



1997 Automotive Technology Development
Customers' Coordination Meeting



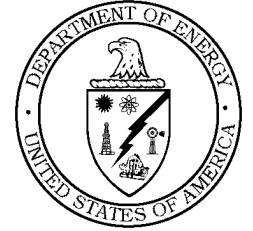
**Low Cost Manufacturing for Composite Natural Gas
Vehicle (NGV) Fuel Tanks**

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October 28, 1997



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Vision Statement

- Technical development and widespread commercialization of compressed natural gas (CNG) as an alternative vehicle fuel
- CNG and other alternative fuels may provide a means for significant petroleum displacement, thereby reducing U.S. dependence on imported oil with the added benefit of reduced emissions



Trunk installation in a
Ford Crown Victoria



Utility truck
application

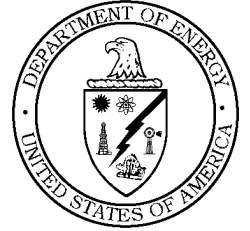
Tool box mounted CNG fuel tank



Photos courtesy of Lincoln Composites



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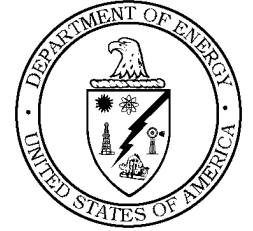


Project Objective

- Develop and/or demonstrate technologies or methods for achieving lower cost and more durable composite over-wrapped NGV fuel tanks
- Supports: U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Transportation Technologies, Office of Advanced Automotive Technologies



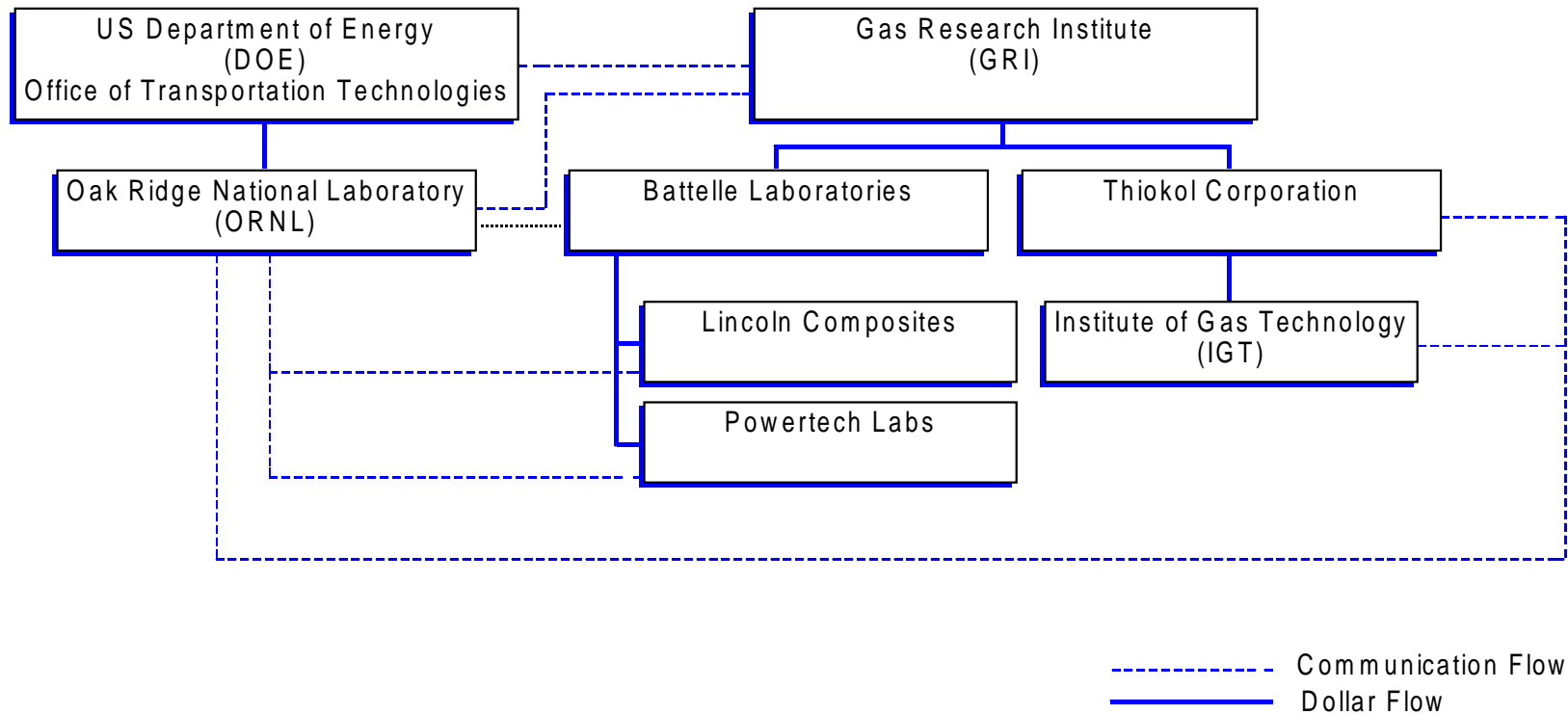
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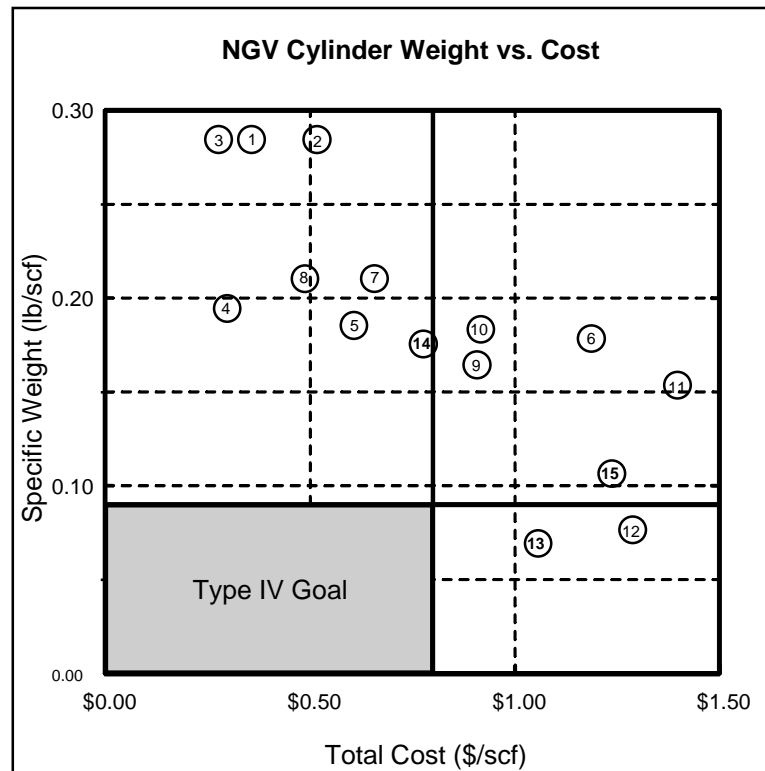
Technical Approach

