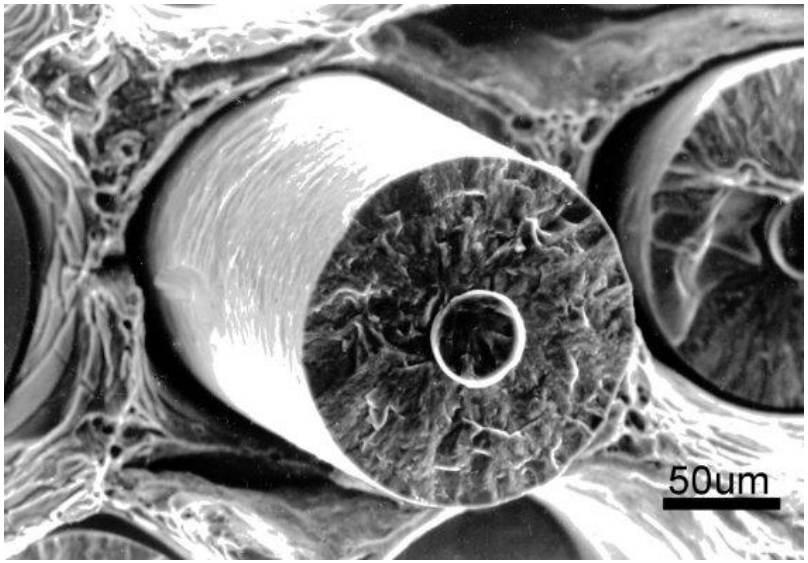
# Composites Processing

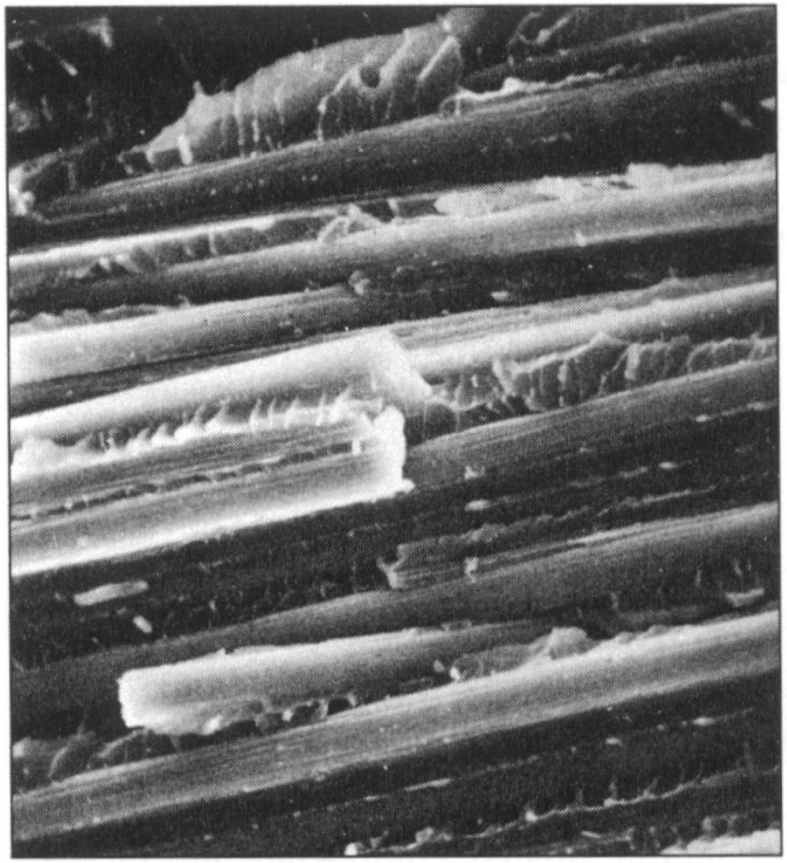
ver. 1

# Definition

- A microscopic mixture of two or more different materials. One typically being the continuous phase (matrix), and the other being the discontinuous phase (reinforcement).
- Its properties are strongly dependent on the composite structure.
- Ductility of matrix combined with stiffness of reinforcement.




Ceramic fiber composite



Polymer matrix composite

# Types / Examples

- People
- Trees
- Fiber reinforced matrices
  - fiberglass - epoxy
- Particulate reinforced matrices
  - tires (carbon black in rubber, but it also has continuous fibers (steel or polymer belts))

# Fibers/Particles Reinforcement

- Glass
- Kevlar
- Carbon
- Thermoplastics
- Alumina
- Boron
- SiC
- Steel
- $Si_3N_4$
- Silica
- Glass beads
- Talc
- Rocks
- Carbon black
- Calcium carbonate

# Reinforcements

- Rovings
  - continuous
  - bulk

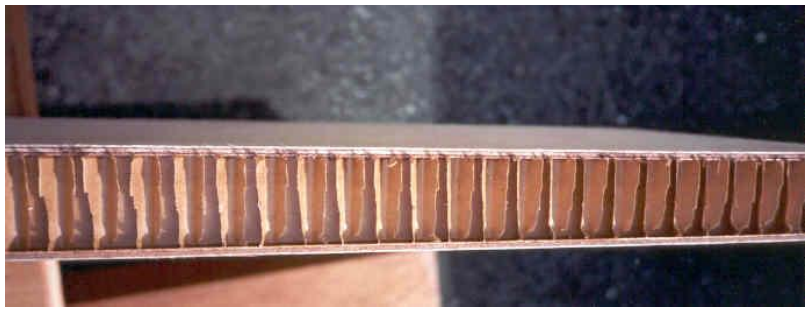
- Continuous strand mat
- Chopped strand mat

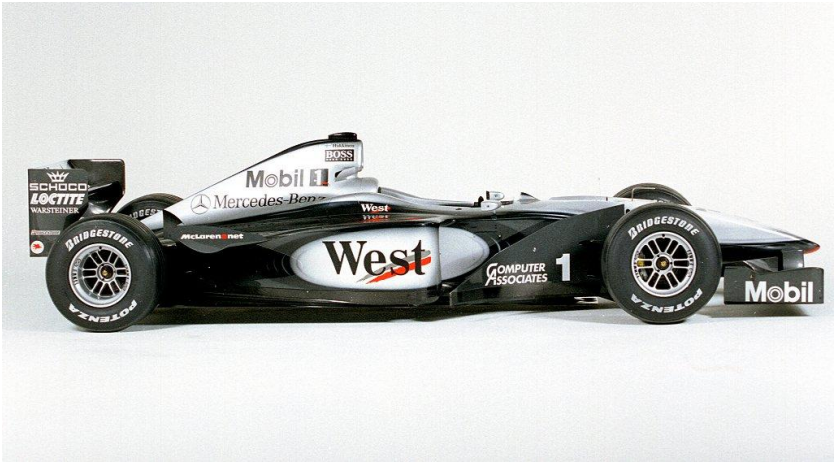
- Surface veils

# Matrices

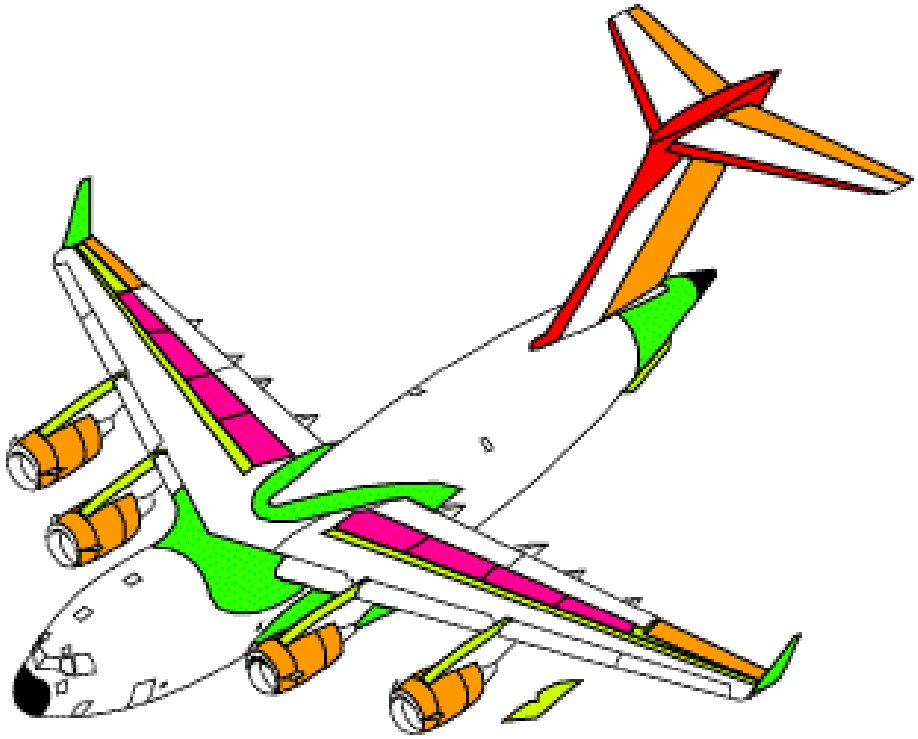
- Protects & separates reinforcement, transmits forces
- Polymer
  - PEEK, epoxy, polyester, polyurethane, rubber
- Metal
  - Al, Cu, Ni, Ti
- Ceramic
  - glass, cement

# Honeycomb composites



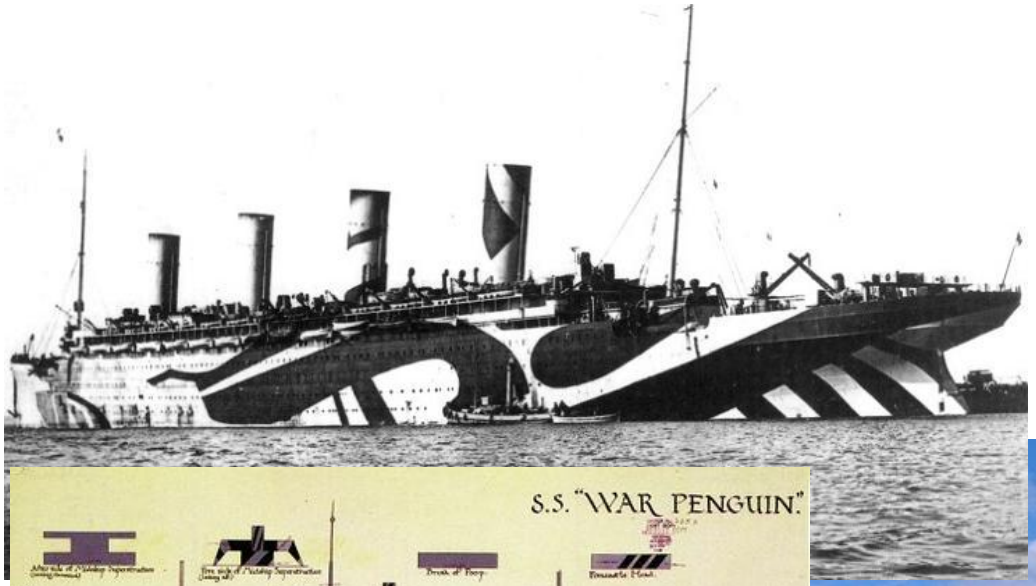


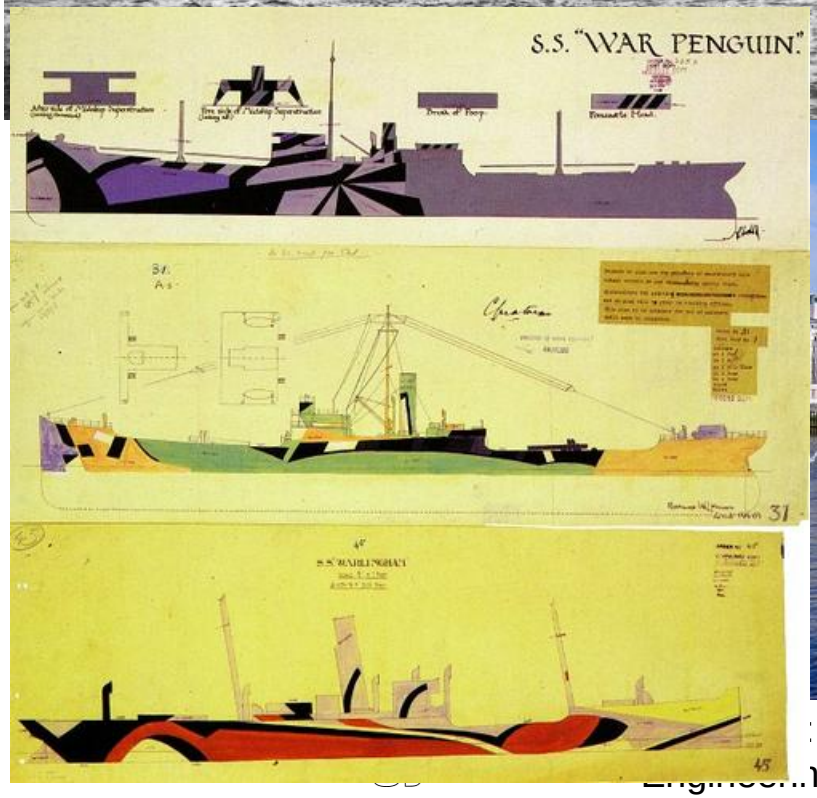
# C-17 Aircraft



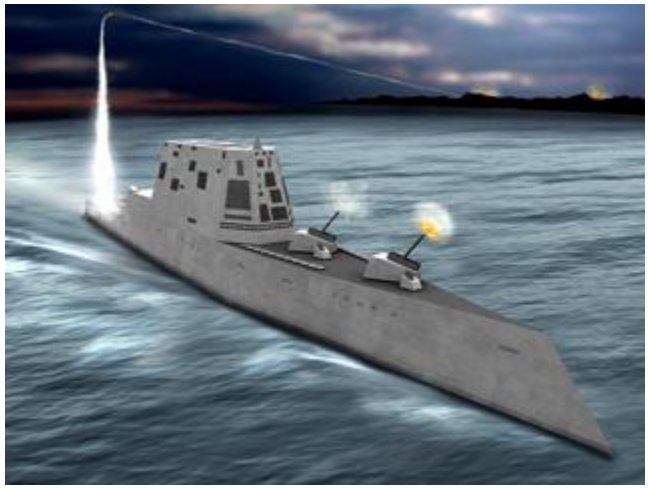
# Visby Corvette

# Razzle Dazzle Camouflage






# Stealth Ships



# IsoTruss Bike

Ascend

1.8 pounds (56)

Size: 50, 54, 56, 58, 60

IsoTruss® Technology

Carbon fiber/Kevlar

Lifetime warranty

Limited production

# Processes

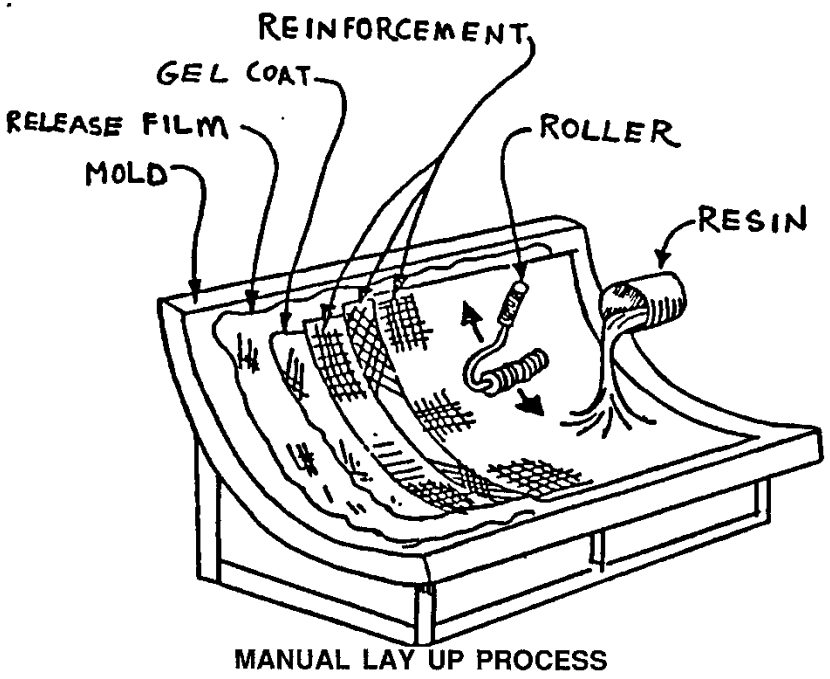
- Hand lay-up
- Vacuum bagging/autoclave
- Compression molding
  - SMC/BMC
- Liquid resin molding
- Resin transfer molding

# Processes

- Pultrusion
- Filament winding
- Injection molding
- Thermoplastics processing
- Automated tape laying

# Manual lay-up

- Definition: A process wherein the application of resin and reinforcement is done by hand onto a suitable mold surface. The resulting laminate is allowed to cure in place without further treatment



