Underground LH2 Off-Board Hydrogen Storage Technology

> U.S. Department of Energy
2005 Hydrogen Program Review

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This presentation does not contain any proprietary or confidential information
Overview

> Timeline
  – Task 1
    > Start: May 2005
    > End: Feb 2006
  – Task 2
    > Start: Mar 2006
    > End: Apr 2008

> Barriers addressed
  – Reduce the cost and footprint of hydrogen storage at refueling stations
    > Barrier F: Hydrogen Delivery Infrastructure Storage Costs
    > Barrier H: Storage Tank Materials and Costs

> Budget
  – Total project funding
    > DOE: $968,000
    > Cost share: $245,000
  – FY05: $90,000

> Partners
  – NexGen Fueling Division of Chart Industries
  – BOC Gases
Project Objectives

> Better understand the technical and economic factors related to bulk hydrogen transportation, storage, and dispensing for vehicle applications
> Operating costs and efficiencies of various hydrogen storage methods
> Capability of fueling system to store and effectively deliver H2 to vehicles
> Understand the safety of the fuel storage and delivery system
Technical Approach

> Two tasks
  1. Design analysis and economic modeling
  2. Demonstration to validate analysis and modeling

> Issues to be investigated
  – Economics
  – Safety
  – Ground freezing
  – Effects of soil pressure
  – Effects of tank leakage
  – Tank integrity monitoring
  – LH2 withdrawal
Benefits of Direct Burial

> Decreased land usage/footprint
> Eliminates some potential hazards
  – Vandalism
  – Fire
  – Vehicle impact
> Inherent spill containment
> Direct burial is preferred over vaulted configuration for additional safety
  – Eliminates confined space issues
Prior GTI/GRI Underground LNG Tank Project

- Previous work done in mid-90s on underground LNG tank burial
- Analytical investigation coupled with real-world empirical testing
- Helped lead to greater acceptance of this practice
New LNG Vehicle Fueling Site With Buried Cryogenic Tanks

> Orange County Transit Authority (OCTA)
Project Work Plan

> Task 1: LH2 off-board storage technology analysis
  – 1.1 Design analysis of H2 off-board storage technologies
> Go / no go decision

> Task 2: Off-board LH2 in-ground tank testing and evaluation
  – 2.1 Analytical investigation of buried LH2 tanks
  – 2.2 Experimental facility and test of underground releases
  – 2.3 Equipment and soil instrumentation
  – 2.4 Soil preparation
  – 2.5 LH2 tank tests
LH2 Off-Board Storage Technology Analysis (Task 1)

> Design analysis for:
  – Above- and below-ground compressed H2 storage
  – Above- and below-ground LH2 storage

> Economic analysis to include:
  – Capital cost
  – Operating cost
  – Operational issues
  – Safety elements

> Site issues analysis to include:
  – Site requirements (system footprint, storage capacity, heat gain/boil-off, etc.)
  – Code and standards, permitting issues
Capital and Operational Cost Evaluation (Task 1.1.1)

> Life-cycle cost model for each case (GH2, LH2 above and below ground)
  – Capital costs
    > Site infrastructure, land, equipment, permitting
  – Operation and maintenance costs
    > Energy, maintenance, product loss (venting), safety
  – Task will consult and coordinate with H2A and DOE/Nexant efforts
GTI’s Life-cycle Cost Model

> Includes time- and hours-of-operation-dependent costs and allowances for incentives, salvage value, and income tax effects
> Probabilistic (Monte Carlo) and sensitivity analysis capabilities
Buried LH2 Tank Site Issues Evaluation (Task 1.1.2)

> Site requirements
  – System footprint, H2 storage capacity, heat gain and boil-off rates, piping and fitting requirements and maintainability
  – Codes for vapor dispersion and thermal radiation zones, buffer zones, spill containment and other safety regulations

> Code and standards issues
  – Contact and participation with appropriate organizations (ICC, NFPA, etc.)

