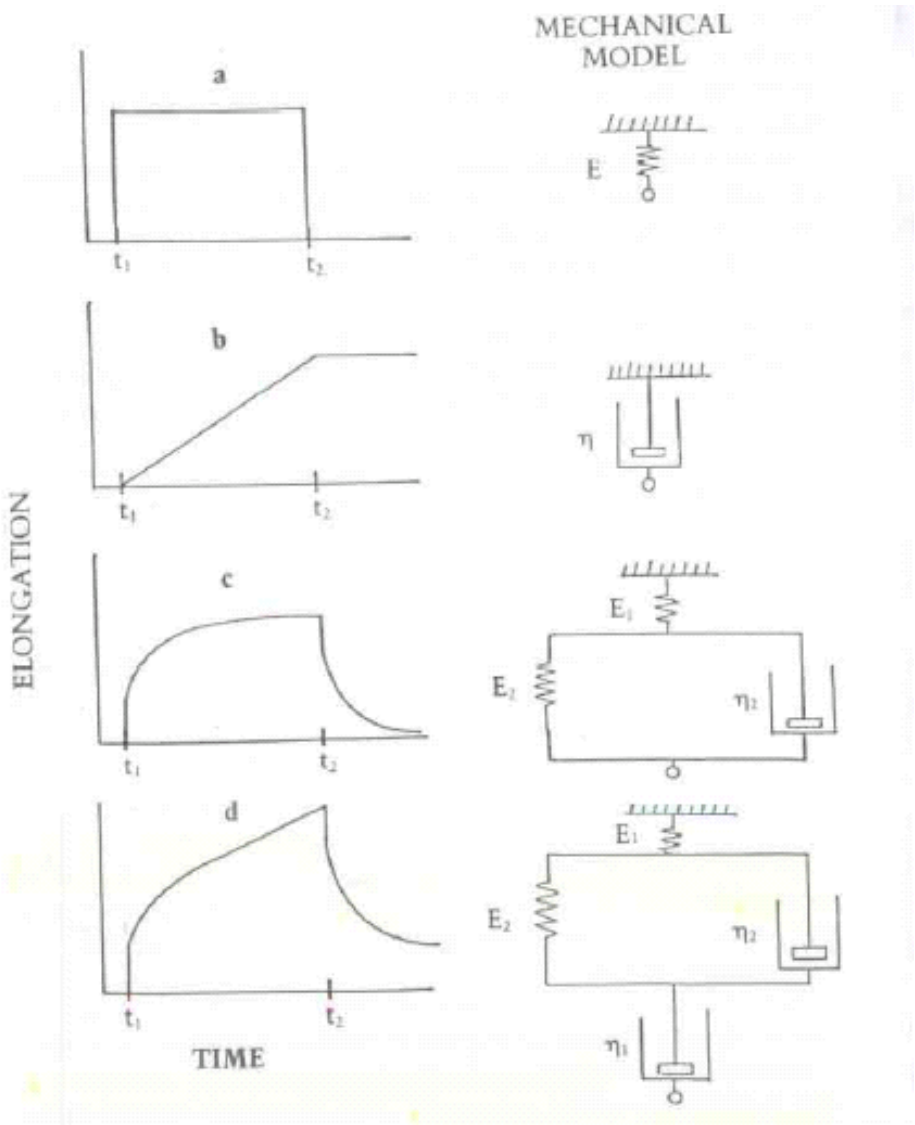
Mechanical Properties

Polymers differ in the Degree of Viscoelasticity

Failures are Influenced by Chain Orientation,
Chain Entanglement, Chain Attraction,
Cross-Linking, Steric Effects from the Structure,
Degree of Crystallinity, Molecular Weight

Mechanical Properties

Viscoelasticity



a – Hookean Solid, no change in displacement with time

b – Newtonian Liquid, displacement is directly proportional to time.