- Assess current state of the art
- Assess potential improvements
- Incorporate selected improvements in a pilot test case
- Support Gas Research Institute (GRI) contract award winners

DOE & GRI Project Participants



GRI project goals for Type IV Tanks



1. Steel: billet
2. Steel: plate
3. Steel: tube
4. HS steel: plate
5. HS aluminum: billet
6. Aluminum: tube/E-glass hoop
7. Steel: plate/E-glass hoop
8. Steel: billet/E-glass hoop
9. Aluminum: tube/E-glass full
10. Aluminum: plate/E-glass full
11. Aluminum: plate/S-glass full
12. Aluminum: thin/carbon full
13. Plastic/carbon full
14. Plastic/E-glass full
15. Plastic/hybrid full

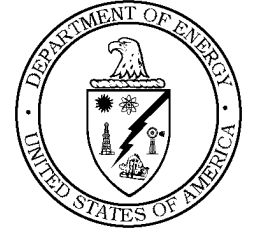
Ref. "Compressed Natural Gas Storage Optimization for Natural Gas Vehicles" Final Report, Dec., 1996, Prepared by IGT and Powertech Labs for GRI

Feasibility Assessment of Low Cost Carbon Fibers

- Weight goal is currently met with a fully wrapped (Type IV) carbon fiber tank, whereas cost goal is not
- Carbon fiber raw material costs account for:
 - > 40% of the total material + manufacturing + overhead cost
 - > 60% of the total material + manufacturing
- Commercial grade carbon fibers with 12K tow size are typically used in current tank designs
 - > 500-550 ksi fiber tensile strength
 - > 33 Msi fiber modulus



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Feasibility Assessment of Low Cost Carbon Fibers

