



**Battelle**  
*The Business of Innovation*



**PROPANE**  
*EXCEPTIONAL ENERGY®*

# **Alternative Composite Materials for Underground Tanks**

---

**Joan T. Muellerleile**  
**Advanced Materials and Process Engineering**  
**Battelle Memorial Institute**  
***Texas Propane Technology Forum***  
***September 12, 2007***

# Motives for Alternative Tank Materials

---

- Recent increases in steel prices (225% since 2001) have closed the gap between steel and composite tanks costs.
- Potentially no need for corrosion protection system with composite tanks.
- Composite tanks are lighter weight, which could lead to easier onsite handling for installation/burial.

# Corrosion Protection

---

- Conventional underground steel tanks need a corrosion protection system
- Typical steel protection systems include:
  1. Protective tank coating (epoxies, enamels, phenolics, urethanes, mastics)
  2. Cathodic protection using sacrificial anodes (passive)
  3. Cathodic protection using impressed-current anodes (active)

## Corrosion Protection (cont.)

---

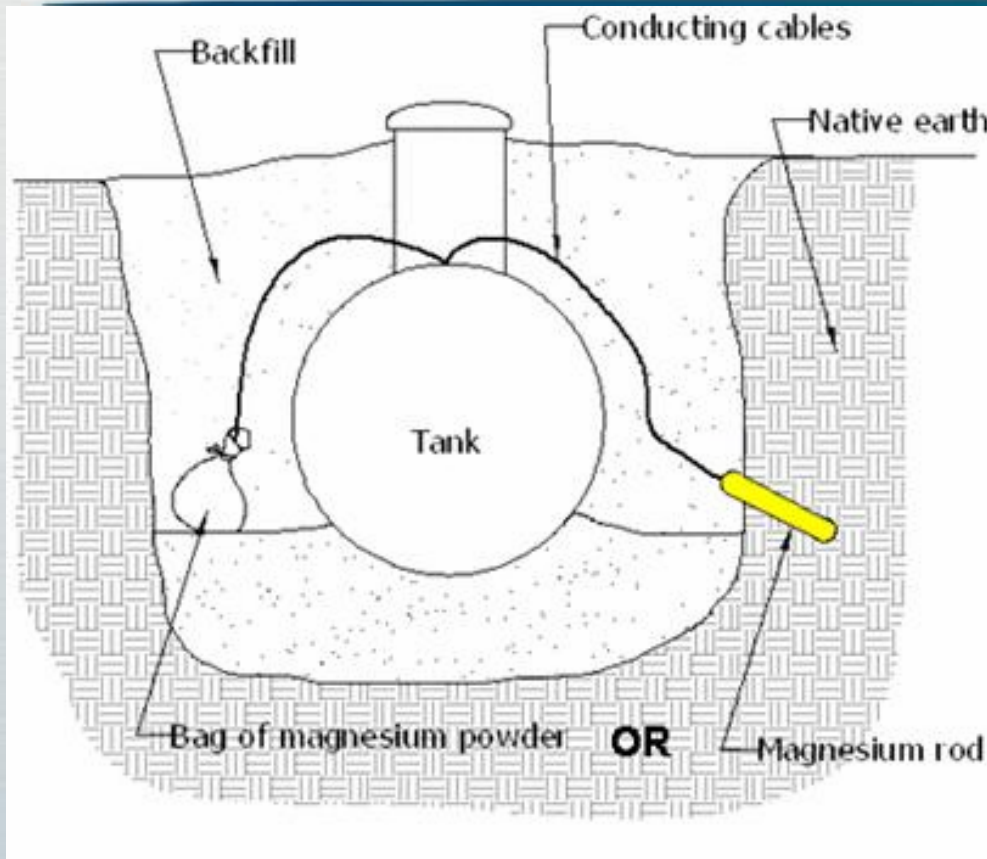
- Coatings always contain flaws (“holidays”) from improper bonding of coating to base metal or scratches from shipping/handling.
- Without cathodic protection, entire voltage potential is concentrated at holiday/scratch, so result is accelerated corrosion at that spot.
- Therefore, coatings and cathodic protection must be used together, not individually.
- Best practices in corrosion protection call for periodic monitoring of the system
  - Direct assessment of coating (not practical)
  - Voltage potential measurement between tank and surrounding earth.

## Corrosion Protection (cont.)

---

- Inspection requirements currently not mandated by regulations.
- With increased scrutiny of buried flammable fluid system, mandatory inspections could be implemented.
- Inspections require additional staff plus monitoring equipment (hydrocarbon analyzer and/or voltage potential measurement). Inspections would therefore not likely be performed by delivery drivers.
- Periodic inspection could add several hundred dollars to the life cycle costs of a steel underground propane tank.

# Cathodic Protection System for a Conventional Underground Steel Tank



# Composite Tank – Preliminary Design

---

- Code requirements
  - Primary design requirements of stress/strain limits based on pressure loading: Boiler and Pressure Vessel Code by American Society of Mechanical Engineers (ASME), Section X: Fiber-Reinforced Plastic Pressure Vessels.
  - Secondary design requirements for soil and aboveground loads: Manual of Water Supply Practices M45 (Fiberglass Pipe Design) by American Water Works Association (AWWA).

