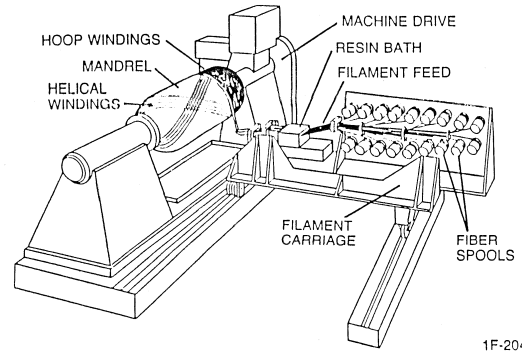


# Filament Winding

ver 1

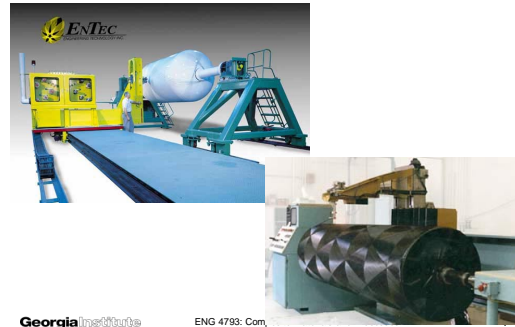


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# GT's machine



# Filament winding machines



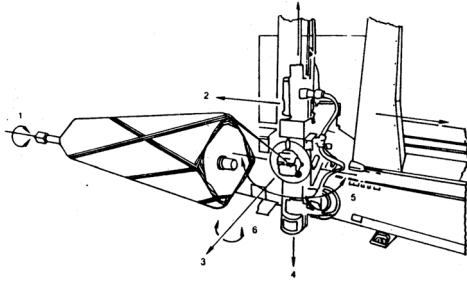
# Creel tensioners



# Integral head resin wet-out bath



Simulated, tapered box beam wound on six-axis computer-controlled filament winder. Actual machine motion indicated by arrows

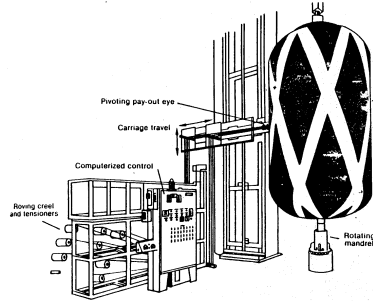


**Fig. 10** Simulated, tapered box beam wound on six-axis computer-controlled filament winder. Actual machine motion indicated by arrows.

### Wet winding box-like structures

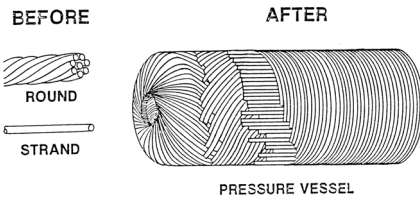


### Layout of a computer-controlled filament-winding machine



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

### Workpiece Geometry



### Spherical pressure vessels



**Figure 6** Filament-wound spherical pressure vessels.

### Gas tanks



### Aerospace, Hydrospace, and Military Applications

- Rocket motor cases
- Rocket motor insulators
- Solid propellant motor liners
- Nose cones for space fairings
- Rocket nose cones
- Rocket nozzle liners
- Jato motor
- APU turbine cases
- High-pressure bottles (gas or liquid)
- Vacuum cylinders
- Torpedo launching tubes
- Rocket launcher tubes
- Flame thrower tubes
- Missile landing spikes
- Deep space satellite structures
- Radomes
- Igniter baskets
- Wing dip tanks
- Helicopter rotor blades
- Thermistors
- Liquid rocket thrust chamber
- Rocket exit cones
- Chemical rockets
- Sounding rocket tubes
- Tactical bombardment rockets
- Tent poles
- Heat shields
- Artillery shell shipping grommet
- Artillery round-protective cones
- Submarine fluid pipes
- Submarine tanks and containers
- Submarine ventilation pipes
- Submarine hulls
- Underwater buoys
- Cryogenic vessels
- Electronic packages
- Submarine fairwaters
- Sonar domes
- Engine cowlings

### Aerospace parts



F-16



Patriot missile



Soviet missile

### Commercial Applications

- High-voltage switch gears
- Electrical containers
- Decorative buildings supports
- Valves
- Boat masts
- Lamp poles
- Race track railing
- Drive shafts
- Air brake cylinder
- Heating ducts
- Pontoons
- Irrigation pipes
- Oil well tubes
- Ladders
- Structural tubing
- Electrical conduit
- Water heating tanks
- Highway stanchions
- Printed circuit forms
- Circuit breaker housing
- High-voltage insulators
- Antenna/dishes
- Motor housing

### Sporting goods



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

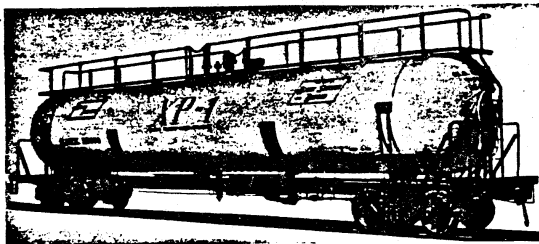
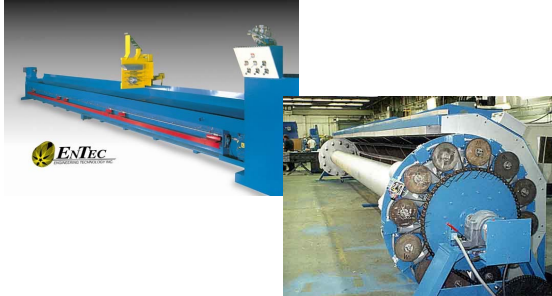


Figure 5. Glass epoxy filament-wound 9-foot-diameter by 55-foot-long assembled railway tank car.