> Evaluate local permitting issues for Task 2 (burial of LH2 tank)
Codes and Standards

- Underground LH2 storage allowed in ICC International Fire Code
  - §2209 Hydrogen Motor Fuel-dispensing and Generation Facilities
  - §3204 Cryogenic Fluid Storage
- NFPA 50B does NOT allow underground storage
  - NFPA 55 will combine NFPA 50, 50A, and 50B and will allow underground storage
- NFPA 52 (draft) will allow underground storage
- Code changes commonly take two to three years for adoption by localities
  - Early outreach to local authorities
ICC IFC Requirements

> §2209 contains general H2 fueling station requirements, including
  – Equipment approval/listing, location on property, dispensing, safety precautions (including venting)

> §3204 contains underground LH2 tank requirements, including
  – Separation from other in-ground structures, fill and cover (1' earth, 4" concrete), vacuum jacket corrosion and load protection, vacuum monitoring, etc.
Go / No-Go Decision

> At the conclusion of Task 1 (ten months) a go / no-go decision will be based on:
  – Economic viability of LH2 compared to alternatives (LH2 costs ≤ alternatives)
LH2 In-Ground Storage Tank Testing and Evaluation (Task 2)

> Task 2: Off-board LH2 in-ground tank testing and evaluation
  – 2.1 Analytical investigation of buried LH2 tanks
    > Heat transfer modeling
  – 2.2 Experimental facility and test of underground LH2 tanks
    > Test hydrogen dispersion profiles
    > Evaluate methods of hydrogen leak detection
  – 2.3 Equipment and soil instrumentation
  – 2.4 Soil preparation
  – 2.5 LH2 tank tests
    > Baseline tank heat loss test
    > Soil moisture effect test
    > Supplemental soil heating effects test
    > Analytical evaluation of LH2 tank vacuum loss
Analytical Investigation of Buried LH2 Tanks (Task 2.1)

> Analyze potential freezing of the soil layer adjacent to the buried LH2 tank
  – Model heat transfer from the soil to the LH2 tank (transient finite element analyses)
    > Different soil compositions
    > Depth of tank burial
    > Ambient temperature
  – The model will be verified / updated in Task 2.5 based on field measurements
  – Quantify heat flux rate
    > Consider supplemental heating
Experimental Facility and Test of Underground Releases of LH2 (Task 2.2)

> Construct a scaled test facility
  – Bury a vacuum jacketed pipe to enable the release of LH2 into several test conditions
    > Different soil compositions
    > Dry and moist soil
    > Several depths of release

> Evaluate issues related to underground LH2 release
  – Test hydrogen dispersion profiles
  – Evaluate methods of hydrogen leak detection
Equipment and Soil Instrumentation (Task 2.3)

> Temperature instrumentation of LH2 tank at several locations of exterior and within vapor space of inner tank

> Temperature instrumentation of soil space around tank consistent with analysis of Task 2.1

> Moisture sensors at selected soil locations

> Strain gauges at selected tank and piping locations
Soil Preparation (Task 2.4)

> Two types of soil:
  – Clay fill
  – Sandy fill

> Each end of buried tank will be backfilled with each type of soil

> Apparatus for inserting moisture into the soil to be implemented
LH2 Tank Tests (Task 2.5)

> Baseline tank heat loss test (Task 2.5.1)
  – Determine relief setting and monitor soil and tank conditions for 90 to 120 days

> Soil moisture effect test (Task 2.5.2)
  – Reheat soil to initial conditions of prior task
  – Approach saturated soil moisture level and monitor soil and tank conditions for 90 to 120 days
LH2 Tank Tests (Task 2.5)

> Tank shell heater effects test (Task 2.5.3)
  – Reheat soil to initial conditions of prior task
  – Maintain soil temperature via heating coils on tank exterior
  – Monitor soil and tank conditions for 90 to 120 days

> Evaluation of LH2 tank vacuum loss (Task 2.5.4)
  – Analytical evaluation of updated model
  – Possible test with actual tank
Project Management and Reporting (All Tasks)

> Project management
  – Overall technical, fiscal, and administrative management of the proposed project
  – Preparation of deliverables, reporting of project progress at review meetings
  – Presentation of the research results

> Reporting
  – Status reports (quarterly and annual)
  – Oral presentation
  – Annual participation in DOE meeting, DOE Program Review and USCAR review
Gas Technology Institute

> Independent non-profit R&D organization

> Focus on energy and environmental issues
  – Natural gas and hydrogen emphasis

> Over 40 years experience with hydrogen and 20 years with gaseous vehicle fueling stations
Chart Industries and NexGen

Chart Industries is a leading supplier for the industrial gas and hydrocarbon processing markets.

- Cryogenic equipment used to purify, liquefy, store, and transport gases such as helium, hydrogen, nitrogen, oxygen, and natural gas for further use in industrial, commercial, and scientific applications.

- NexGen Fueling Division meets the needs of natural gas and hydrogen vehicle markets. They supplied over 98% of on-board LNG fuel tanks for transit buses and heavy-duty trucks.