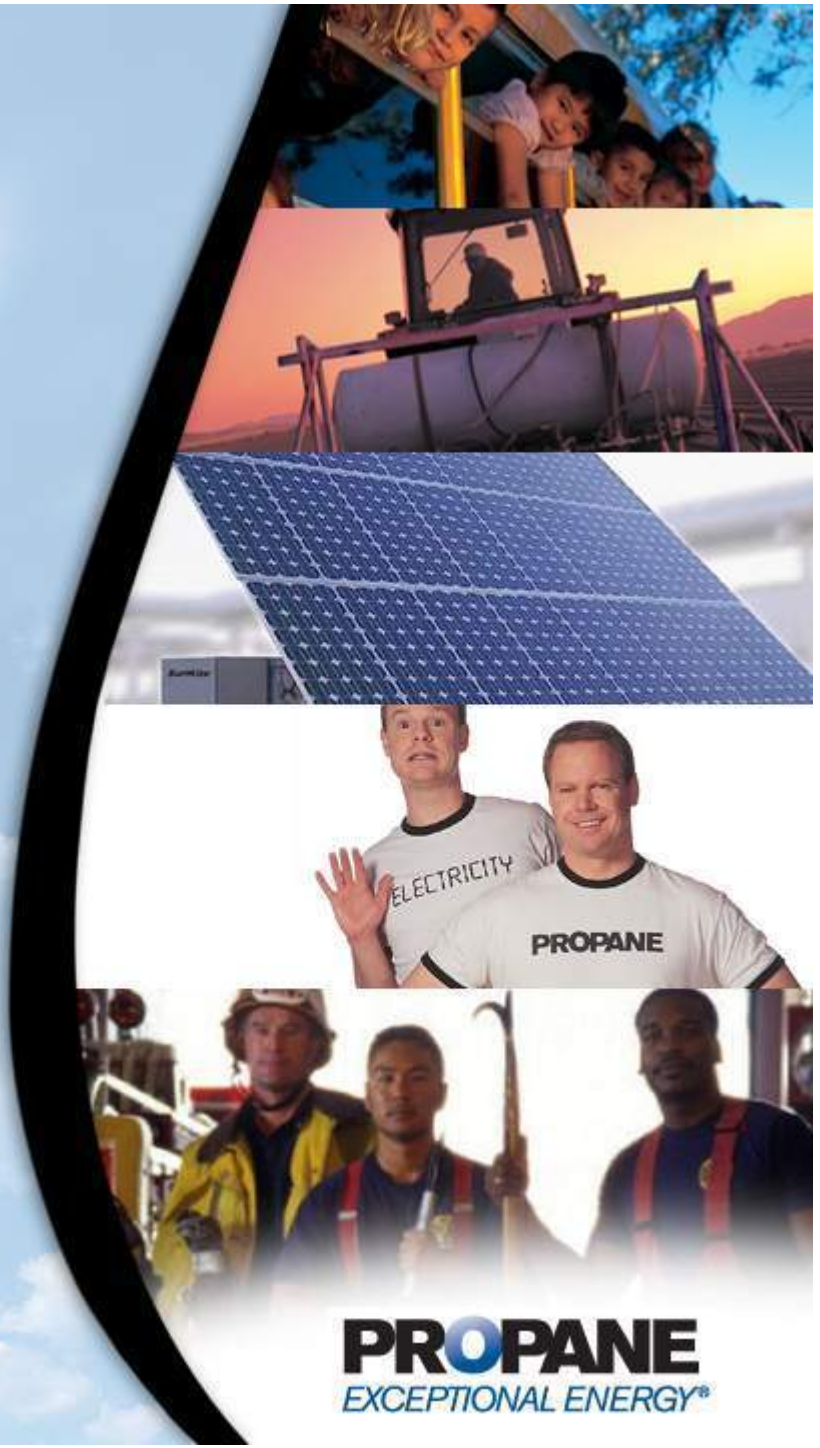
Study of Alternative Materials for Underground Propane Tanks

Greg Kerr
Director of Research
Propane Education & Research Council



Background and Motivation

- Material costs have dramatically increased
  - steel, anodes
- Increased concern for performance of corrosion protection systems; need for corrosion protection monitoring (now required in some states in the USA, recommended by NFPA 58
  - “A periodic test program should be established to monitor the effectiveness of the corrosion protection for the container. Inspection records should be made available to the container owner.”

