PLASTIC RESINS AND FIBERGLASS OPERATIONS

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Course Overview

• Plastic resin uses
• Plastic resin theory / operation
• Air pollution control devices
• Implementing regulations
• Typical permit conditions
• Inspection procedures
• Federal regulations

Uses of Polyester Resins

• Aircraft / Aerospace / Automotive
• Marine / Railroad applications
• Electrical / Electronic components
• Construction / Building materials
• Packaging materials
• Consumer / Institutional products
• Corrosion resistant products
• Business equipment
• Furniture / Furnishings
Advantages

- Structural strength & rigidity
- Heat resistance
- Corrosion resistance
- Dielectric strength
- Design flexibility
- Low finish cost
- Moisture resistance
- Reuse & recycle
- Light weight
- Durable

Disadvantages

- VOC emissions
- Toxicity issues
- Flammability
- Storage
- Disposal
Emissions From Polyester Resins

- Ethylene
- Styrene / MMA
- Ethylene Glycol
- Pentane
- Acetone / MEK
- MEKP
- Dibasic Ester

Coming to Terms

- Plastic
  - Organic compounds that can be molded
- Polymer
  - Two or more like molecules joined to form a more complex, physically different molecule
- Resin
  - Carbon compound polymers used in reinforced products to surround and hold fibers

How are Plastics made?

- Consist of building blocks: HC
  - derived from petroleum or NG
  - Monomers (mono=one, mer=unit)
  - bonded into chains → Polymers
- Reaction known as Polymerization
  - Ethylene → Polyethylene
  - Propylene → Polypropylene
Let’s Discuss Common Plastics

Common Plastic Materials

- Polycarbonate
- Polyethylene
- Polystyrene
- Polypropylene
- Polyurethane
- Polyvinyl Chloride
- Polyesters

Polycarbonates

- Created to compete with die-cast metals
- Strong, tough & rigid
- Excellent electrical insulators
- Mostly electrical uses
Plastic Resins & Fiberglass Operations

**Polyethylene : PET**

- Clear, very tough polymer
- Excellent barrier against $O_2$ and $CO_2$
- Good chemical resistance
- Soft drink bottles
- Fiber (the polyester 70s!!!)
- Magnetic tape (audio & video)

Polyester Fiber Jacket

Fleece Made From Recycled “PET”
Plastic Resins & Fiberglass Operations

PET Product

High Density Polyethylene

• High density version of PE
• Excellent protective barrier properties & Strong

• Milk, juice & H₂O container
• Household chemicals
• Detergents
Low Density Polyethylene

- Low density version of PE
- Offers clarity & flexibility
- Provides ductility
- Grocery & garbage bags
- Shrink & stretch films

Composite Decking

Polypropylene

- “Workhorse” of plastics
- High tensile strength
- High melting point
- Good chemical resistance
- Packaging & carpeting
- Automotive & appliances
Polystyrene

- Foamed or Expanded Polystyrene: EPS
- Exceptional insulation properties
- Foam cups & containers
- Foodservice products
- Packaging & protecting

Expanded Polystyrene Foam

Recycled Polystyrene
Recycled Polystyrene
Baseboard Molding

Polyurethanes

• Foam: bedding, auto seats, cushioning, carpet underlay

• Insulation & flotation
• Polyurethane coatings
• Abrasion resistant: printing rolls, conveyor belts, gaskets & seals

Polyurethane Foam

Convolutes use patterned dies to efficiently produce profile shapes from sheets of foam.
Polyvinyl Chloride (PVC)

- Chemical, abrasion & weather resistance
- Pipes & sidings
- Leather-like upholstery
- Gloves, boots & apparel

What are Composites?

Introduction to Composites

- Made up of 2 or more components
  - Fibrous reinforcing network embedded in the cured resin matrix
  - Types of reinforcements → Fiberglass, Carbon fiber & Kevlar®
  - Thermosetting type resin is a plastic that cures from a liquid to a solid state
    → Polyester, Vinyl, Epoxy & Urethane
Types of Reinforcements

- Fiberglass
- Carbon Fiber
- Kevlar

Carbon Fiber

- Stiffest & strongest reinforcing fibers for polymer composites
- Used together with epoxy

- Race cars
- Space applications
- Sporting equipment
Fiberglass

- Made of silicon oxide
- Produced by a spinning process
- Pulled through a nozzle from molten glass
- Reinforcing materials
- Automotive and naval industries, sporting equipment

Fiberglass Forms

- Surfacing Mat (Veil)
- Chopped Strand Mat
- Roving (Spool)
- Woven Roving
- Cloth (Hand Lay-up)
Fiberglass Advantages

- High strength
- Low price
- Dimensional stability
- Temperature resistance
- Corrosion resistance
- Low weight
- Excellent dielectric properties
Types of Fiberglass