MANUAL LAY UP PROCESS

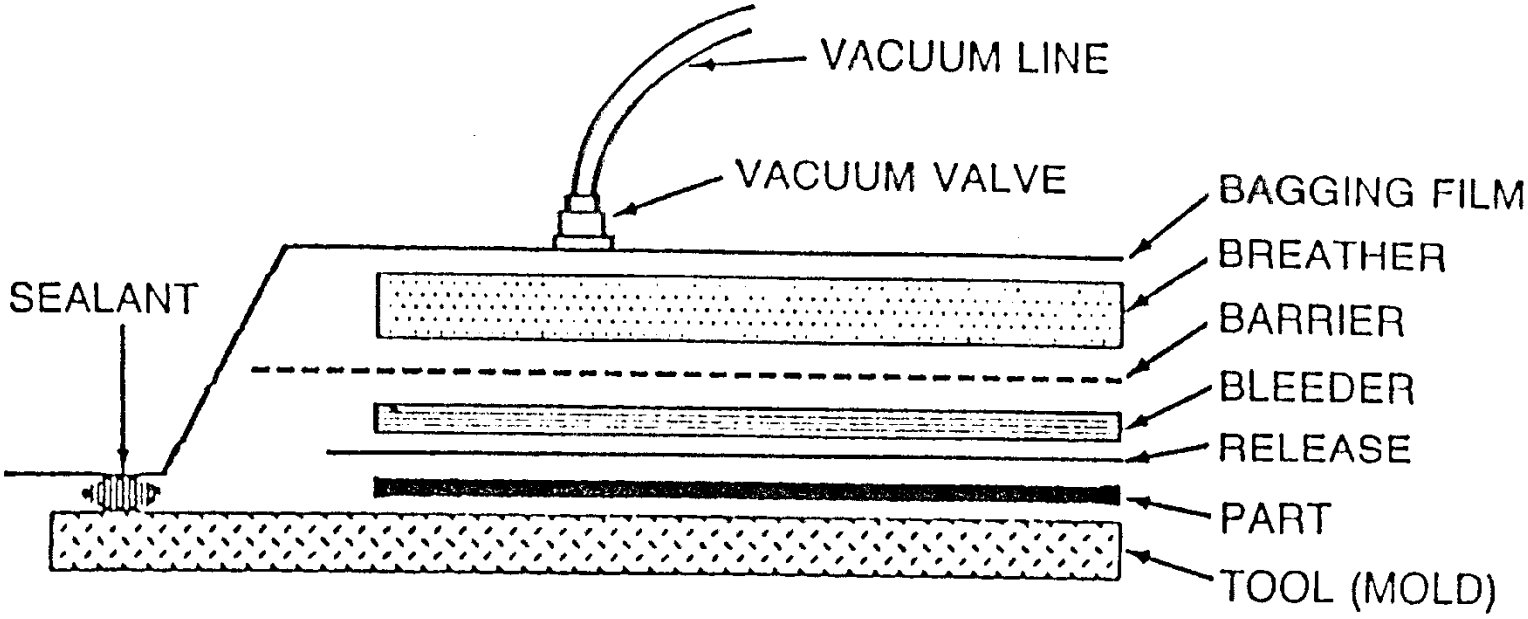
# Hand spray-up

# Hand lay-up shop

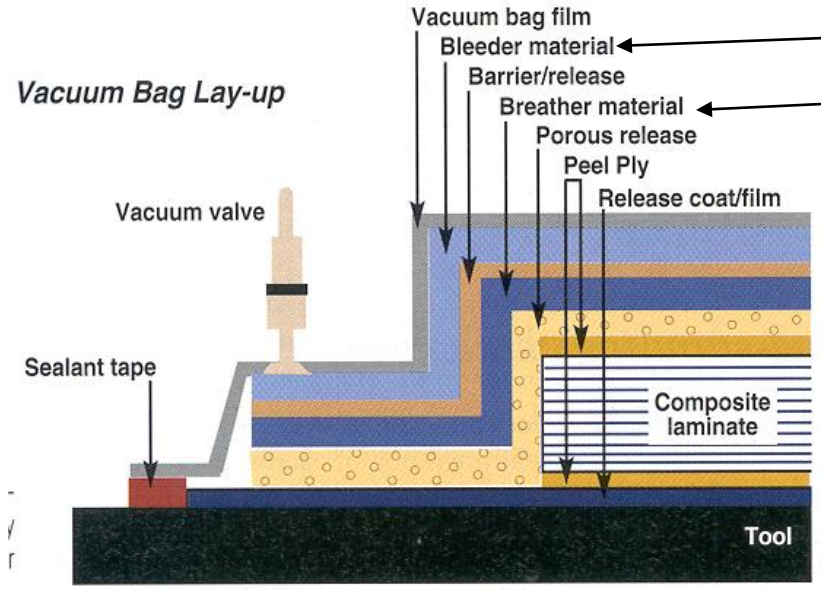
# Molds

# Mold

# Vacuum bag assembly



# Vacuum bag




Breather

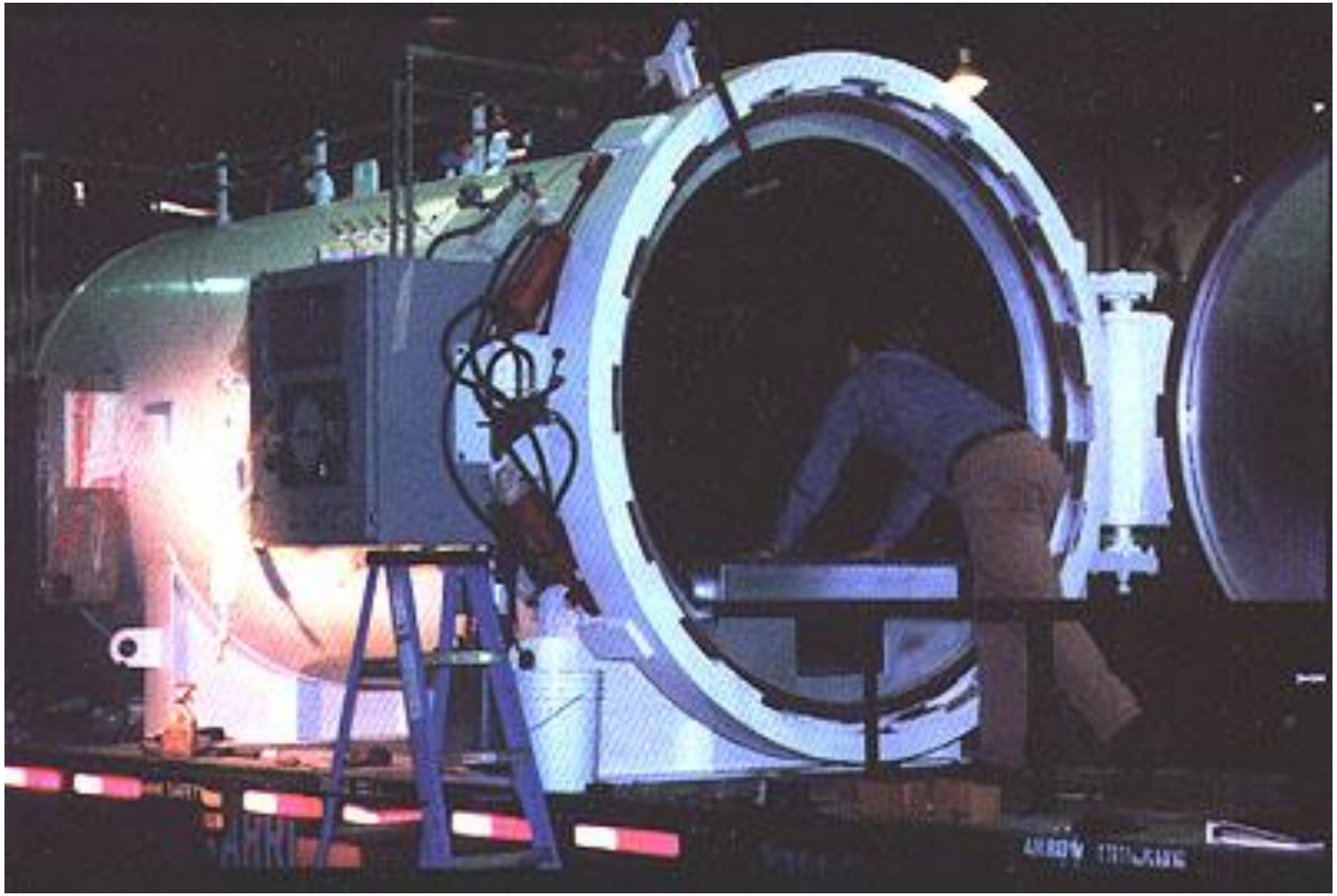
Bleeder

# Lay-up

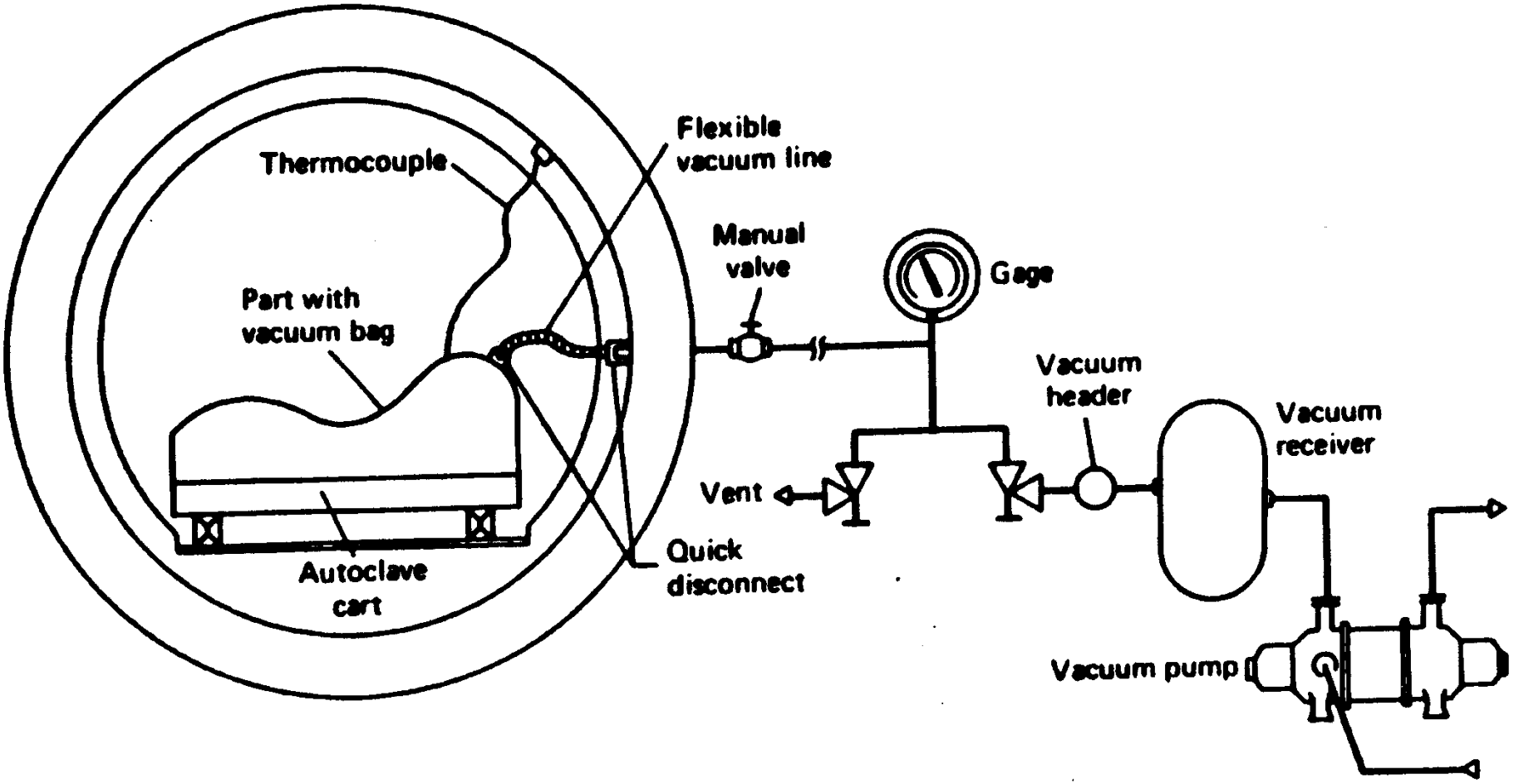
Material on stiffening structure

Vacuum bag and fittings attached

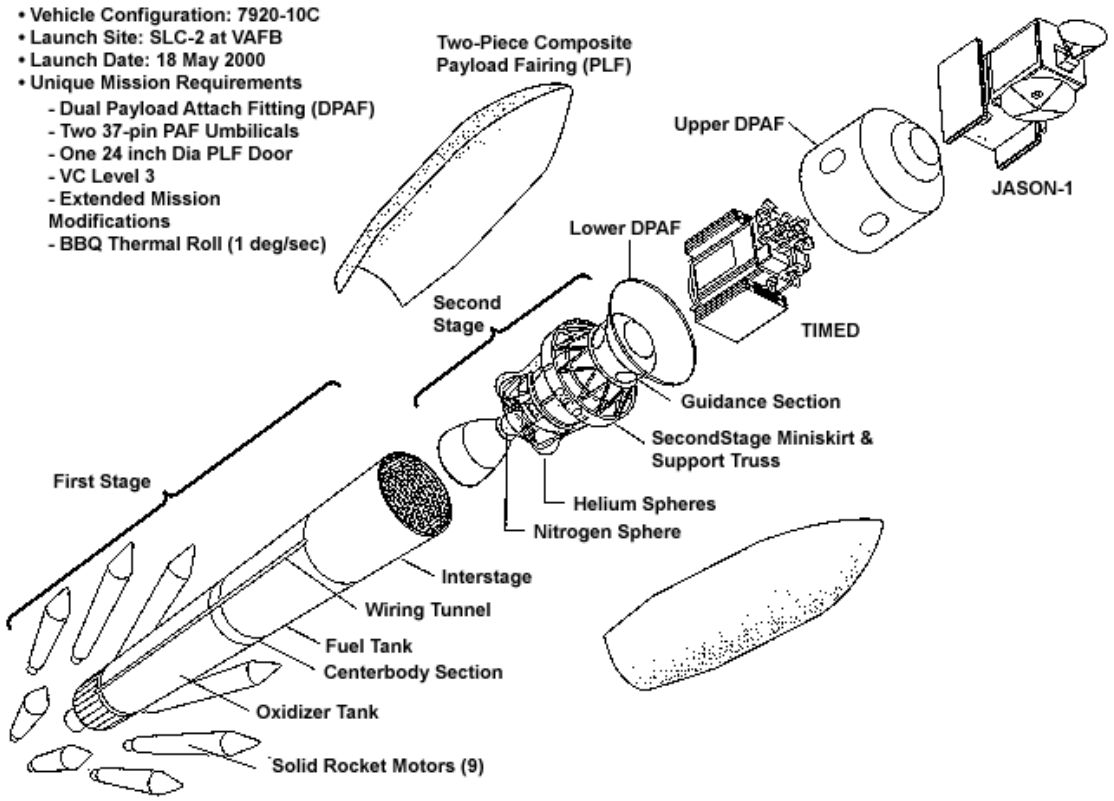
# Autoclave



# Autoclave

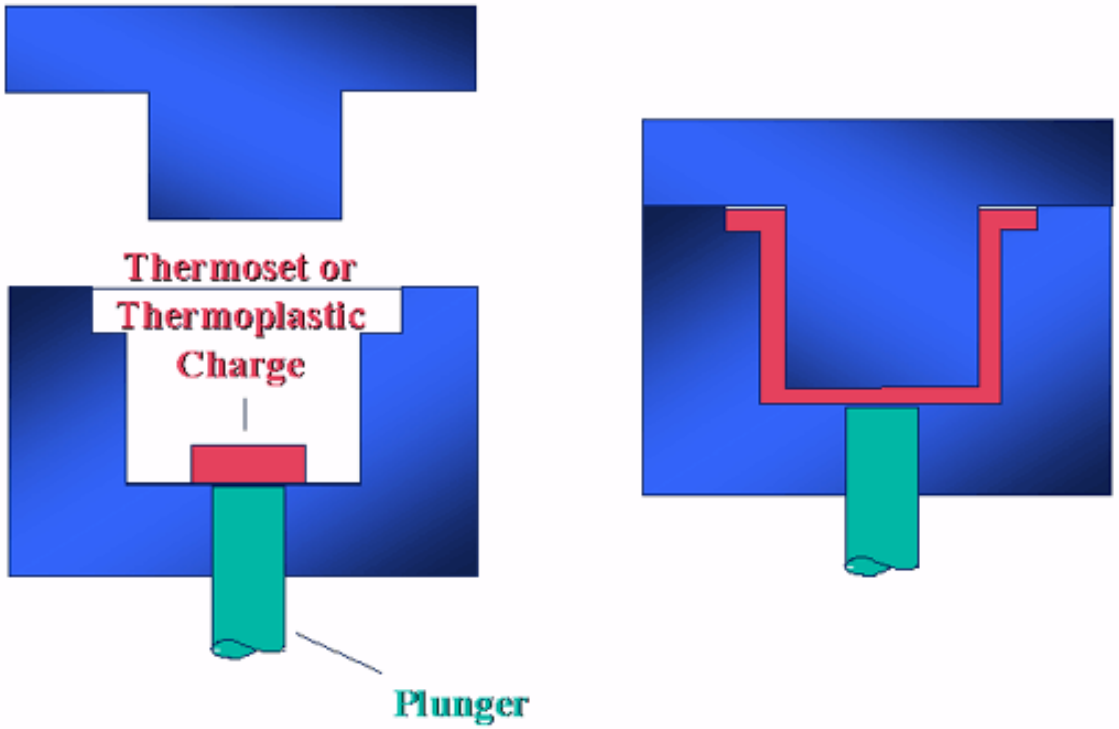

Thermocouple
Flexible vacuum line
Manual valve
Gage
Part with vacuum bag
Vacuum header
Vacuum receiver
Vent
Quick disconnect
Autoclave cart
Vacuum pump

# Delta II Rocket




# Delta II rocket

# Compression Molding Process




Can be used with bulk molding compound (BMC)


(Photo Courtesy of Automated Systems, Inc.)

Press shown is a 25" x 25", 4 opening, electric hot press with an inline cool press

# Schematic of a compression molding press

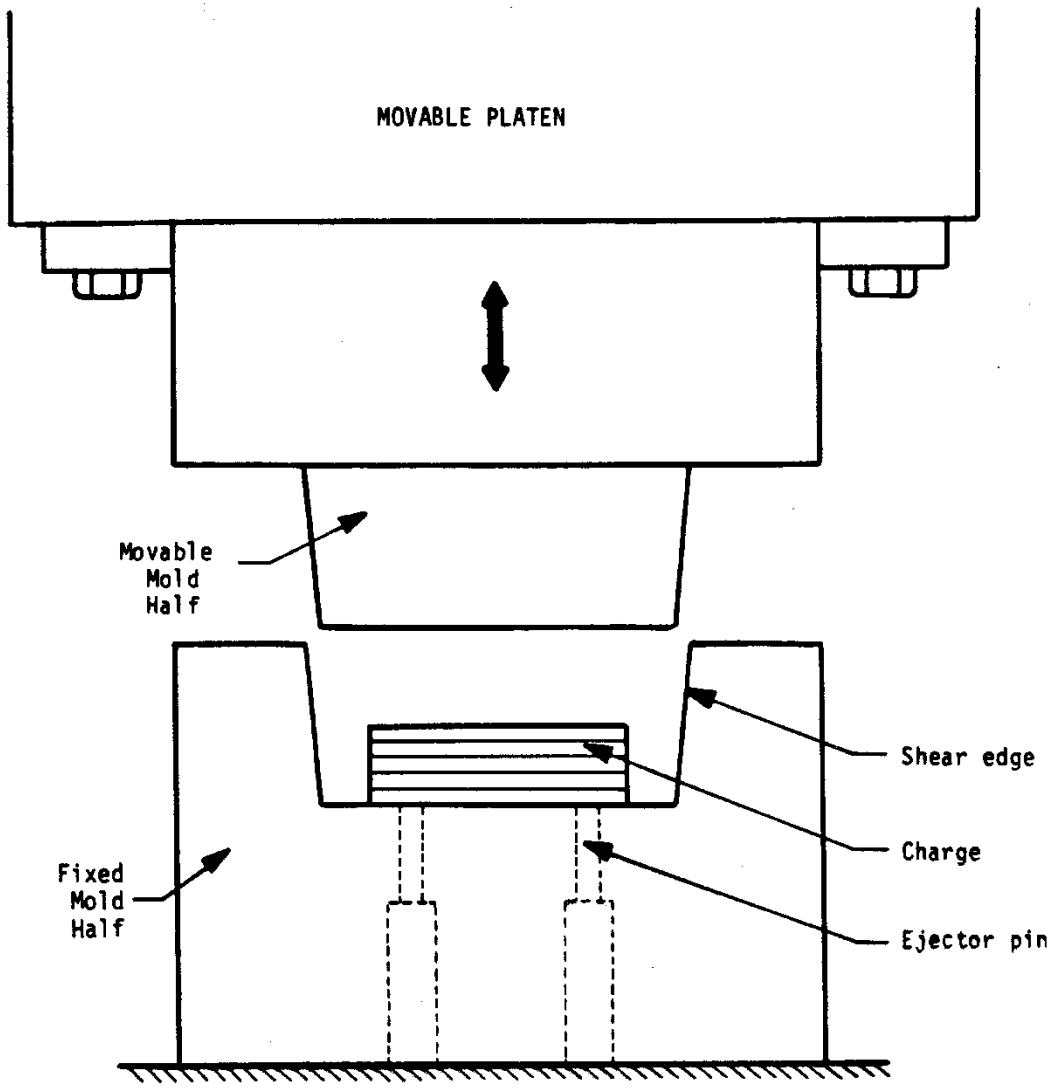
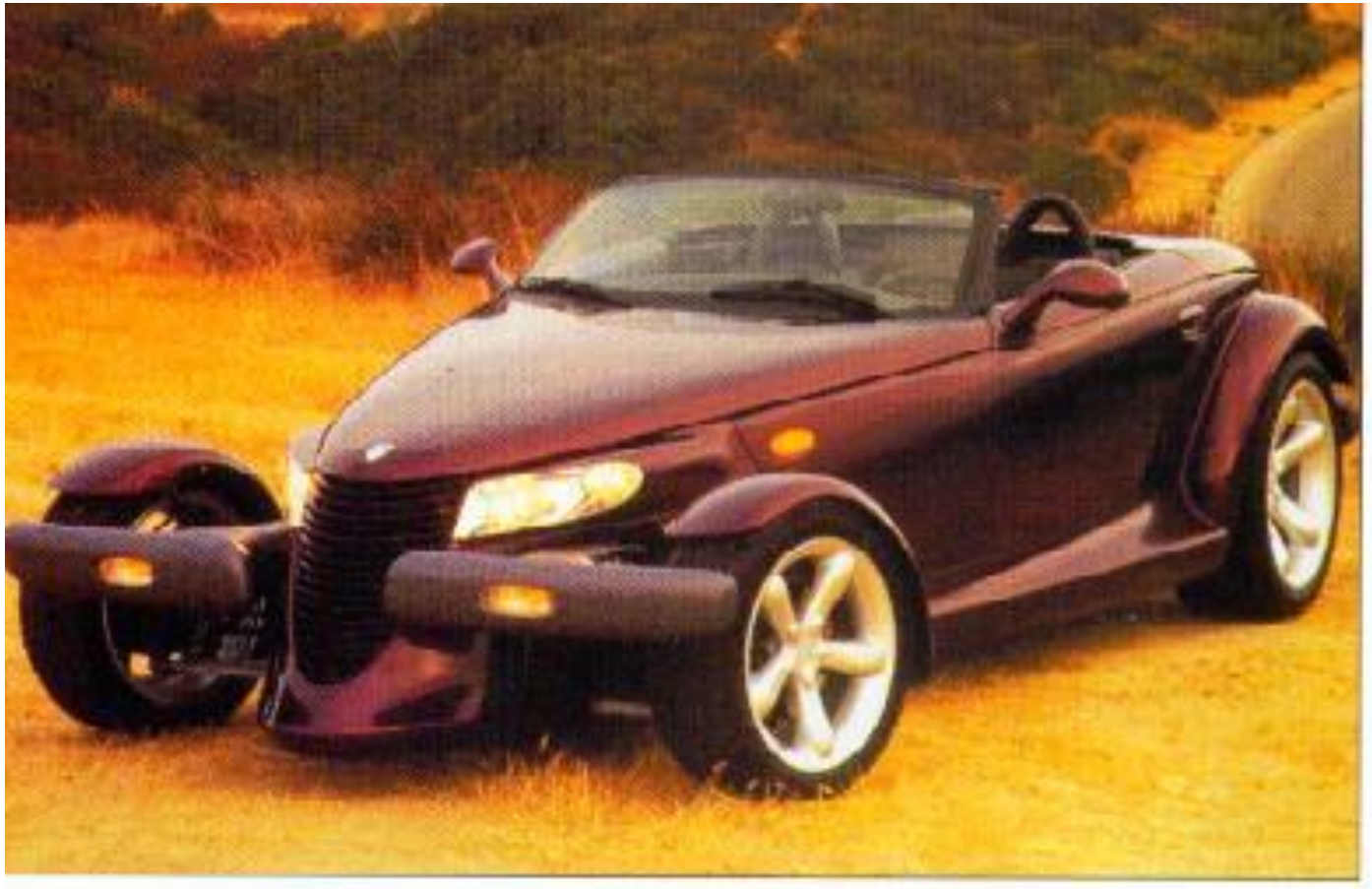



FIG. 5.11 Schematic of a compression molding process.