### Large tanks



## Pipe machine and cure oven



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## Light pole



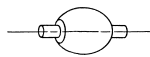
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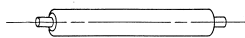
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## Typical Tools & Geometry Produced

### MANDRELS



PLASTER LEACHABLE



COLLAPSIBLE RUBBER

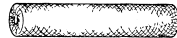


NON-REUSEABLE FOAM

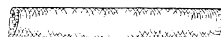
### WORKPIECES



SPHERICAL TANK



PRESSURE VESSEL



AIRCRAFT WING FLAP

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## Large self-driven mandrel



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## Delta IV Rocket Faring Mandrel

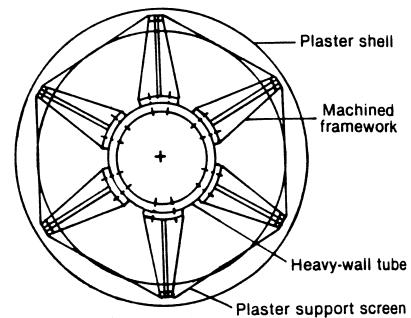


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## Framework for Plaster Mandrel



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**Fig. 8** Framework for plaster mandrel

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### Process Needs

- Wet Wind
  - Low viscosity
  - Long pot life
  - Resin should gel
  - Toxicity
- Advantages -- cheap, one step, no compaction
- Disadvantages -- poor resin control, mixing at plant, QC needed at plant
- Prepreg
  - High viscosity
  - Latent curatives
- Advantages -- no mixing or QC at plant, potential for high speed automated processing
- Disadvantages -- more costly, compaction needed

### Thermoset Resins

- Plus
  - small molecules react to form larger ones after part winding--easy processing
  - tight crosslinking provides strong, chemically hard, and thermally resistant glass
  - very easy to modify by blending, mixing, tweaking, and thumping
  - old, well known technology
- Minus
  - brittle
  - cure takes time and energy
  - may crack under thermal cycling
  - type of polymerization may cause volatiles which hurt performance

### Thermoplastic resins

- Plus
  - molecule in fully reacted--only heat and pressure needed to fuse
  - remeltable--flows and heals defects
  - possibility for fully automated, rapid manufacturing
- Minus
  - new emerging technology for winding
  - creeps or flows under stress and heat
  - no wet wind--only PREPREG form

### Conditions for Slipping or Bridging

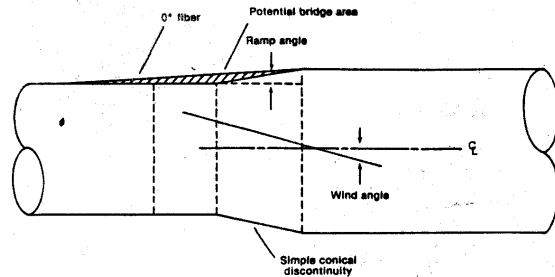
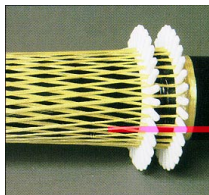
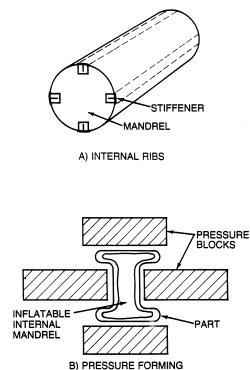


Fig. 7 Conditions for slipping or bridging Georgia Institute of Technology ENG 4793: Composite Materials and Processes 28

### Winding pins for low angle winding



### Special Filament Winding Methods



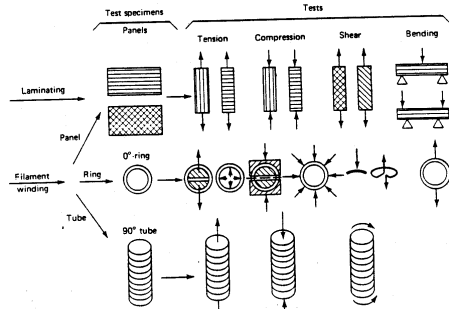
## Continuous curing oven



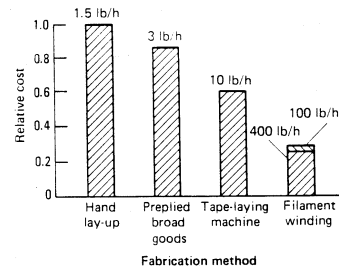
## Multiple spindle machine



## Methods of material fabrication and respective specimens and test methods



## Fabrication Method Costs



**Fig. 2** Relative costs of filament winding and other composite fabrication methods. Source: Ref 1

## Filament Winding Evaluation

- Investment
  - High Capital equipment
  - Modest tooling
  - Consistent parts
- Materials
  - Tailored for filament winding
  - Variety growing
  - New for thermoplastics
  - Multiple tows needed for economics
- Processing
  - Fast
  - Low labor (automated)
  - Hazards remote (sometimes)
- Quality
  - Only inside surface smooth
  - Voids likely without autoclave
  - Properties can be high
- Products
  - Low to high volume
  - Small to large areas
  - Simple contours (avoid undercuts)
  - Low cost possible