Background and Motivation (continued)

- In response, the Propane Education & Research Council initiated studies to investigate alternative materials for underground propane tanks
- Phase 1 – preliminary feasibility study to identify possible designs, manufacturing methods, and partners
- Phase 2 – construction of mockup for 2006 World LP Gas Forum, detailed design by manufacturing partner, Lincoln Composites, material compatibility, corrosion of appurtenances

Manufacturing Partner
Lincoln Composites (USA)

- Manufacturer of composite pressure vessels since 1963
- Products include: breathing cylinders, satellite propulsion systems, oil platform tensioning systems, compressed natural gas vehicle fuel containers, hydrogen fuel cell vehicle fuel containers
- Recently-opened manufacturing facility can produce vessels 1.1 meter in diameter, 11 meters long

Design Summary

- Based upon previous experience with underground petroleum storage tanks
- Design requirements
  - tank design pressure (17 bar)
  - cyclic pressure caused by initial vacuum purge/vapor purge, temperature changes
  - soil loading, including vehicular
- Polymer-lined composite pressure vessel design using tooling developed for a 1.1 meter diameter pressure vessel
  - Composite propane tank consists of an HDPE copolymer liner that is fully wrapped with Type E-CR glass fiber-reinforced epoxy.

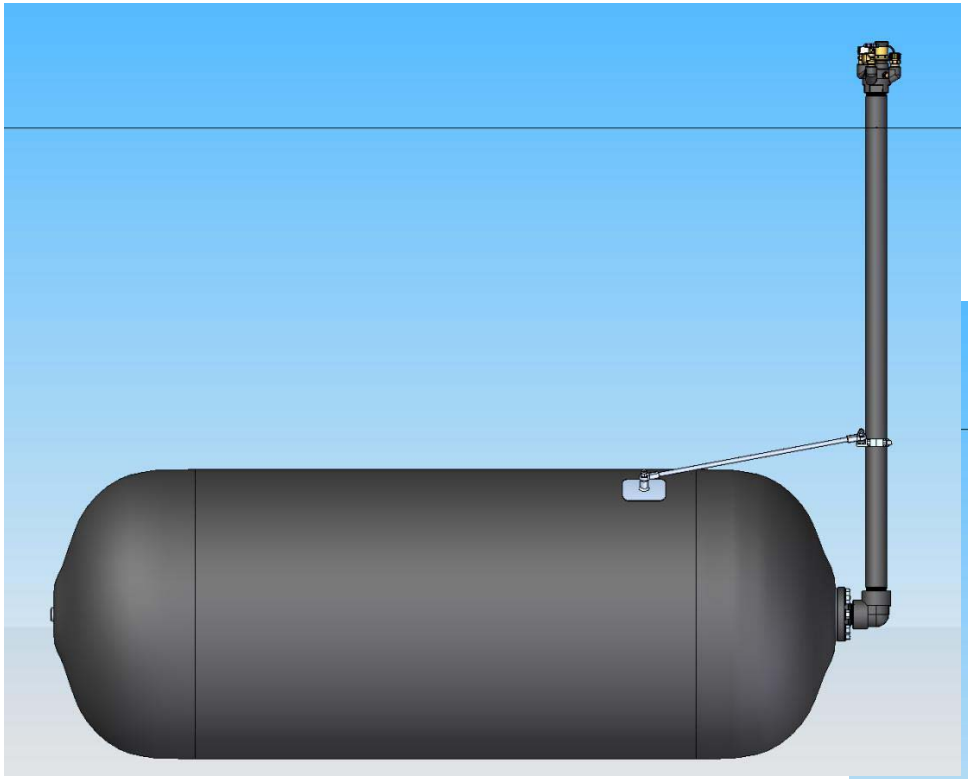
Design Summary (continued)

- **Chemical compatibility of the proposed composite components with the chemical components of commercial propane**
  - **No apparent issues based upon public technical literature; also, no compatibility problems in over 40 years experience of underground storage tanks with gasoline, diesel, jet fuels**

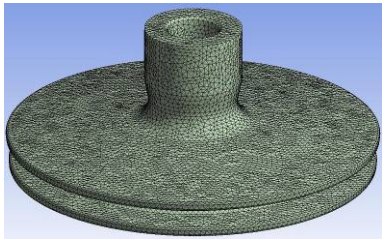
Design Summary (continued)

- Corrosion of appurtenances: based upon a literature evaluation, only steel and possibly zinc components of appurtenances will require coatings to protect them from atmospheric corrosion
- Steel components should have satisfactory service life if they are sufficiently sheltered and protected from the atmosphere