# Car parts with Sheet Molding Compound (SMC) - Prowler



# SMC manufacture using a configuration that can make chopped-fiber SMC-R; continuous fiber SMC-C; or continuous, random SMC-C/R material

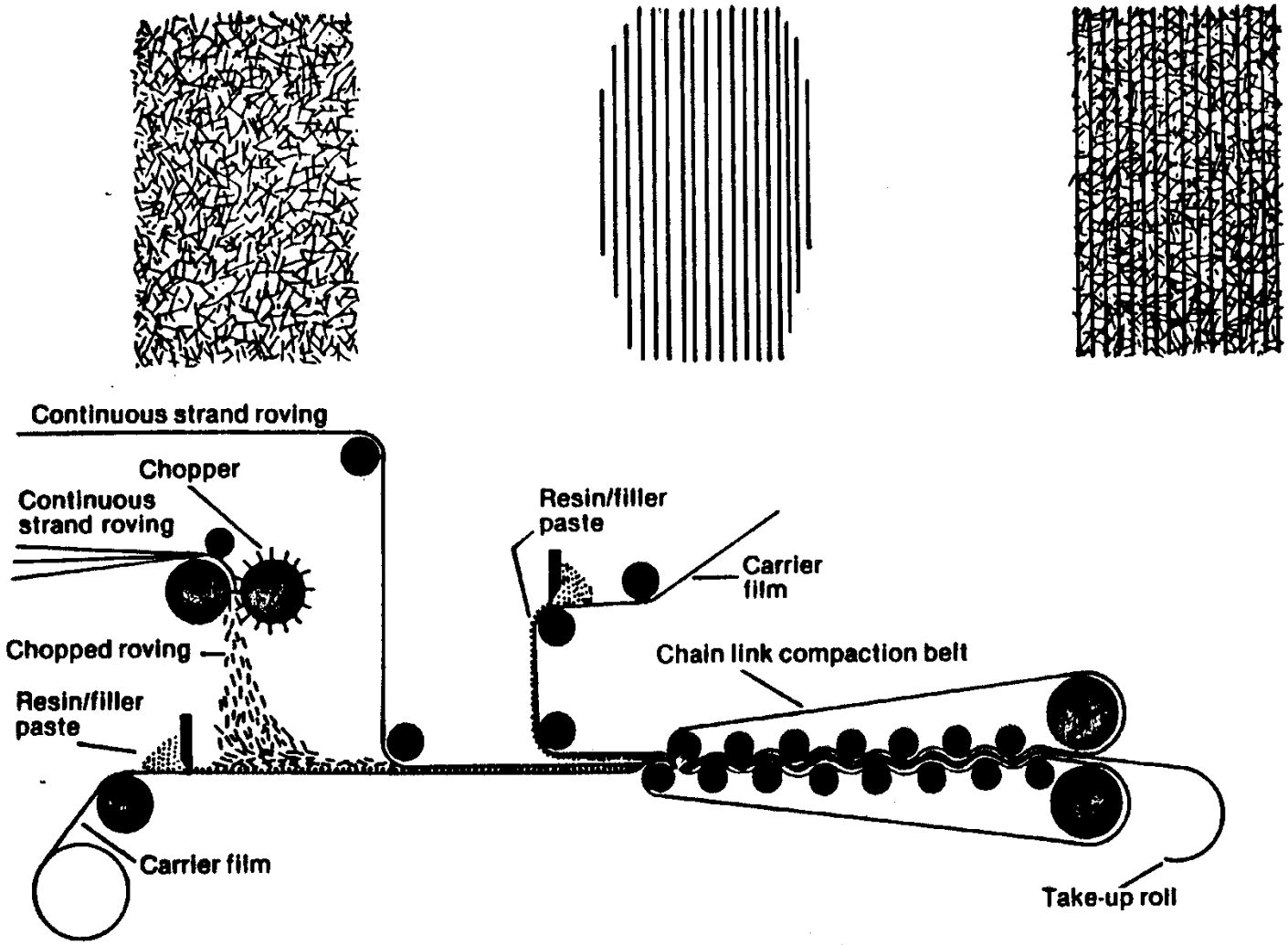
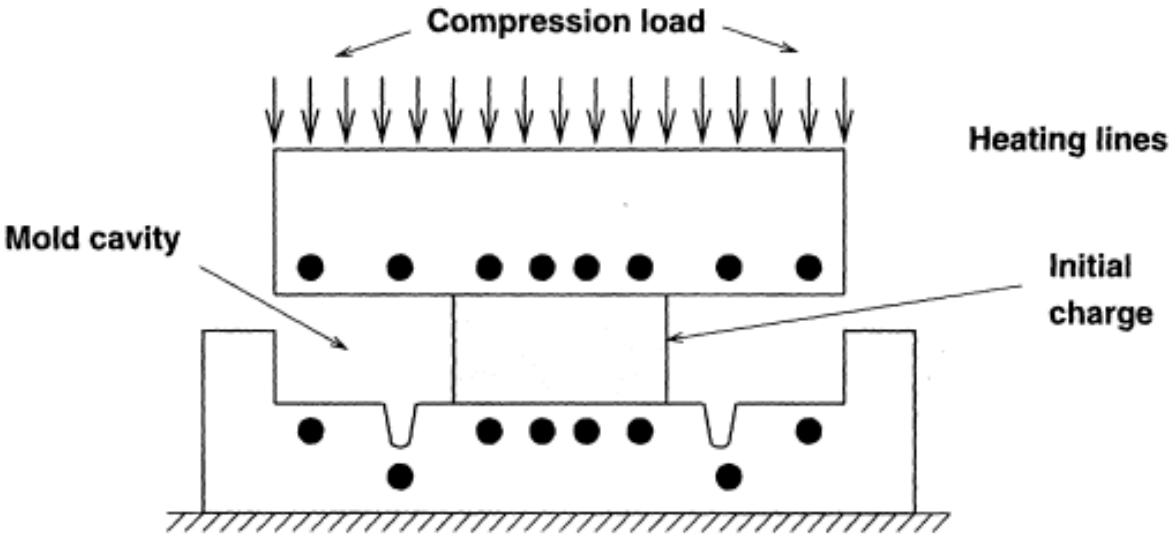
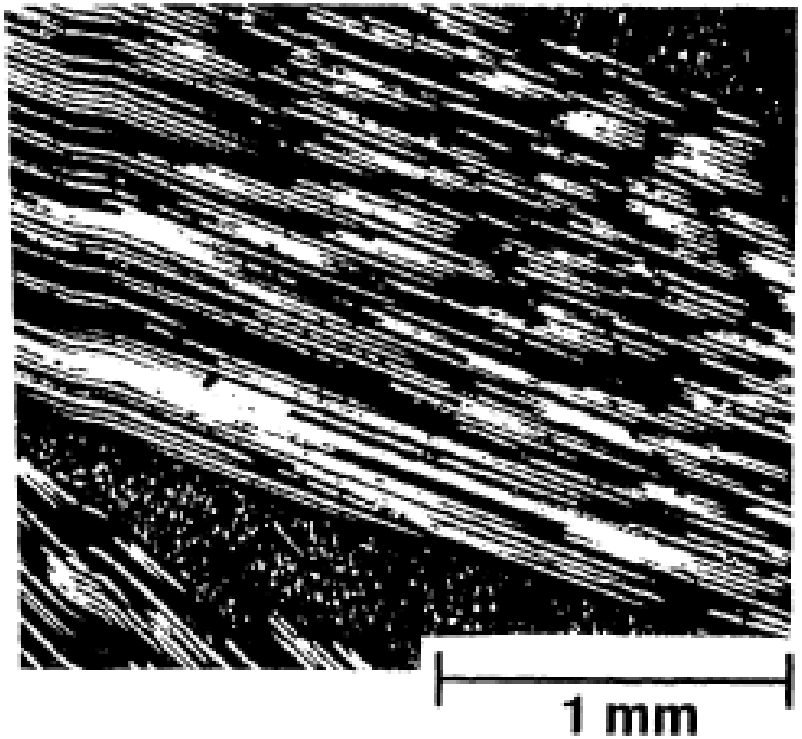



**Fig. 1** SMC manufacture using a configuration that can make chopped-fiber SMC-R; continuous fiber SMC-C; or continuous, random SMC-C/R material

# Molding process

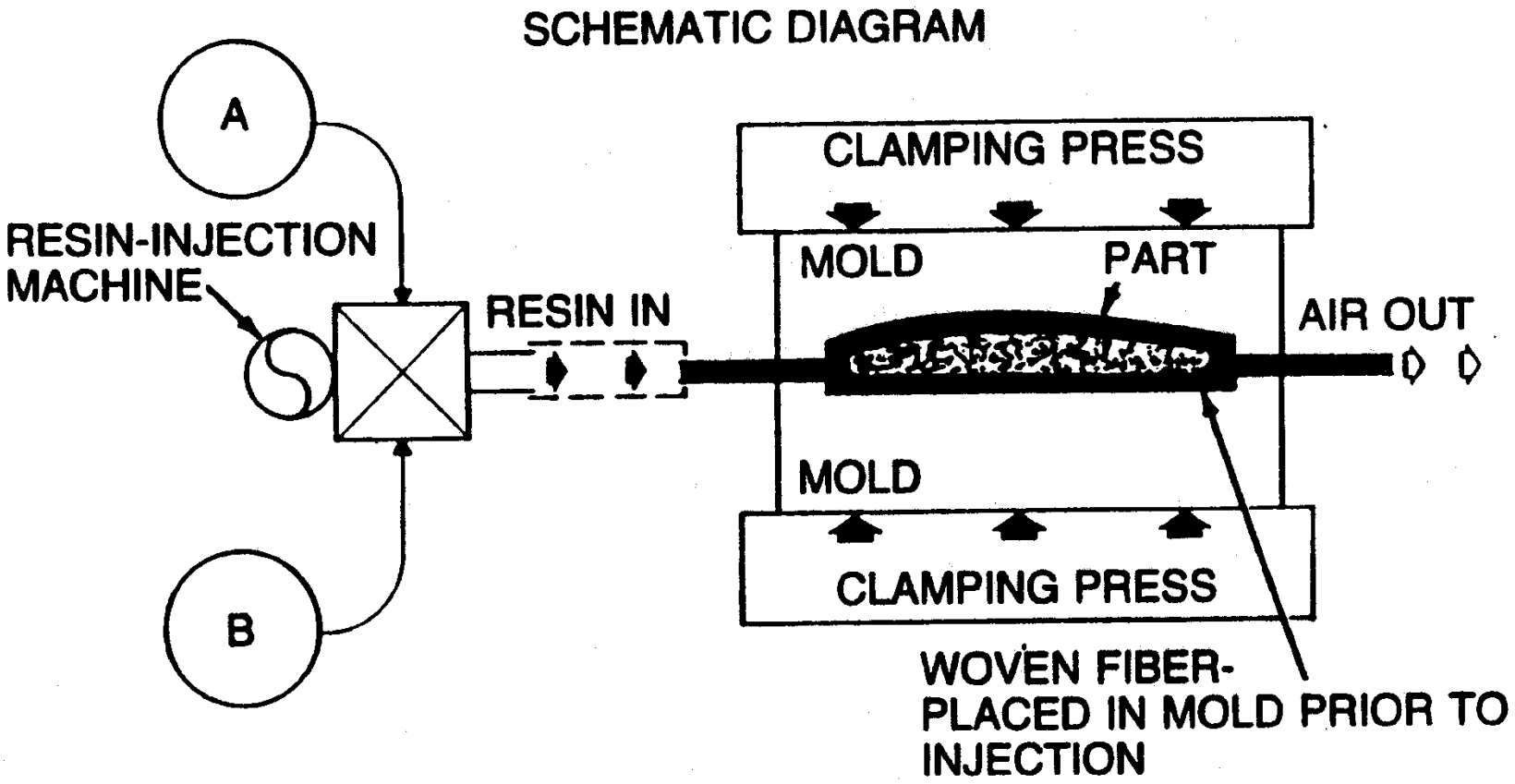


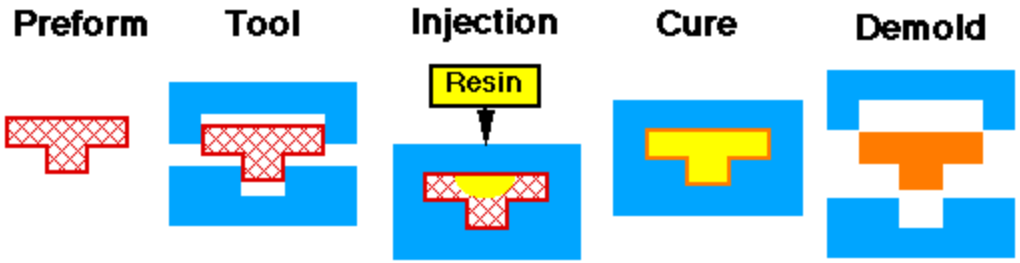
# Fiber orientation




Compression Molding

# Resin transfer molding (RTM) process

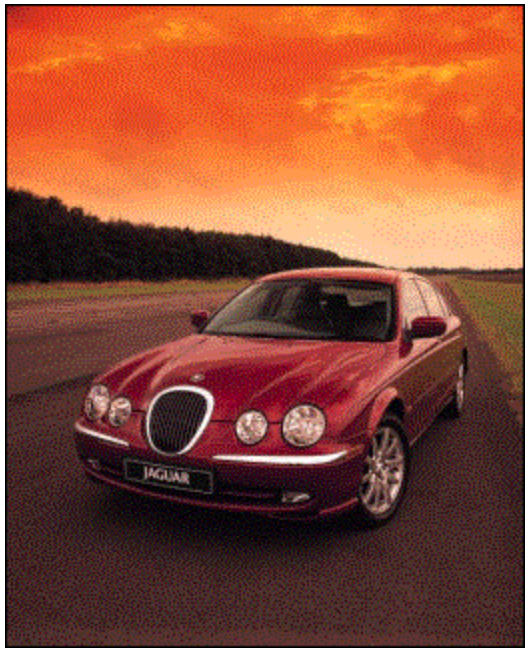


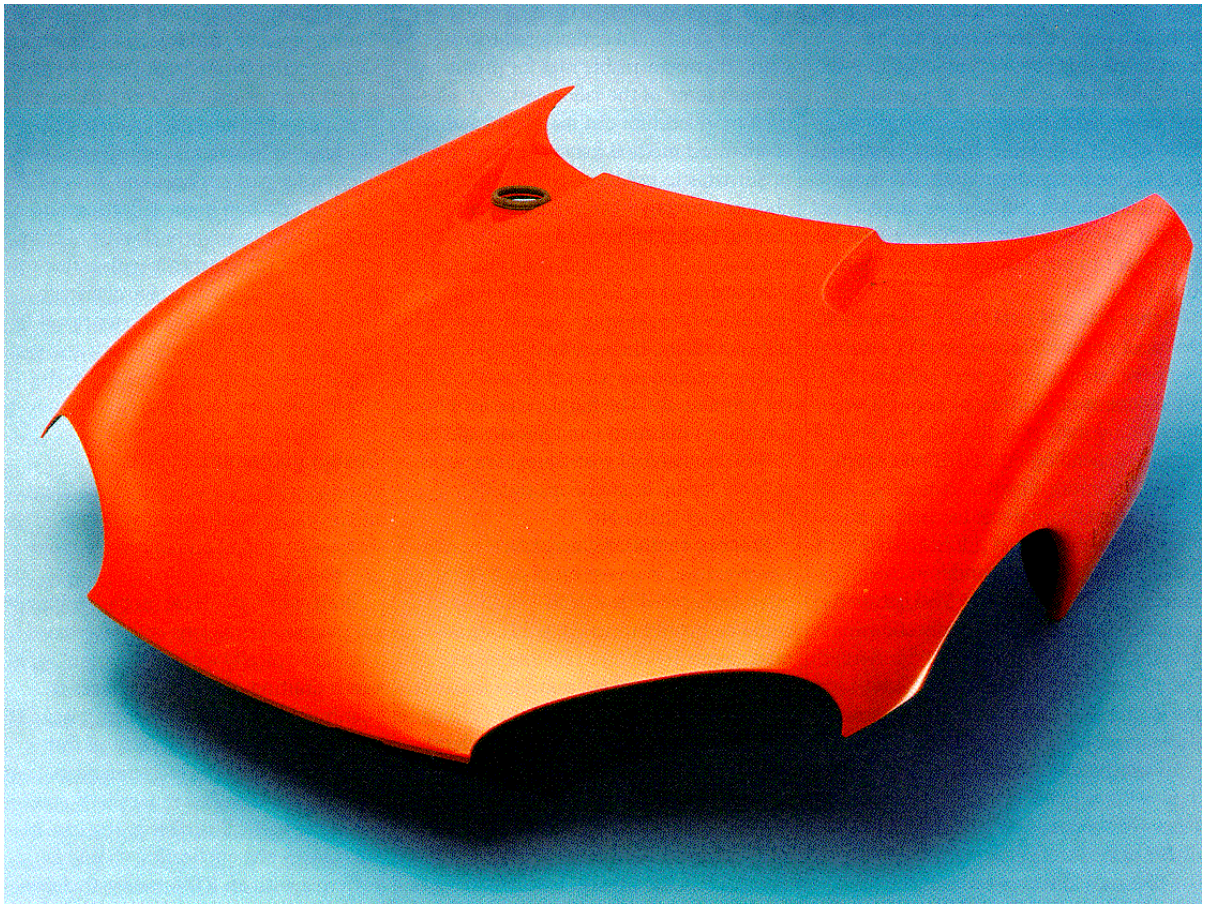



# RTM applications

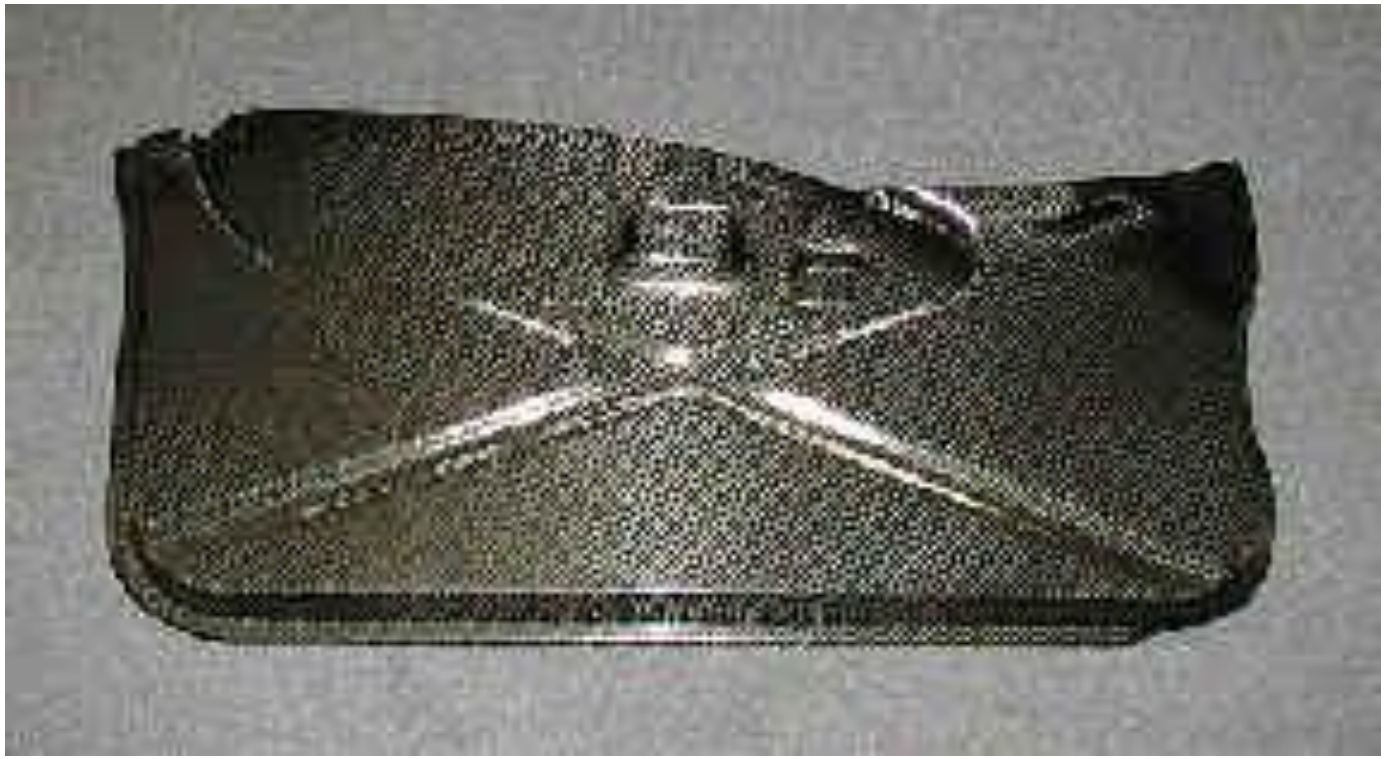
- Auto body panels
- Truck air deflectors
- Wind blades
- Chemical storage tanks
- Solar collectors (40 ft diameter, 36 parts)
- RV components
- Propellers
- Bathtub/shower units
- Antenna dishes
- Chairs
- Swim pool panels