• E-glass and S-glass

• E-glass → Good electrical properties

• S-glass → Very strong, stiff, and temperature resistant
### Glass Fiber Reinforced Resin

- Most used composites
- Temp resistance & strength
- Impregnating fibers with liquid epoxy resins
- Aircraft components
- Casings for missiles, pipes, tanks, pressure vessels

### Kevlar®

- Lightweight
- Flexible
- Comfortable
- High Tensile Strength
- Excellent Dimensional Stability
- High Flame Resistant
- High Chemical Resistant
- Used with epoxy or vinyl resin
Plastic Resins & Fiberglass Operations

Kevlar®

- Protective & Performance Apparel
- Composites: aircraft parts/boats
- Fiber-Optic Cables
- Tires
- Ropes & Cables
- Brake Pads & Clutch Linings
- Power Transmission Belts / Hoses

Let’s Discuss Types of Plastic Materials
Types of Plastic Materials

**Thermoplastic Resins**
- become fluid upon heating
- repeatable & reversible process
- no chemical change
- no permanent change in physical prop.
- readily extruded or molded
  e.g., film, fibers, bottles etc.

Polyethylene, Polystyrene & Polypropylene

**Thermosetting Resins**
- irreversibly polymerizes and solidifies
- chemical structure permanently altered
- cannot be resoftened
- process called curing or hardening
  e.g., Molding, casting, powder coating

Polyurethanes, Polyester & Epoxy resins

Thermoplastic vs. Thermosetting

<table>
<thead>
<tr>
<th>Thermoplastic</th>
<th>Thermosetting</th>
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<tbody>
<tr>
<td>Faster molding</td>
<td>Design constraints</td>
</tr>
<tr>
<td>Lower emissions</td>
<td>Limited unit production</td>
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<tr>
<td>Lower costs</td>
<td>Performance requirements</td>
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<tr>
<td>Easy recycling</td>
<td>Market demands</td>
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<td>Low labor intensity</td>
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Plastic Resins & Fiberglass Operations

Raw Materials

- Resins
- Fiber substrate
- Fiberglass
- Catalysts
- Additives
- Solvents
- Initiators

Typical Raw Materials

What is a Resin?
Thermoset Resins

- Two Common Types
  - Epoxy & Polyester
  - Molding, Laminating, Casting ....

  - Epoxy
    - Higher Performance & Higher Price
    - High Strength, Weight Critical
    - Dimensionally Accurate Applications

Polyester Resins

- Building Blocks for Polyester Resins
  - Acids & Glycols Cooked Together
  - Dissolved in Styrene Monomer
  - Inhibitors Added to Delay Reaction

- Product Added to a Peroxide Catalyst
  - Unsaturated Portions of Monomer and Polyester React Together
  - Hard Solid Mass
Fabrication With Polyesters

- Reinforcements such as a Glass Fiber in a Mold
- Saturated with Polyester Resin
- Resin Mixed with Catalyst Causing Crosslinking Reaction
- This Causes Resin to Harden from Liquid to Solid
- Polyester Resin in Fiberglass Boat Mfg.

Let's Discuss Fabrication With FRP
Fabrication With FRP

→ Fabricating with Metals: Structure is Produced & External Paint is Applied
→ Fabrication with FRP: Reverse
→ Start with Mold
→ Pigmented Polyester Coating (Gel Coat) is Applied to the Mold
→ Structural Reinforcement is Built Using Fiber Glass & Polymer Resin
→ Finished Part is Removed from Mold

First Step: Mold

Second Step: Wax Application
Plastic Resins & Fiberglass Operations

Gel Coat Applied to Mold

Chopped Fiberglass Application

Chopped Fiberglass Application
Plastic Resins & Fiberglass Operations

Saturating with Resin

Curing Process

Curing Process
Plastic Resins & Fiberglass Operations

Assembly Line

Finished Product
Plastic Resins & Fiberglass Operations

Let's Discuss Fabrication of Cultured Stone

Types of Cultured Stone
- Cultured Marble
- Cultured Granite
- Cultured Onyx
Cultured Marble

• Consists of
  – Crushed Marble & Stone (Mined)
  – High Strength Polyester Resin
  – Protective Gel Coat on the Surface

• Mixture is Poured into a Mold
• Allowed to cure and shrink
• Part is trimmed and polished

Protective Gel Coat

Fabrication of Cultured Marble
Plastic Resins & Fiberglass Operations

Cultured Marble Products

Trimming & Polishing

Cultured Marble Product
Cultured Onyx

- Consists of →
  - Alumina Trihydrate
  - Polyester Resin Content 28 - 35%
  - Protective Gel Coat on the Surface

- Products are translucent
- They have an added visual depth or a 3-D effect

Cultured Granite

- Consists of →
  - Crushed Stone & Mineral Chips
  - Polyester Resin Content 40%
  - Protective Gel Coat

- Offers the Beauty of Quarried Granite
- Low Cost
- Stain Resistant Coating
Plastic Resins & Fiberglass Operations

Crushed Stone

Polyester Resins

[Images of Crushed Stone and Polyester Resins]
Plastic Resins & Fiberglass Operations

Curing Process

Cultured Granite

Let’s Discuss Open Molding Operations
Process and Control

- Types of Open Molding Operations
  - Hand lay-up & Spray-up
  - Continuous lamination
  - Pultrusion
  - Filament winding
  - Casting or molding
  - Infusion or scrimp

Hand Lay-Up

- Simplest Type / Very Flexible
- Apply Gel Coat, Resin, Fiberglass by Hand
- Roller or Brushes Used for Resins
- High Strength to Weight Ratio
- High Styrene Emissions
- Suitable for Prototypes & Low Volume Production
Plastic Resins & Fiberglass Operations

Hand Lay-Up

Examples of Hand Lay-Up Operations

Hand Lay-Up Product
Plastic Resins & Fiberglass Operations

Let’s Discuss Hand Lay-Up Product: Surf Board Manufacturing

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First Step: Foam Core

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Foam Core: Shaping & Sizing
Plastic Resins & Fiberglass Operations

Fiberglass Surfacing Mat

Fiberglass & Resin Applied to Core

Fiberglass Surfacing Mat

Fiberglass & Resin Applied to Core
Plastic Resins & Fiberglass Operations

Fiberglass & Resin Application

Grinding & Sanding Operation

Grinding & Sanding Tools
Plastic Resins & Fiberglass Operations

Top & Bottom Half of Mold

Bicycle Frame: After Curing Process

Spray Painting Operation
Plastic Resins & Fiberglass Operations

Bicycle Frame: Finished Product

Spray-Up

- Versatile Process
- Cost Effective Method of Producing Large Open-Molded Parts

- Chopped Fiberglass is Sprayed With
  → Catalyzed Resins onto Gel Coat
  → Compacted
Chopped Fiberglass Spray-up Operation

Controlled Spraying

Reduces styrene emissions
Increases transfer efficiency
Low fluid tip pressure
Employee gun handling training
Close containment flanges
Plastic Resins & Fiberglass Operations

Gel Coat Application

Gel Coat Application in a Spray Booth

Gel Coat Storage
### Approved Spray Guns

- High Pressure Airless Guns
- Air-Assist Airless Guns
- Electrostatic Spray
- High Volume Low Pressure (HVLP) *
- Fluid Impingement Technology (FIT) Spray Gun *
Let's Discuss other Open Molding Operations

**Pultrusion**

- Pulled extrusion process
- Fiberglass under tension
- Immersed in Resin bath or injection
- Pulled through forming dye
- Pulled through heated dye to cure
- Produces flat stock for cutting
- VOCs at resin bath and forming area

![Pultrusion Diagram]

Roving Strands

Strand Tension Device

Forming Die

Pull Rollers

Resin Bath

Heated Die

Formed Impregnated Strands
Filament Winding Operations

- Used in Manufacture of:
  - large pipes and storage tanks
  - hollow vessels subject to high internal pressure

- Strand Rovings are Pulled under Tension into a Resin bath
- Wound into Shape & Cured

Let's Discuss Closed Molding Operations
Resin Transfer Molding

- Gel Coat is Applied to Mold
- Reinforcing Fibers are Placed into the Mold Cavity
- Mold Halves are Closed & Clamped
- Liquid Resin is Injected into the Mold Cavity

→ Suitable for High Vol. Production
→ Reduced VOC emissions
Let’s Discuss Emissions & Controls
Emission Sources

- Gel coat - Styrene Emissions
  - Application (atomization)
  - Curing
- Resin
  - Styrene most common monomer
- Mixing
- Clean-up solvents

Process Materials

- General Purpose Resins: 35% styrene
- Specialty Resins: <50% styrene
- Most AQMD Rules: 35% styrene
- Tough Low Profile Resins <35% styrene
  - Higher viscosity
  - Need better surface prep
  - Need good wet-out procedures

<table>
<thead>
<tr>
<th>Application Step</th>
<th>38% Monomer</th>
<th>25% Monomer</th>
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</thead>
<tbody>
<tr>
<td>Loss due to Atomization</td>
<td>5.7%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Loss due to Curing</td>
<td>6.11%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Total Loss</td>
<td>11.16%</td>
<td>8.11%</td>
</tr>
</tbody>
</table>
Plastic Resins & Fiberglass Operations

**Solvents**

- Acetone (widely used)
- Methyl Ethyl Ketone (MEK)
- Dibasic Ester (DBE)
  - less volatile, less flammable than acetone
- Water-based resin emulsifiers
  - detergent cleaners

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Open Acetone Container

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**Clean-Up Rules**

- Cleaning with Compounds 50 to 200 g/liter VOC
- Closed containers
- Self-Closing Containers
- Styrene soaked rags in closed containers

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**Open Containers**

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**Potential Emissions ??**

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Let's Discuss Styrene Emissions

Styrene: HAP Source

- Unsaturated aromatic HC
- Petroleum By-Product
- In Polyesters:
  - Reactive Diluent
- Styrene: HAP (Hazardous Air Pollutants)

Styrene: HAP Source

- Foamed or Expanded Polystyrene: EPS
- Exceptional insulation properties
- Foam cups & containers
- Foodservice products
- Packaging & protecting
Plastic Resins & Fiberglass Operations

Styrene Emissions Determination Models

- A 540 lb. Drum of Gel Coat
  - 38% VOC
  - Applied by “Uncontrolled Spray” Techniques
  - Emit 100 lb. of Emissions

- Two Drums of Gel Coat/day
  - 25 Tons of Emissions/Yr

Let’s Discuss VOC Control
Control of VOC Emissions

- Process change to control monomer emissions
- Low VOC Gel Coat
- Change from acetone to less volatile solvent
- Reclaim acetone (distill)
- ADD-ON equipment

Add-On Control Methods

- Incineration
- Absorption
- Adsorption
- Condensation

Thermal Oxidizer/Afterburner
Regulatory Requirements

- Federal, state, and local requirements
- Resin specific limits
- Permit requirements
- Monitoring requirements
- Visible emission limits
- Nuisance regulations
- Breakdowns & variances.
Federal Regulations

• 1990 Clean Air Act
  – NESHAPS: National Emissions Standards for Hazardous Air Pollutants
  – HAPS: Hazardous Air Pollutants
  – MACT: Maximum Achievable Control Technology
  – New & Existing Major Sources

Federal Regulations

• 40 CFR Part 63 Subpart VVVV -- NESHAP for Boat Manufacturing
• 40 CFR Part 63 Subpart MMMMM -- NESHAP for Flexible Polyurethane Foam Fabrication
• 40 CFR Part 63 Subpart U -- NESHAP for Group I Polymers & Resins
• 40 CFR Part 63 Subpart JJJ -- NESHAP for Group IV Polymers & Resins

Federal Regulations

• 63 WWWW -- Reinforced Plastics Composites Production
• 63 III -- Flexible Polyurethane Foam Production
• 63 6O -- Area Source Flexible Polyurethane Foam
• 63 YY -- Generic MACT Acetal Resins, Polycarbonate, etc.
• 63 W -- Group II Polymers and Resins
• 63 000 -- Group III Polymers and Resins
• 63 6L -- Area Source Acrylic and Modacrylic Fiber Production
• 63 7H -- Polyvinyl Chloride and Copolymers Production
• 63 6D -- Area Source Polyvinyl Chloride and Copolymers
• 63 4H -- Wet Formed Fiberglass Mat
• 66 HHH -- NSPS for Synthetic Fiber Production
• 66 VVV -- NSPS for Polymeric Coating for Supporting Substrates
Plastic Resins & Fiberglass Operations

**BACT and BARCT**

<table>
<thead>
<tr>
<th>Polyester Resin Material</th>
<th>Monomer Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Purpose Resin</td>
<td>&lt;35%</td>
</tr>
<tr>
<td>Specialty Resin</td>
<td>&lt; 50%</td>
</tr>
<tr>
<td>Clear Gel Coat</td>
<td>&lt;50%</td>
</tr>
<tr>
<td>Pigmented Gel Coat</td>
<td>&lt;45%</td>
</tr>
</tbody>
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**Typical Permit Conditions**

- Daily Emissions Limits
- Gel Coat Monomer Content (weight %)
- Resin Monomer Content (weight %)
- Amount of Material Used
- Cleaning Material
- Logs
Reasons for Inspections

- Compliance determination
- Complaint investigation
- Source plan approval
- Review or renewal of permits
- Special studies.

Pre-Inspection

- Prepare inspection report form
- File review
- Regulation review
- Equipment check
- Pre-entry & entry
- Pre-inspection meeting
- Permit check.
**Inspection**

- Visible emission evaluation
- General upkeep & maintenance
- Maintenance records
- Operational records
- Any open containers?
- Self-closing containers
- Rags and waste in closed containers
Plastic Resins & Fiberglass Operations

Closed Paint Containers

Inspection

• Coating Application Equipment
• VOC content of solvents and other chemicals
• MSDS
• Spray Booths
• Dust control equipment
  – Filters and screens
  – Cleaned as often as necessary

Compliant Spray Gun
Plastic Resins & Fiberglass Operations

Filter Inspection

Inspector Safety

Proper equipment
Plant evacuation
Inhalation hazards
Hazardous materials
Chemicals & Machinery

The End