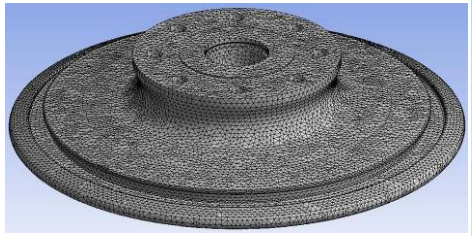
Side View of Proposed 500 Gallon / 1900 Liter Tank Design



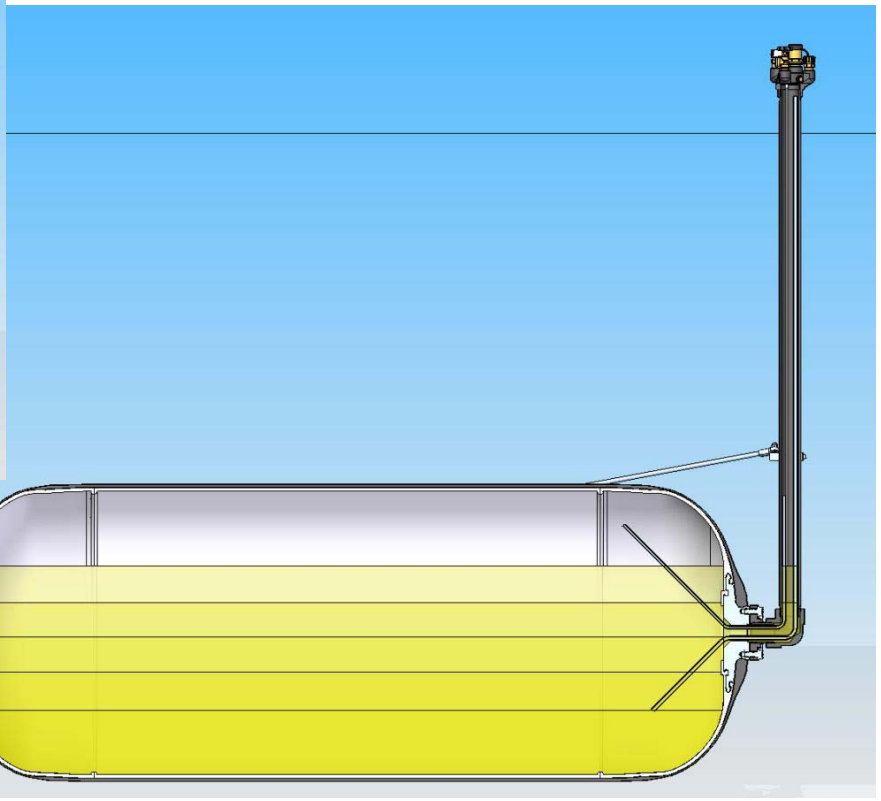
Head connection significantly lower cost than standard sidewall connection because of cutting of wound fibers