c – Viscoelastic solid with complete recovery

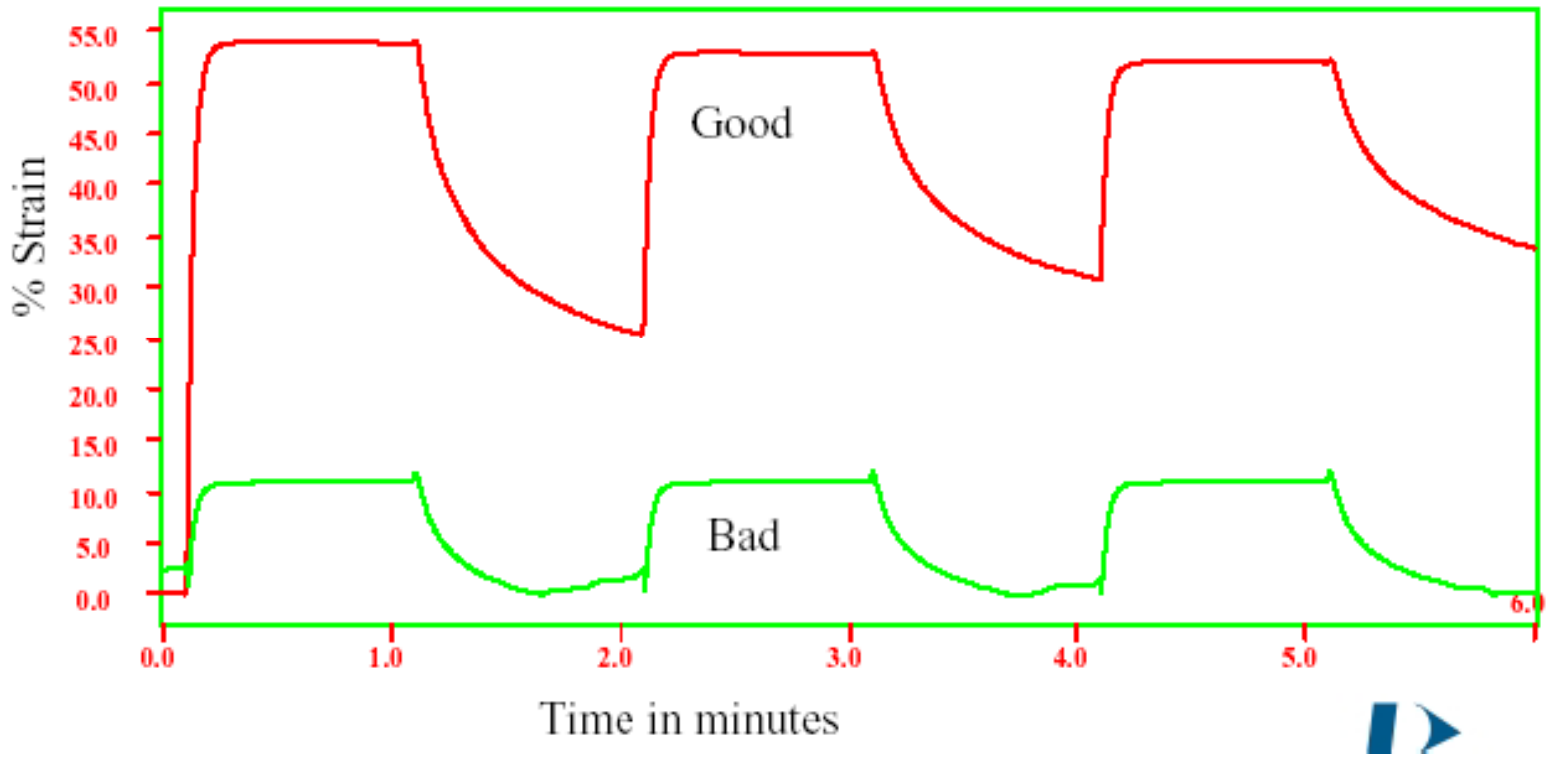
d- Viscoleastic solid with permanent deformation

Mechanical Properties

- Non-Traditional Flexibility / Crack Resistance Tests
  - Four Point Bending – Dynamic Fatigue
    - Coated panels on MTS
      - U. of Utah four point bending experiments show lining toughness not only a property of the formulation chemistry, but also depends on substrate properties – smooth substrates minimize coating cracks
  - Dynamic Mechanical Analysis (DMA)
    - Measures viscoeleastic properties of polymers over range of test conditions.
    - Viscoelastic solids have a time dependent modulus
    - Creep and Recovery – strain vs time
      - Apply constant load for long time, and remove load from sample, and measure recovery – shows how polymer relaxes
    - Damping
    - Glass Transition Temperature – storage modulus vs temperature

Mechanical Properties

Creep and Recovery



Surface Tension

For a liquid coating to wet out the steel substrate, the coating must have a lower surface tension than the surface.