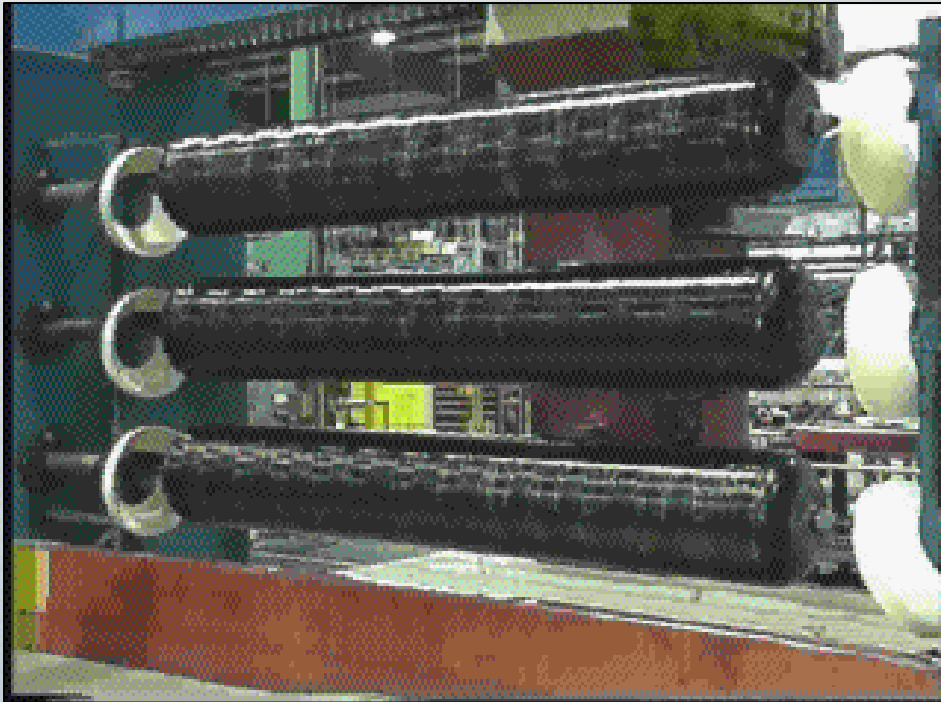
# Composite Tank - Preliminary Design (cont.)

---

- Battelle is partnering with Lincoln Composites in Lincoln, NE, for the detailed design task currently underway.
  - Lincoln Composites manufactures composite cylinders for aerospace, petrochemical, and transportation applications.
- Resin – initially isophthalic polyester; currently amine-cured epoxy:
  - Environmental and worker exposure issues with isophthalic polyester
  - Lincoln Composites has significant experience working with the epoxy
  - Will be more cost-effective initially to use epoxy system, as Lincoln is already set up to use that system.
- Glass fiber – currently planning to use type E-CR (calcium alumino-silicate variant of the E-glass composition, without boron, exhibiting better corrosion resistance).
- Standard filament wound pressure vessel construction.

# High Speed Filament Winding

---



- Multi-axis filament winding machine
- Resin content and tension are controlled parameters
- Winding speeds may reach 150 meters per minute

Slide courtesy of Lincoln Composites

# Preliminary Design Cost Estimates

Parameter	1000-Gallon (3785 Liter) Water Capacity	
	Steel	Composite
Weight	1741 lb (790 kg)	970 lbs (440kg)
Total length	13 feet (4 m)	13 feet (4 m)
Diameter	41 inches (1 m)	41 inches (1 m)
Thickness	0.25 inch (6 mm)	0.51 inch (13 mm)
Cost (F.O.B. plant site)	\$ 2075 + \$ 150 (2 anodes) \$ 2225	\$ 2400 (appurtenances in head) \$ 2550 (appurtenances in side wall)

# Composite Underground Tanks – Additional Issues

---

- Current United States LP Gas Code (National Fire Protection Association Standard 58) requires containers to be designed to US Department of Transportation or ASME Boiler and Pressure Vessel Code Section VIII requirements; thus, code must be modified to add acceptability ASME Section X design requirements.
- Current ASME Boiler and Pressure Vessel Section X code is based on late-1950s, early-1960s design equations; thus, excessive design margin requirements for external loading (such as when empty tank is first buried).
- If Section X requirements used up-to-date material property equations, effective design margin could be reduced from 7 to 5, resulting in 25% material cost savings.

# Additional Information and Contacts

---

Funding for this work is provided by the Propane Education & Research Council under Dockets 11728, 12069, and 12096.

Final report is available through the following link:

[www.propanecouncil.org/industry/resLib\\_councilDetail.cfv?id=451&t=Research%20%26%20Development](http://www.propanecouncil.org/industry/resLib_councilDetail.cfv?id=451&t=Research%20%26%20Development)

For more information, please contact:

Joan Muellerleile

(614) 424-7925

[muellerleile@battelle.org](mailto:muellerleile@battelle.org)

Rod Osborne

(614) 424-4833

[osborner@battelle.org](mailto:osborner@battelle.org)

[www.battelle.org](http://www.battelle.org)