# Car parts

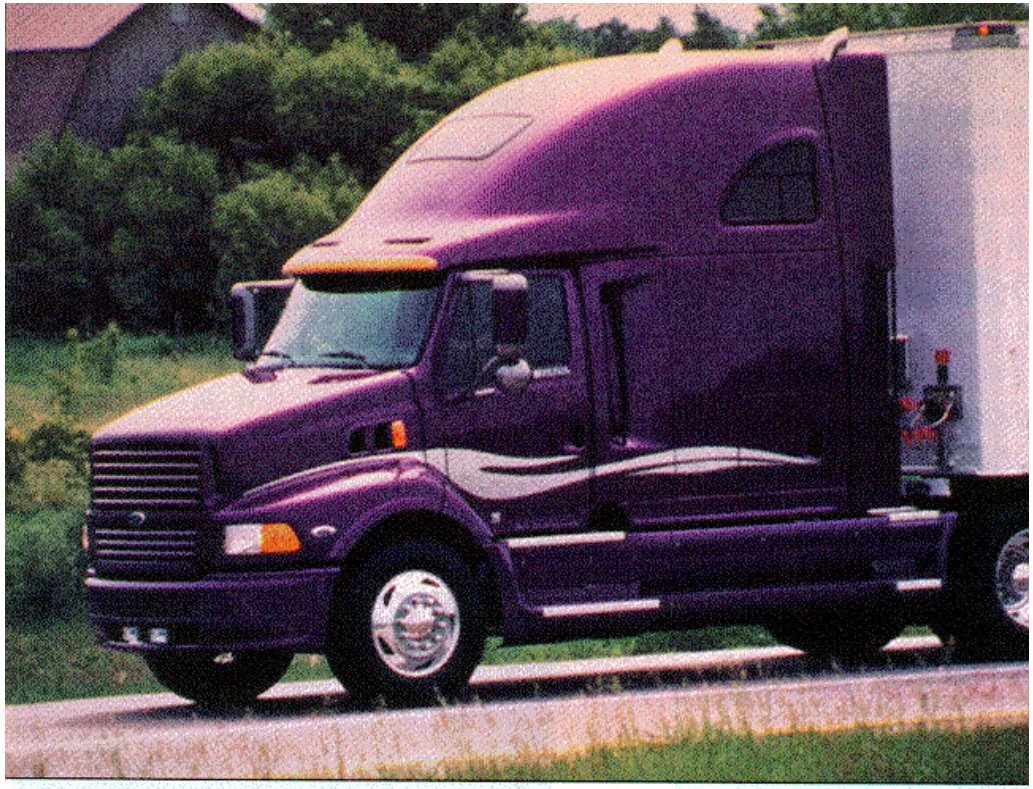


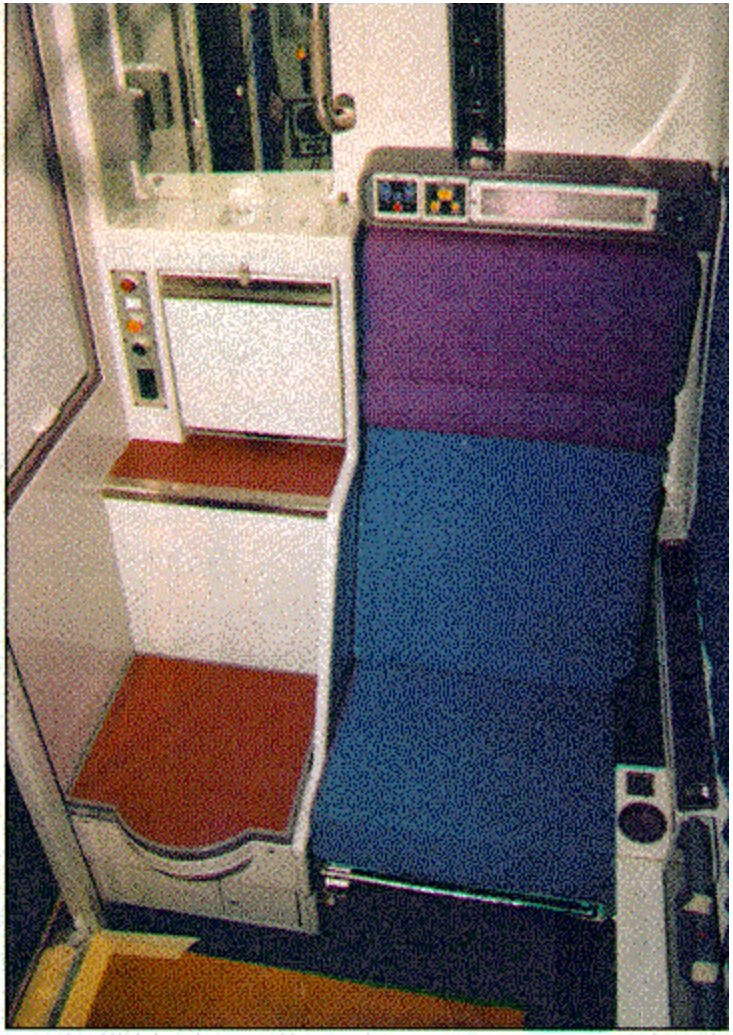
# RTM automobile structure



# Truck

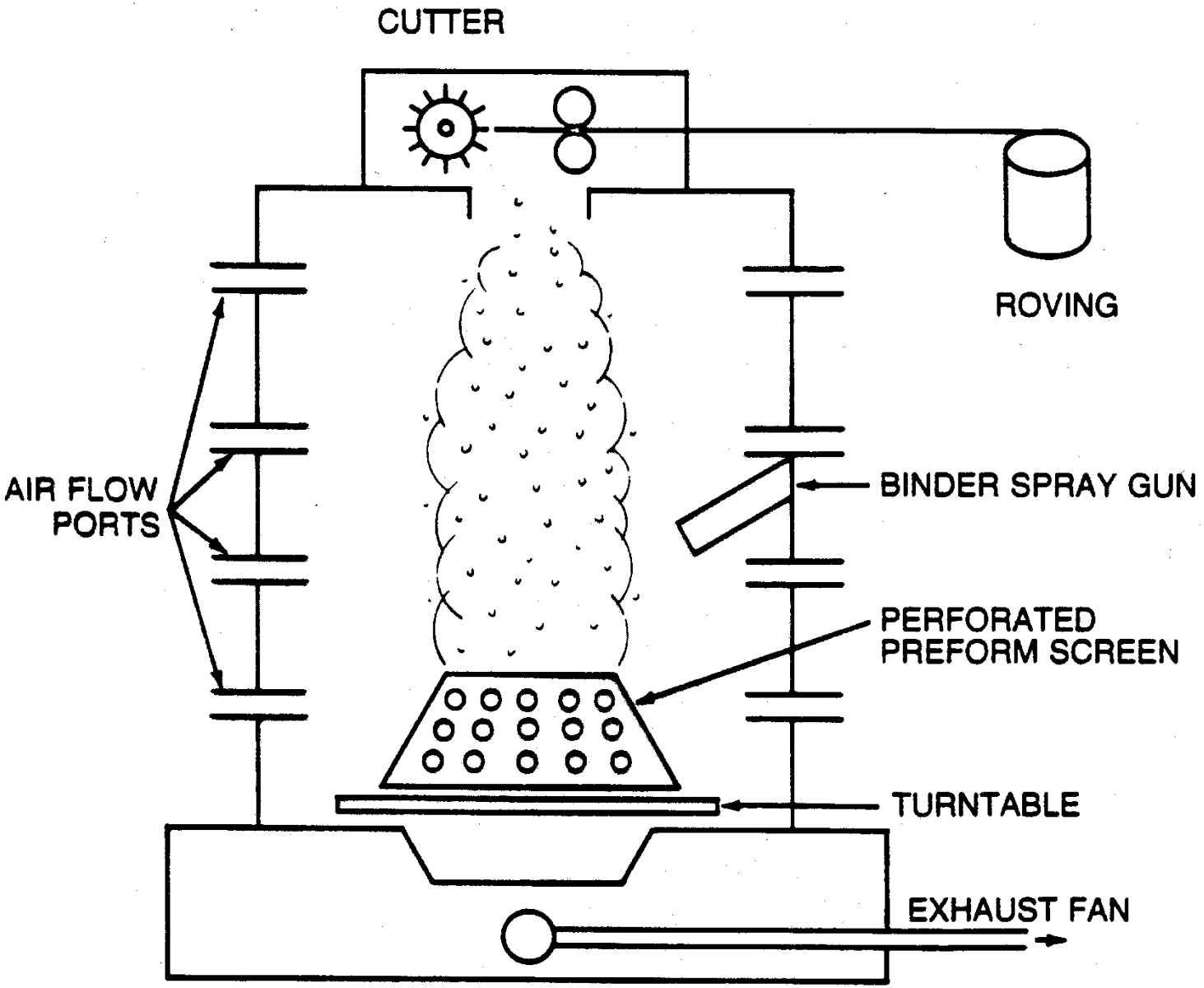


# Train Compartment



# Train Compartment


# Plenum method for making preforms



# Schematic of high-speed RTM process

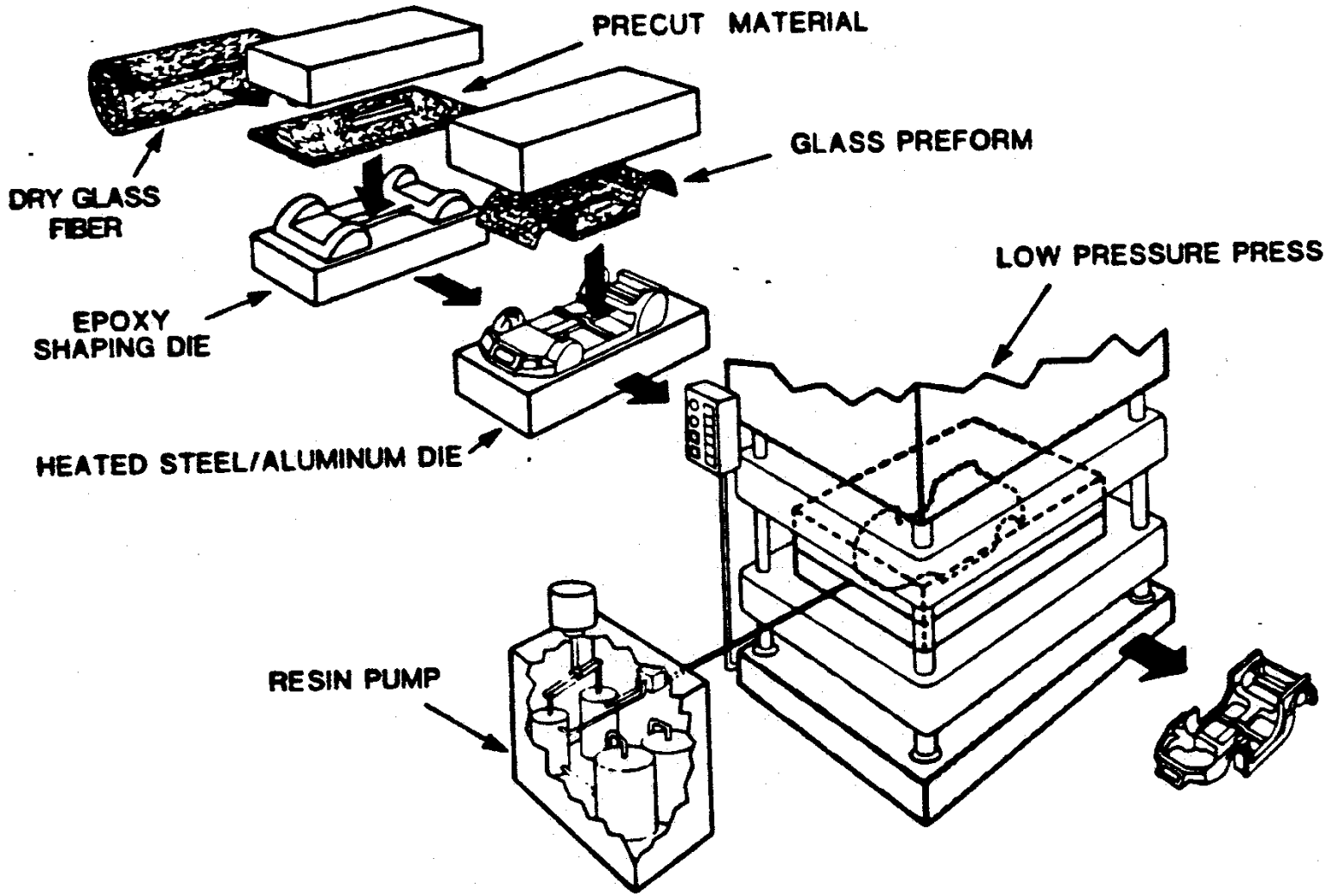
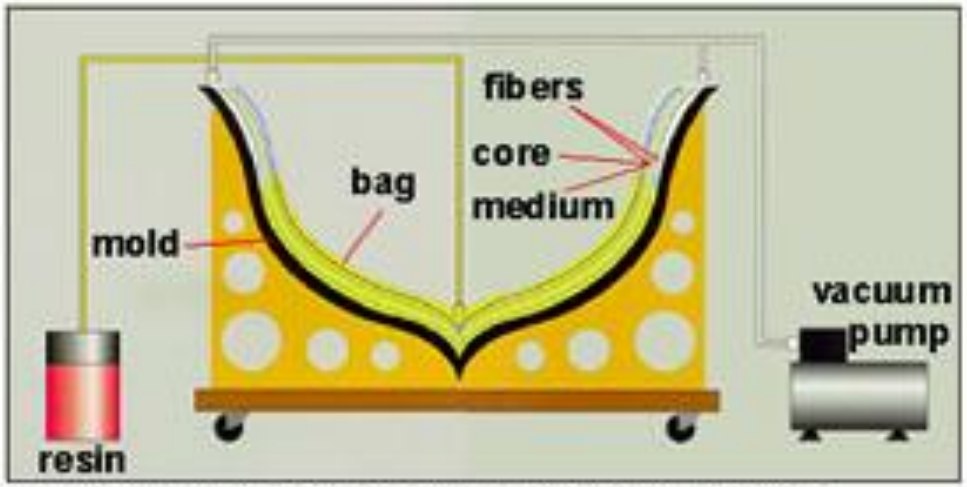



**Fig. 1** Schematic of the high-speed resin transfer molding process

# SCRIMP SYSTEM SCHEMATICS




source illustration from Hardcore DuPont Composites

Boat Hull Manufacture

- Process developed and patented by Seamann's Composites
- Single-sided tooling
- Injection achieved through high-permeability surface layer to cause through-the-thickness flow

# SCRIMP – Boat Hulls

# Pultrusion process

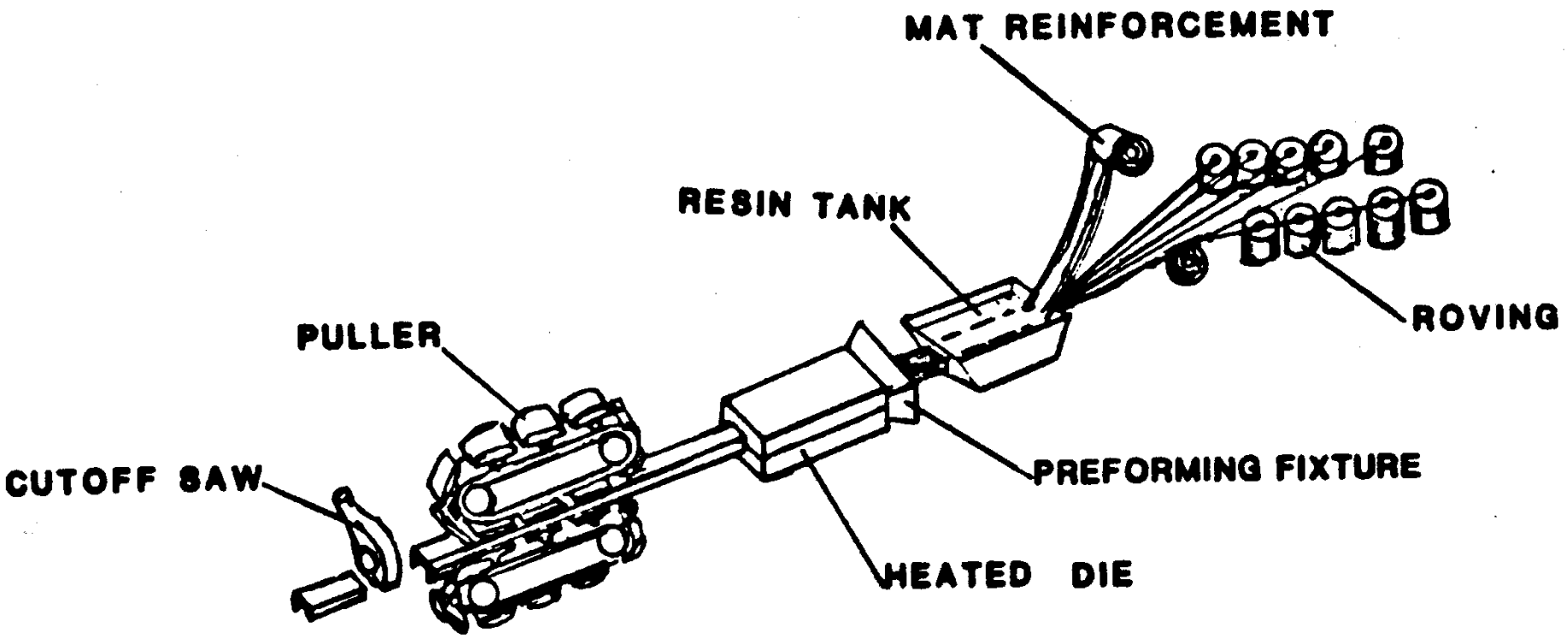


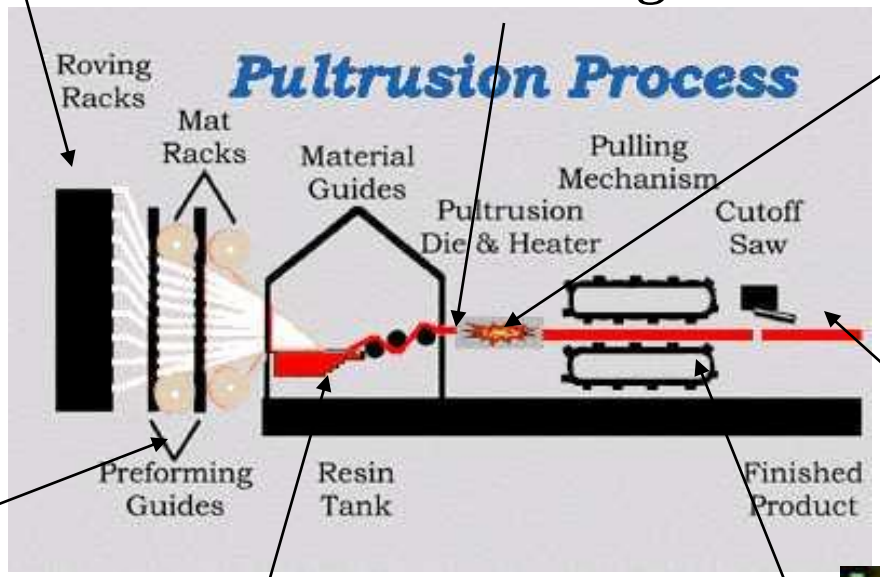

**Figure 1. Typical Pultrusion Process [1].**

Fiber let-off

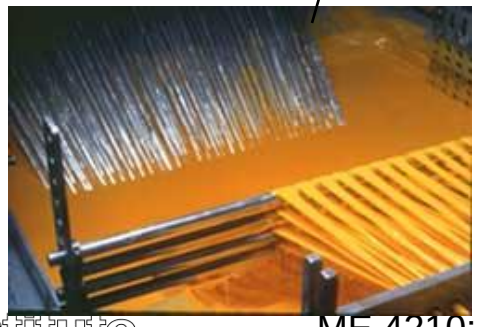
Preforming

Curing die

Fiber guides




Cut-off saw



Resin impregnation

Puller

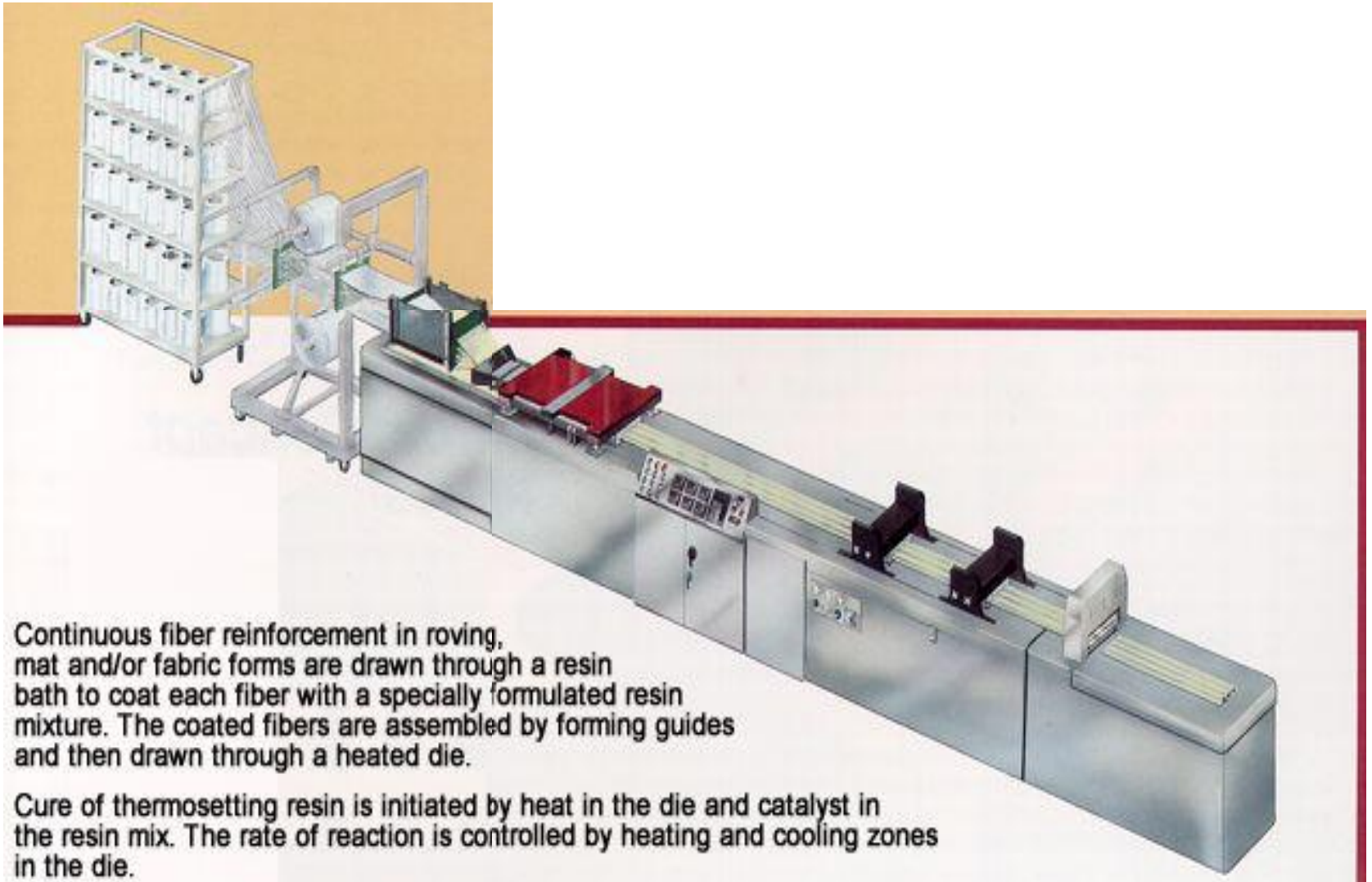
# Reinforcements

- Rovings
  - continuous
  - bulk

- Continuous strand mat
- Chopped strand mat

- Surface veils

# Continuous fiber reinforcement pultusion

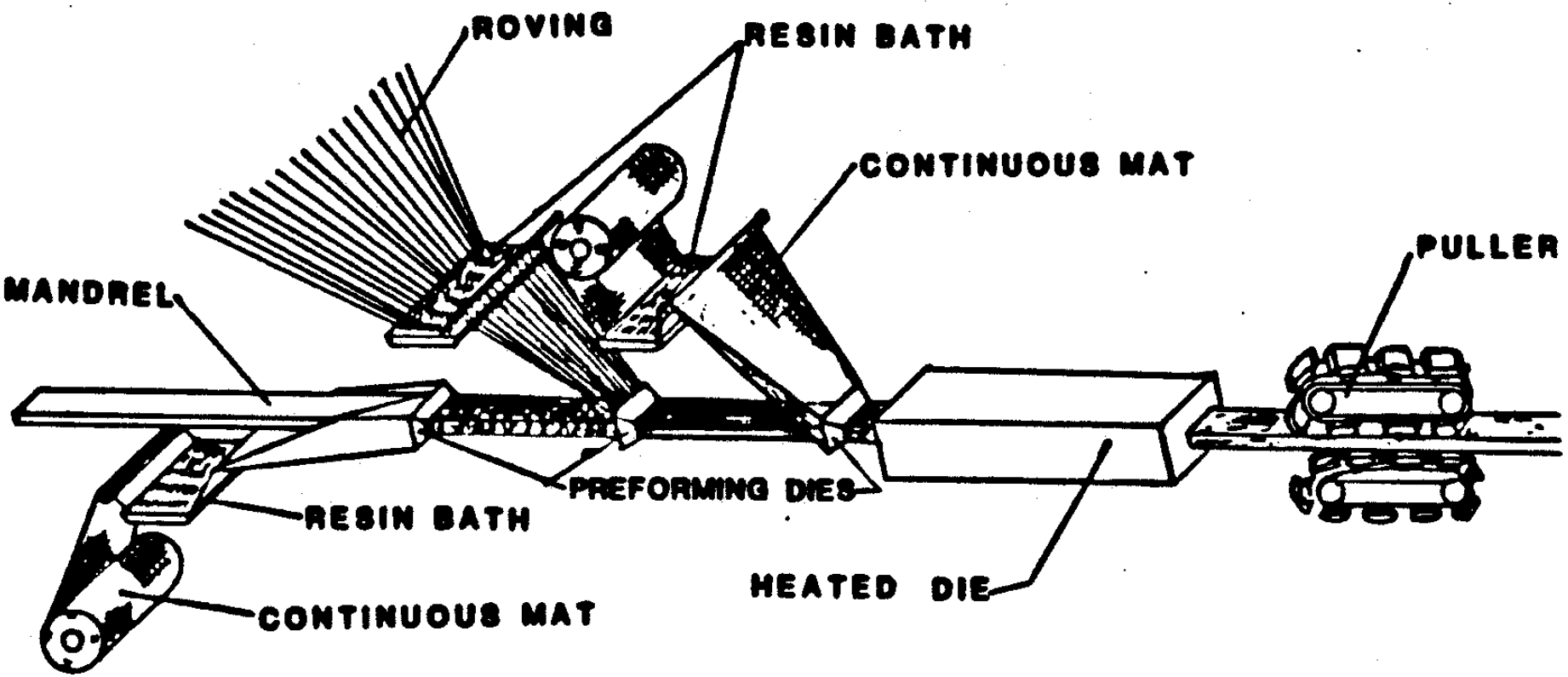


Continuous fiber reinforcement in roving, mat and/or fabric forms are drawn through a resin bath to coat each fiber with a specially formulated resin mixture. The coated fibers are assembled by forming guides and then drawn through a heated die.

