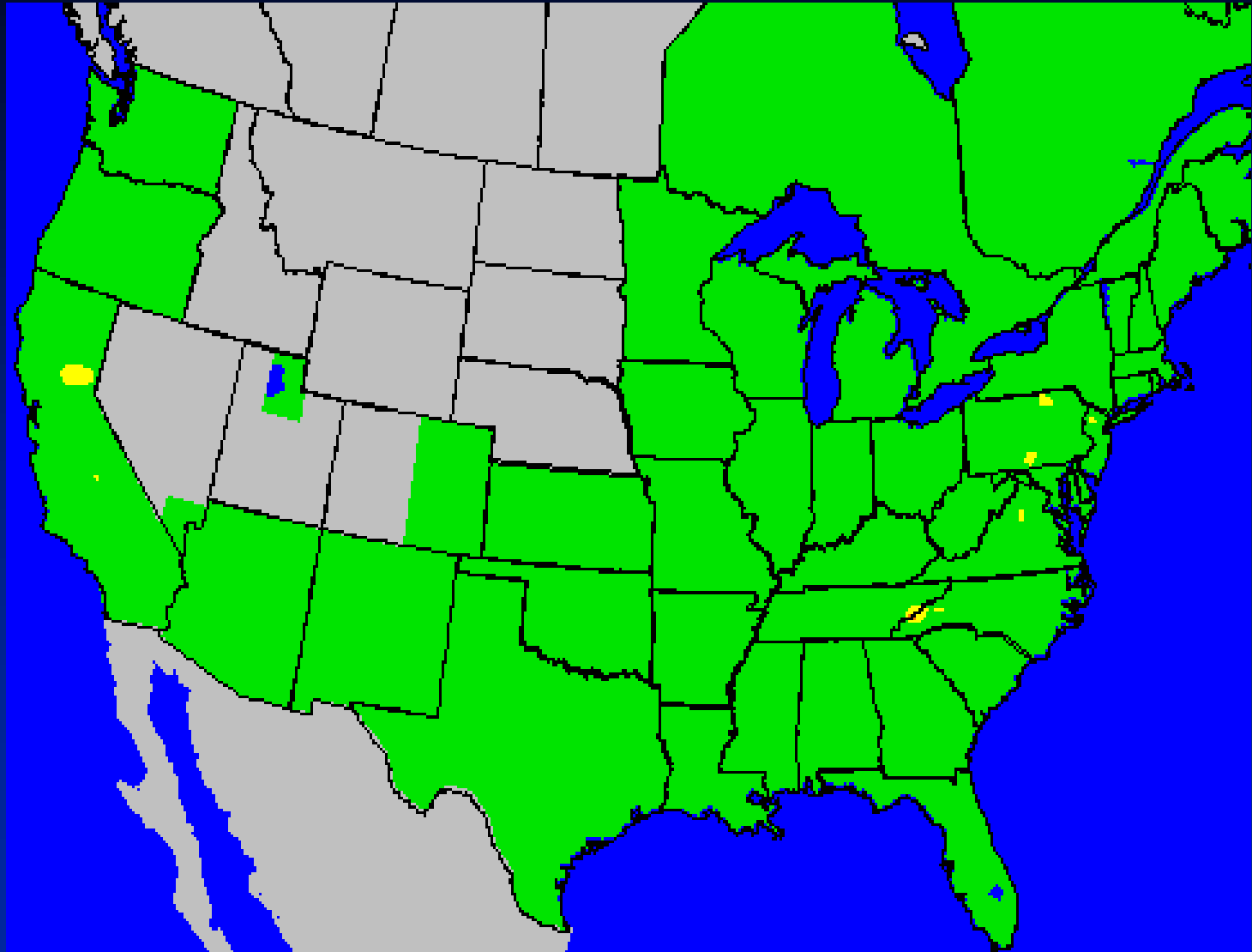
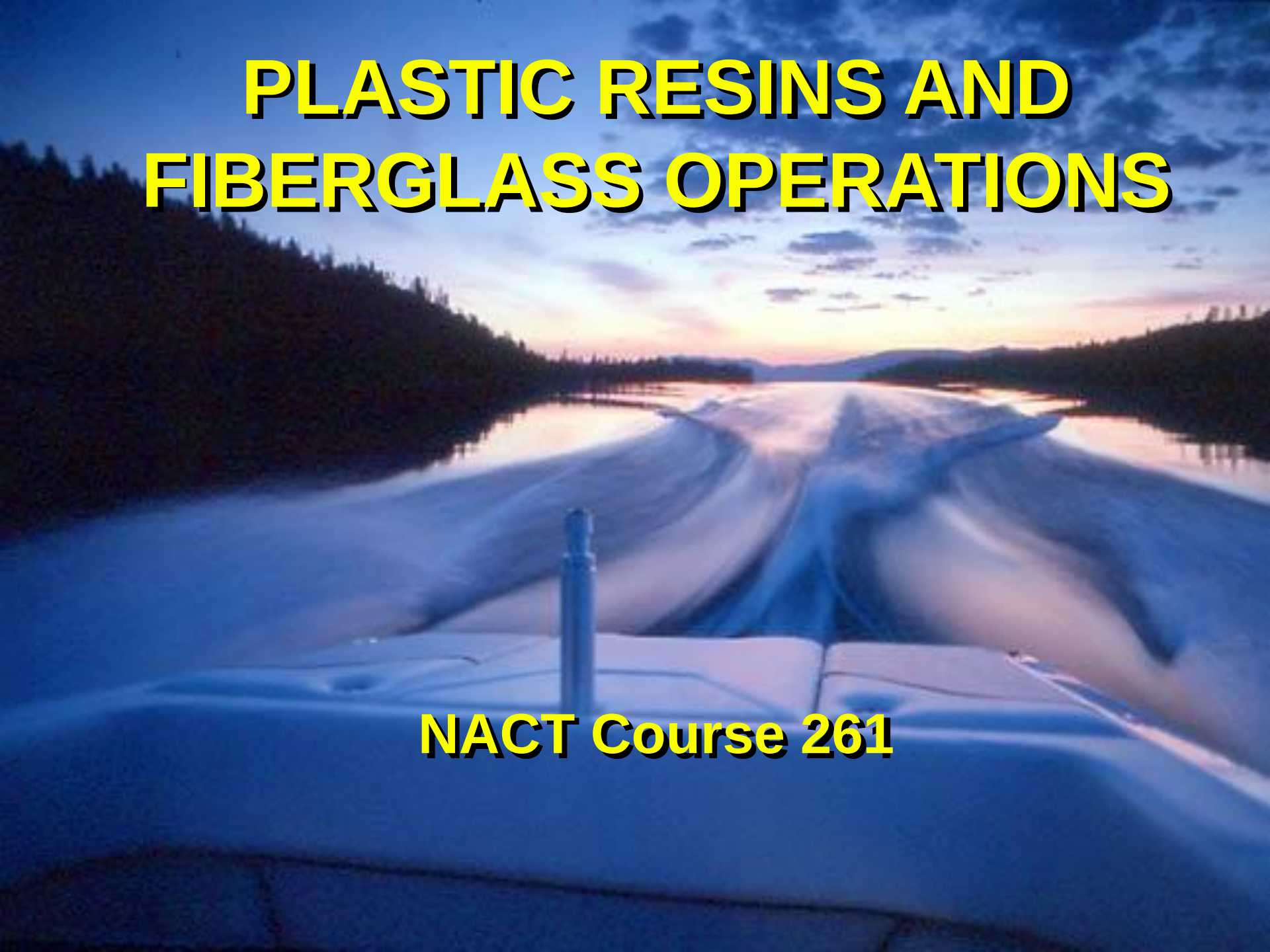


OZONE Formation



July 2, 2002 8:00 am EDT

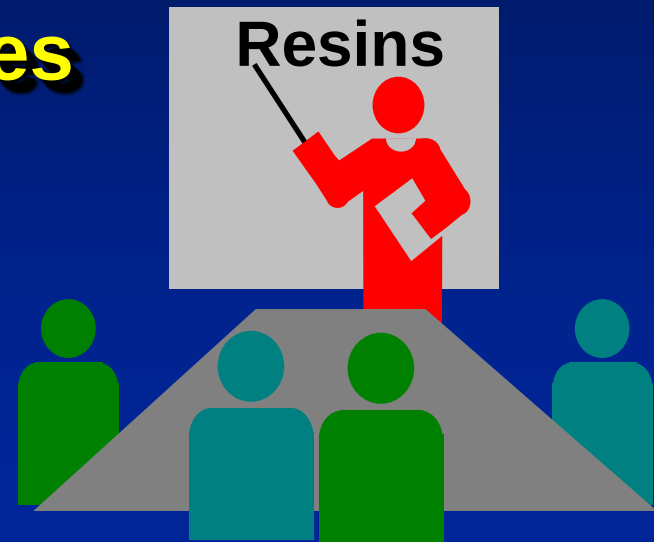
PLASTIC RESINS AND FIBERGLASS OPERATIONS

A speedboat is moving across a calm lake at sunset. The boat's wake is visible in the water, and the sun is low on the horizon, casting a warm glow. The shoreline is lined with trees, and the sky is filled with soft clouds.

NACT Course 261

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**



Composite Decking

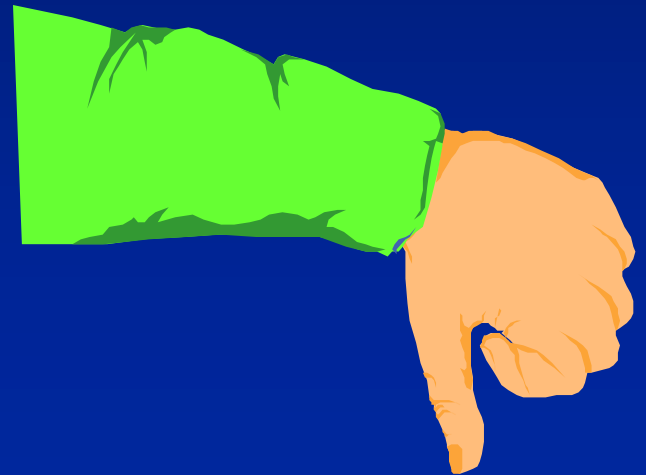
Advantages

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



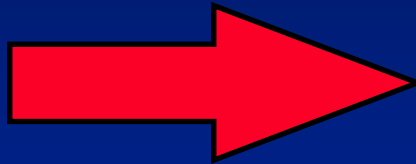
Disadvantages

- VOC emissions
- Toxicity issues
- Flammability
- Storage
- Disposal



Emissions From Polyester Resins

**Resins
&
Glass
Fiber**



- 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

A close-up photograph of a vibrant red, plush fleece fabric. The material is folded, creating deep creases and shadows that emphasize its soft texture. A small, dark, rectangular tag is visible on the right side of the fabric, featuring the word "POLARTEC" in white capital letters. In the bottom left corner, there is a yellow rectangular box with a red border containing text.