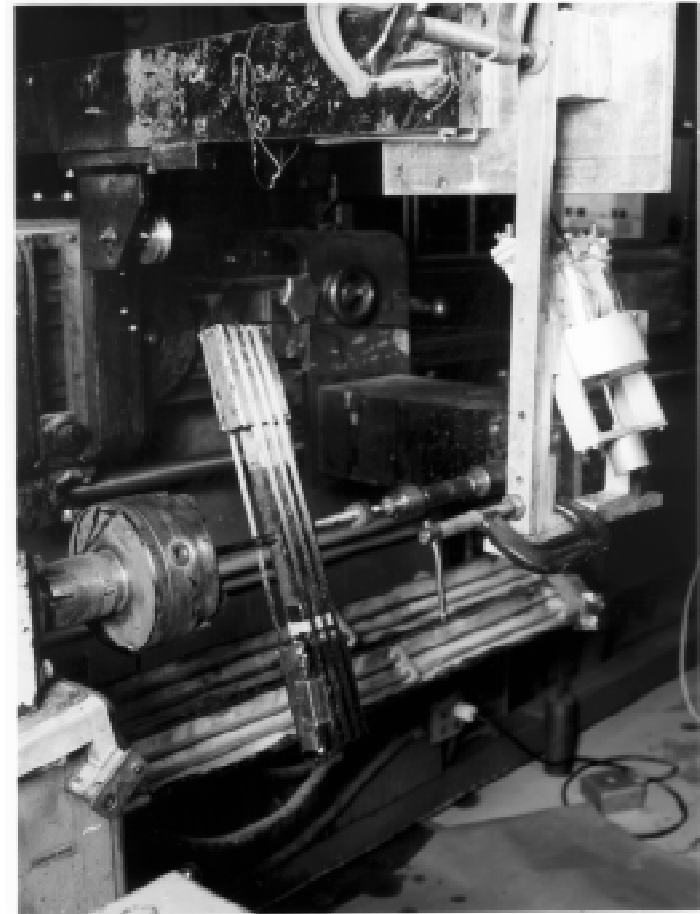
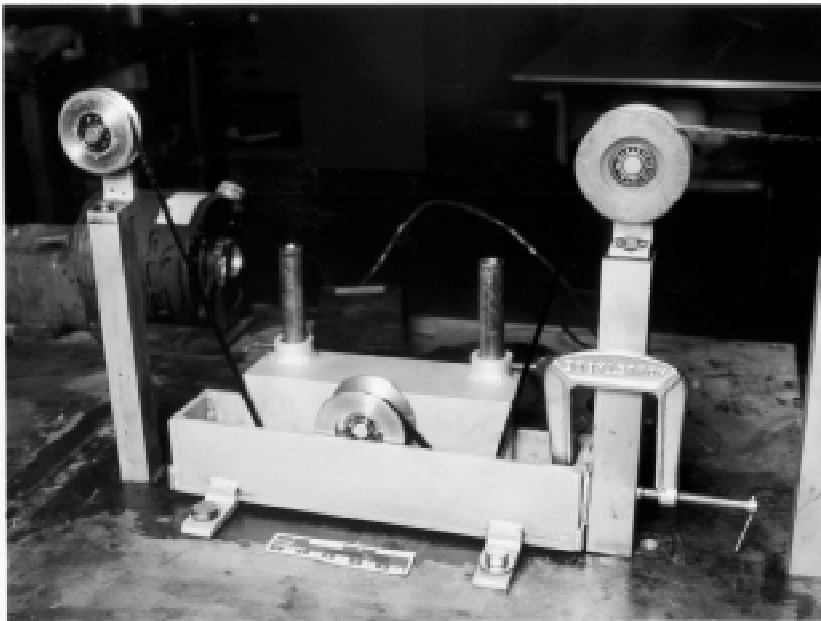
- PAN-based carbon fiber suppliers and products
 - > Toray Torayca
 - > Hercules Magnamite
 - > Amoco Performance Products Thornel
 - > Grafil
 - > Akzo Nobel Fortafil (50K tow)
 - > Zoltek Panex (50K tow)
- 50K tow carbon fiber can be produced for less \$/lb. than the standard 12K tow, thereby reducing the total NGV tank cost

Evaluation of Candidate 50K Tow Carbon Fibers

- Technical approach
 - > Fabricate and test resin impregnated strand tensile strength specimens
 - > Fabricate and test all-hoop wound composite ring specimens
 - Split-D hoop tensile strength
 - Short-beam-shear strength
 - Transverse flexure strength
 - Composition