Blank-end boss

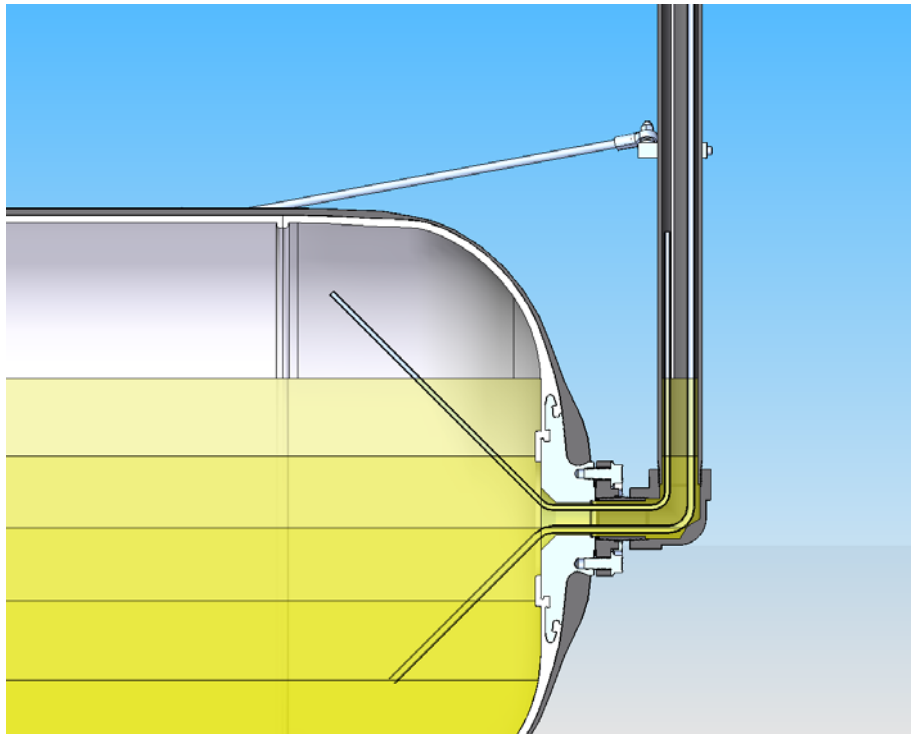


Riser-end boss



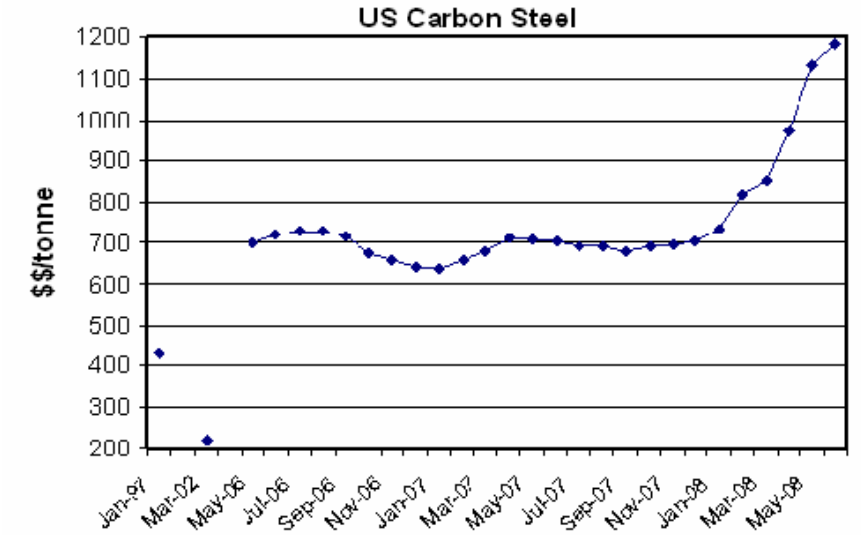
Proposed Tank Design Vapor Space Connection

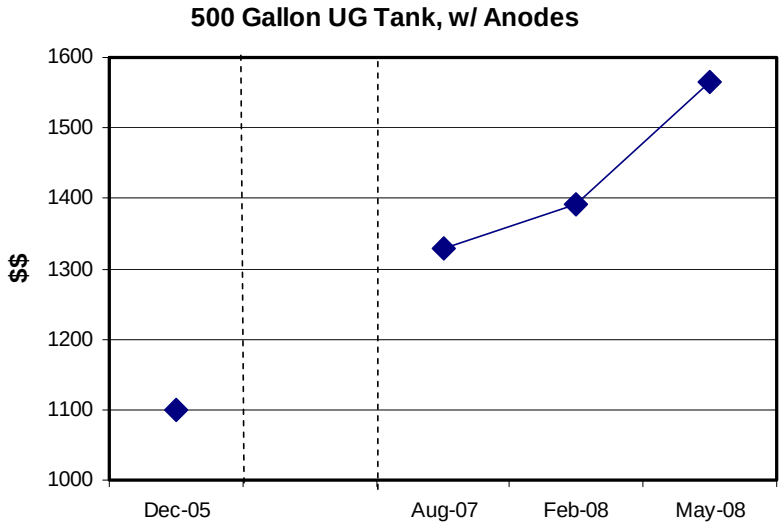
- **Head connection presents unique challenges**
  - **Connection to vapor space for service, relief valve**
  - **Liquid withdrawal → Connector tubes from riser to vapor space, tank bottom**
  - **Liquid level monitoring**
    - →Variation on standard float
    - →Also considering Ultrasonic, radar
      - —Fiber optic