- Surface additives
  - Silicones
  - PTFE
- Tests
  - ASTM D 3825 Dynamic Surface Tension By the Fast-Bubble Technique
    - Sensadyne Surface Tensiometer
  - Dyne solutions
  - Dyne test markers

Surface Tension

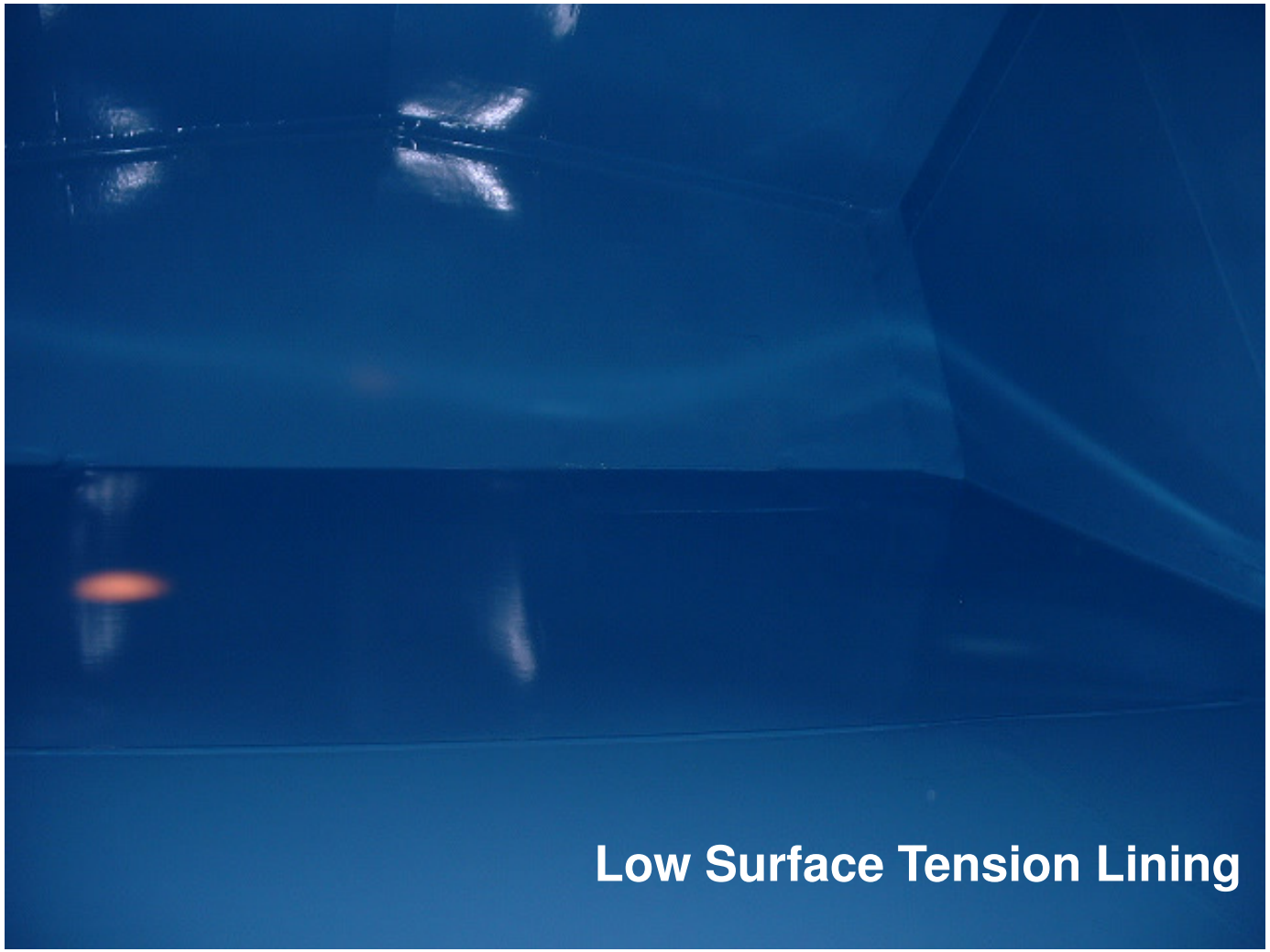
Solid	Surface Tension (dynes/cm)
PolytetraFluoroethylene	18
Silicone oil	21
Xylene	29
Polypropylene	29
Polyethylene	31
Polyvinyl Chloride	39
Hopper Car Lining	?
Epoxy resin	47
Steel	50
Water	73