**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

High Density Polyethylene

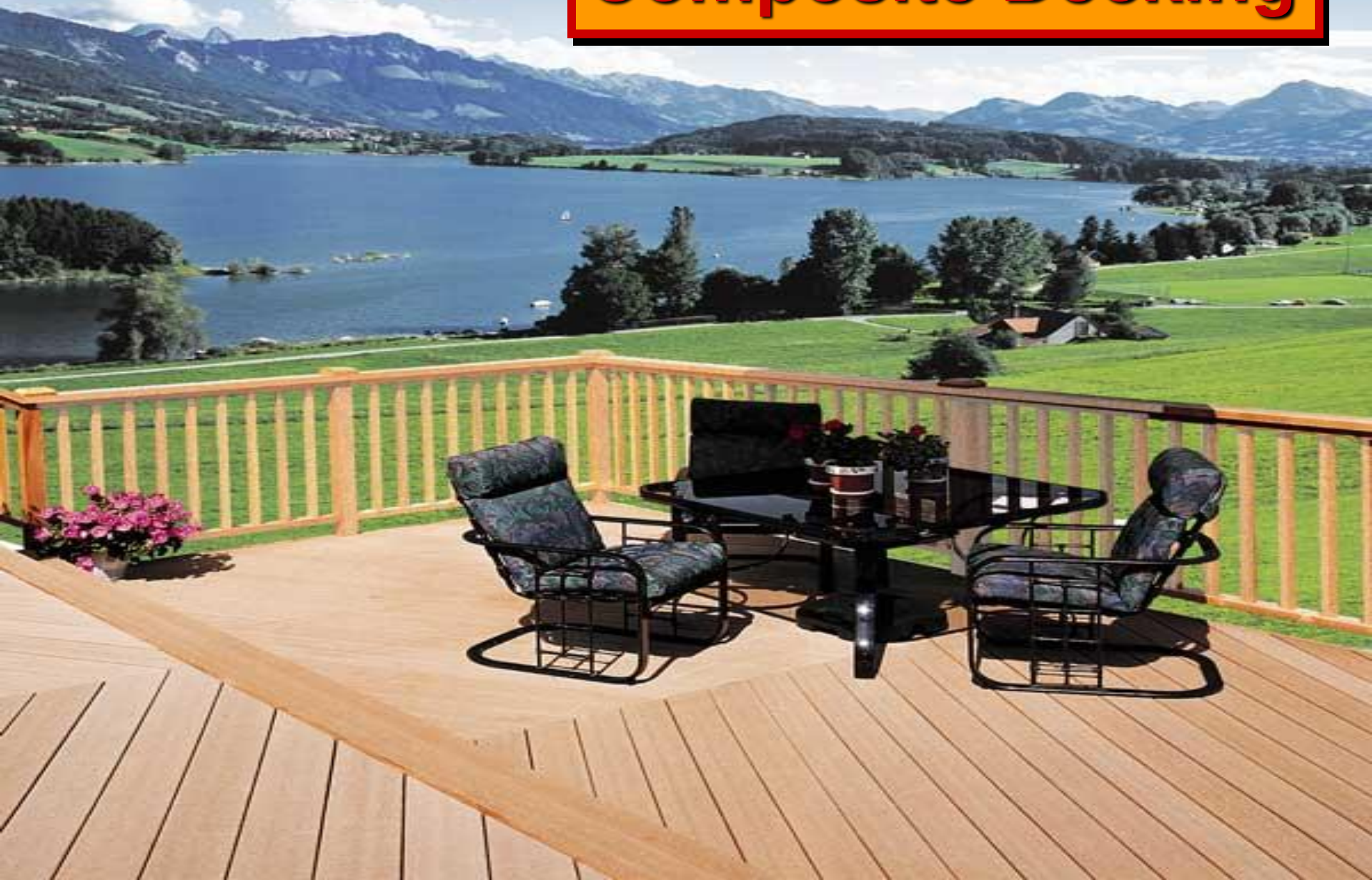


Low Density Polyethylene

- **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**

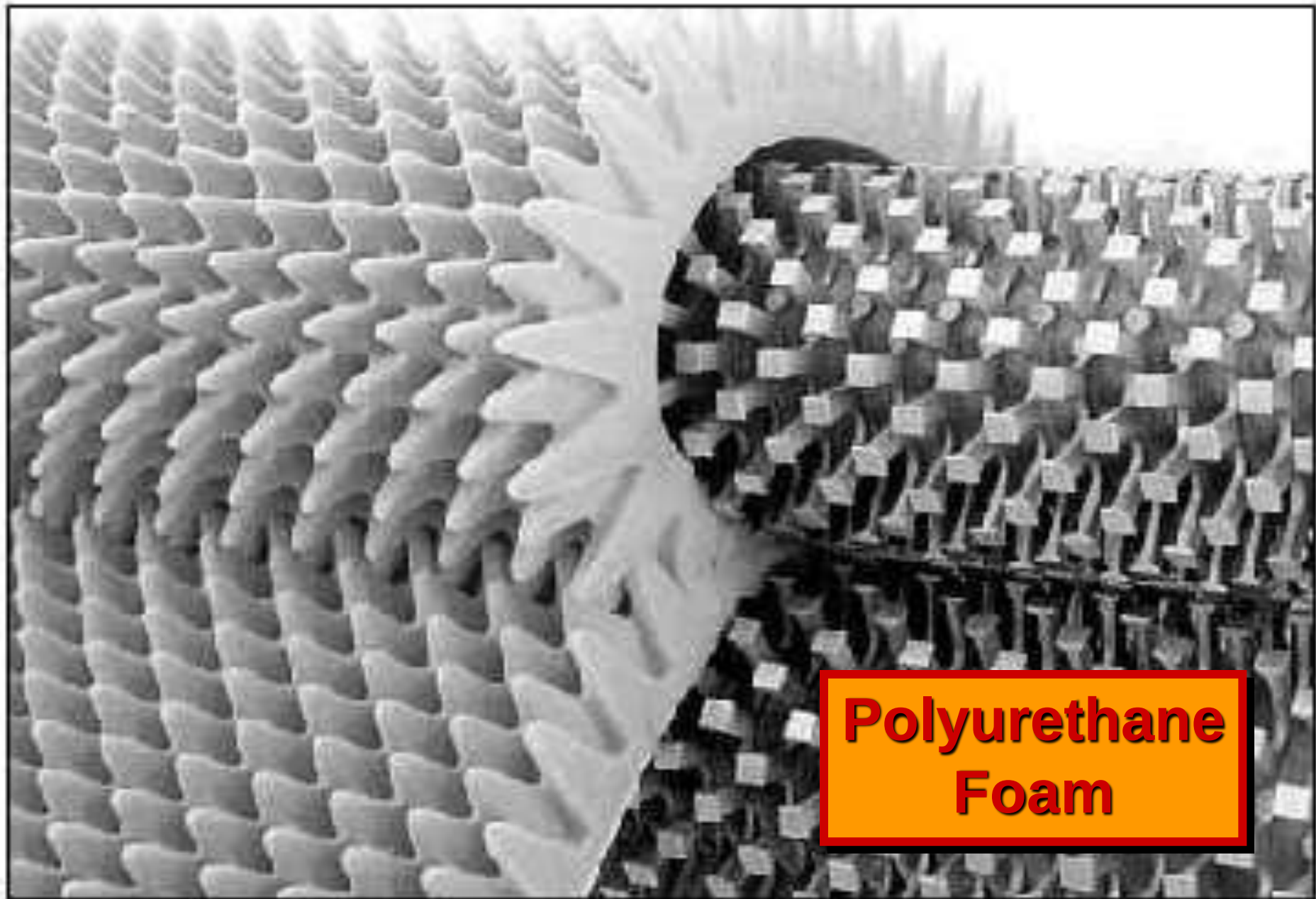




Recycled Polystyrene Baseboard Molding

Polyurethanes

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



Polyurethane Foam

Convoluters 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**

Composite Material



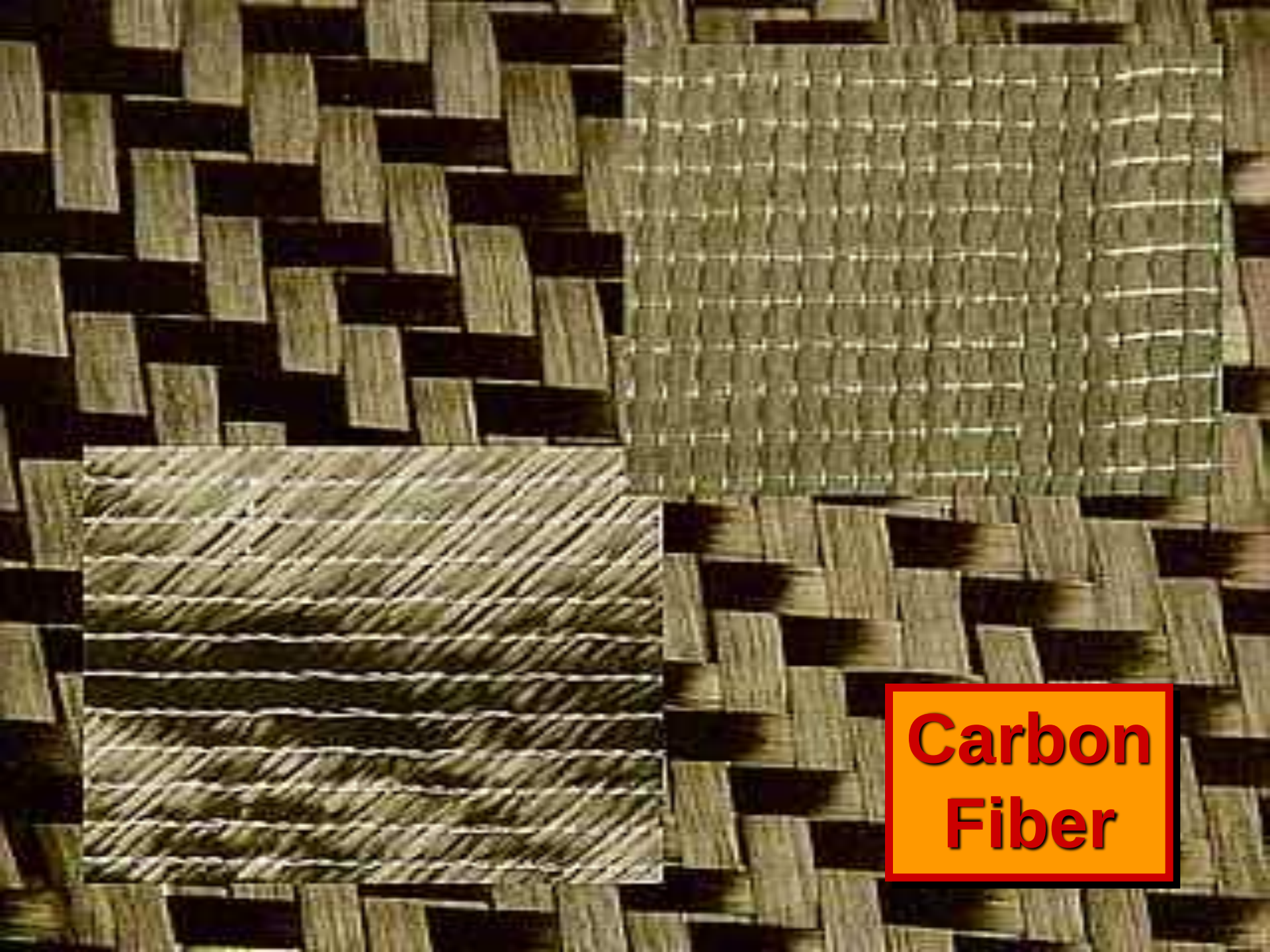
Types of Reinforcements

- **Fiberglass**
- **Carbon Fiber**
- **Kevlar**



Carbon Fiber

- Stiffest & strongest reinforcing fibers for polymer composites
- Used together with epoxy
- Race cars
- Space applications
- Sporting equipment



**Carbon
Fiber**



Carbon Fiber

**Carbon Fiber
Product**



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



Fiberglass Forms

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

Fiberglass Forms





BLACK & DECKER

Spacemaker

The Spacemaker is a unique, portable, and easy-to-use device that allows you to create a space between two surfaces. It is ideal for use in a variety of applications, including:
• Creating a space between two surfaces for painting or staining.
• Creating a space between two surfaces for sanding or polishing.
• Creating a space between two surfaces for drying or curing.
• Creating a space between two surfaces for storage or display.

**Fiberglass
Forms**

Fiberglass Advantages

- **High strength**
- **Low price**
- **Dimensional stability**
- **Temperature resistance**
- **Corrosion resistance**
- **Low weight**
- **Excellent dielectric properties**



Fiberglass Product



**Fiberglass
Spa**

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



Kevlar®

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

**Kevlar
Product**





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

Types of Plastic Materials

- **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

Thermoplastic	Thermosetting
- Faster molding - Lower emissions - Lower costs - Easy recycling - Low labor intensity	- Design constraints - Limited unit production - Performance requirements - Market demands