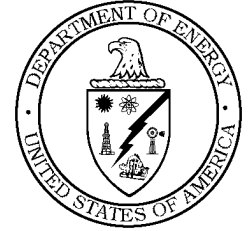
Impregnated Stands Process and Test Trials

- Modifications to 12K tow fabrication process
 - > Increased pulley width from 3/8 in. to 1/2 in.
 - > Increased orifice size from 0.042 in. to 0.090-0.114 in.
 - > Switched to McClean Anderson winder
- Modifications to 12K tow test method
 - > Pressurized grips with rubber faces - Used foil tabs with higher pressure
 - > Mechanical grips with serrated faces - Used fiberglass tabs with greater tab thickness
- Improvements to test method still needed to better correlate with vendor data





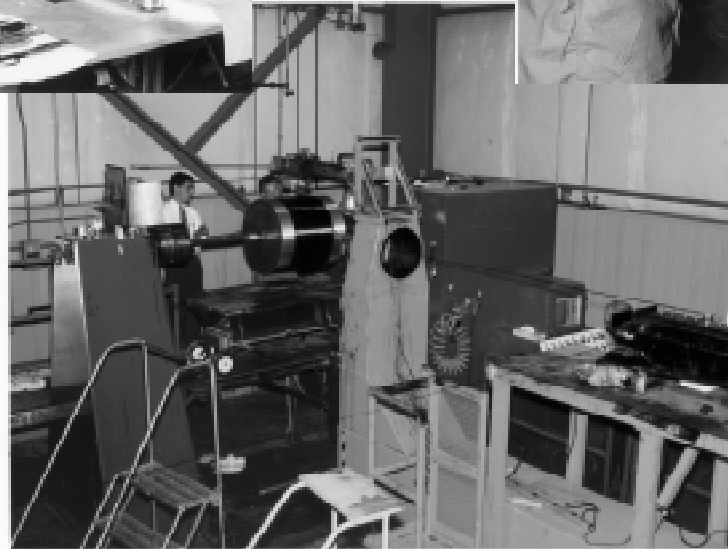
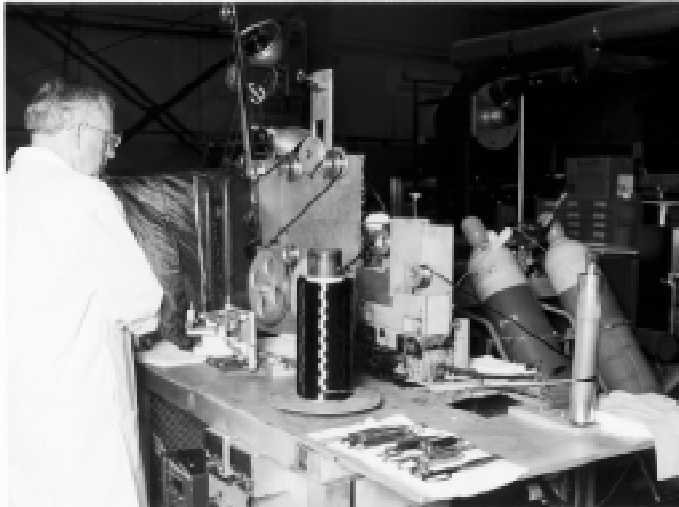
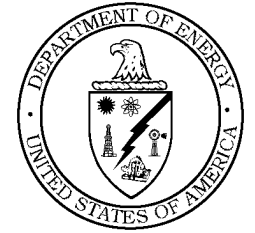
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Composite Cylinder Process Trials

- Wet-filament winding method with epoxy resin
- Process modifications
 - > Increased width of pulleys/brake wheels to 1/2 in.
 - > Increased fiber tension from 12 lb. to 25 lb.
 - > Set winding advance for an average tow width of 0.4-0.5 in.

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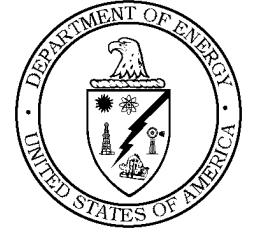


Future Direction

- Work with 50K tow carbon fiber suppliers to reduce product variability, increase fiber strength translation, and to develop improved test method for large carbon fiber tow sizes
- Conduct long-term durability testing for strand stress-life and composite cylinder stress rupture
- Investigate potential of hybrid designs utilizing both glass and carbon fibers to further reduce cost
- Evaluate other methods for cost reduction



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Acknowledgements (Technical Support)

- Ron Meyers
- Ken Yarborough
- Tommy Thompson