Hydrophobic – lacks functional groups to form hydrogen bonds with water.

Hydrophillic – forms hydrogen bonds with water

Surface Tension

Surface Tension



Chemical Resistance

- Chemical Resistance
  - Test chemicals
    - Acetic acid
    - Hydrochloric acid
  - Spot Tests
  - Panel Immersion
  - Acceptance Criteria
    - Blistering
    - Rusting
    - Cracking
    - Discoloration
    - Softening
  - Test Duration
    - 1 week
    - 1 month
    - 3 months

Lining Design Properties

- Mechanical
  - Flexibility – crack resistant
    - Heat Aged - Tensile Strength, Elongation, Toughness
    - Creep and Recovery
    - Damping
- Physical
  - Surface Tension, dynes/cm
  - Abrasion Resistance, mg
  - Impact Resistance
  - Heat Resistance
- Chemical Resistance
  - Acetic Acid (terephthallic acid)
  - Hydrochloric Acid (polyvinyl chloride)

Lining Design Properties

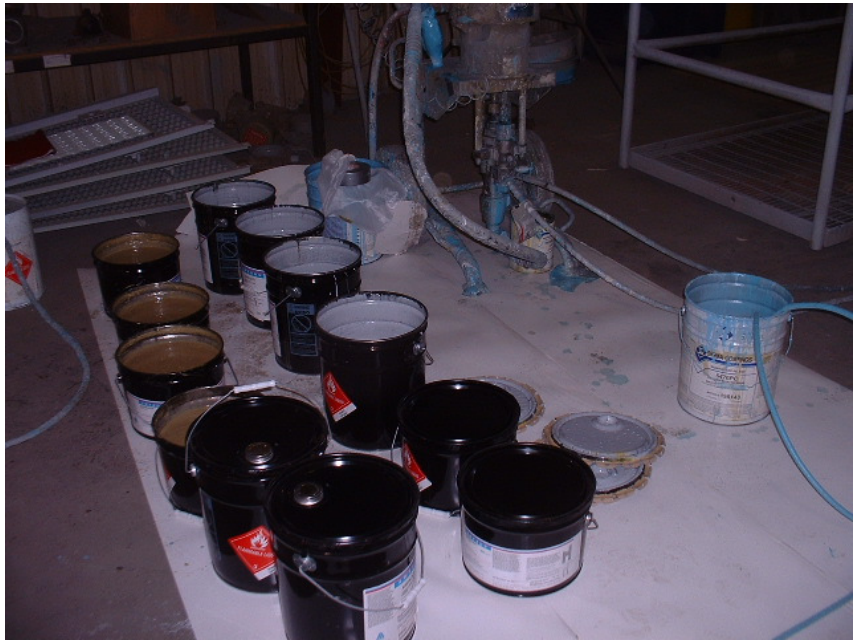
Application Properties

- EHS
  - Low VOC's
  - Low HAP's
  - Nontoxic, nonsensitizing
  - Low odor
- Sag Resistance
  - DFT + 5 mils
- Potlife time
- Can Storage Stability