Raw Materials

Resins

Fiber substrate

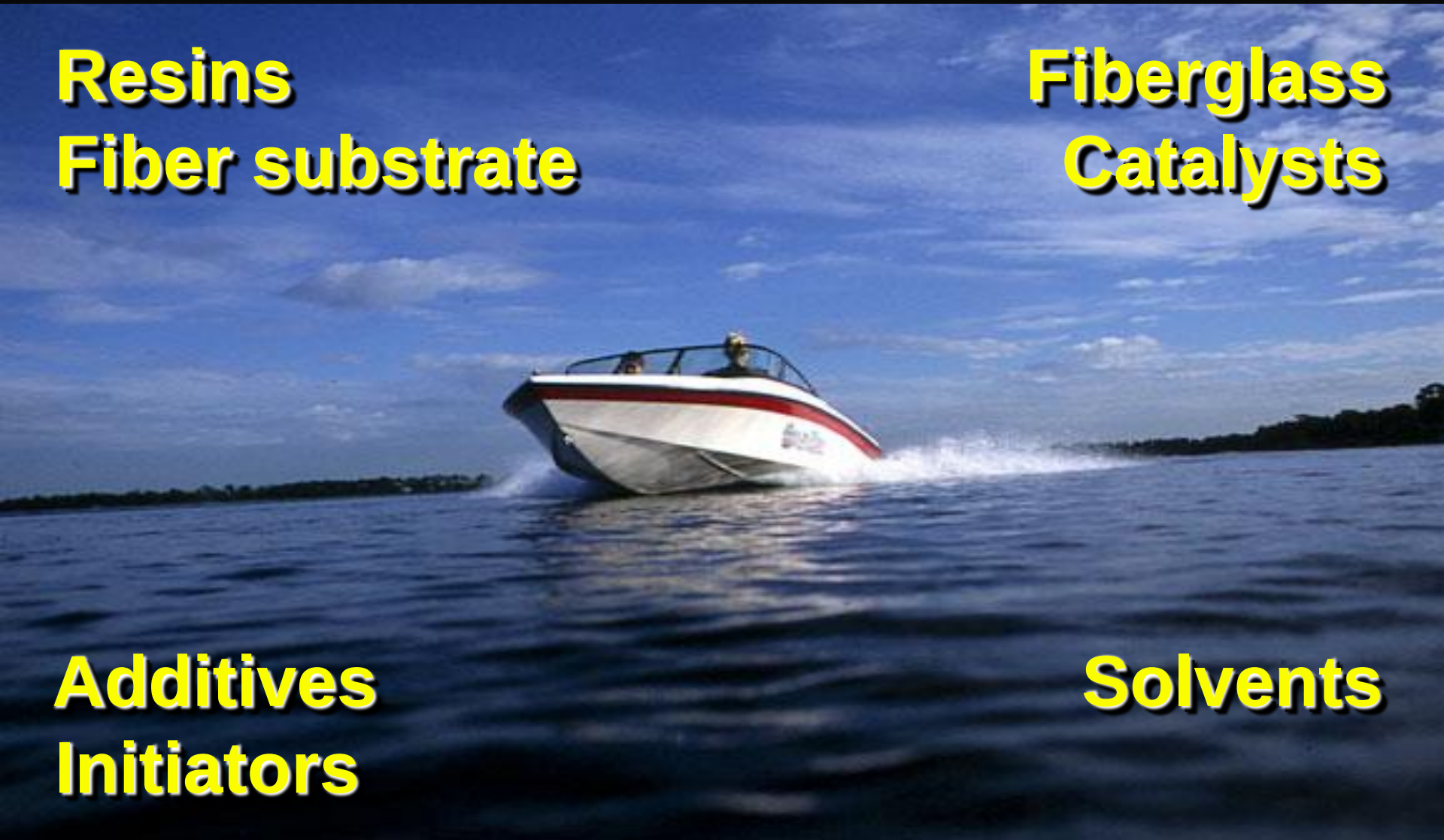
Fiberglass

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

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**

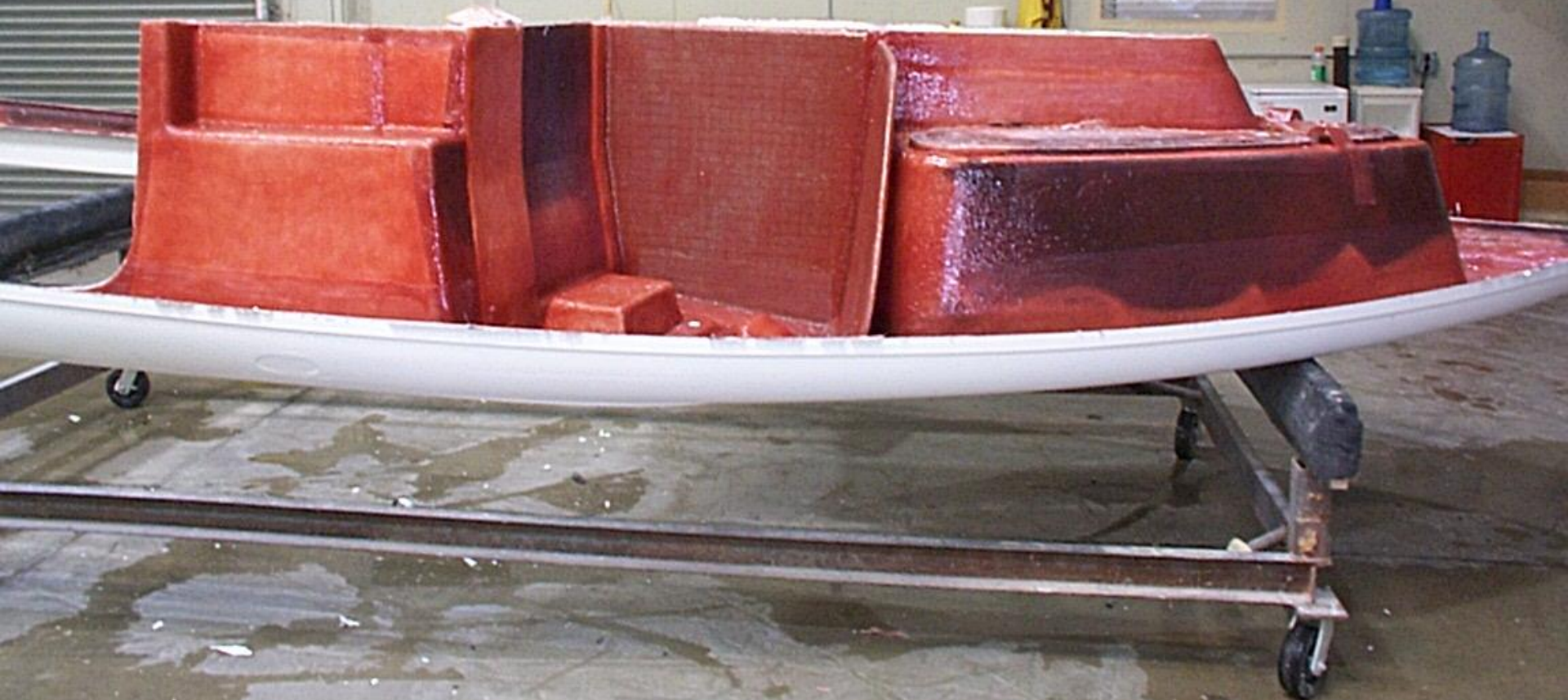


First Step : Mold

**Second
Step : Wax
Application**



Gel Coat Applied to Mold



Chopped Fiberglass Application



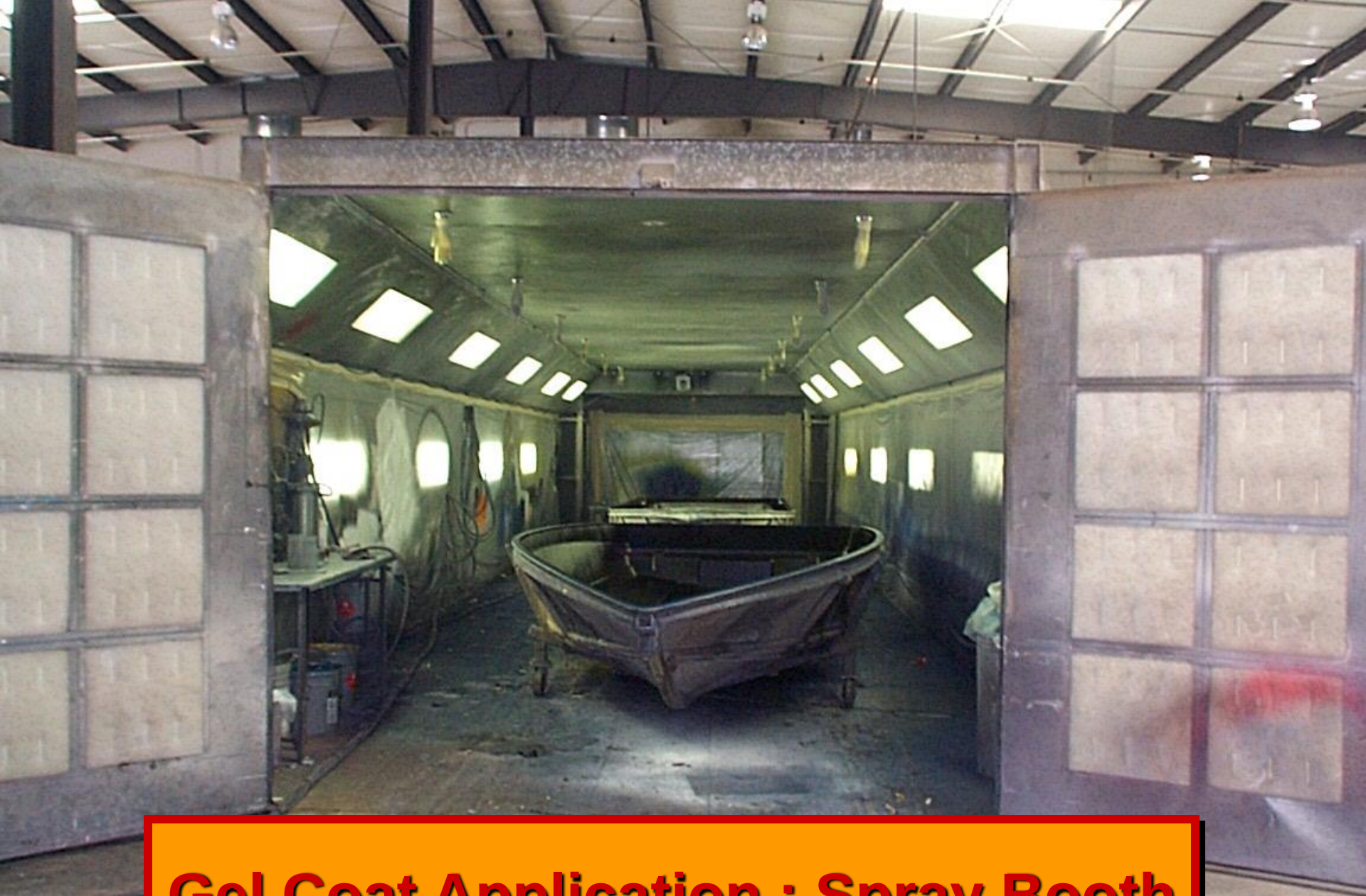


Chopped Fiberglass Application



Chopper Gun





Gel Coat Application : Spray Booth

Gel Coat : Spray Booth





Gel Coat Applied to Mold



Fiberglass Reinforcements



Saturating with Resin

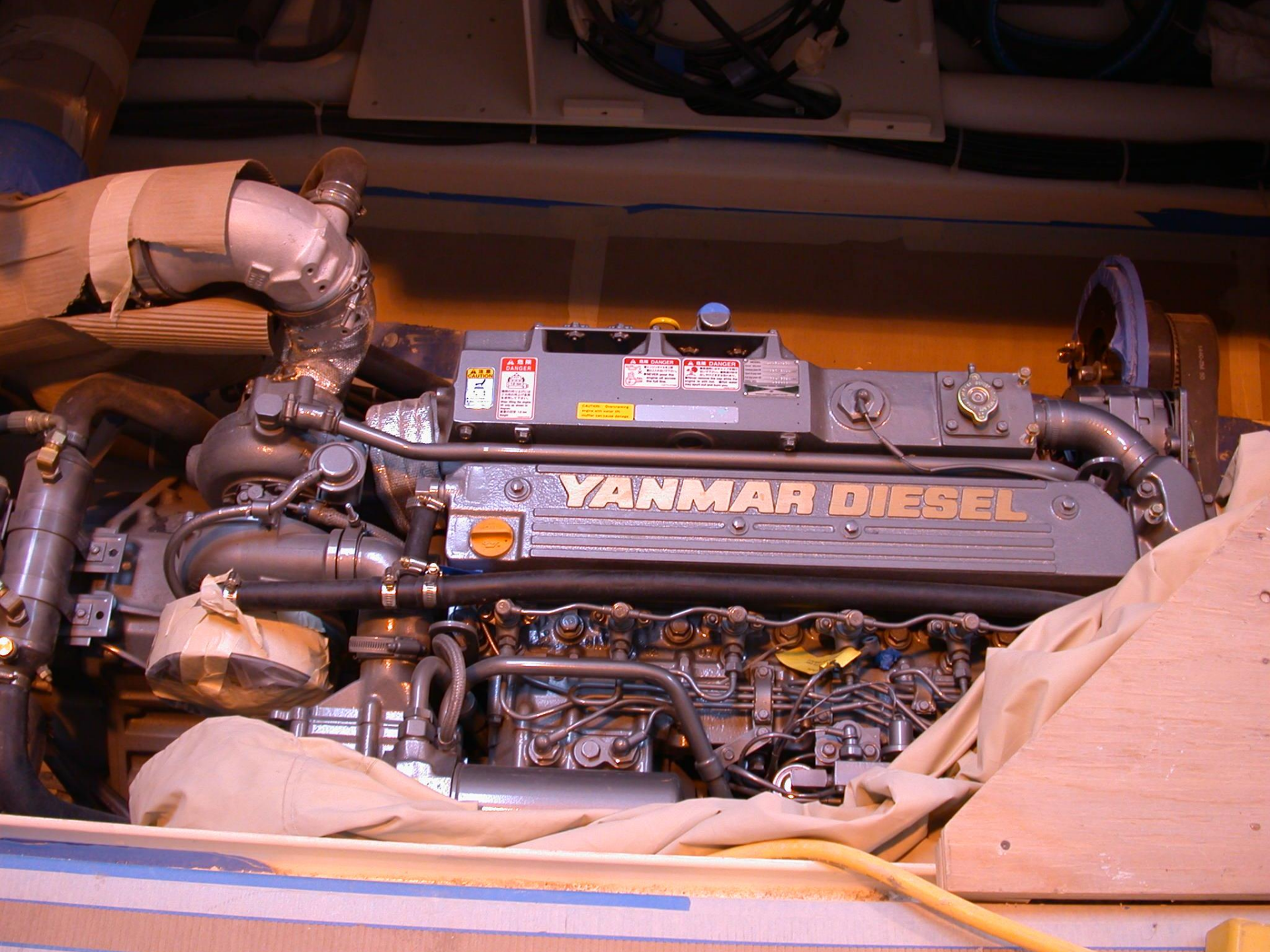


Curing Process



**Curing
Process**









Assembly Line





Finished Product



Finished Product

A scenic landscape photograph of a mountain lake. In the background, a large, rugged mountain with patches of snow rises steeply. The lake is calm, reflecting the sky and the surrounding forest. A small, rocky island with a few evergreen trees sits in the middle of the lake. The foreground is framed by the dark, silhouetted branches of evergreen trees on both sides.

**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**

A photograph showing a production line of white, dome-shaped protective gel coats. The domes are arranged in a row, with some having wires attached. The foreground dome is in sharp focus, showing its smooth, glossy surface. The background shows more domes and the industrial setting.

**Protective
Gel Coat**

Fabrication of Cultured Marble





**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 Onyx Product

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**

Crushed Stone

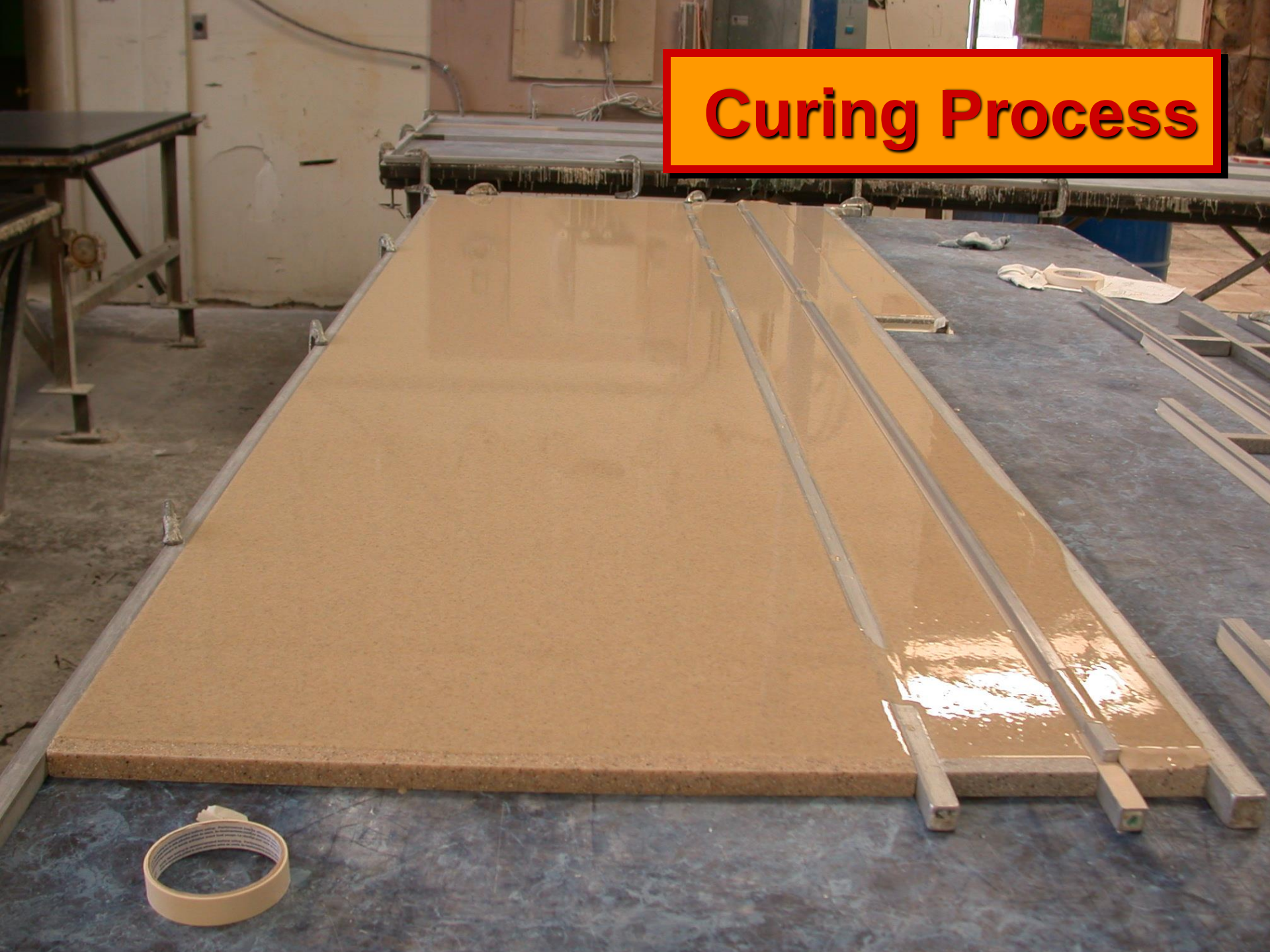


Polyester Resins





Curing Process





Cultured Granite

A photograph of a sunset over the ocean. The sky is filled with soft, wispy clouds in shades of orange, pink, and blue. The sun is low on the horizon, creating a bright glow. The ocean is dark with white-capped waves. A yellow rectangular box with a red border is positioned at the bottom of the image, containing the text "Let's Discuss Open Molding Operations" in bold red font.