Cure of thermosetting resin is initiated by heat in the die and catalyst in the resin mix. The rate of reaction is controlled by heating and cooling zones in the die.

The resulting high strength profile is cut to length, ready for use as it leaves the pultrusion machine.

# Hollow structure pultrusion process



# RIM (Reaction Injection Molding) pultrusion

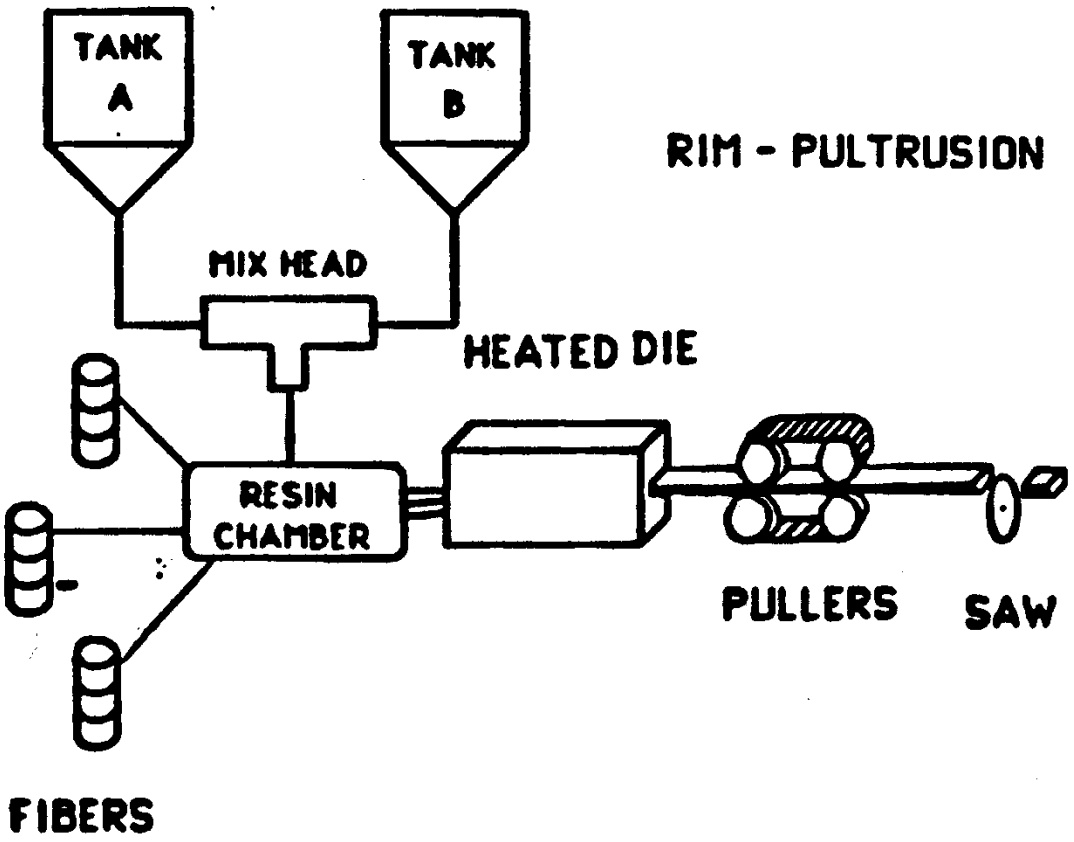



**Figure 3. RIM (Reaction-Injected Molded) Pultrusion [3].**

# Exploded view of pultruded composite

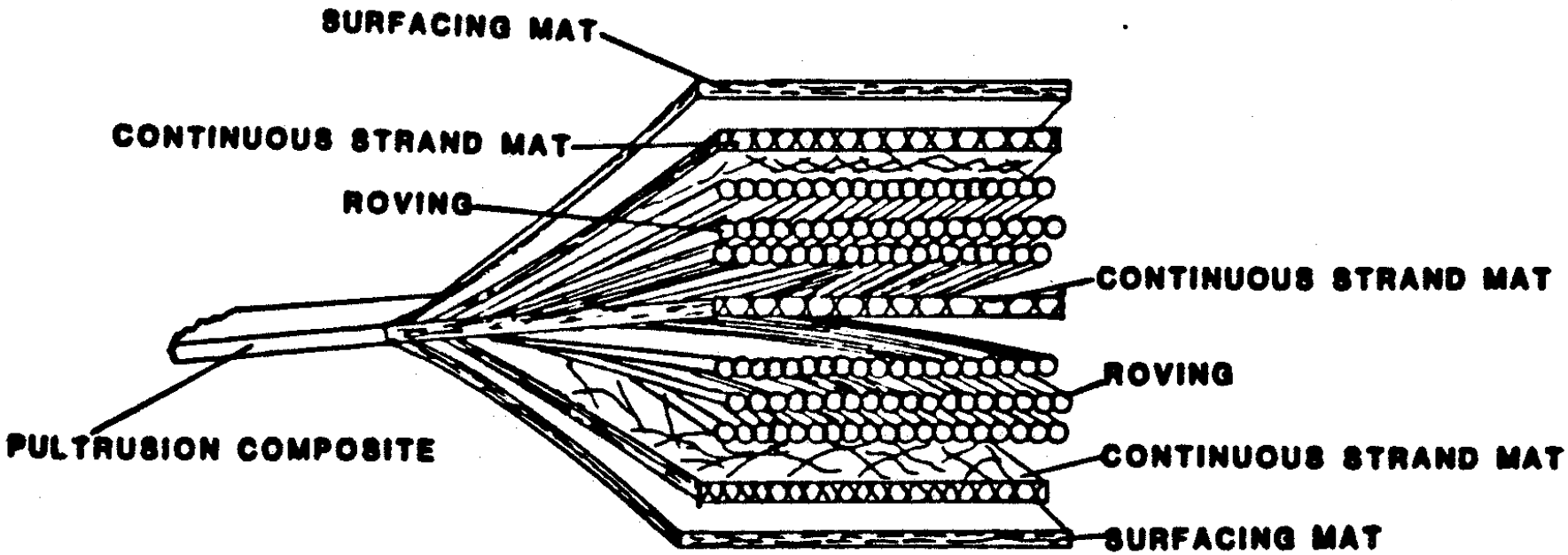
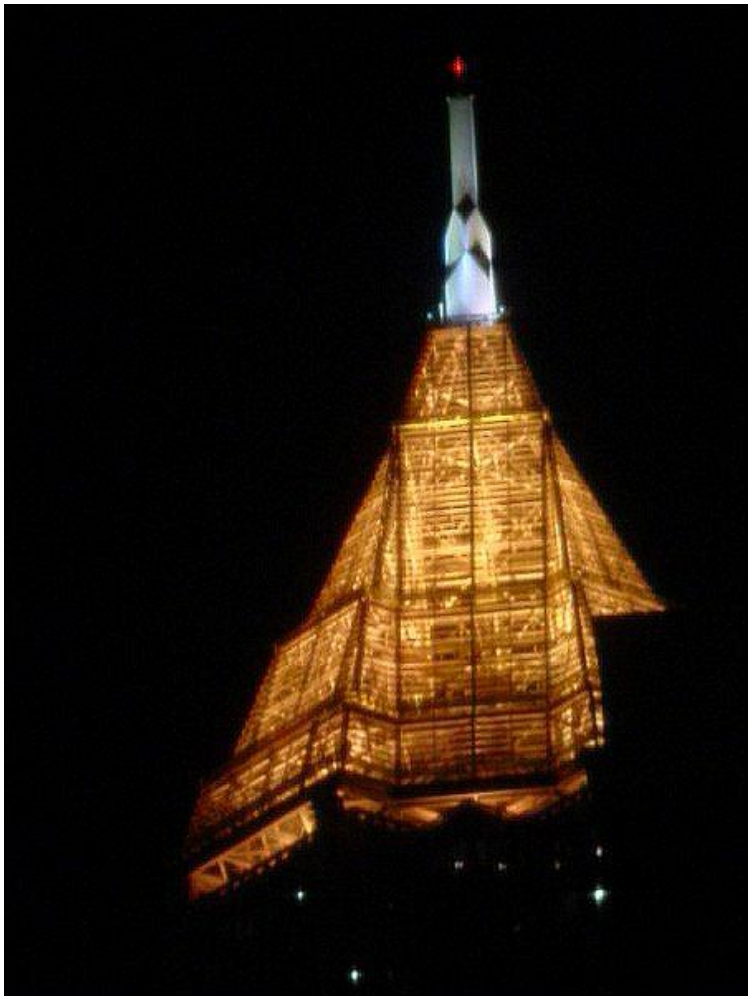



**Figure 6. Exploded View of Pultruded Composite [1].**

# Bank of America Building Spire



# Pultruded bridges

# Pultruded I-beam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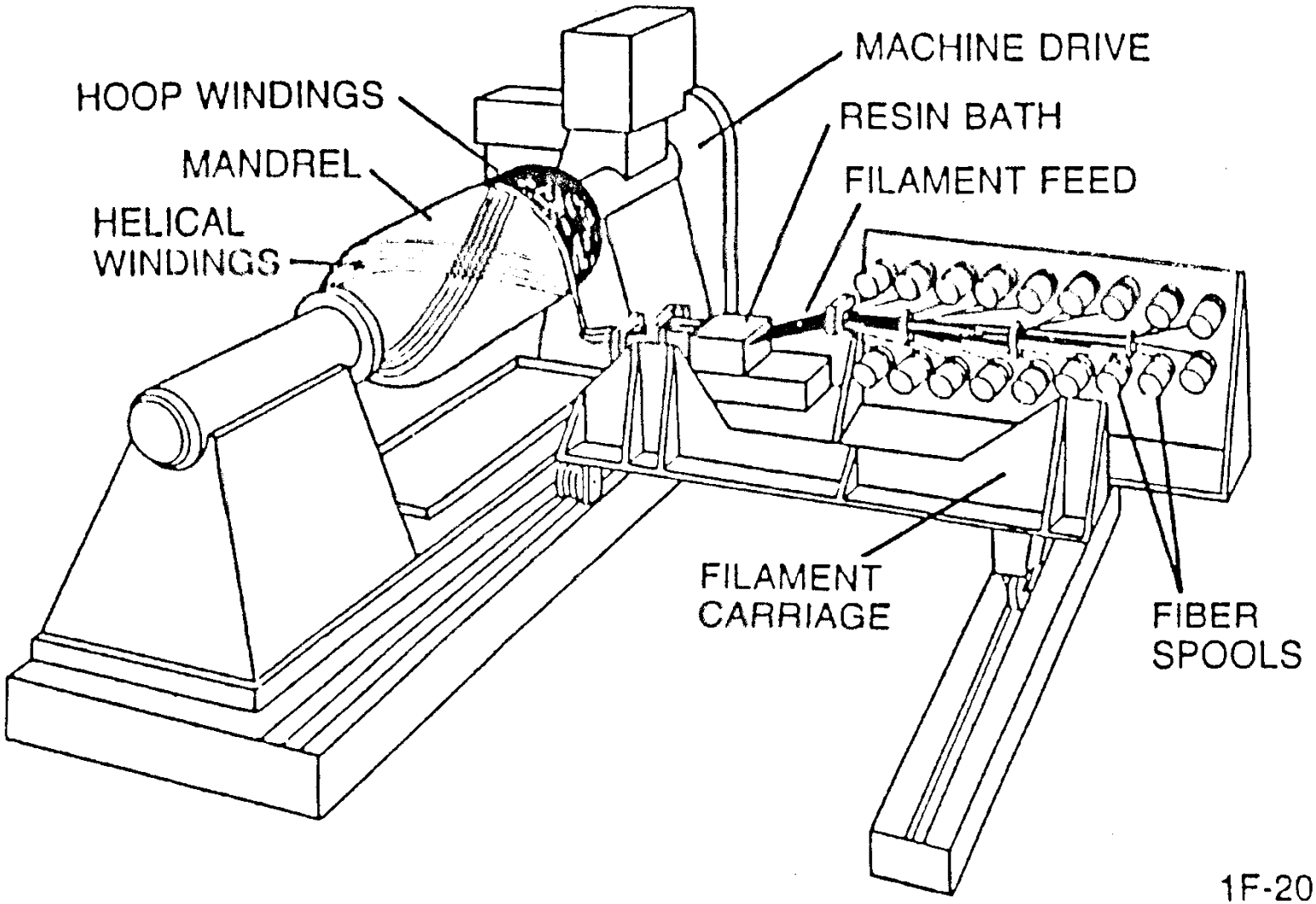
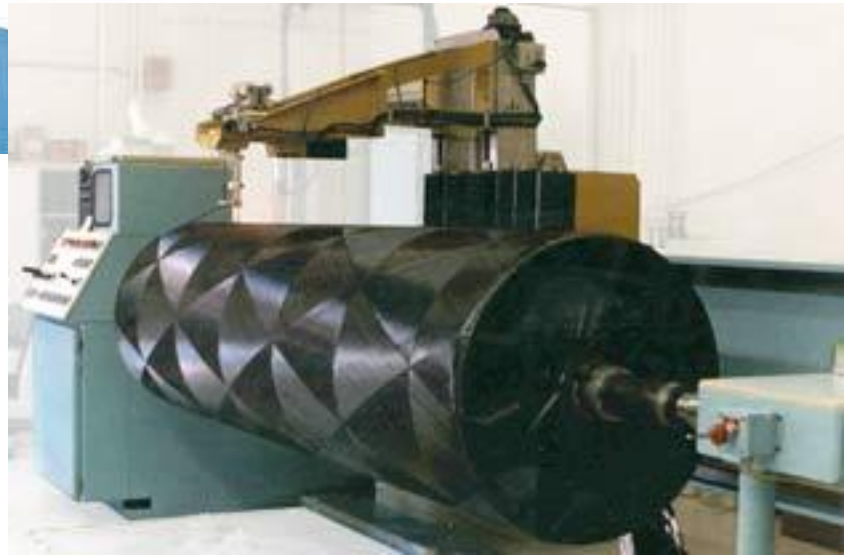
Strongwell's pultruded double-webbed internally-flanged 36-inch composite beam incorporates carbon fiber in the top and bottom flanges.

# Filament winding



# GT's machine

# Filament winding machines

# Delta IV Rocket faring mandrel

# Reusable Mandrels

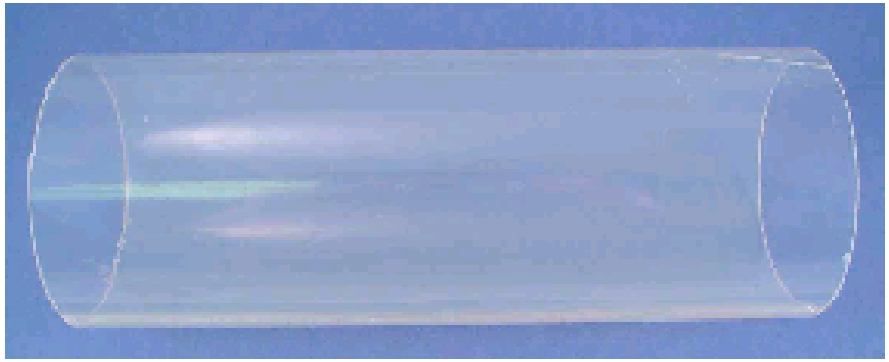


Figure 1: A Veriflex™ cylinder is fabricated.

Figure 2: The cylinder is placed in a clamshell mold, heated, and blow-molded into a complex-shaped mandrel.

# Reusable Mandrels

Figure 3: The mandrel is cooled below the transition temperature resulting in a rigid mandrel.

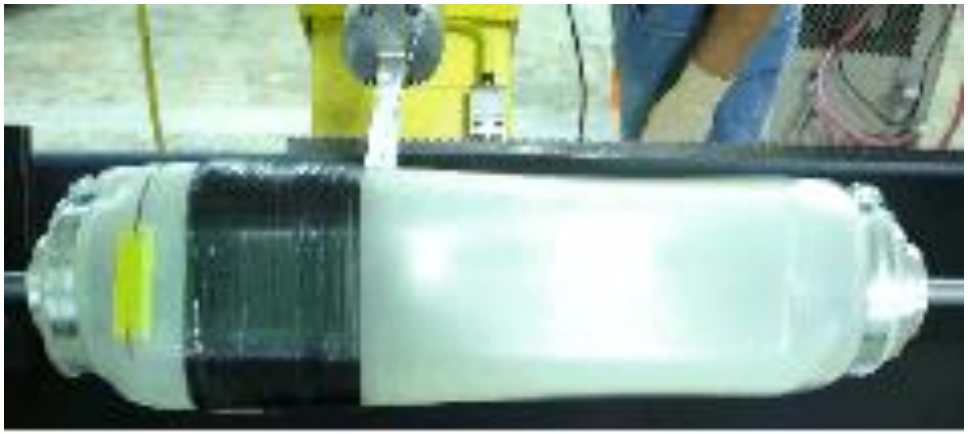


Figure 4: The mandrel is filament-wound and then cured.
The cure process for the composite does not affect the mandrel.

# Reusable Mandrels

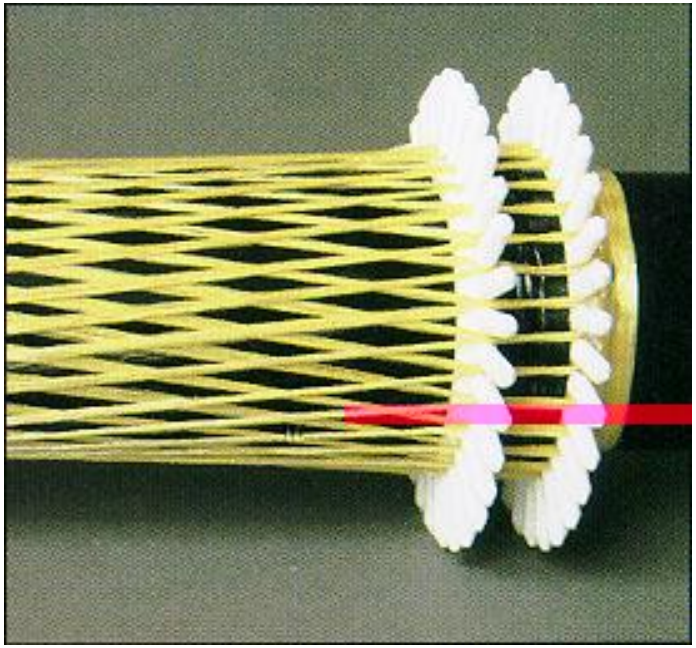
Figure 5: After the composite is cured, the Veriflex™ mandrel is heated above its activation temperature. The Veriflex™ then becomes pliable and is removed. The transition temperature does not affect the composite.

Figure 6: The complex part is completed. The cylindrical Veriflex™ mandrel, which returned to its "memory" shape while above its transition temperature, can be reused.