Lining Application

Hand Mix Application

- Material control
- Potlife time
- Thinning adjustment



Lining Application

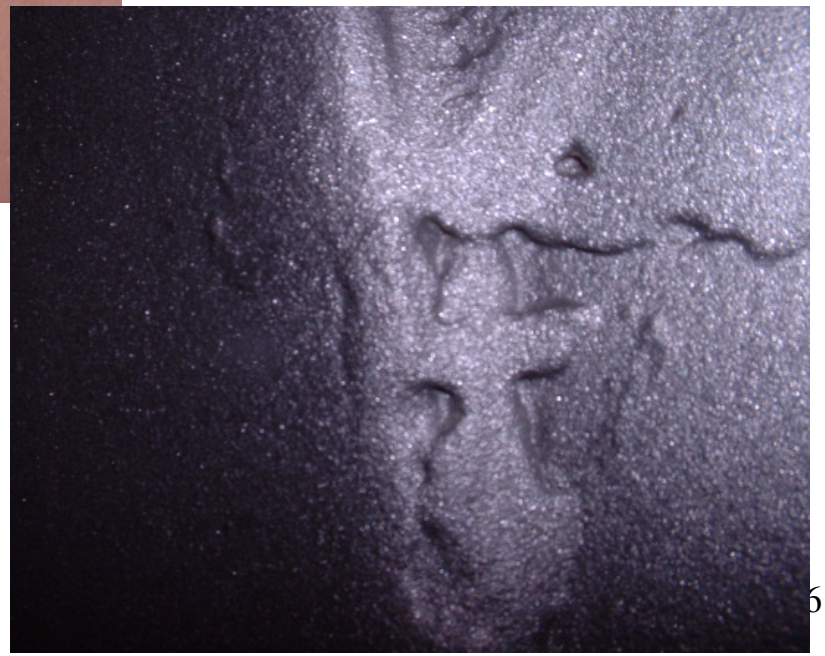
Hand Mixing

- Different methods
- Drums
  - Unlined drums
  - Lined drums
  - Plastic drums
  - PE bag liners
- 5 gallon cans
  - Less mix volume, better potlife control
  - Labor intensive
- Stainless steel cone-bottom tank

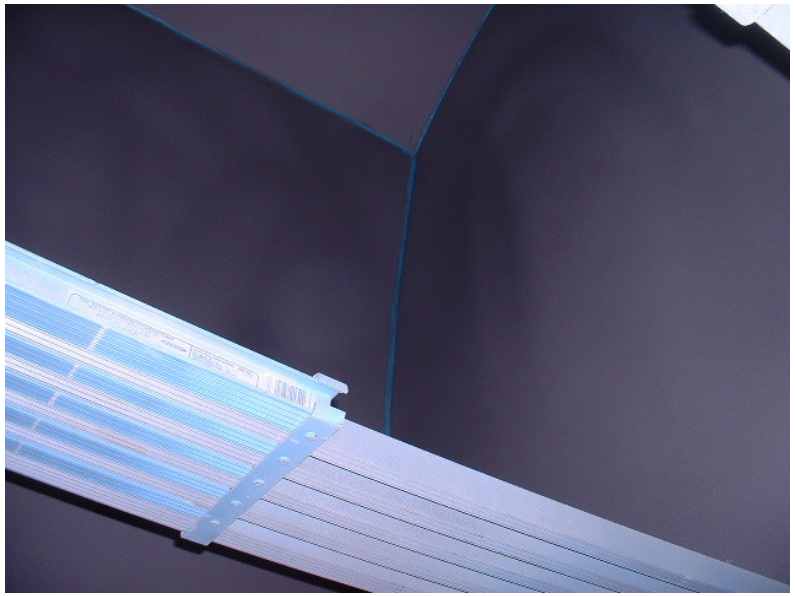
Lining Application

Weld Striping

- Manufacturer's requirements
- Old cars have rough welds
- Striping kits
  - Plural component vs hand mix