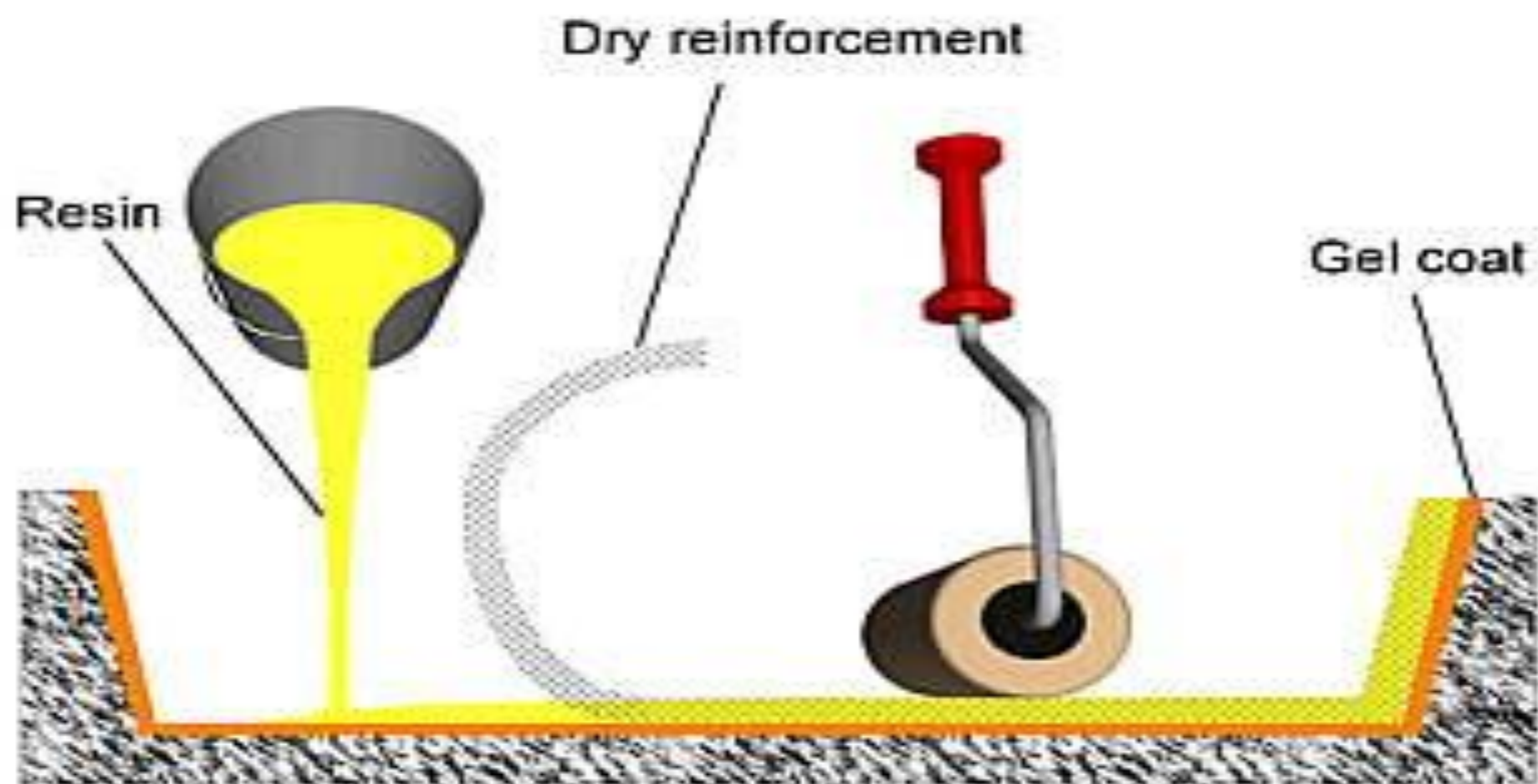
**Let's Discuss Open
Molding Operations**

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**



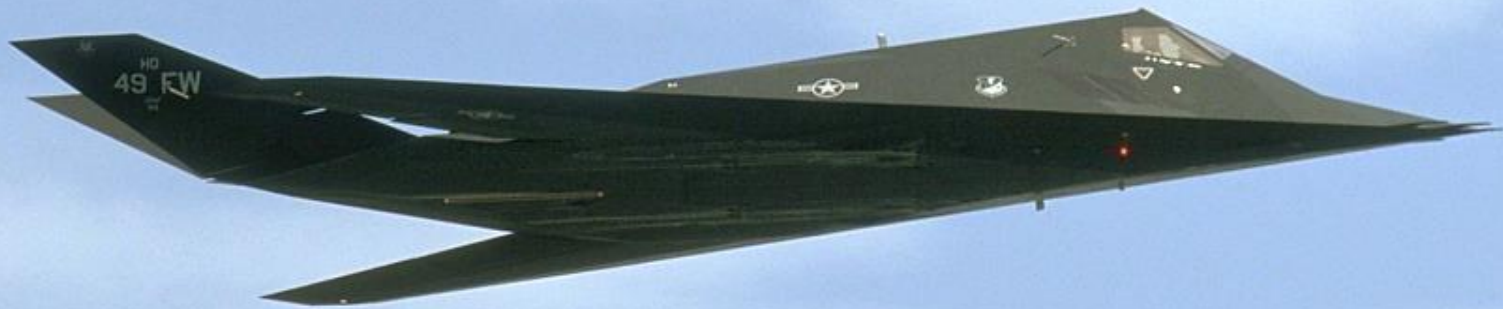


Hand Lay-Up



Examples of Hand Lay-Up Operations

Hand Lay-Up Product



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



First Step : Foam Core

63H
ROG..

1 1/2

H-1/8EX

6'3"

2 1/4

Flat Behind Rocker
single Cable for Flat

2/5

CLARK FOAM

1st QUALITY
SUPERLIGHT

Foam Core : Shaping & Sizing



Fiberglass Surfacing Mat

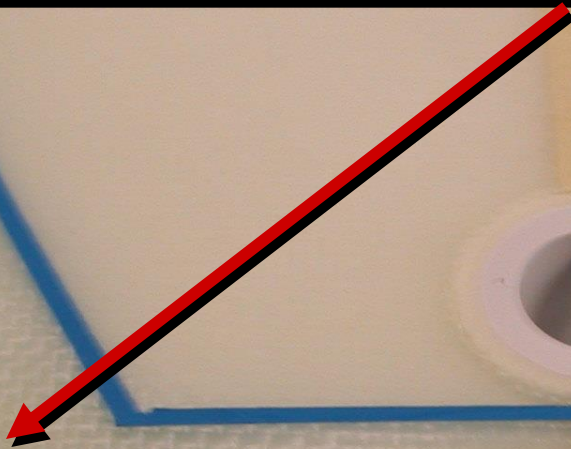


Fiberglass & Resin Applied to Core





Fiberglass & Resin Application



Grinding & Sanding Operation



Grinding & Sanding Tools



Waxing & Coating Operation







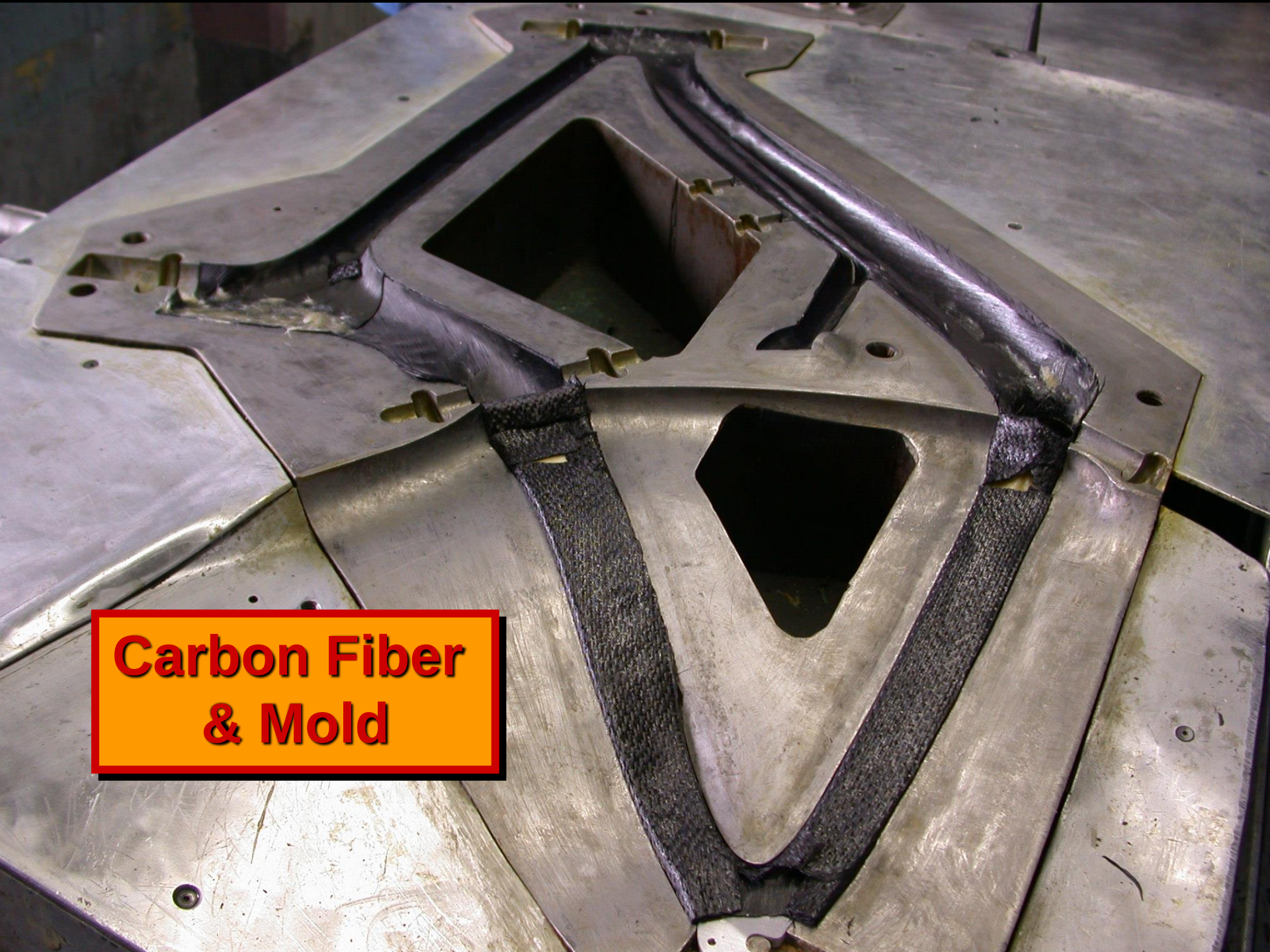
Curing Operation

**Let's Discuss
Carbon Fiber
Epoxy Resin Mfg.**



Bicycle Frame Components

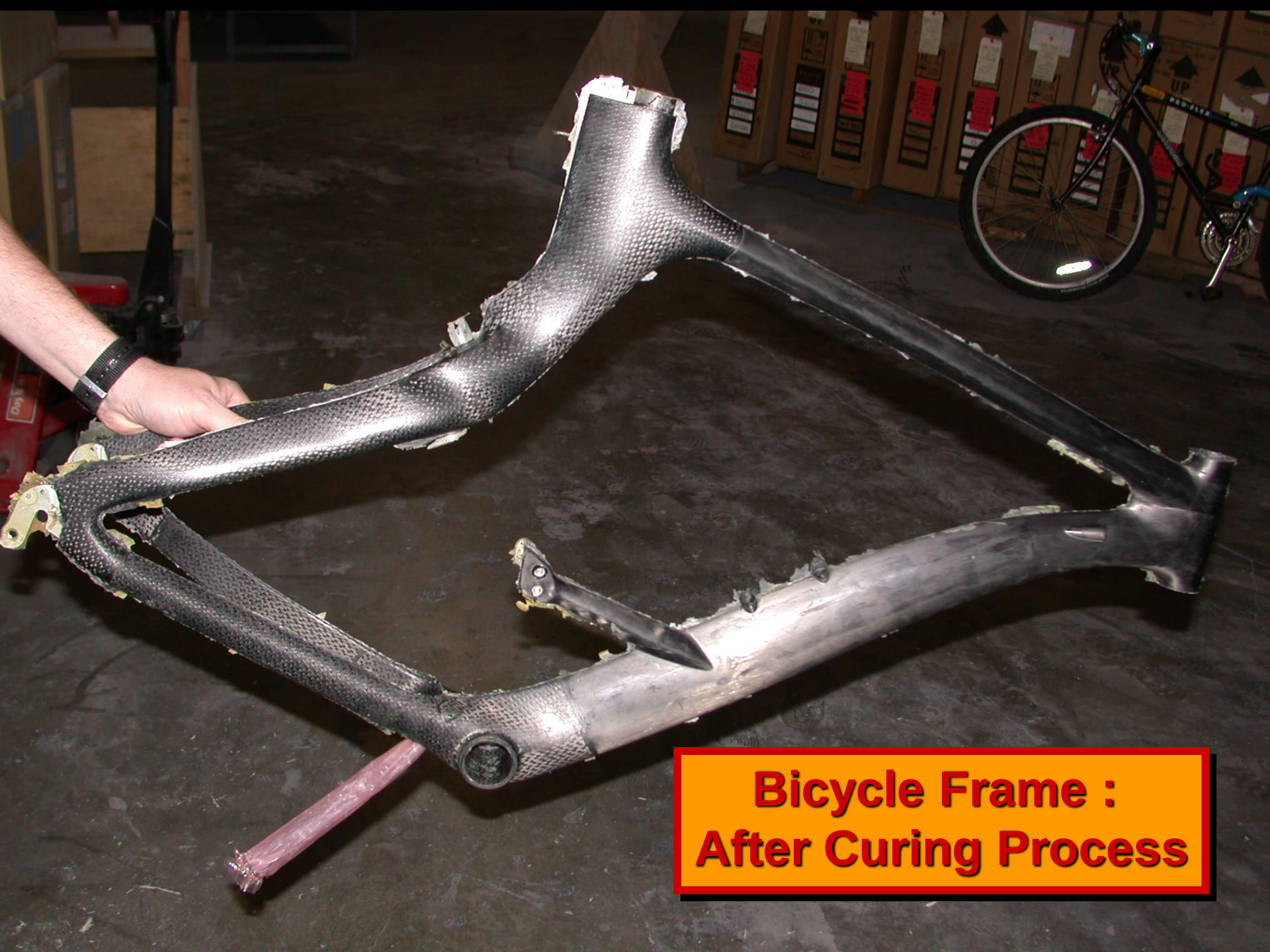


A close-up photograph of a complex, multi-ported metal mold assembly. The mold is made of polished, reflective metal, likely aluminum or stainless steel, and features several large, irregularly shaped openings. A dark, woven carbon fiber material is being applied to the inner surfaces of these openings, forming a reinforcement or lining. The carbon fiber is visible as a dark, textured material that follows the contours of the mold's internal structure. The overall appearance is industrial and technical, suggesting a high-precision manufacturing process.