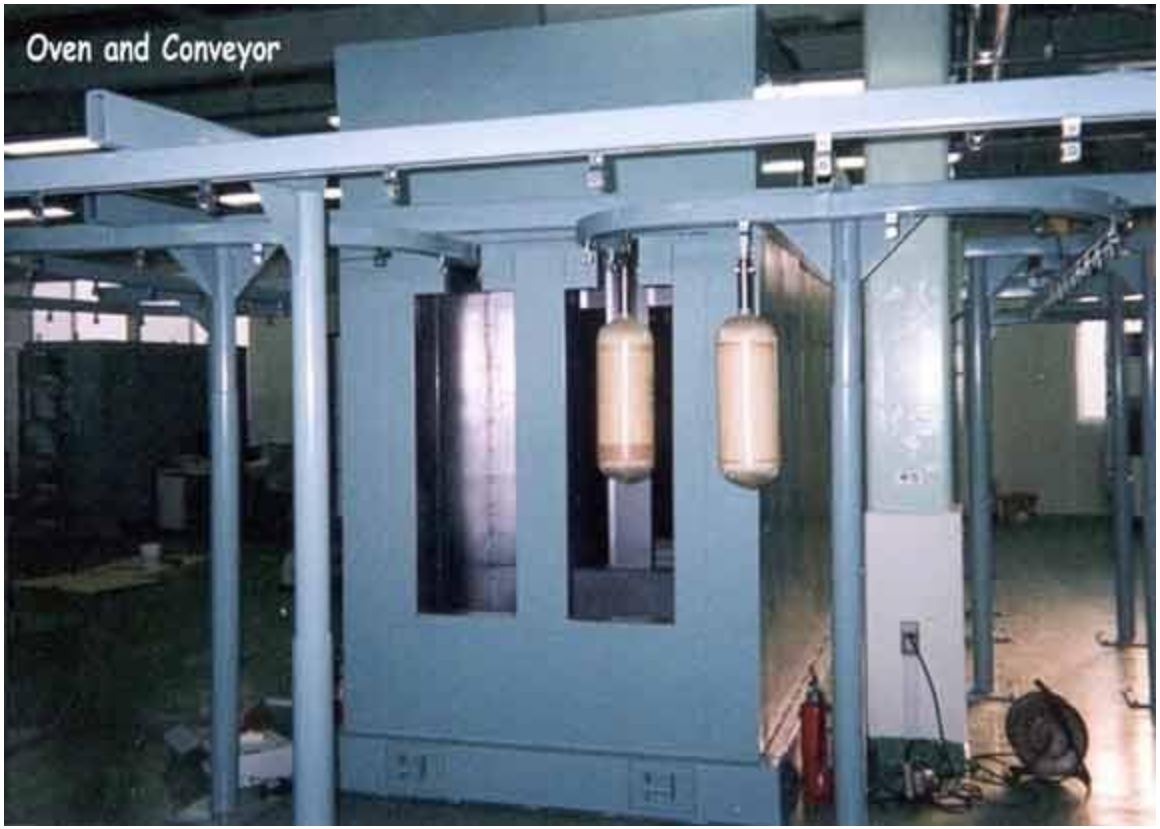
# Creel tensioners


# Integral head resin wet-out bath

# Winding pins for low angle winding



# Continuous curing oven



# Layout of a computer-controlled filament-winding machine

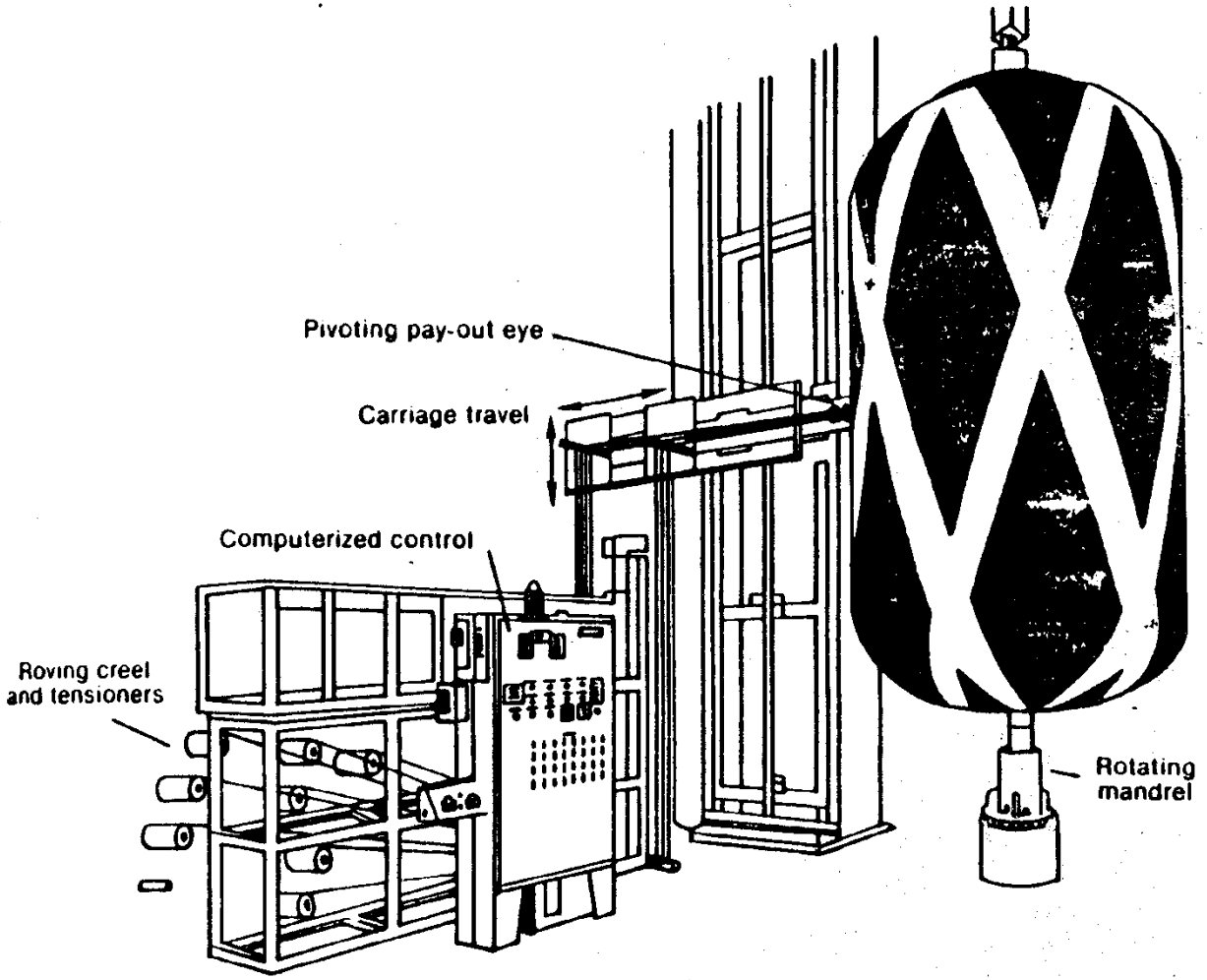


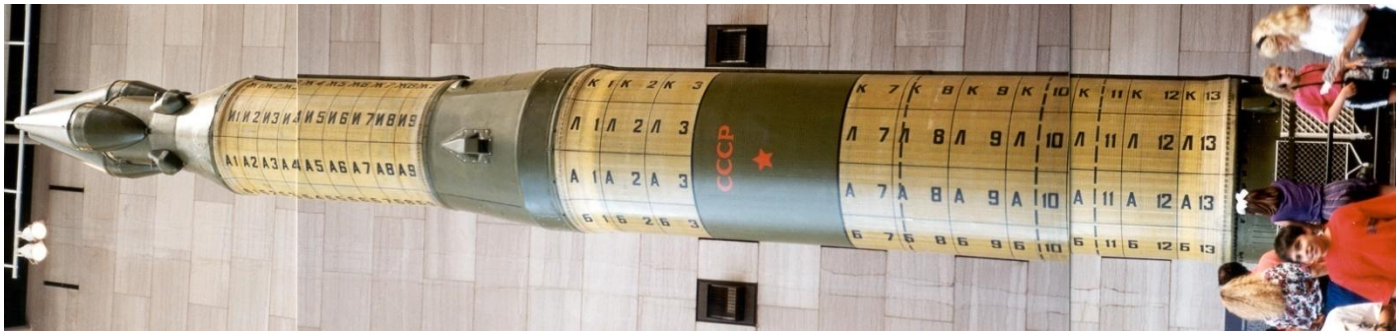

Fig. 9 Layout of a computer-controlled filament-winding machine

# Gas tanks

# Aerospace parts

F-16

Patriot missile




Soviet missile

# Rocket Motor Casings


# Tape laying – 787 fuselage


# Tape laying – 787 fuselage

# Composite motors

# Sporting goods


# Glass epoxy filament-wound 9-foot-diameter by 55-foot-long assembled railway tank car

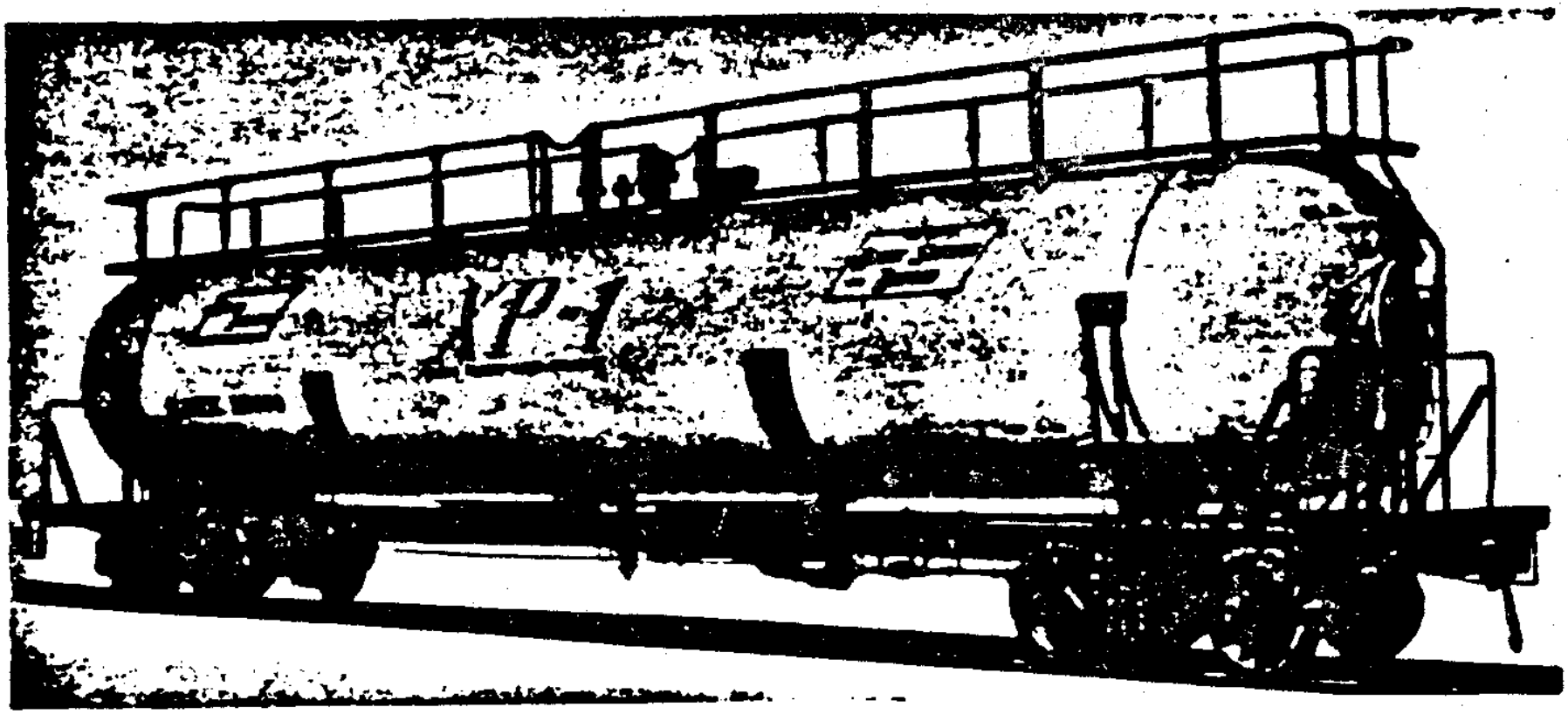


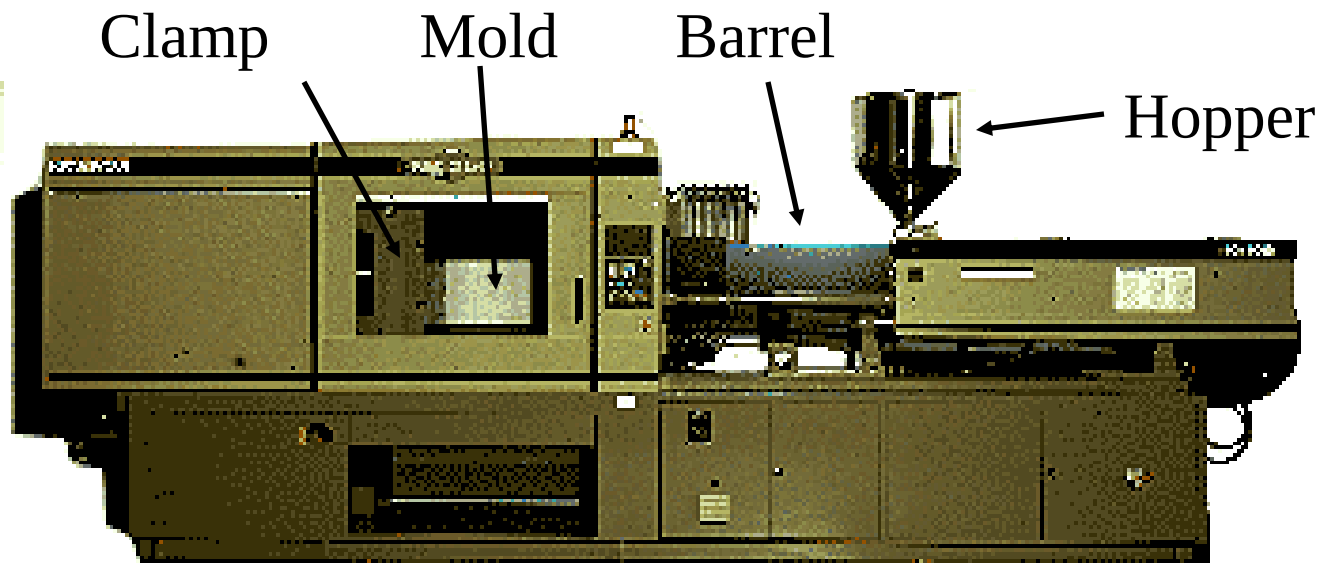

**Figure 5. Glass epoxy filament-wound 9-foot-diameter by 55-foot-long assembled railway tank car.**

# Pipe machine and cure oven

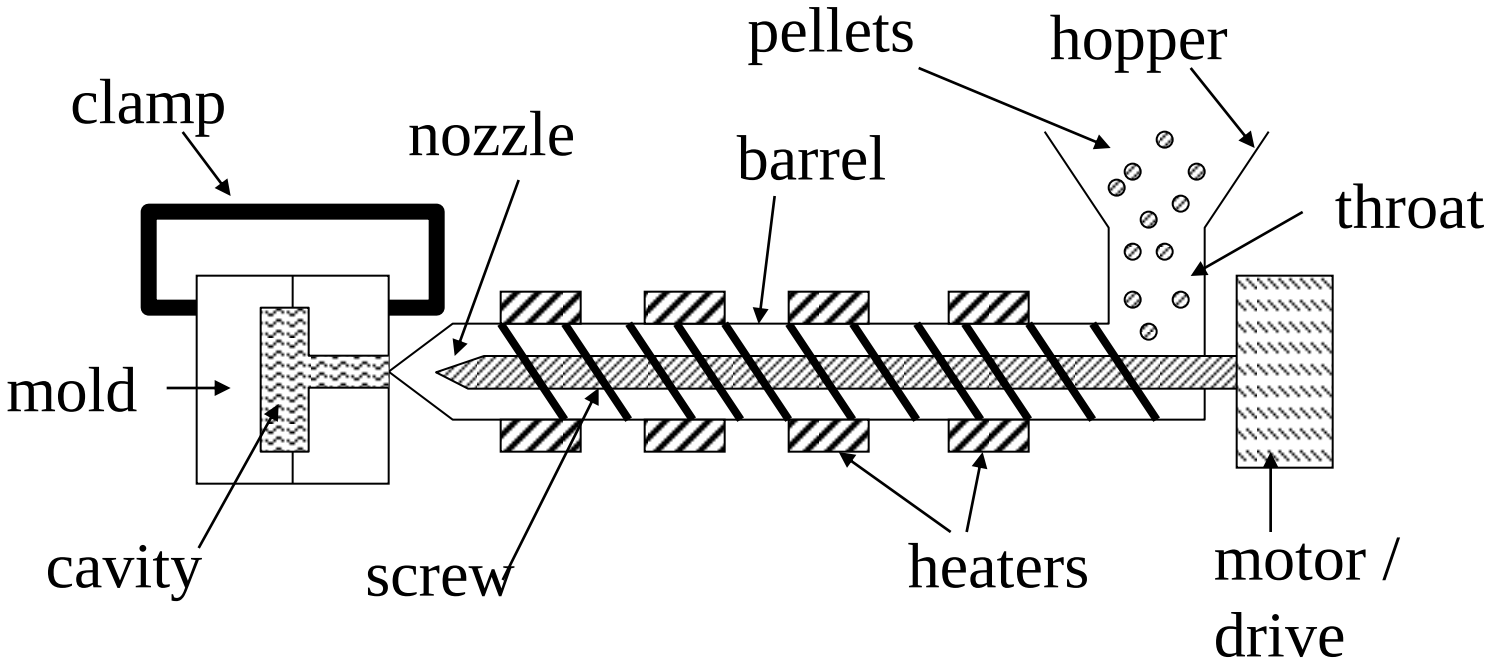