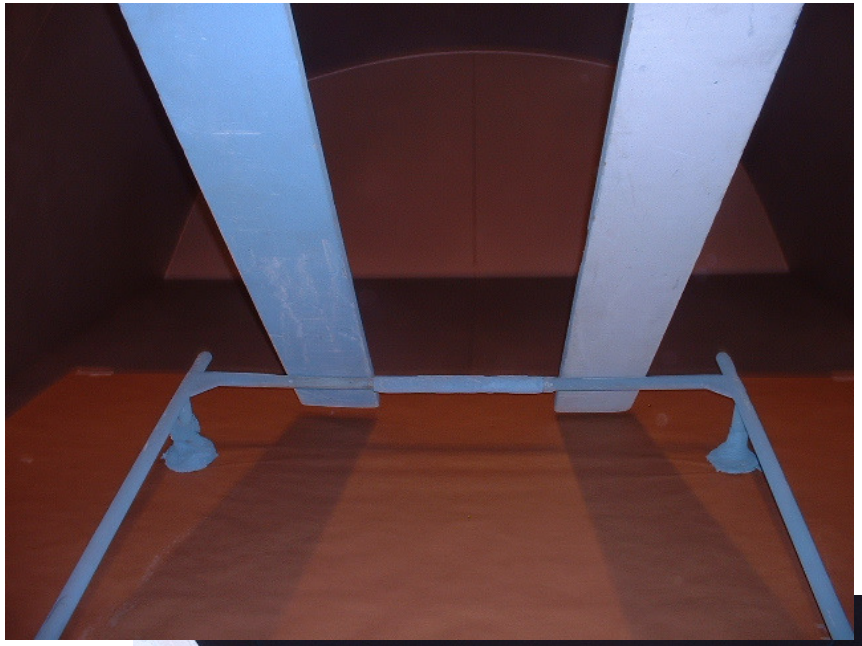
Lining Application



Boards

- Fixed
  - Screw locked for safety
  - Paper becomes heavy
- Collapsible
  - Lightweight
  - Strapped to outlet frame

Lining Application



Wood Boards
- Slide over support
  - Only need one
- Bolted to outlet frame

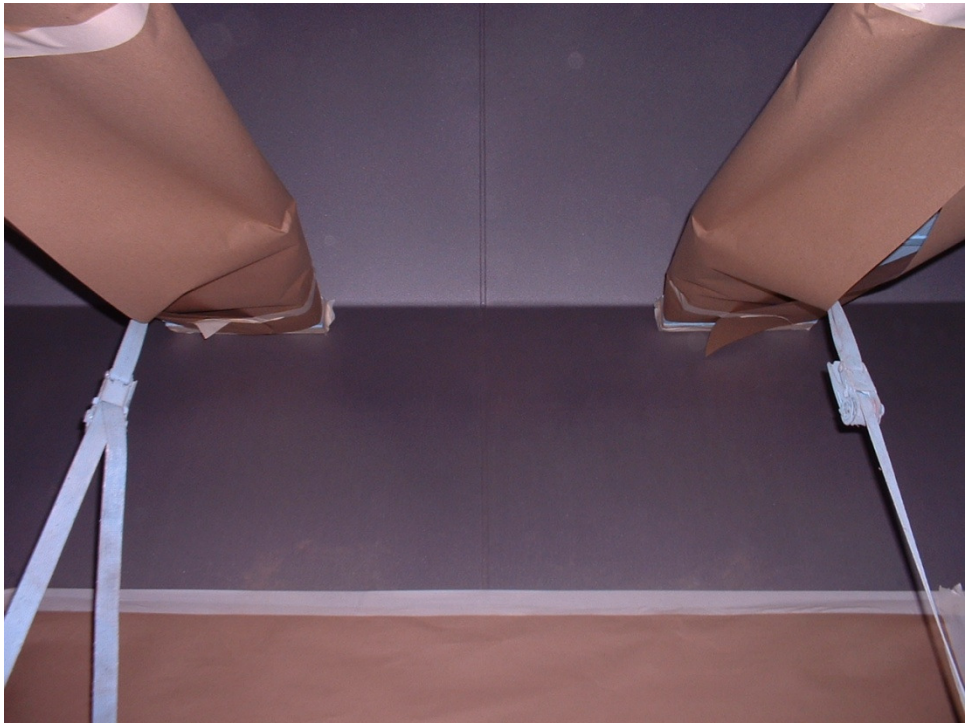
Collapsible Aluminum Boards
- Strapped to outlet frame
  - Must have two
    - Prevents dry spray

