Composite Tank Development

- Cryogenic fluid containment
- Storage of chemically unstable fluids

Background of Technology Needs

- Need for reliable, lightweight fuel and oxidizer tanks
  - Engineered to match operating environments
  - Designed to match operating temperatures and pressures, loads, impact resistance, chemical compatibility, permeability, etc.
- Need for cost-effective and scalable manufacturing
- Apply tank technology to lines, ducts, and manifolds

Approach for Achieving Technology Goals

- Develop tooling methods for tank development
- Develop method for producing easily adaptable and scalable vessel liners
- Develop insulation layer or protective barrier for containers
- Identify appropriate fiber/resin system for composite overwrap structures

Tooling Methods

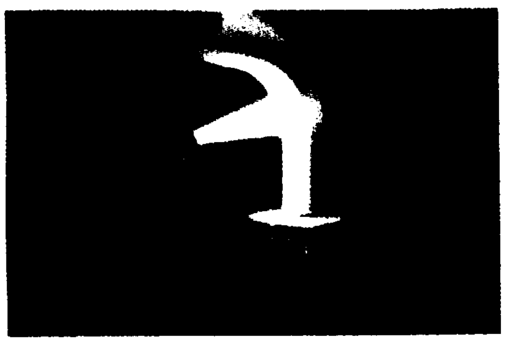
- Multi-segmented metallic
  - Lightweight (cast aluminum)
  - Better performance at higher temperatures (machined steel)
  - Must engineer thermal expansion mismatches between mandrel and liner

- Eutectic salt
  - Easily removed with water
  - Melts at higher temperatures
  - Proved useful for electroplating liners

Tooling Methods

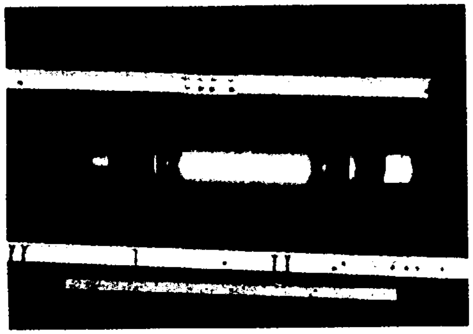
- Urethane foam
  - Ideal for inexpensive and rapid prototypes
  - Difficult to remove from smaller openings
  - Stable for cure cycle of composite overwrap
  - Poor performance for thermal spray

Thermoplastic Liner Options



- Thermally sprayed nylon-6, nylon-11, PVDF, FEP, ETFE, polyethylene
  - Nylon and polyethylene: Easy to process and compatible with fossil fuels
  - Fluorinated polymers: Harder to process but more compatible with hydrogen peroxide
- Extruded PVDF
  - Bonds to graphite/epoxy overwrap
  - Easily scalable to larger tanks
  - Chemically compatible if adhesive also compatible

Electro-Formed Metal Liner Options



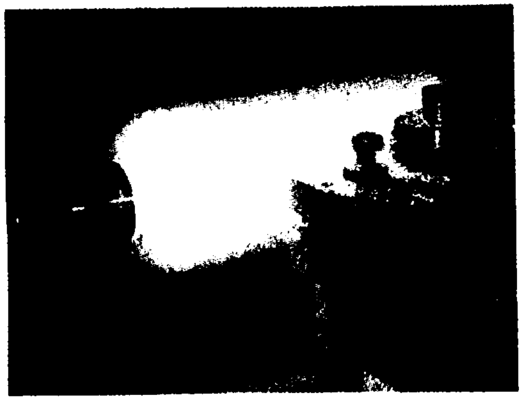
<u>Current Options</u>

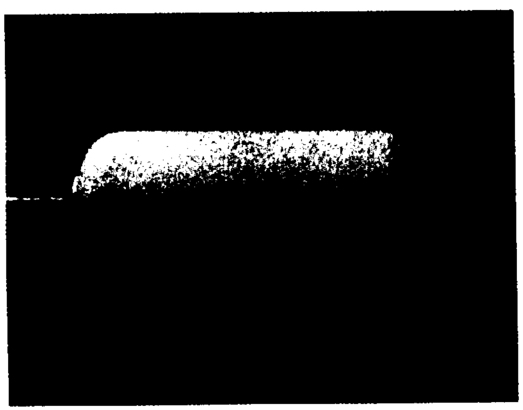
- Nickel and copper liner (5 & 15 mils) plated over silver-coated eutectic salt mandrel
  - Nickel ideal for liquid oxygen compatibility
  - Copper resists hydrogen embrittlement
- Tin
  - Potential for containing hydrogen peroxide
  - Thermally sprayed tin or aluminum provides conductive plating surface

<u>Future Options</u>

- High-temperature wax mandrels and segmented metallic mandrels

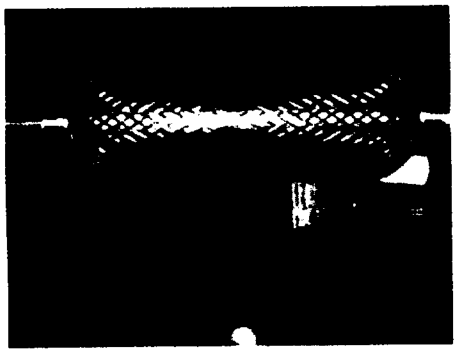
Thermal/Cryogenic Insulation

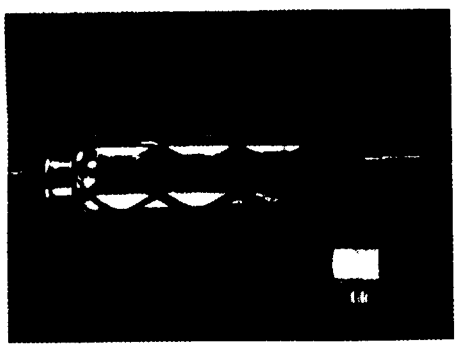




- Low-density urethane foam
  - Impact-resistant protective layer
  - Sprayable to approximate thickness
  - Castable in molds
  - Machineable to desired thickness
  - Variable density possible by tailoring formulation and process parameters
- Others materials can be used
  - Phenolic foam or PVC foam

Composite Overwrap





- Liner filament wound with impregnated fibers
  - Epoxy resin system chosen for application
    - Toughened epoxies for cryogenics
    - Oven-curable resins rotisserie cured
    - Lower temperature cure epoxies for foam layer
    - Resin cure temperature matched to liner melting point
  - Various fibers to engineer tank performance
    - Carbon, Pbo: High strength, low weight
    - Glass, Aramid fiber: Abrasion resistance
- Protective layer for foam filament wound
  - Fibers and resins chosen for application

Upcoming Activities

- Testing and inspection of tank and duct concepts
  - Long-term storage of 90% hydrogen peroxide
  - Cryogenic testing of tanks for liquid oxygen
- Development of cost-effective 5,000 psi helium pressurant tank
- Fabrication of toroidal tanks with internal slosh/antivortex baffles and external support struts