# Light pole


# Thermoplastics processing

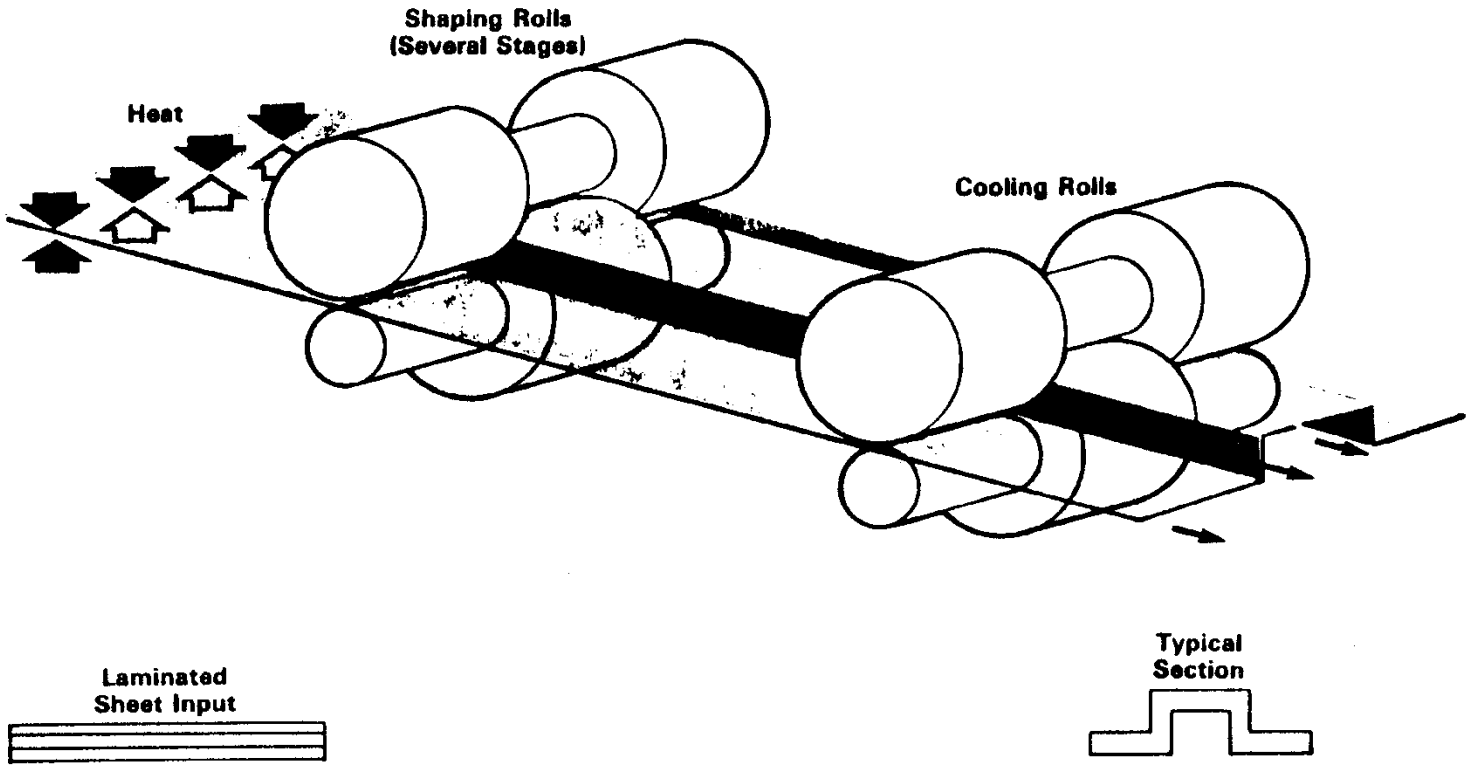
# Injection molding



# Injection molding



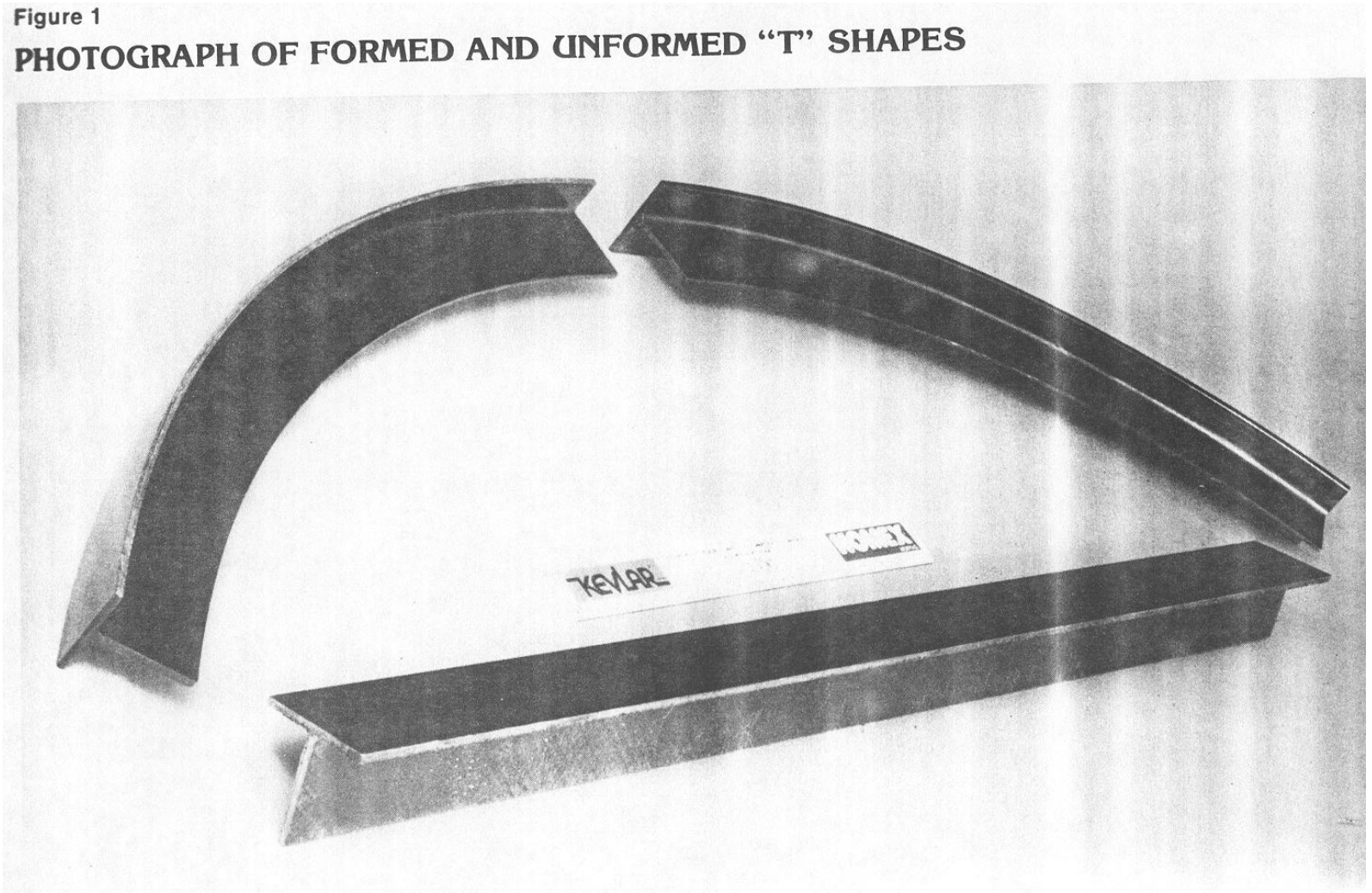
# Roll forming



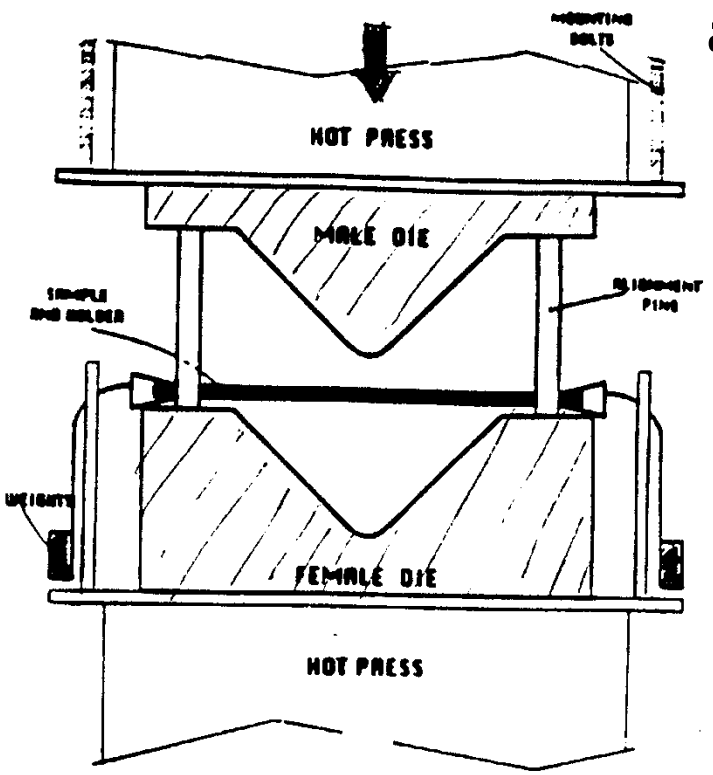
# Roll-formed part

Figure 1

PHOTOGRAPH OF FORMED AND UNFORMED "T" SHAPES

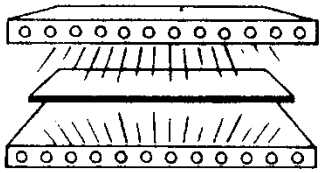


# Matched die forming

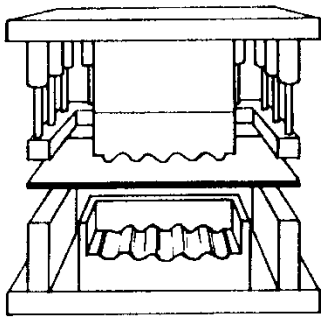


# Press forming of LDF
## (long discontinuous fibers)

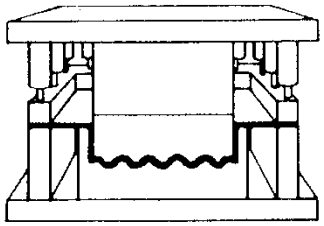
Heat material



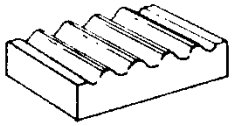
Transfer into heated dies



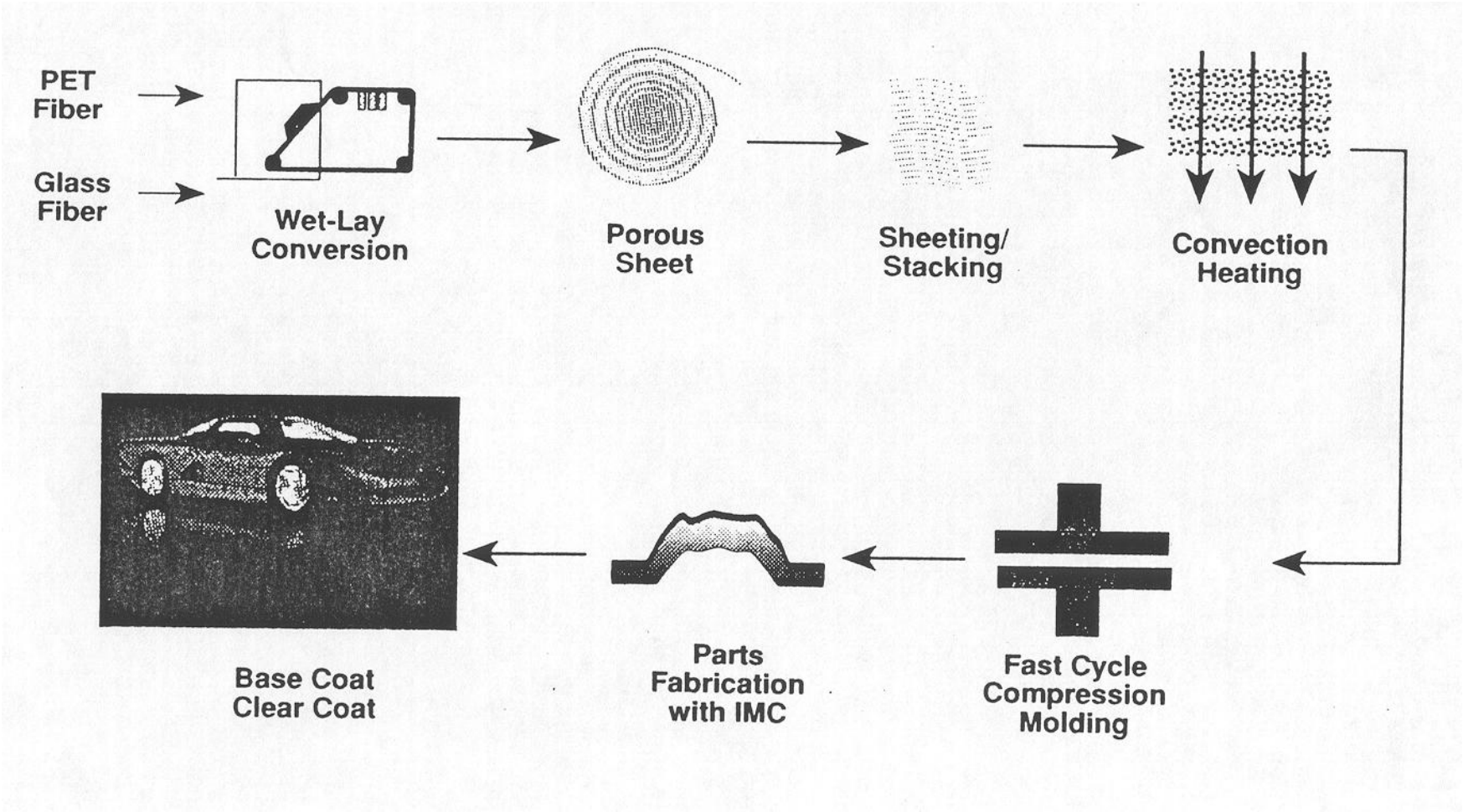
Clamp and thermoform



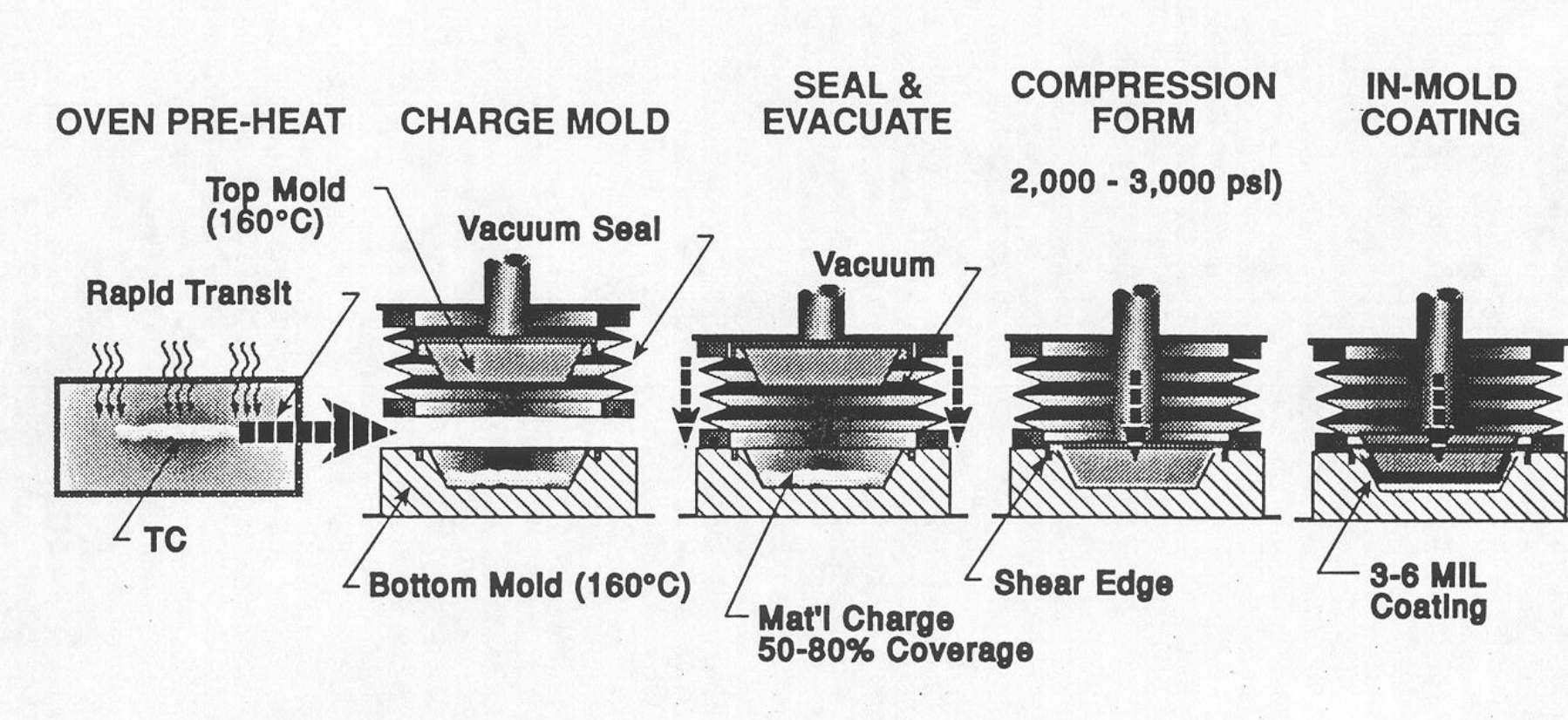
Formed component after trimming



# Compression molding



# Compression molding sequence



# Hydroforming

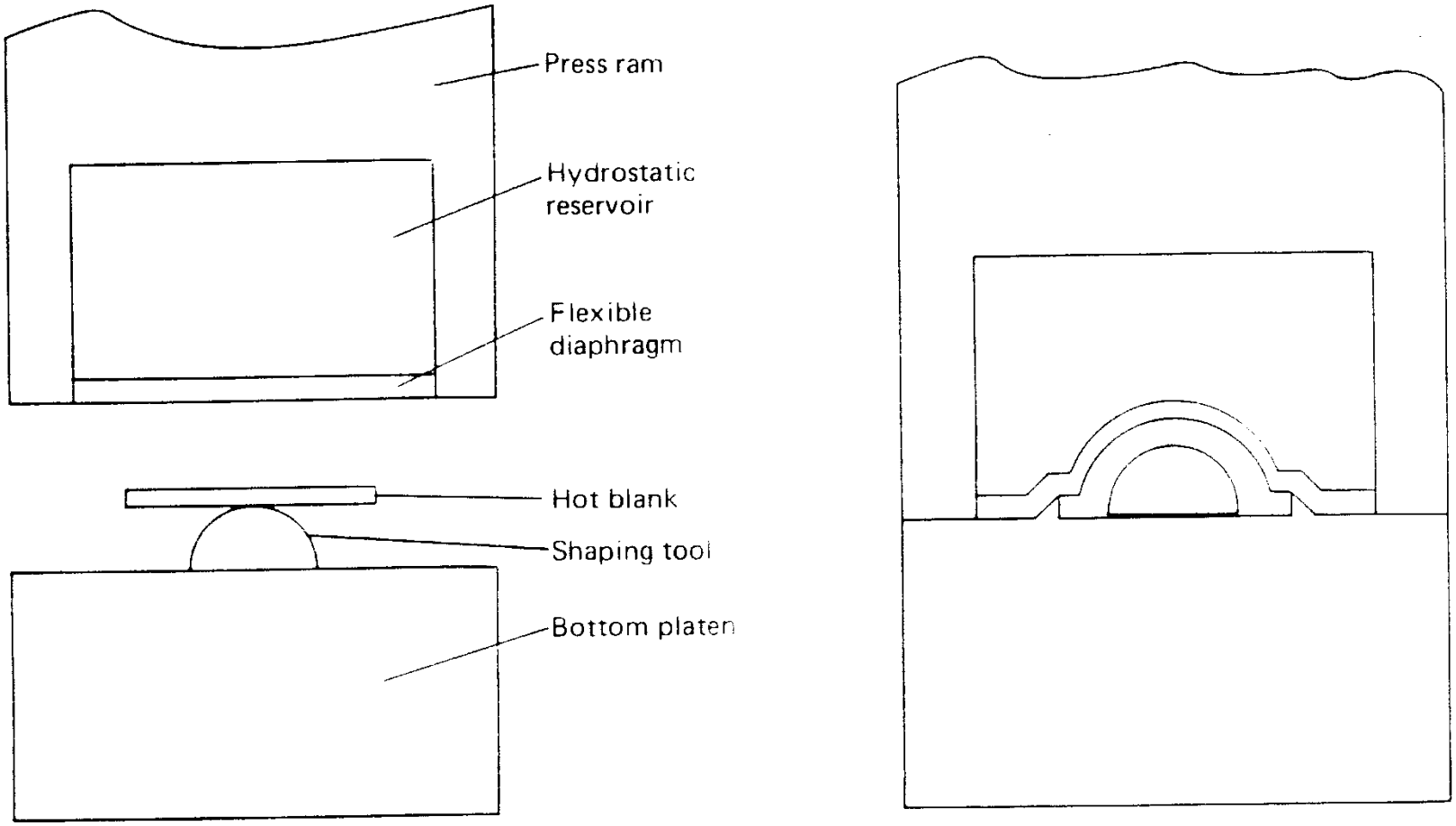
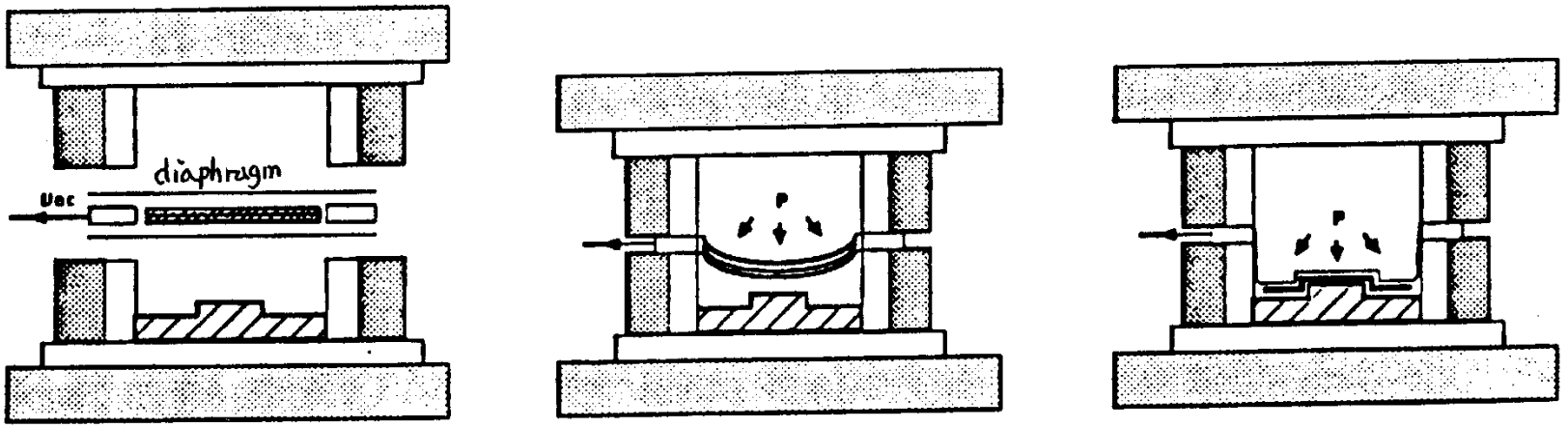
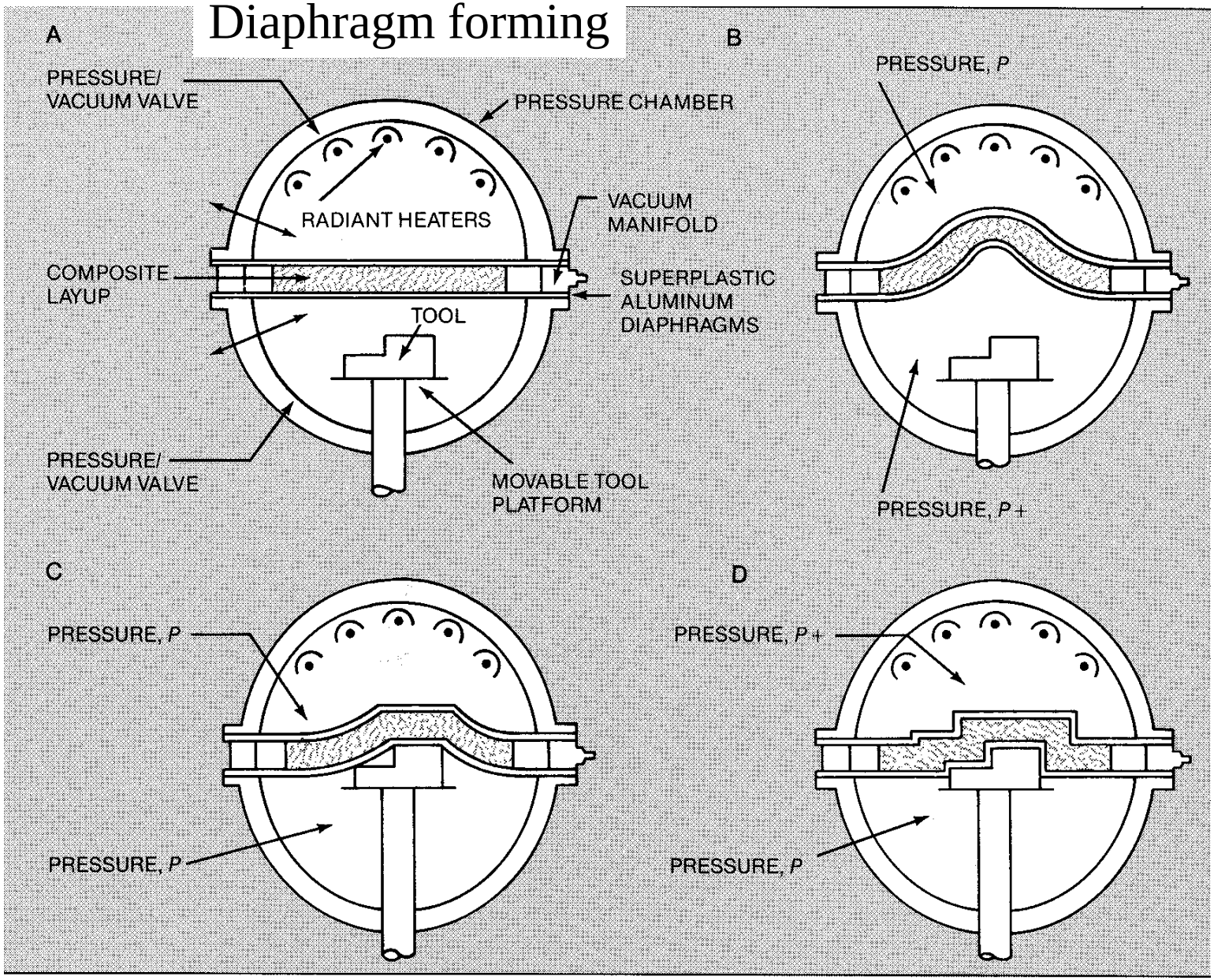