**Carbon Fiber
& Mold**



**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**

Spray-Up



Spray-up

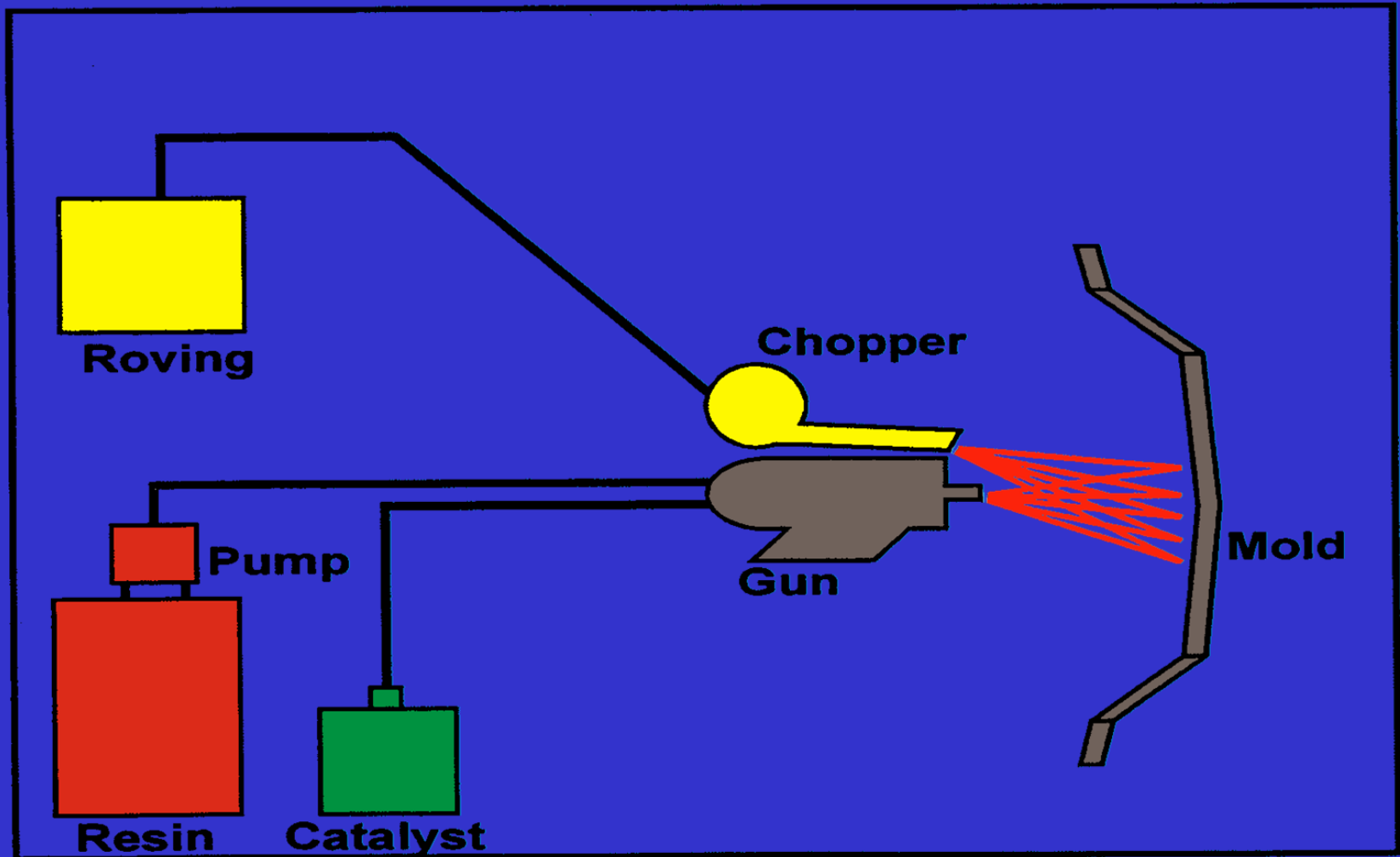


Figure 300.3: Spray-Up



Chopped Fiberglass Spray-up Operation



Controlled Spraying

**Reduces styrene emissions
Increases transfer efficiency
Low fluid tip pressure
Employee gun handling training
Close containment flanges**



Gel Coat Application



Gel Coat Application in a Spray Booth

DISCLAIMER AND LIMITATION OF LIABILITY TO THE EXTENT ALLOWED BY LAW

Approved Spray Guns

- **High Pressure Airless Guns**
- **Air-Assist Airless Guns**
- **Electrostatic Spray**
- **High Volume Low Pressure (HVLP) ***
- **Fluid Impingement Technology (FIT) Spray Gun ***

HVLP Spray Gun





Fluid Impingement Technology Spray Gun

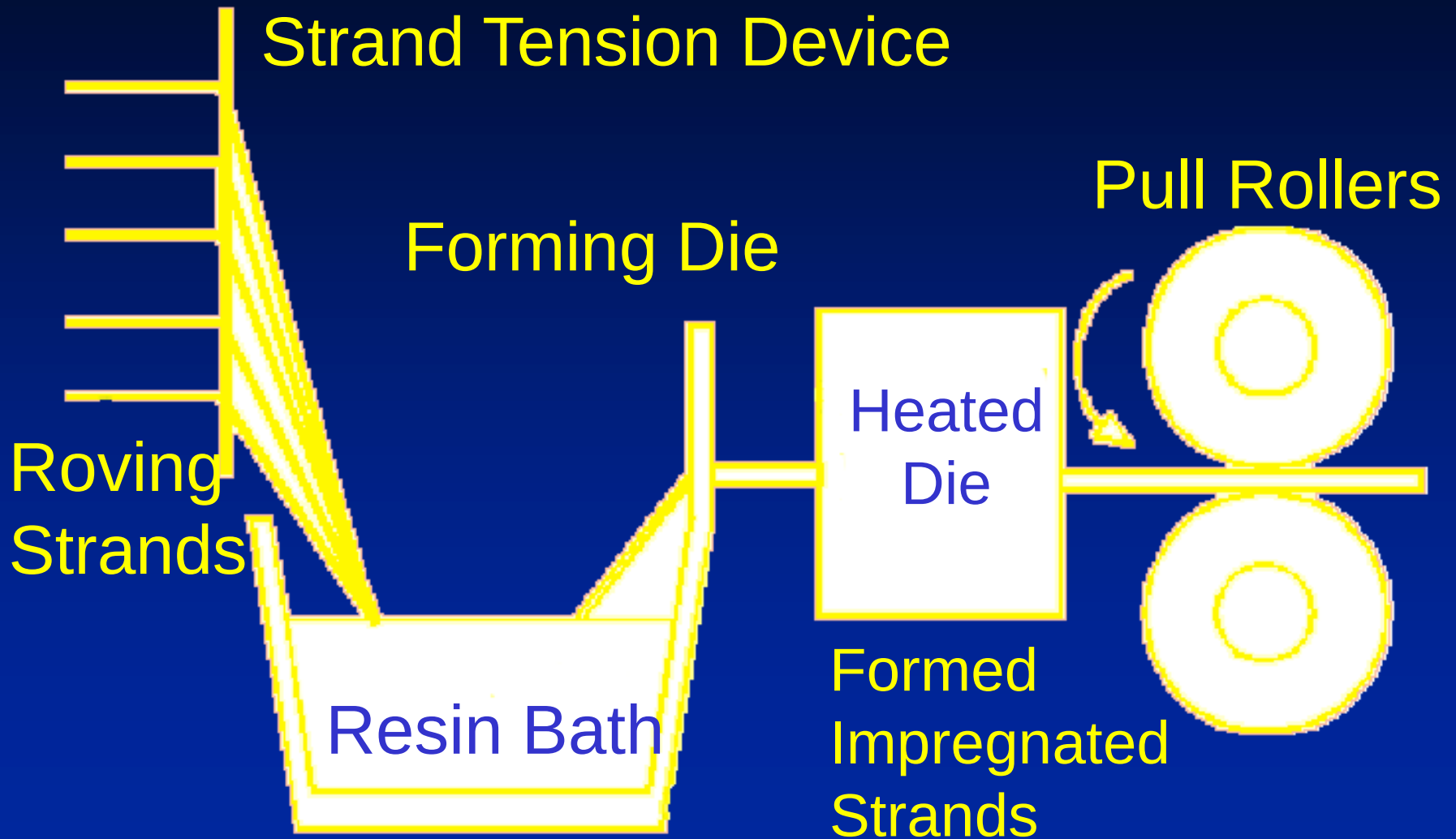
Let's Discuss other Open Molding Operations



