

HYDROGEN REGIONAL INFRASTRUCTURE PROGRAM IN PENNSYLVANIA

Melissa Klingenberg, Ph.D.
Concurrent Technologies Corporation
May 25, 2005



This presentation does not contain any proprietary or confidential information

PDP49

Overview

Timeline

- Award notification:
 - September 1, 2004
- Contract start date:
 - November 23, 2004
- Contract end date:
 - March 31, 2006
 - Plan for POP extension
- 10% completed

Budget

- FY04 funding
 - DOE: \$2,943,232
 - Contractor: \$738,965

Barriers

- Natural gas pipeline materials and new storage tank materials compatibility with pure H₂ and gas blends at higher pressures
- Long-term material lifecycle
- Cost effective H₂ delivery
- Implementing low cost, innovative H₂ sensors

Partners

- Resource Dynamics Corporation
- Air Products and Chemicals Inc.
- EDO Corporation



Objectives

- Capture data pertinent to H₂ delivery in PA
- Establish means for ensuring safe/reliable delivery options

H₂ Delivery

- Determine the feasibility of co-transporting H₂ and natural gas in existing pipelines
- Determine the feasibility of separating H₂ from H₂/natural gas blends at the point of use
- Perform tradeoff analysis to determine the best H₂ delivery approach(es) in PA

New Material Development

Evaluate novel material approaches for pipelines and compressed gas storage tanks

Hydrogen Sensor Development

 Establish capability of H₂-specific sensors to determine %H₂ in feed gas (including gas blends) and ppm-level H₂ for leaks



H₂ Delivery Approach

- Assess current gas pipeline materials and operational characteristics
 - Identify construction materials used in PA according to:
 - Feed gas composition
 Pressure Flow Rate
 - Ambient conditions– Temperature
- Identify and quantify tradeoffs between alternative H₂ delivery approaches in PA
 - Examine the economic, risk, technology, and public safety tradeoffs via data collection, economic analysis and sensitivity analysis
 - Recommend best approaches for delivering hydrogen from production facilities to end users
- Examine delivery scenarios and resulting effects on separation technology selection
 - Test and determine suitability of available technologies



Materials/Sensors Approach

- Conduct baseline assessment of innovative materials/processes for H₂ delivery
- Benchmark current or potential material issues
- Select materials for investigation and test
 - Use test data in lifing/survivability models
- Fabricate/test prototype off-board storage tank
- Define H₂ sensor requirements
- Assess sensor potential based on requirements
- Test priority sensor technologies in H₂ and gas blends
 - Identify effects of:
 - Contaminants Pressure
 - HumidityTemperature
 - Assess calibration, maintenance, and in-field sensing abilities



H₂ Delivery Accomplishments

Characterized PA pipelines

Leak Sources During 2003 Organized by Percent		
Corrosion	71.8%	
Material and Welds	18.8%	
Excavation	1.2%	
Natural Forces	0.6%	
Other	7.7%	



2003 PA Transmission Pipeline Data

Miles of pipe	9500
Steel	98.5%
Cathodically Protected - Coated	81.0%
Cathodically Protected - Bare	13.5%
Other	4.3%
Cast or Wrought Iron	0.4%
Plastic	1.1%
Pipe Catagorized by Size	
Over 20" Diameter	43.5%
Over 10" to 20" Diameter	35.4%
Under 10" Diameter	21.1%
Pipe Catagorized by Installation Date	
1980 to End of 2003	30.2%
1960 - 1980	27.3%
Before 1960	42.1%
Unknown	0.4%



H₂ Delivery Accomplishments

- Established the H₂ Pipeline Working Group
- Identifying H₂ co-transport issues in existing natural gas system
 - Working with utility companies and PA Public Utility Commission
 - Examining potential effects of pressure drop losses in pipelines for various hydrogen/natural gas blends
 - Estimated that increased flow rates are required for H₂ mixtures due to the lower hydrogen heating value
 - Assumed constant energy delivery
- Identified potential separation technologies
 - Assessed hydrogen loss cost to the end user
 - Assumed loss via incomplete recovery in a separation device or to natural gas consumers
 - Realize increased H₂ costs if recovery to H₂ applications is less than 50%
 - CTC team aiming to achieve >80% recovery
- Assessed thermodynamic models and property data for methane, H₂, and their mixtures
 - Using NIST software to estimate the thermodynamic properties of H₂natural gas mixtures



H₂ Delivery Accomplishments

 Performed research* and demographic studies for PA H₂ demand scenarios

LDV Data (per vehicle)

Mass Use	Early Entry		
0.72 kg/day	0.96 kg/day		
14,950 miles/year 20,000 miles/year			
57.5 mpg equivalent			

Avg. # LDVs per person

Large City (~ 1,000,000)	0.89
Small City (~ 100,000)	1.16
Pennsylvania	0.78

^{*} based on H2A model of NREL

- Assumed refueling station sizes
 - 100 kg/day (70 kg/day based on 70% capacity factor)
 - 1,500 kg/day (1,050 kg/day based on 70% capacity factor)



Estimated PA H₂ Usage (based on gas use and per capita)

Basis	Estimate of Total Gasoline Usage in 2005*	14.63	million gal/day
Estimate	1% Market Share	0.06	million kg/day
Estimate	10% Market Share	0.61	million kg/day
Estimate	30% Market Share	1.8	million kg/day

Note:

* US Energy Information Administration, State Energy Data Report, 2000

Basis	Population (U.S. Census 2005 Estimate)	12.4	million people
Basis	Estimated Number of Light Duty Vehicles	81,738	LDVs
Estimate	1% Market Share	0.08	million kg/day
Estimate	10% Market Share	0.7	million kg/day

Notes:

0.78 LDV/capita, PA-specific, Federal Highway Administration,

0.72 kg hydrogen/ldv/day (15,000 miles per year) H2A Scenario Analysis

0.96 kg hydrogen/ldv/day (fleet - 20,000 miles per year) H2A Scenario Analysis



PA Demand Scenarios

Market Penetration

	1%	10%	30%
H2 Demand (kg/day)	78,500	699,000	2,100,000
Refueling Stations			
Required	75	666	1,998

Sample Calculation – Johnstown, PA - Population of 230,377

- 17,969 H₂ LDVs required for 10% market penetration
 - Assumes 0.78 LDV/person
- 12,938 kg/day H₂ demand
 - Assumes 0.72 kg/vehicle/day
- 12 refueling stations needed
 - Assumes 1,050 kg/day capacity refueling station



H₂ Demand vs. Gasoline Sales

Market Penetration

	1%	10%	30%
H2 Demand Baseline			
(kg/day)	78,500	699,000	2,100,000
H2 Demand Based			
on Gas Sales (kg/day)	61,000	610,000	1,830,000
% Difference	22	13	13

- Indicates substantial margin of error possible
- Subject to sensitivity analysis



Materials Accomplishments

- Performed baseline assessments related to hydrogen delivery materials
 - Established current practice, technology gap areas, and near-term research to fill gaps
 - Metals
 - Composites
 - Coatings
 - Modeling lifecycle effects of hydrogen service
 - Test methods to determine hydrogen effects on materials
 - Conducted activity to reduce duplication of efforts



Materials/Sensors Accomplishments

- Creating existing and new infrastructure material issue matrix
 - Separating issues according to:
 - New pure H₂ lines and existing natural gas lines
 - Low and high pressure and pure H₂ and gas blends
 - Found existing H₂ lines (<1200 psig) have no issues
 - Assumes guidelines are followed
 - <30 Y.S. and no pressure cycle
 - Need lifing/survivability models based on destructive analysis of existing materials
 - Identified valve seals, packing, and gaskets as problem areas in existing infrastructure
 - Found that high pressure H₂ or gas blends is not an option in existing infrastructure
 - