PLASTIC RESINS AND FIBERGLASS OPERATIONS

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Air Resources Engineer

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
Plastic Resins & Fiberglass Operations

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
Plastic Resins & Fiberglass Operations

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
Polyethylene: PET
- Clear, very tough polymer
- Excellent barrier against O₂ and CO₂
- Good chemical resistance
- Soft drink bottles
- Fiber (the polyester 70s!!)
- Magnetic tape (audio & video)

Polyester Fiber Jacket

Fleece Made From Recycled “PET”
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

- “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
Plastic Resins & Fiberglass Operations

Recycled Polystyrene Baseboard Molding

Polyurethanes

- Foam: bedding, auto seats, cushioning, carpet underlay
- Insulation & flotation
- Polyurethane coatings
- Abrasion resistant: printing rolls, conveyor belts, gaskets & seals

Convoluters use patterned dies to efficiently produce profile shapes from sheets of foam.
Plastic Resins & Fiberglass Operations

Polyvinyl Chloride (PVC)

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

What are 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

Introduction to Composites
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
Fiberglass Product

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

Kevlar Product
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

<table>
<thead>
<tr>
<th>Thermoplastic vs. Thermosetting</th>
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<tbody>
<tr>
<td><strong>Thermoplastic</strong></td>
</tr>
<tr>
<td>Faster molding</td>
</tr>
<tr>
<td>Lower emissions</td>
</tr>
<tr>
<td>Lower costs</td>
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<tr>
<td>Easy recycling</td>
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<tr>
<td>Low labor intensity</td>
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Plastic Resins & Fiberglass Operations

Raw Materials

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

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

Epoxy Resin Product

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
Polyester Resins

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
Plastic Resins & Fiberglass Operations

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

Gel Coat: Spray Booth

Gel Coat Applied to Mold

Fiberglass Reinforcements
Plastic Resins & Fiberglass Operations

Assembly Line

Finished Product
Let's Discuss Fabrication of Cultured Stone

Types of Cultured Stone

Cultured Marble
Cultured Granite
Cultured Onyx

Finished Product
Plastic Resins & Fiberglass Operations

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

Fabrication of Cultured Marble
Plastic Resins & Fiberglass Operations

Cultured Marble Products

Trimming & Polishing

Cultured Marble Product
Cultured Onyx

- Consist 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
Plastic Resins & Fiberglass Operations

Curing Process

Let’s Discuss Open Molding Operations

Cultured Granite
Plastic Resins & Fiberglass 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
Let’s Discuss Hand Lay-Up Product: Surf Board Manufacturing

First Step: Foam Core

Foam Core: Shaping & Sizing
Plastic Resins & Fiberglass Operations

Let's Discuss Carbon Fiber Epoxy Resin Mfg.

Bicycle Frame Components

Carbon Fiber & Mold
Plastic Resins & Fiberglass Operations

Top & Bottom Half of Mold

Bicycle Frame: After Curing Process

Spray Painting Operation
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
Plastic Resins & Fiberglass Operations

Spray-up

- Roving
- Chopper
- Gun
- Mold

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
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

<table>
<thead>
<tr>
<th>Application Step</th>
<th>38% Monomer</th>
<th>25% Monomer</th>
</tr>
</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>

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
Solvents

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

Open Acetone Container

ACETONE ACETONE

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

5 Major Styrene Resin Families (20 million tons, more than 40 billion pounds)

- PS - Polystyrene: cups, plates, toys, packaging, dairy containers, building panels, casettes
- ABS - Acrylonitrile-butadiene styrene: appliances, transportation, business machines
- SAN - Styrene-acrylonitrile: appliances, battery casings, packaging, automotive materials, housewares
- SBR - Styrene-butadiene rubber: shoe, automotive applications
- SBR - Styrene-butadiene latex: carpet and upholstery backing, coatings
- UPR - Unsaturated polyester resins: boats, tubs, shower stalls, spas, hot tubs, cultured marble

Industry Estimates
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
Plastic Resins & Fiberglass Operations

Thermal Incinerator

Venting to Oxidizer

Catalytic Oxidizer/Incinerator

Optional Heat Recovery

Waste Gas

Catalyst Bed

Auxiliary Fuel Burners

Stack
Plastic Resins & Fiberglass Operations

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**Wet Scrubber**

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**Carbon Adsorption System**

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Plastic Resins & Fiberglass Operations

Remediation System with Carbon Adsorbers

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 OOO** – Group III Polymers and Resins
- **63 6L** – Area Source Acrylic and Madaacrylic Fiber Production
- **63 7H** – Polyvinyl Chloride and Copolymers Production
- **63 6D** – Area Source Polyvinyl Chloride and Copolymers
- **63 6H** – Wet Formed Fiberglass Mat
- **66 HHH** – NSPS for Synthetic Fiber Production
- **66 VVV** – NSPS for Polymeric Coating for Supporting Substrates
### Plastic Resins & Fiberglass Operations

#### Operation (Open Mold - Boat Mfg)

<table>
<thead>
<tr>
<th>Operation</th>
<th>Application Method</th>
<th>HAP Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooling Gel Coat</td>
<td>Any Method</td>
<td>40%</td>
</tr>
<tr>
<td>Pigmented Gel Coat</td>
<td>Any Method</td>
<td>33%</td>
</tr>
<tr>
<td>Clear Gel Coat</td>
<td>Any Method</td>
<td>48%</td>
</tr>
<tr>
<td>Production Resin</td>
<td>Atomized (Spray)</td>
<td>28%</td>
</tr>
<tr>
<td>Tooling Resin</td>
<td>Atomized (Spray)</td>
<td>30%</td>
</tr>
</tbody>
</table>

#### BACT and BARCT

<table>
<thead>
<tr>
<th>Polyester Resin Material</th>
<th>Monomer Weight %</th>
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<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>
</table>

#### Typical Permit Conditions

- Daily Emissions Limits
- Gel Coat Monomer Content (weight %)
- Resin Monomer Content (weight %)
- Amount of Material Used
- Cleaning Material
- Logs
Inspection Procedures

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

Closed Containers

Open Container
Plastic Resins & Fiberglass Operations

Potential Emissions ??

Catalyst (MEKP) Emissions

Self-Closing Container
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
Filter Inspection

Inspector Safety

Proper equipment
Plant evacuation
Inhalation hazards
Hazardous materials
Chemicals & Machinery

The End