Lining Application

Lining Application

Locked Boards
- Short ladders
- All slope sheets paper

Lining Application



Collapsible Aluminum Boards
•Paper to prevent overspray

Tape Creates Edge On Slope

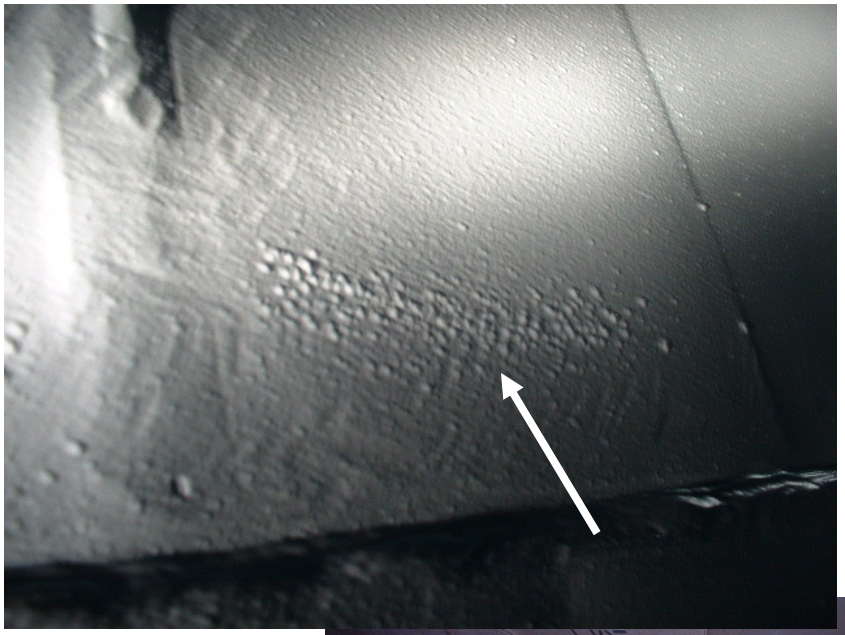
Lining Application

Outlet Frame Flange
- Plastic for over spray
- Rolled flange vs spray
- Boards/plastic/tarps on trucks
- Light held by painter during spray application

Lining Application

Locked Board
- Paded ends
- Touchup for topcoat
- No board marks in primer

Lining Application



Ladder for long slope sheets
- Prevents warts
- Prevents dry spray in corners

Warranty

- Warranty Period
  - Start date
- Scope of Work
  - Number of cars and car type
  - Application requirements
    - Film thickness, pinhole-free, striping, cure, etc.
  - Description of service
    - Commodity chemistry
    - Loading conditions

- Definition of failure - defects
  - ASTM Standards – rusting, blisters, cracking, loss of adhesion
  - Frequency of defects
    - Spot – isolated area
    - Uniform – over entire area
  - SSPC Guide to Visual Standard No. 2
    - Table 2 – Re, ASTM D610, ISO
  - Excluded defects – discoloration, staining, cosmetic changes
- Weld Seams

SSPC Guide to Visual Standard No. 2

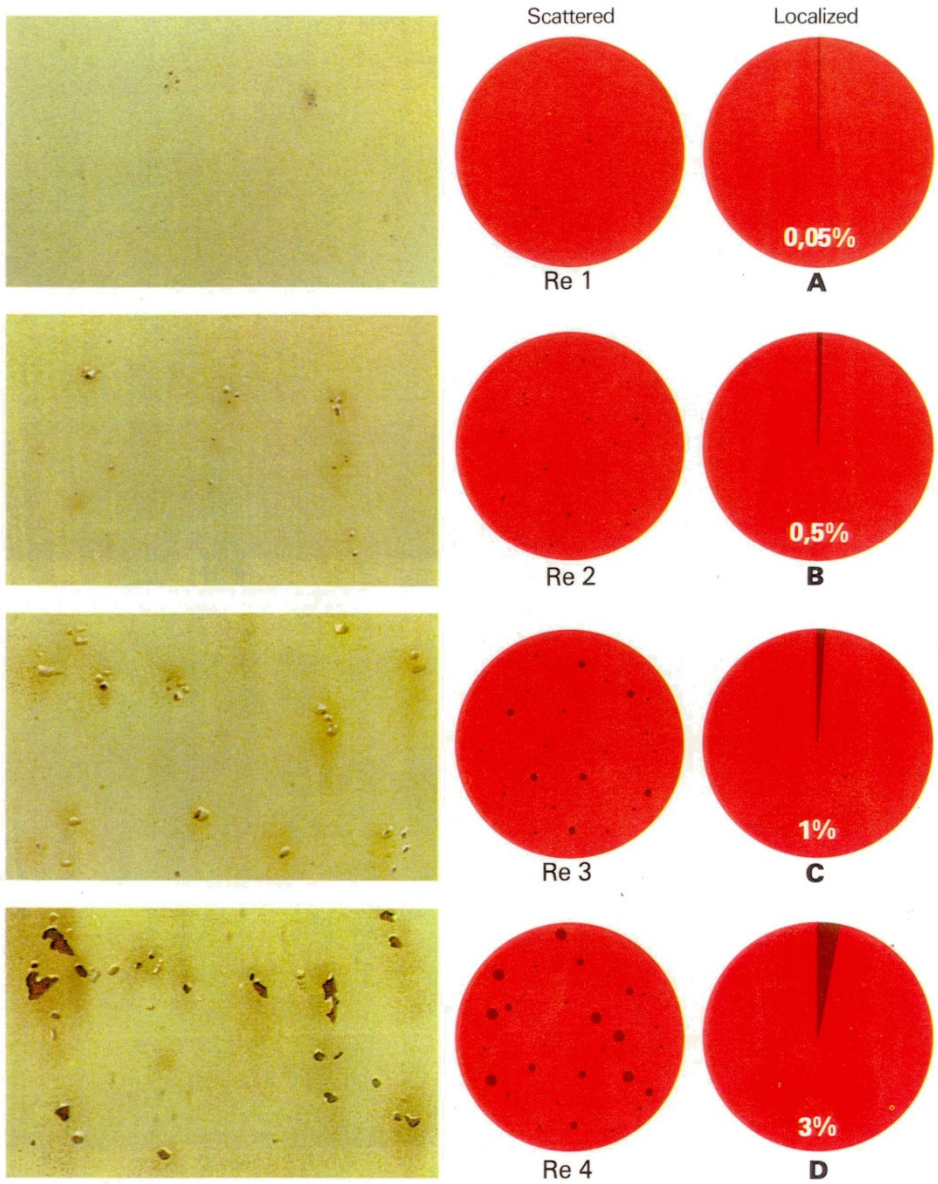
Table 2
Approximate Correlation Among SSPC/ASTM, ISO, and European Rust Grade Scales

SSPC-VIS 2/ASTM D 610		ISO*		European Rust Grade**
Area Rusted, %	Rust Grade	Area Rusted, %	Rust Grade	
<0.01	10	0	Ri 0	Re 0
0.03 to 0.1	8	0.05	Ri 1	Re 1
0.3 to 1	6	0.5	Ri 2	Re 2
0.3 to 1	6	1	Ri 3	Re 3
3 to 10	4	8	Ri 4	Re 5
33 to 50	1	40/50	Ri 5	Re 7

* ISO 4628-3

** "European scale of degree of rusting for anticorrosive paints" published by the Comité Européen des associations de fabricants de peintures et d'éncres d'imprimerie in 1964.

Re Corrosion Numbers



Warranty

- Conditions
  - According to procedures and product data sheet
  - Holiday-free
- Exclusions
  - Application versus defective material
  - Mechanical abuse, cleaning, vibrating
  - Normal wear and tear
  - Nonapproved commodity or concentration
  - Excessive temperatures
- Claim Procedure
  - Notification period
  - Access for inspection
- Reimbursement
  - Materials
  - Labor
  - Maximum amount
  - Limit of liability
  - Payment schedule

Warranty

- Payment schedule

In the event of failure, the prorated value of the lining shall be worth:
for year 1 through 3, the value of the lining shall be worth 100%
for year 4, the prorated value of the lining shall be worth 75%
for year 5, the prorated value of the lining shall be worth 50%

100% payment if lining fails over weld seam occurs within 2 years
50% payment if lining fails over weld seam between years 2 – 3
25% payment if lining fails over weld seams between years 3 – 4
10% payment if lining fails over weld seams between years 4 – 5

- Addendums
  - Procedures
  - Photographs, reference standards, etc.