**Fig. 11** Hydroforming

# Diaphragm forming



# Diaphragm forming



# Vacuum forming in autoclave

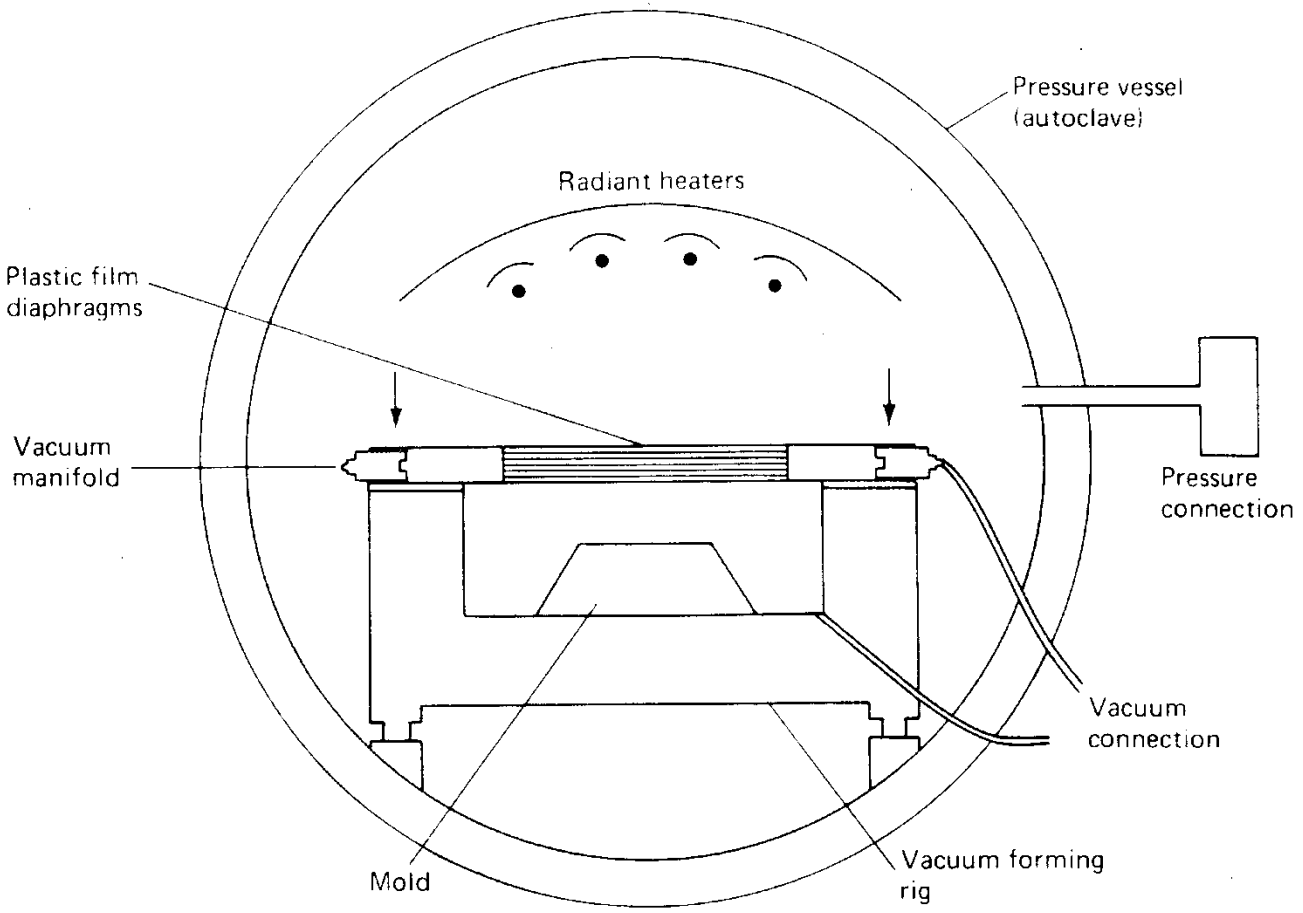
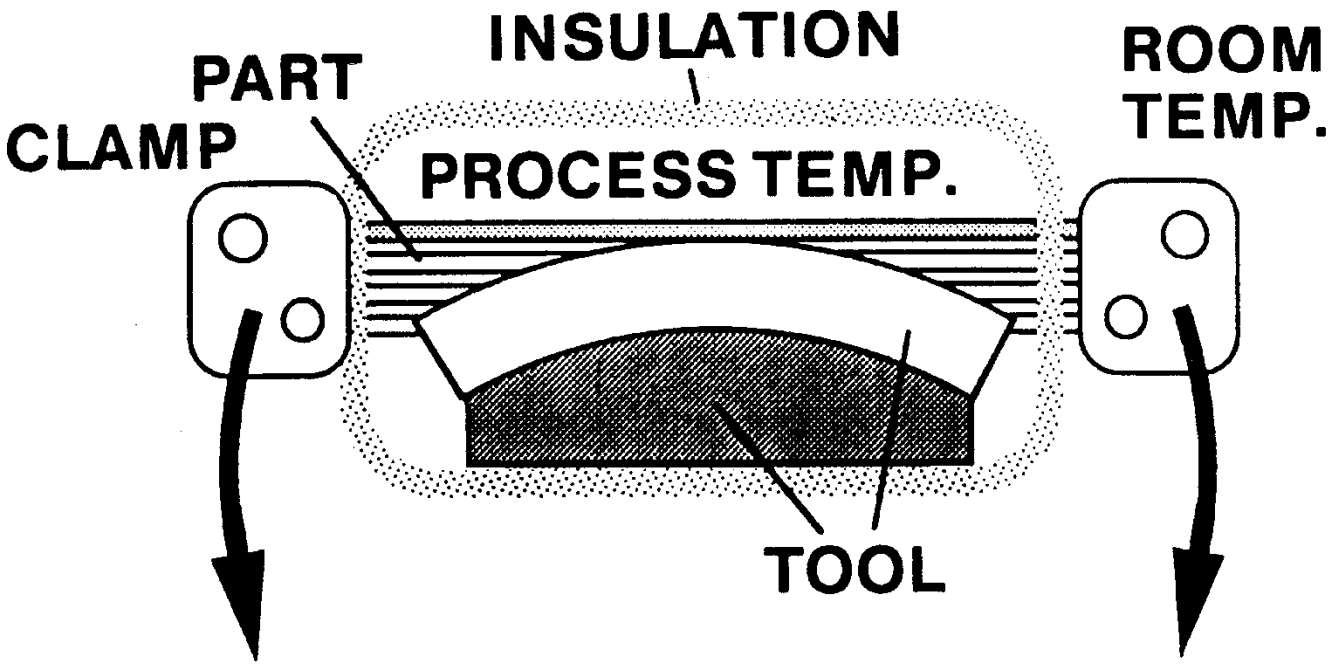



**Fig. 17** Vacuum-forming fixture design for use in autoclaves

# Stretch forming



# Tape laying

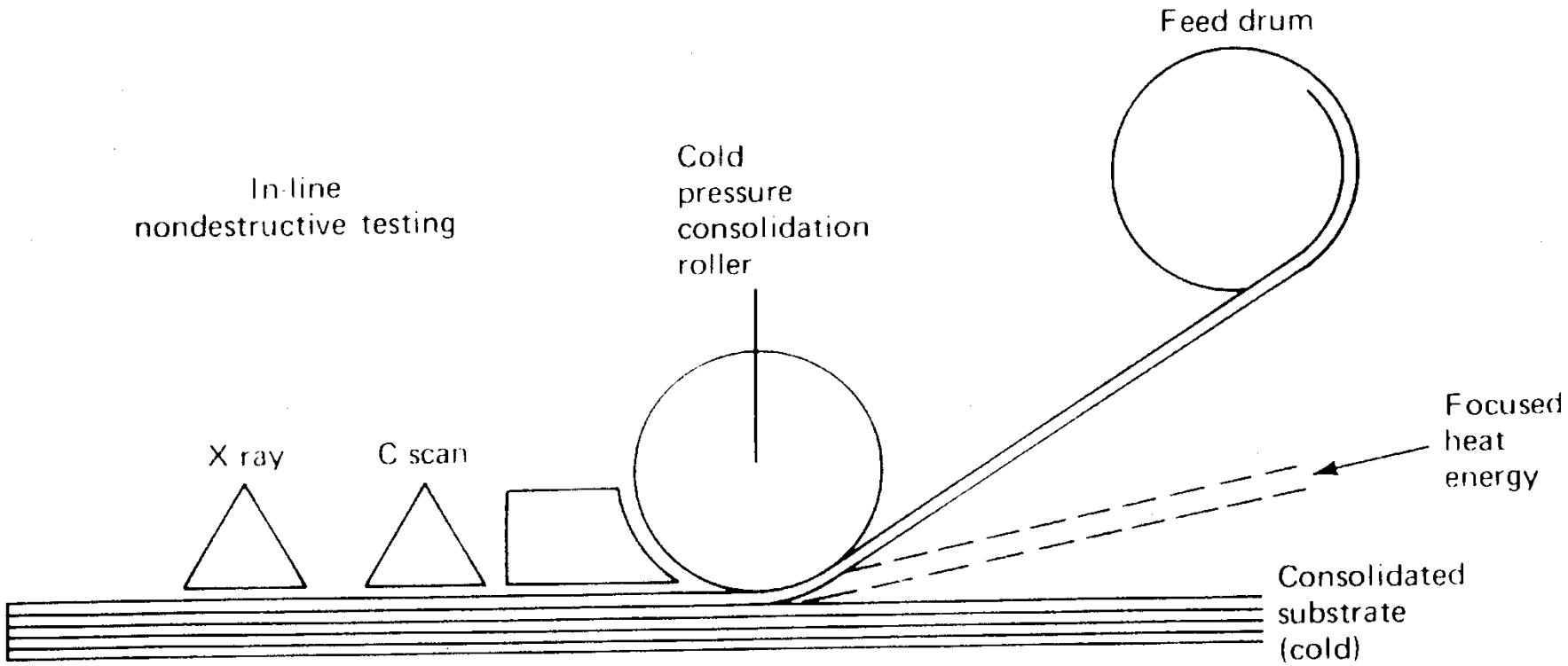



**Fig. 12** Automated tape-laying process

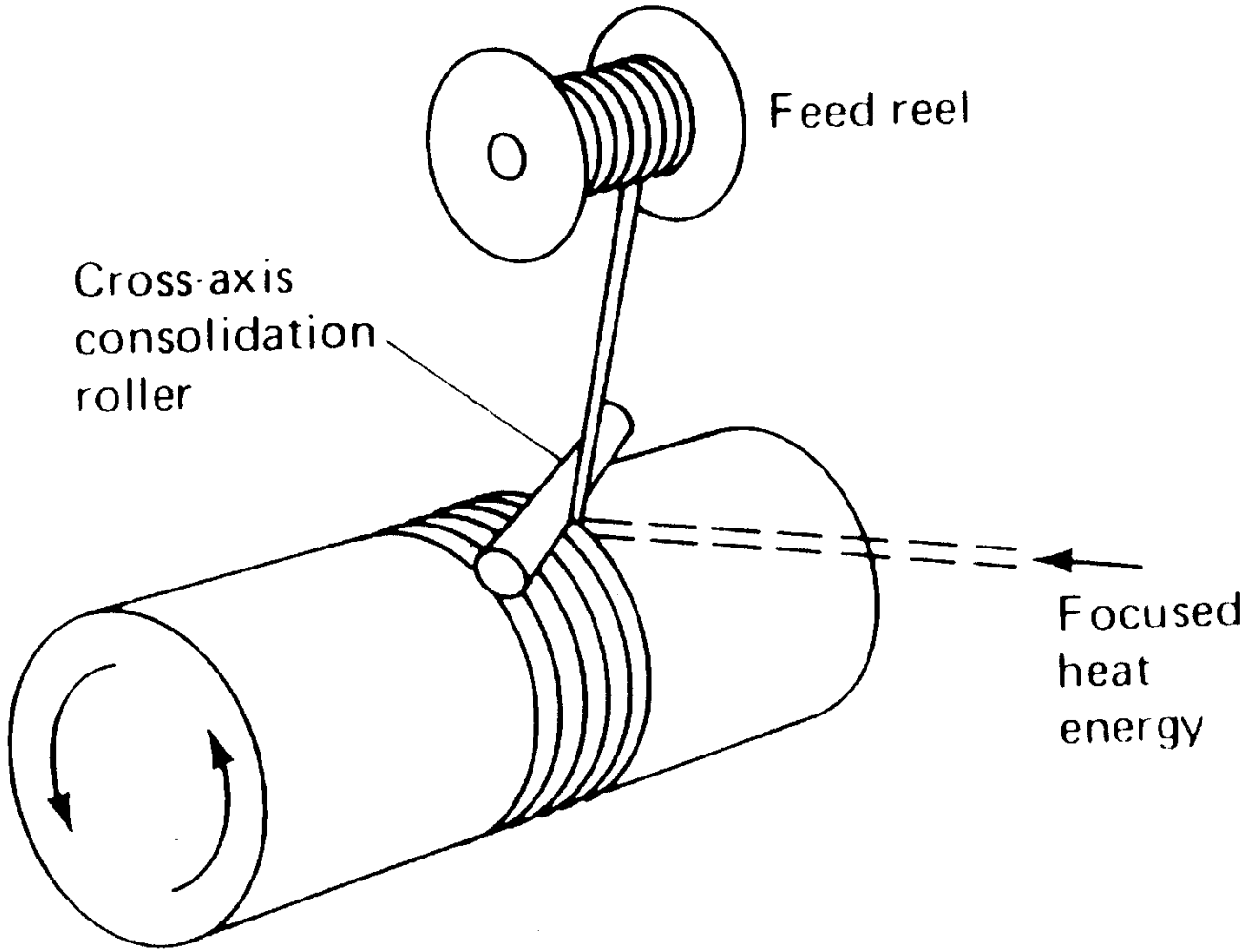
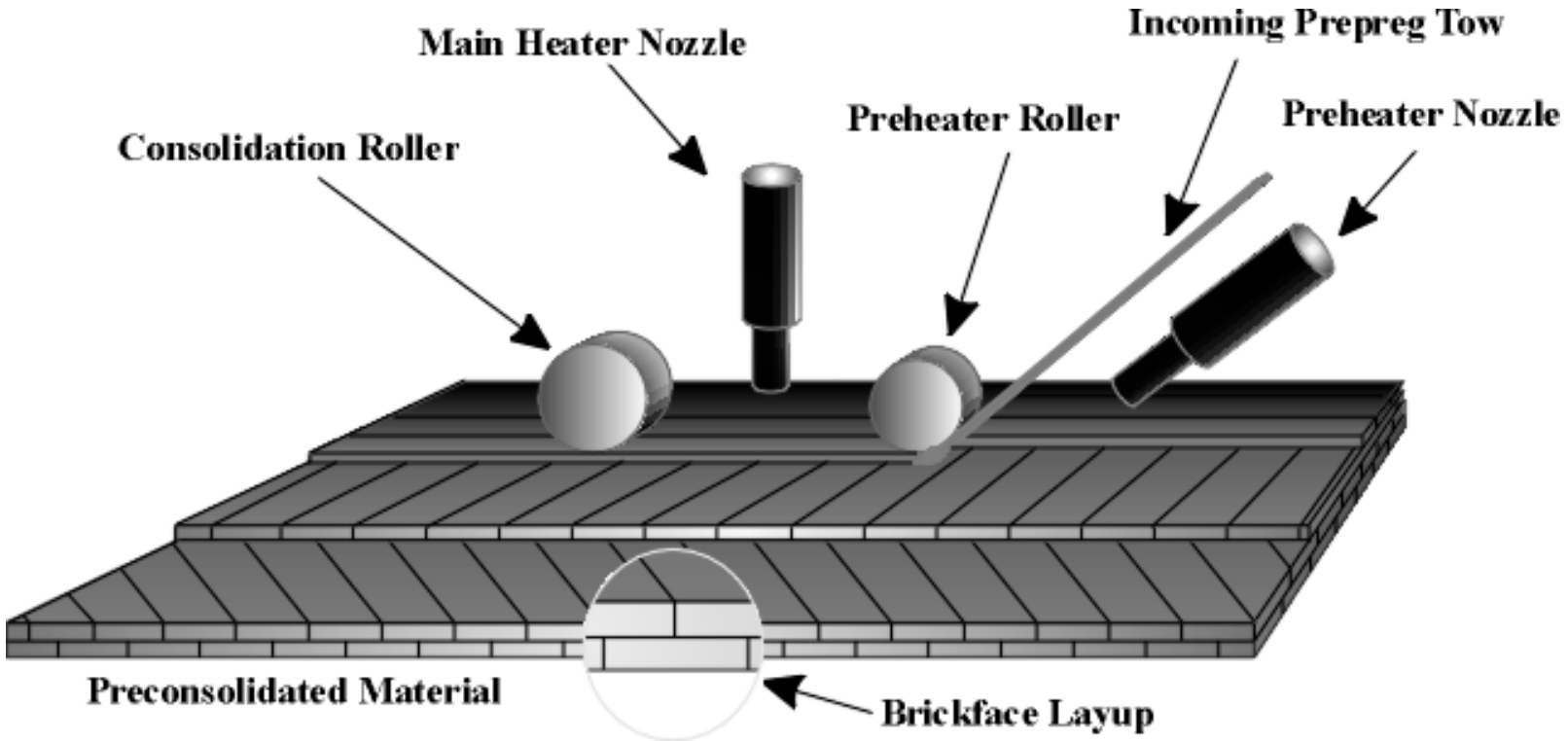
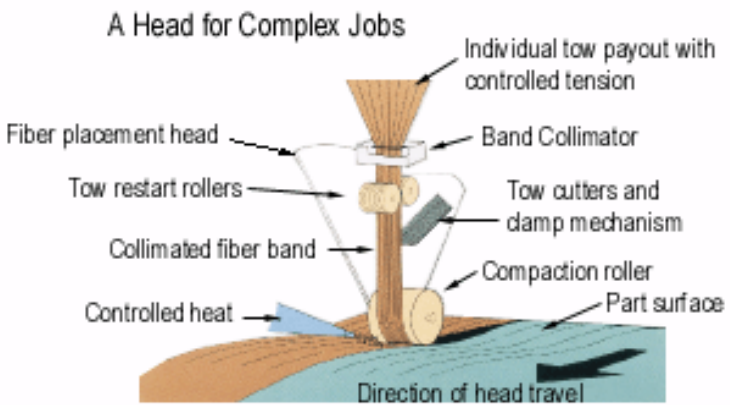



**Fig. 13** Thermoplastic filament winding with continuous consolidation

# Automated Tow Placement - Thermoplastics

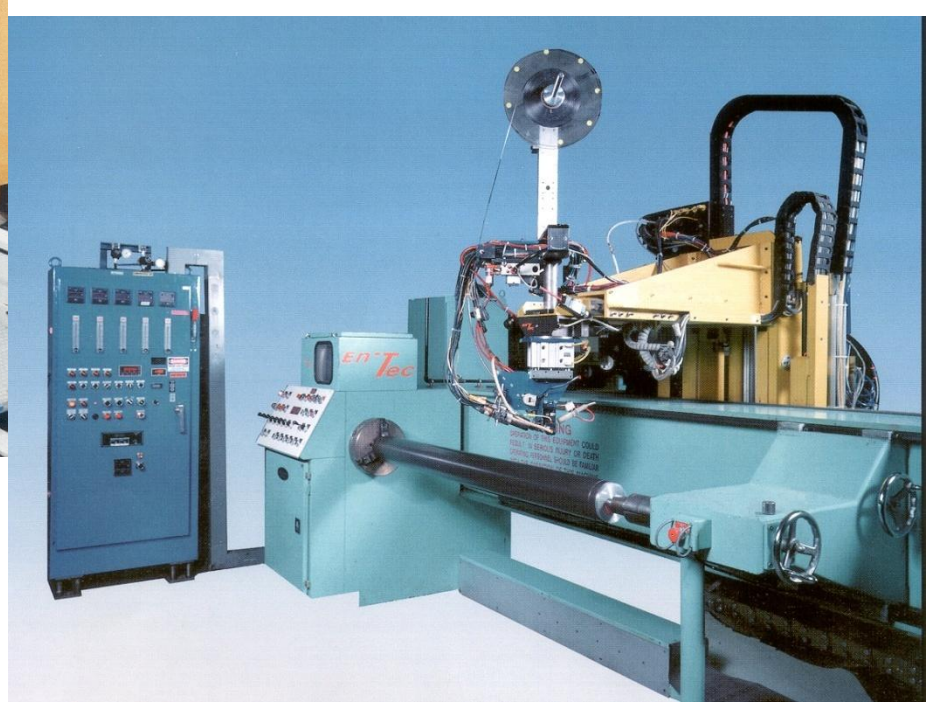


# Robotic thermoplastic ATP machine

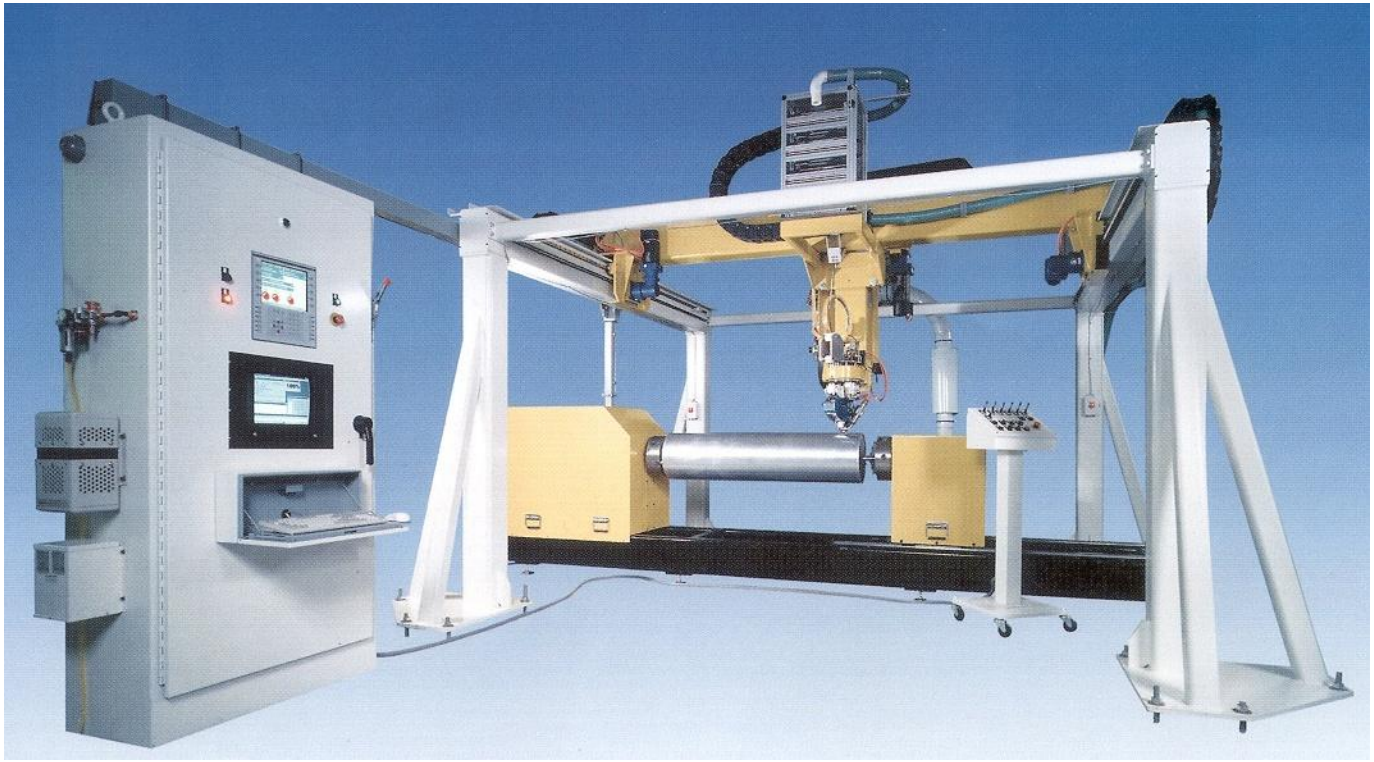



NASA Langley

# Filament winding thermoplastic ATP machines



# Filament winding thermoset ATP machine



# Large ATP machine

# Typical parts