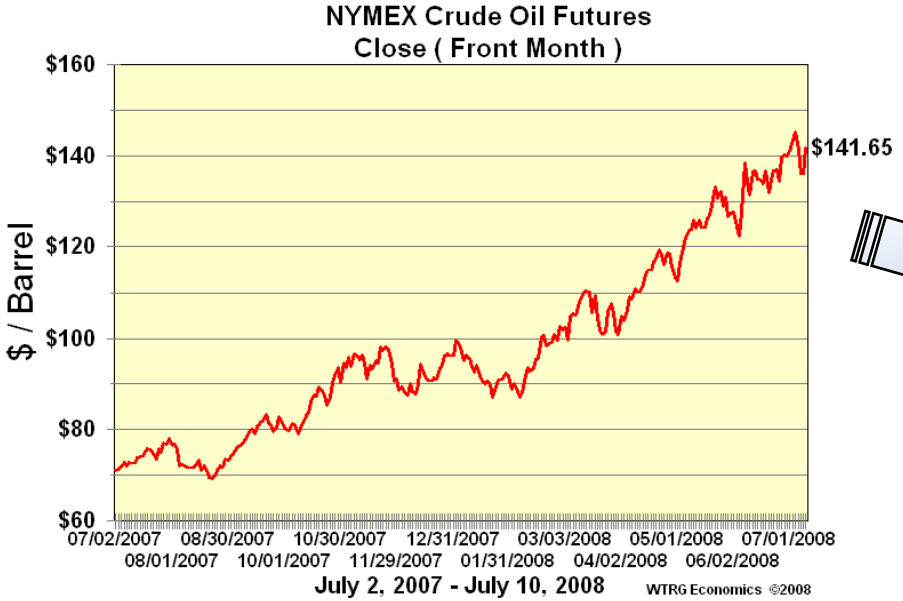


Costs of all materials are increasing rapidly

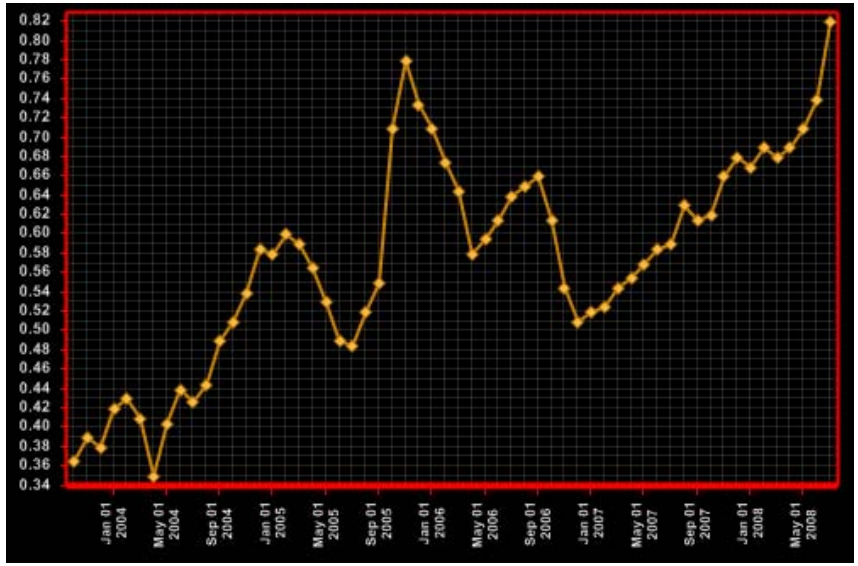
PROPANE
EXCEPTIONAL ENERGY®







Polyethylene Resin cost



Estimated Costs – Composite versus Standard Steel

Tank Size (gallons / liter)	Composite* <estimated initial> (US $)	Composite* <potential> (US $)	Steel* (US $)
250 / 950	3676	1700	1230
500 / 1900	4406	2400	1716
1000 / 3800	5863	3600	2810

* Price is FOB factory and includes riser, combination valve, and for steel tank, anodes

Recommendations for Future Work

- **Further optimization of the propane tank design in order to reduce the tank cost**
  - **Current proposed design uses the HDPE copolymer as a consumable liner, which also adds to the overall propane tank expense – consider non-consumable mandrel for winding**
  - **Bosses (winding and riser) are one-pieced machined; higher volumes could use stamped parts (outside of Lincoln's expertise)**

Recommendations for Future Work (continued)

- Wall thickness is approximately 50 percent thicker than design that has no negative pressure (tank exterior because of soil loading)
  - Requires revision to ASME Section X – Fiber-Reinforced Plastic Pressure Vessels
  - Revision to NFPA 58 – current design requirement is ASME Section VIII (metallic materials only); revision required to also include ASME Section X

- If the finalized cost estimate is practical, then build a prototype based upon the detailed design.