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

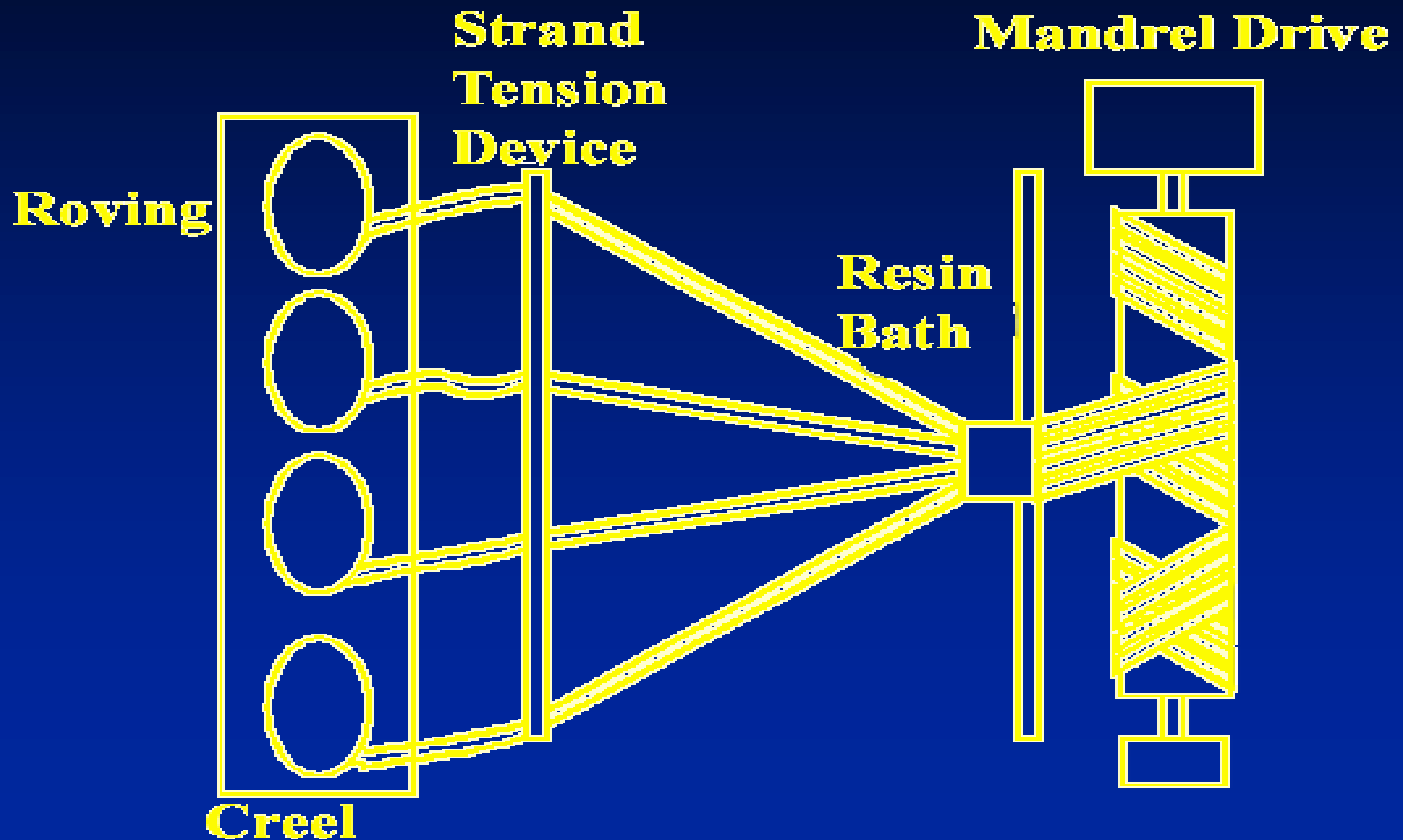
Pultrusion



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**

Filament Winding



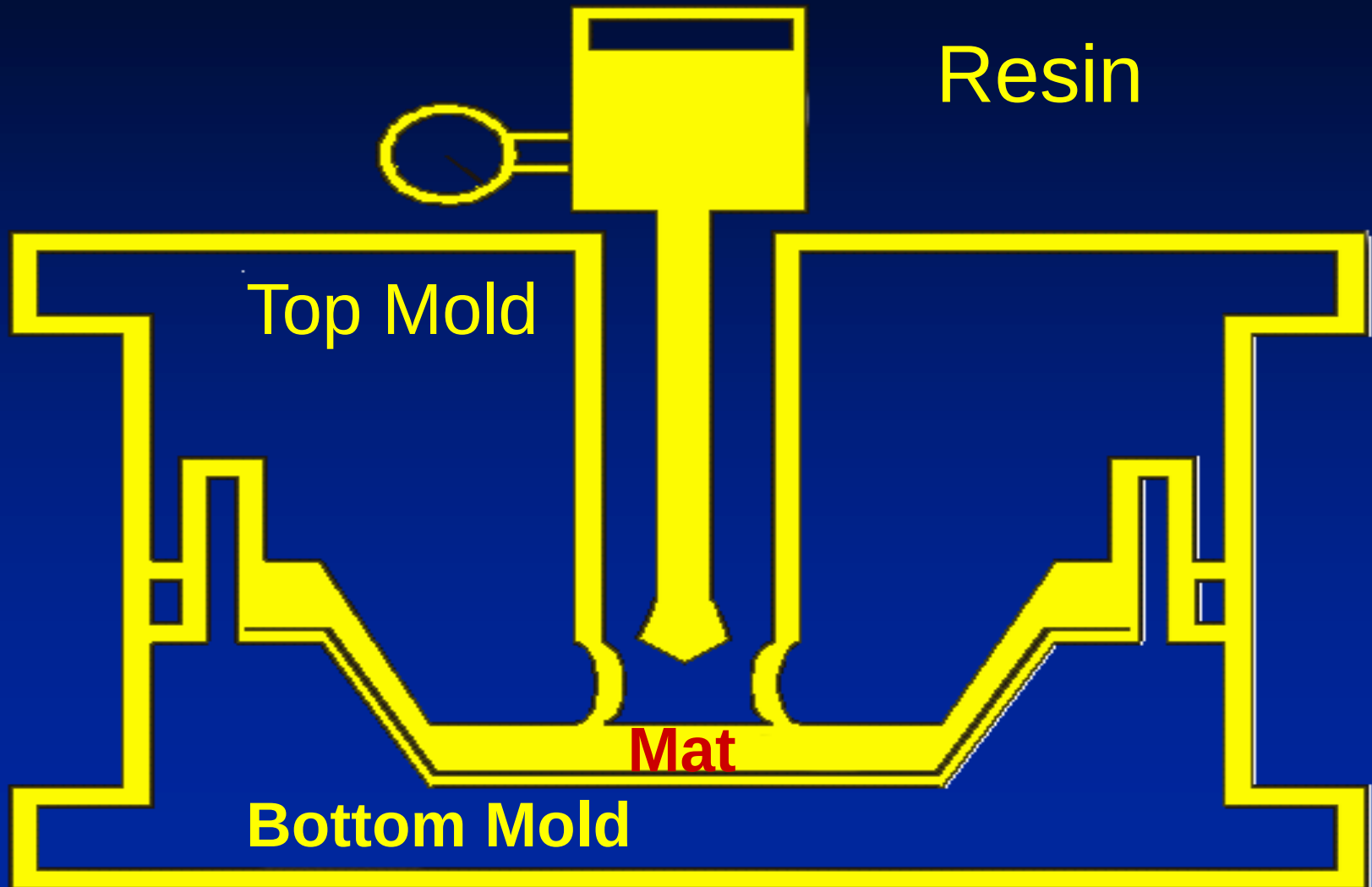


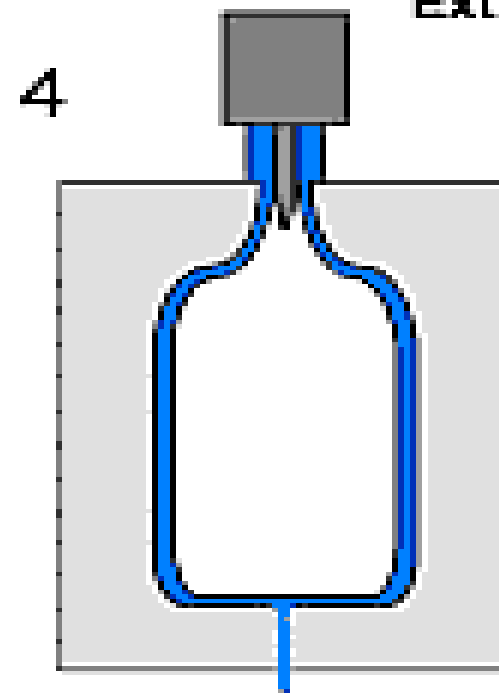
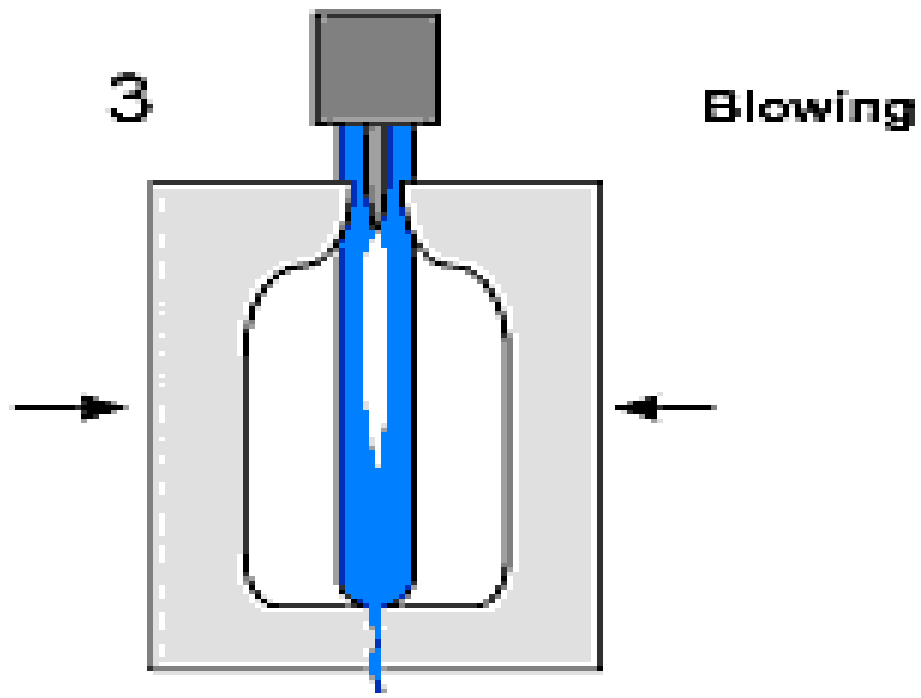
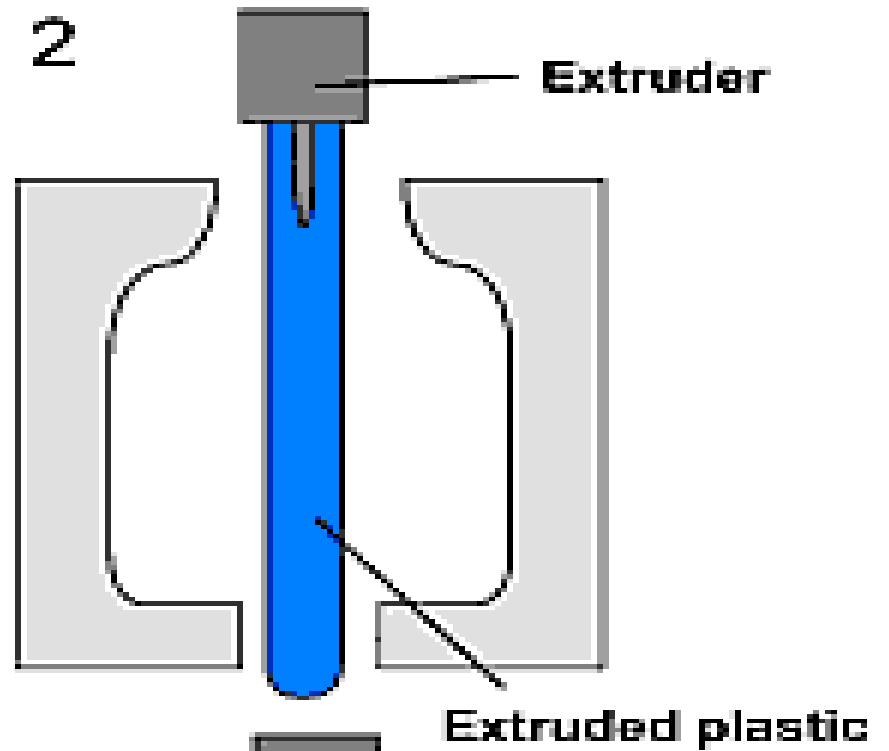
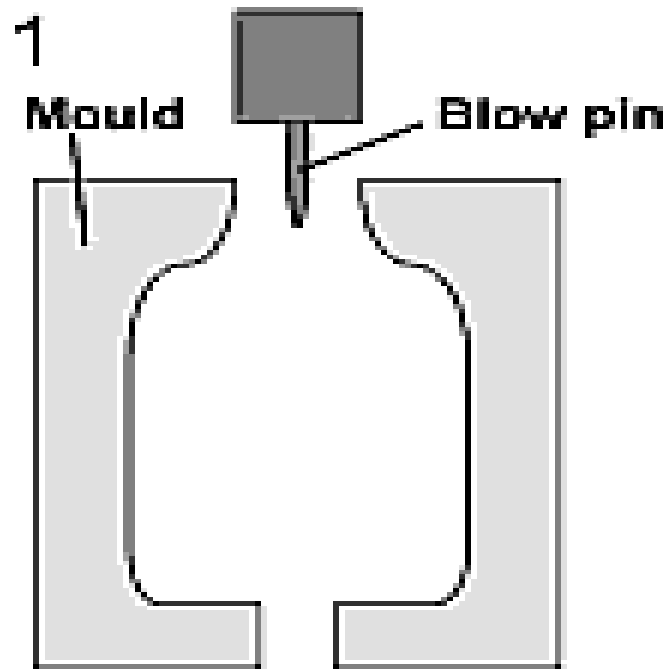
Let's Discuss Closed Molding Operations

Resin Transfer Molding

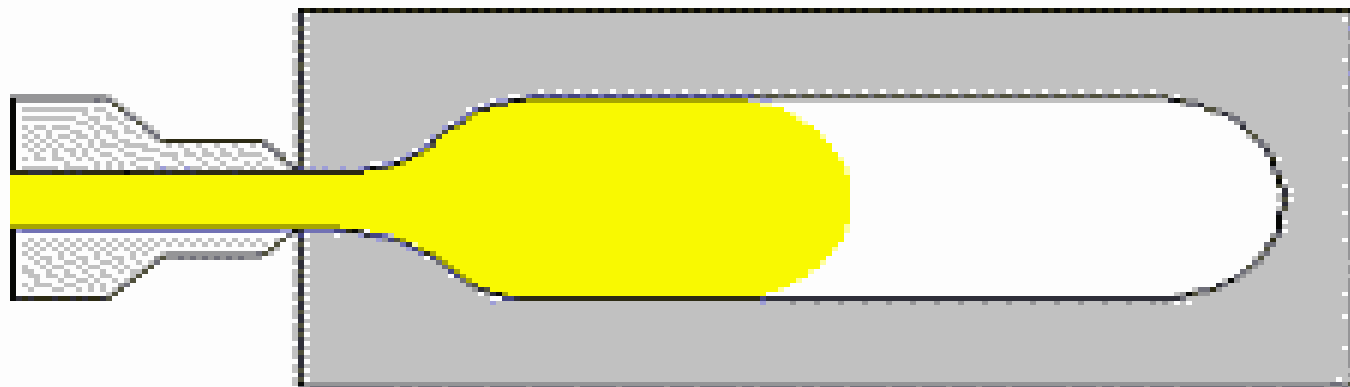
- **Gel Coat is Applied to Mold**
 - **Reinforcing Fibers are Placed into the Mold Cavity**
 - **Mold Halves are Closed & Clamped**
 - **Liquid Resin is Injected into the Mold Cavity**
-
- **Suitable for High Vol. Production**
 - **Reduced VOC emissions**

Resin Transfer Molding

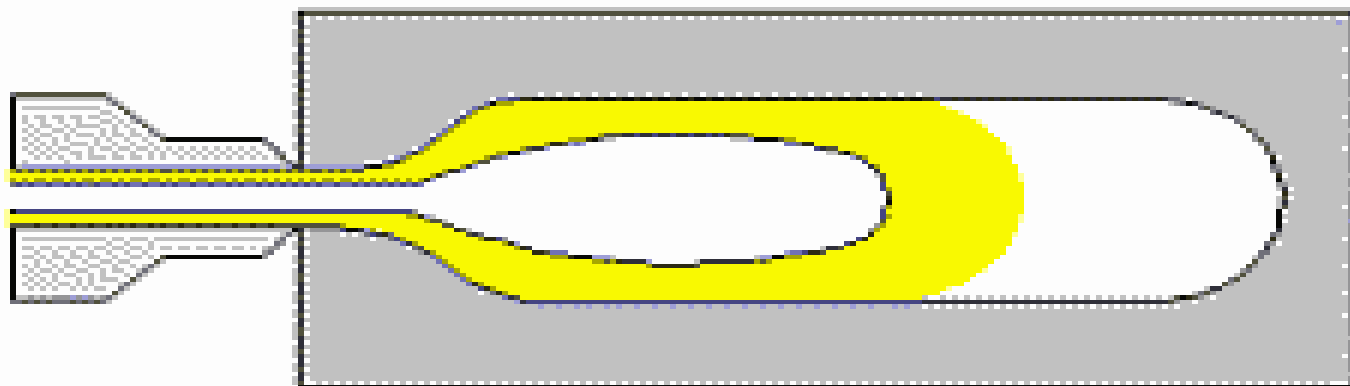




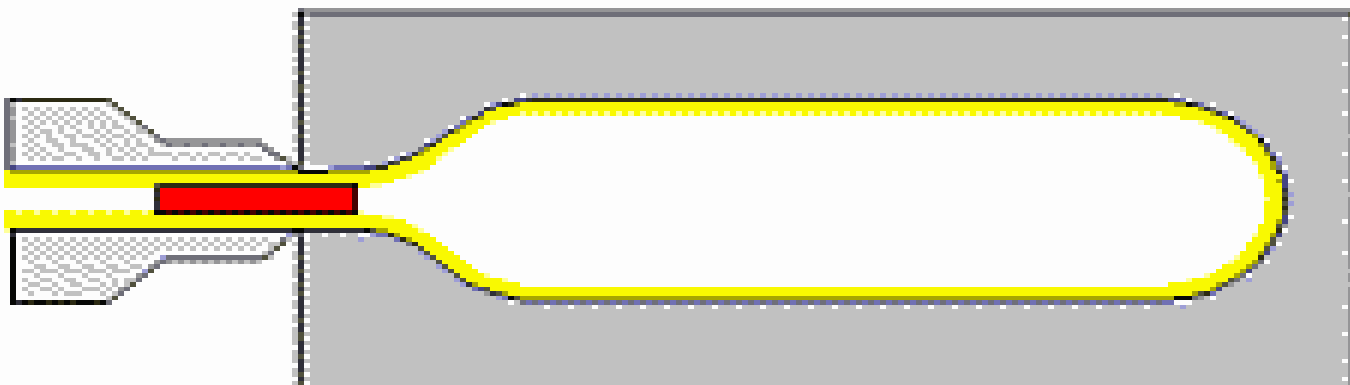
Plastic

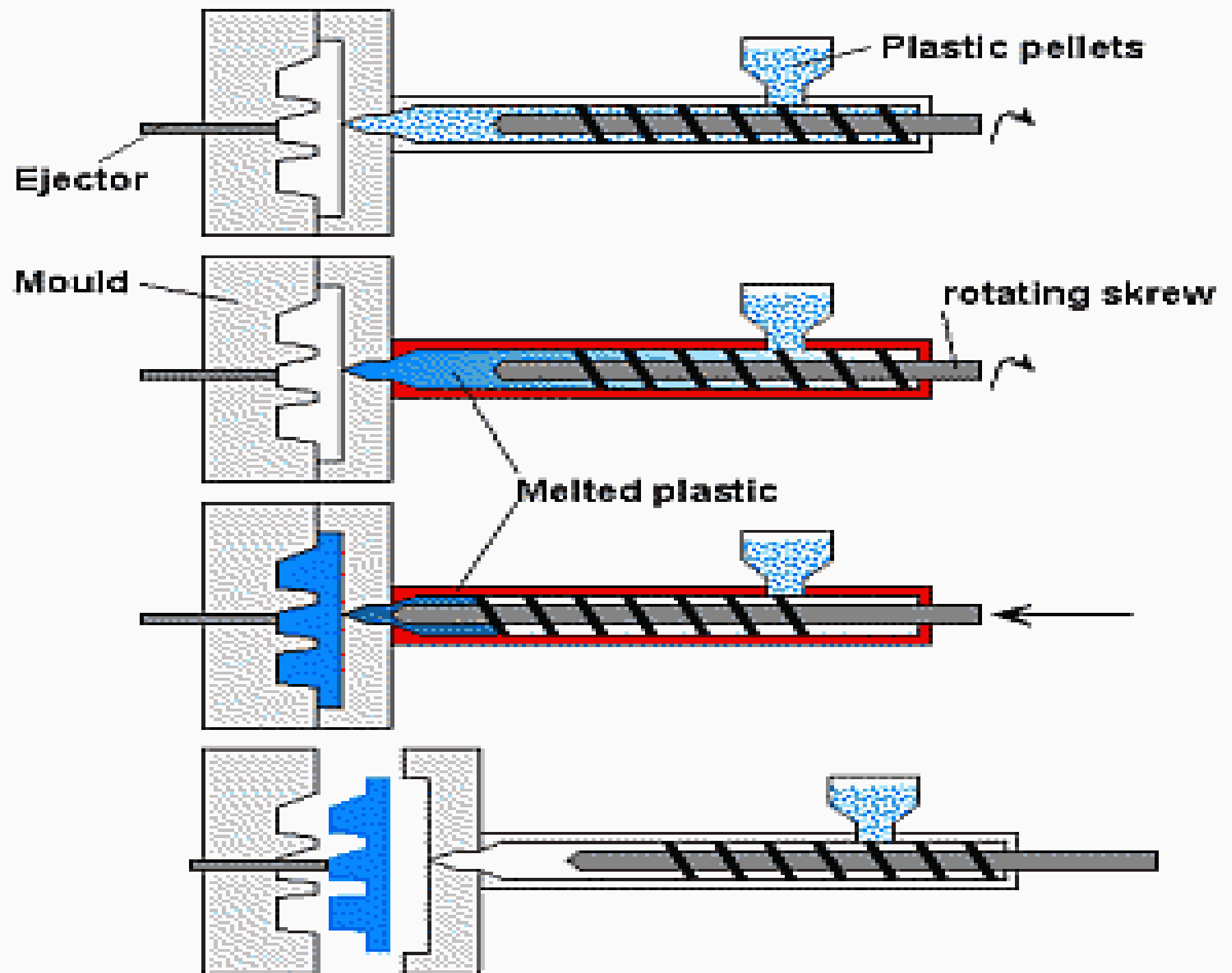


Air



Plastic







Let's Discuss Emissions & Controls

Emission Sources

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

Application Step	38% Monomer	25% Monomer
Loss due to Atomization	5-7%	2-4%
Loss due to Curing	6-11%	4-9%
Total Loss	11-16%	8-11%

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

CAUTION HAZARDOUS MATERIAL

ACETONE

CAUTION HAZARDOUS MATERIAL

ACETONE



Clean-Up Rules

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

Open Containers



Potential Emissions ??



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

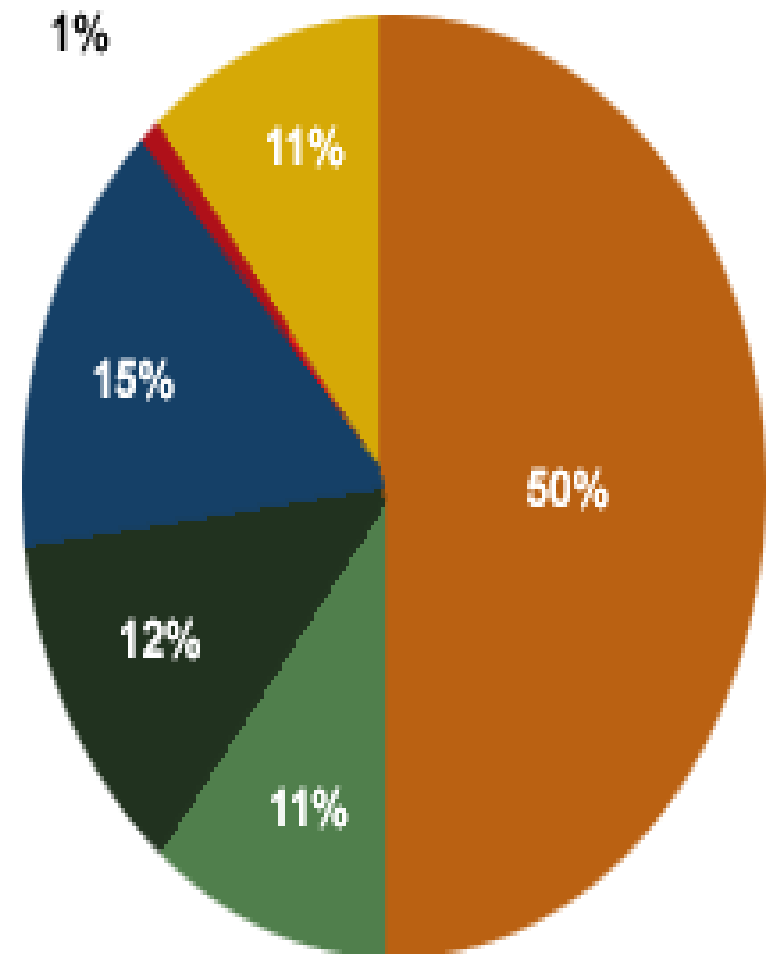
- **Foamed or Expanded Polystyrene : EPS**
- **Exceptional insulation properties**
- **Foam cups & containers**
- **Foodservice products**
- **Packaging & protecting**

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**

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

- PS - Polystyrene**
cups, plates, toys, packaging, dairy containers, building constr., cassettes
- ABS - Acrylonitrile-butadiene styrene**
appliances, transportation, business machines
- SAN - Styrene-acrylonitrile**
appliances, battery castings, packaging, automotive materials, housewares
- SBR - Styrene-butadiene rubber**
tires, automotive applications
- SBL - Styrene-butadiene latex**
carpet and upholstery backing, coatings
- UPR - Unsaturated polyester resins**
boats, bath tubs, shower stalls, spas, hot tubs, cultured marble



Industry Estimates

Let's Discuss VOC Control

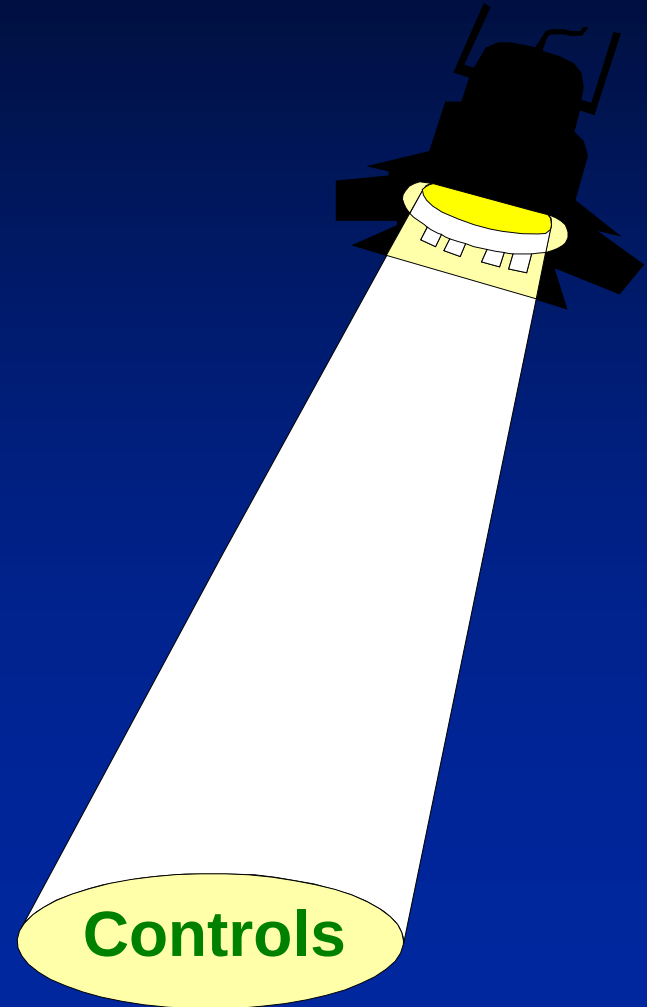


Control of VOC Emissions

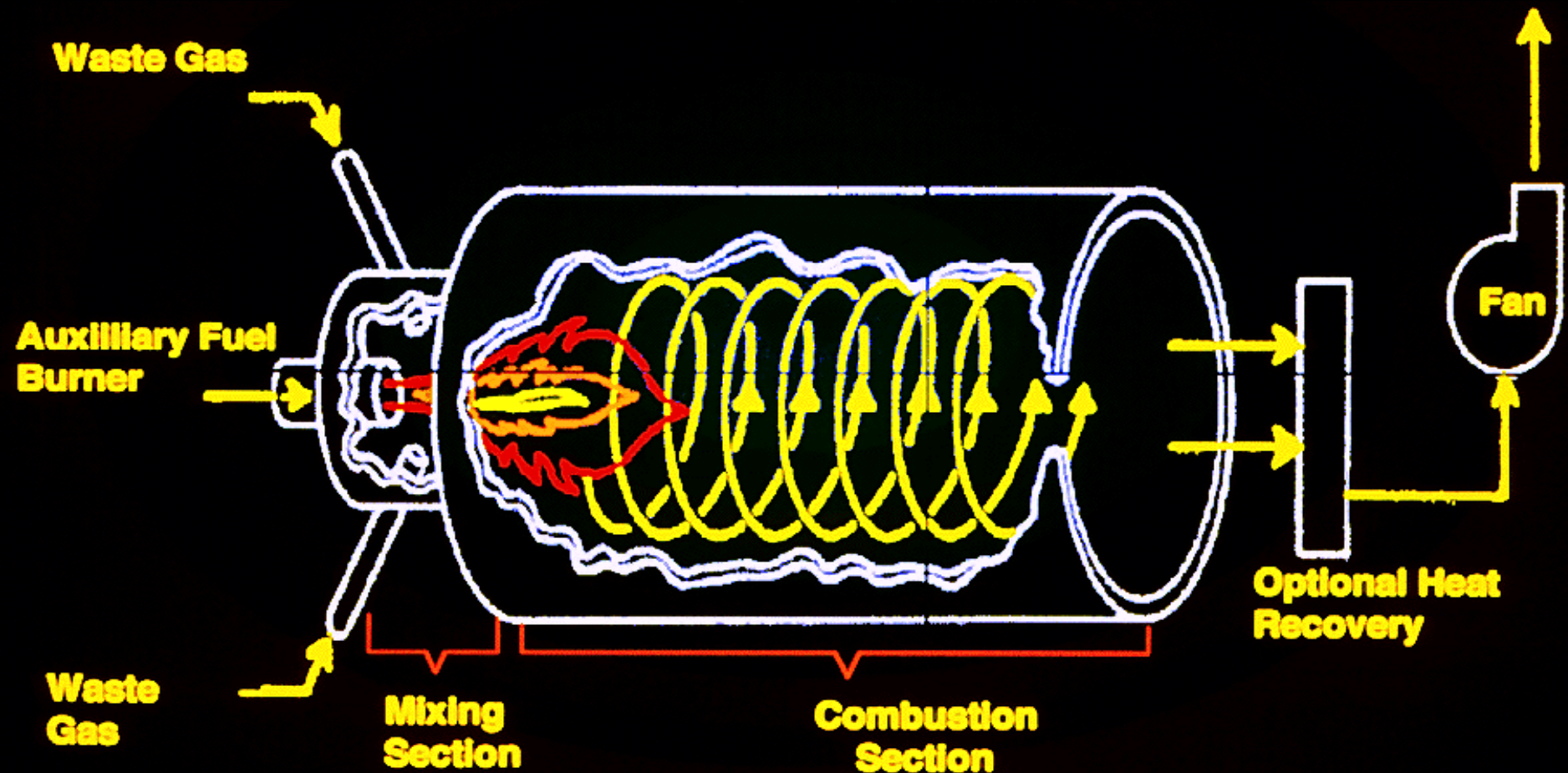
- **Process change to control monomer emissions**
- **Low VOC Gel Coat**
- **Change from acetone to less volatile solvent**
- **Reclaim acetone (distill)**
- **ADD-ON equipment**

Add-On Control Methods

- **Incineration**
- **Absorption**
- **Adsorption**
- **Condensation**

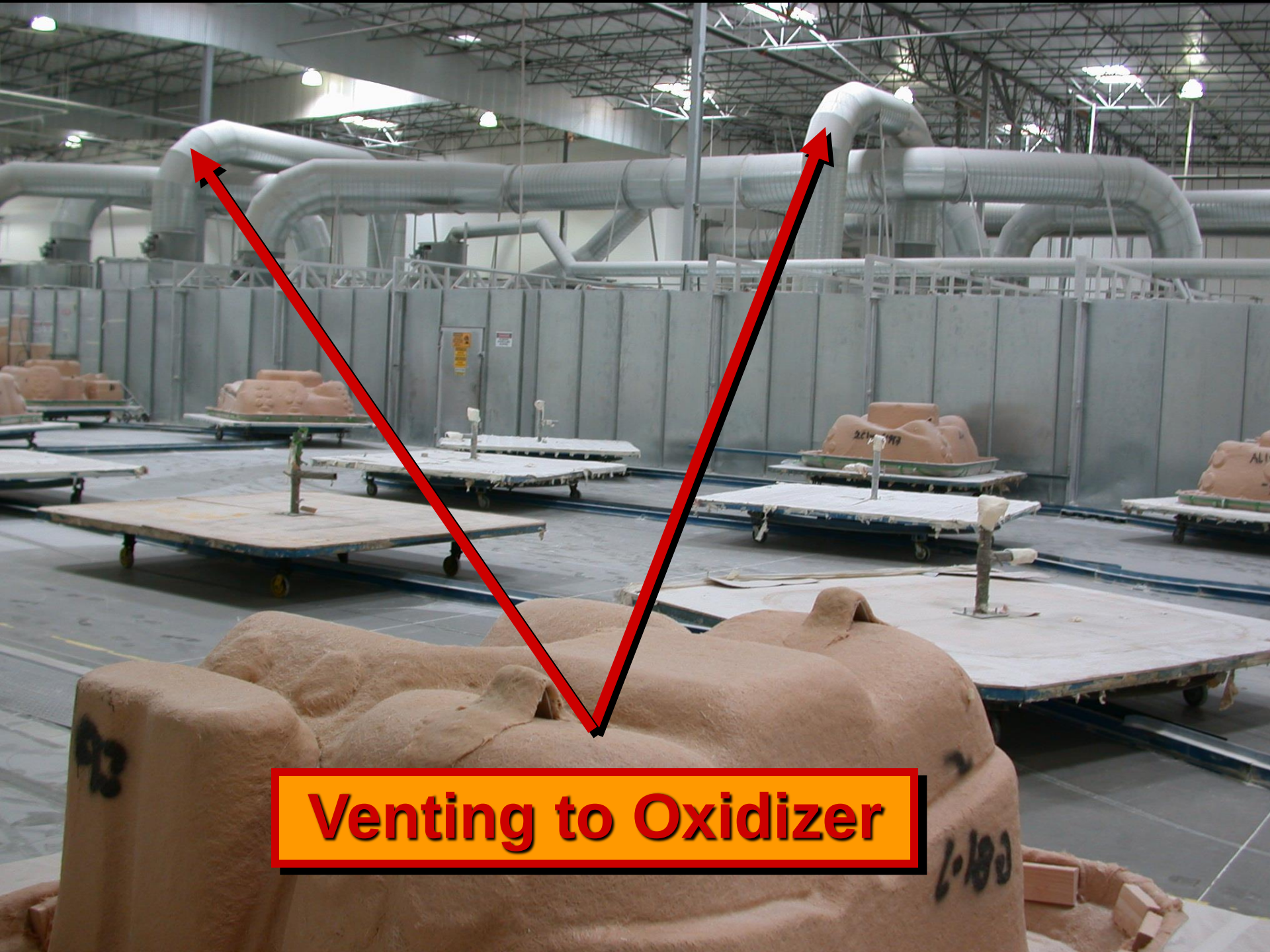


Thermal Oxidizer/Afterburner



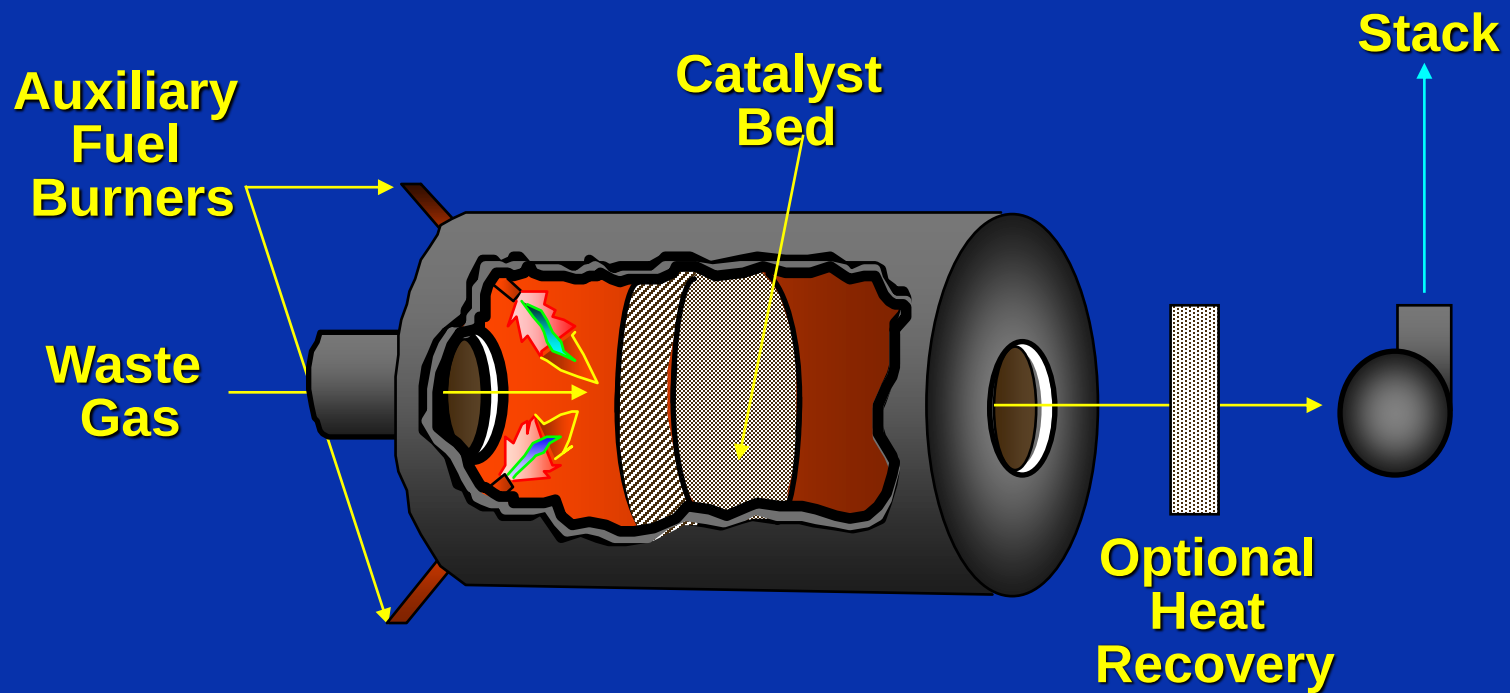
Thermal Incinerator



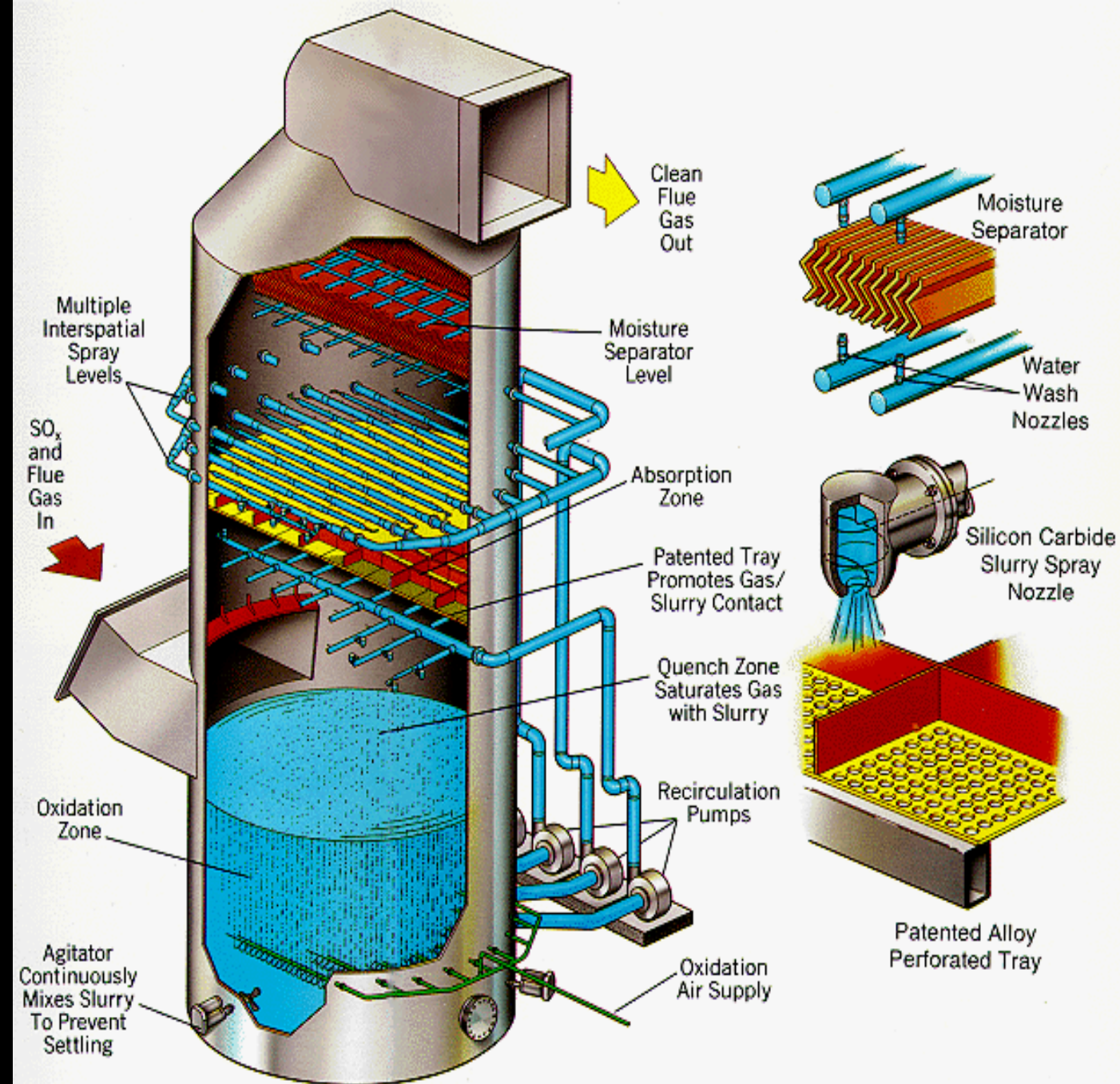


Venting to Oxidizer

Catalytic Oxidizer/Incinerator

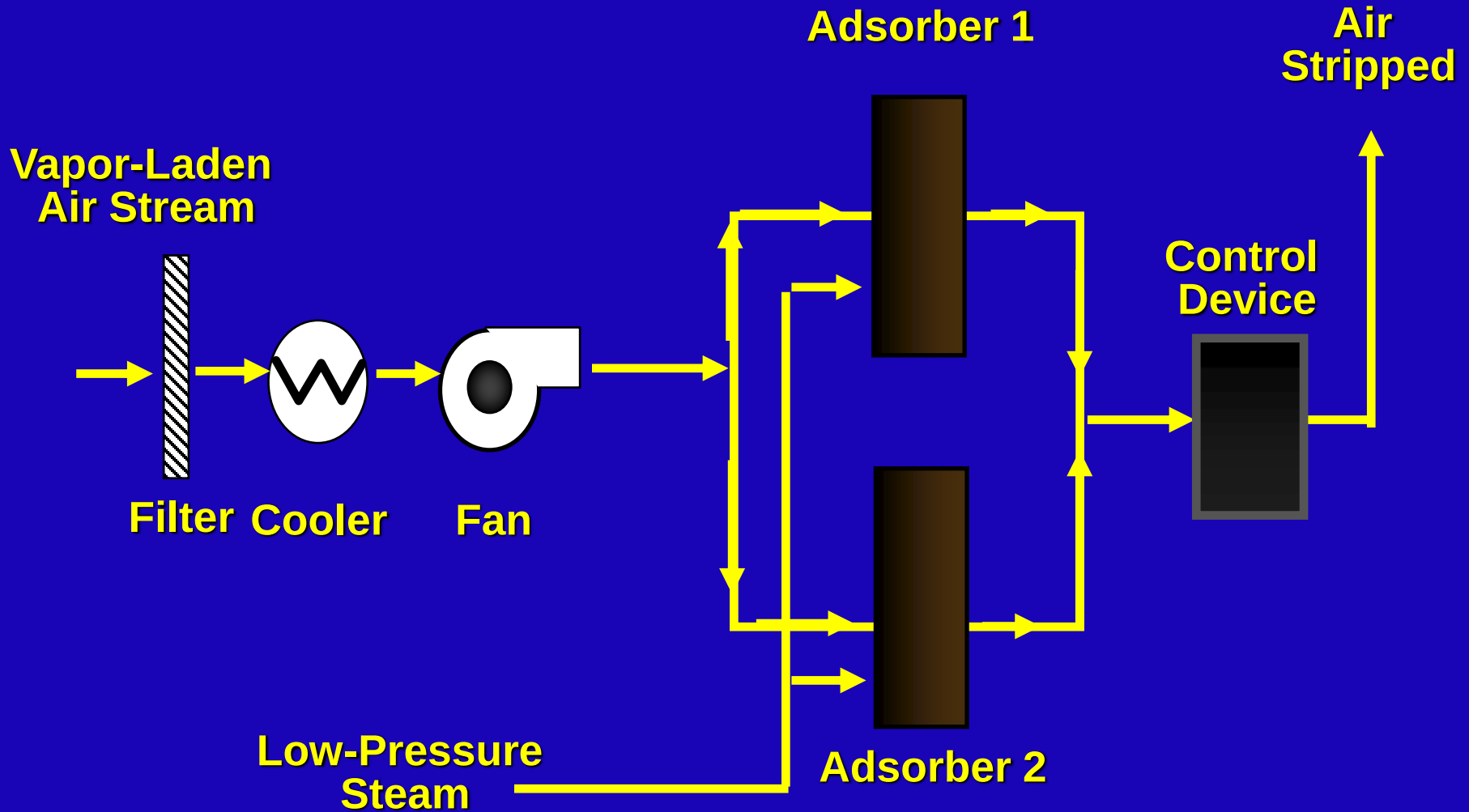






Wet Scrubber

Carbon Adsorption System



Remediation System with Carbon Adsorbers



Regulatory Requirements



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 MMMM -- 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 WWW – 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 Modacrylic Fiber Production
- 63 7H – Polyvinyl Chloride and Copolymers Production
- 63 6D – Area Source Polyvinyl Chloride and Copolymers
- 63 4H – Wet Formed Fiberglass Mat
- 60 HHH – NSPS for Synthetic Fiber Production
- 60 VVV – NSPS for Polymeric Coating for Supporting Substrates

Operation (Open Mold – Boat Mfg)	Application Method	HAP Weight %
Tooling Gel Coat	Any Method	40%
Pigmented Gel Coat	Any Method	33%
Clear Gel Coat	Any Method	48%
Production Resin	Atomized (Spray)	28%
Tooling Resin	Atomized (Spray)	30%

BACT and BARCT

Polyester Resin Material	Monomer Weight %
General Purpose Resin	<35%
Specialty Resin	< 50%
Clear Gel Coat	<50%
Pigmented Gel Coat	<45%

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**

**Potential
Emissions ??**

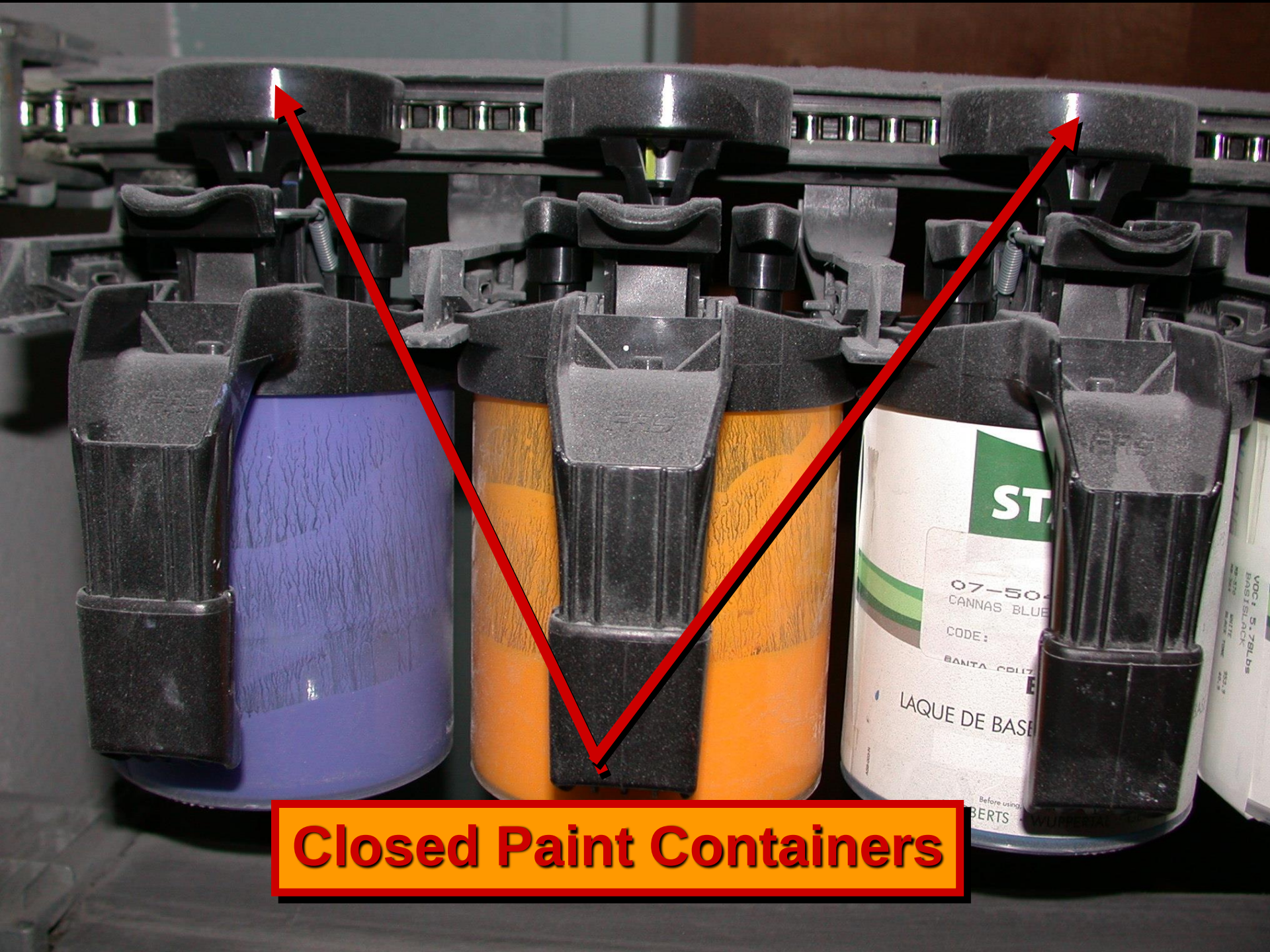
SHINY POLYCOR
ADD SURFACING
~~AGENT~~ (FOR FINAL
COAT)

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**

A photograph of a spray booth in a workshop. The booth is constructed from metal and features a large wall of glass blocks. A long, vertical strip of light-colored, fibrous material hangs from the top of the booth. On the left, a workbench is partially visible, covered with a white cloth. In the background, there are various workshop items, including a large metal tank and a control panel. The floor is concrete, and a white bucket is visible on the right side.

**Spray
Booth**

Spray Booth Filters



Spray Booth Application



Filter Inspection



Inspector Safety

**Proper equipment
Plant evacuation
Inhalation hazards
Hazardous materials
Chemicals & Machinery**





The End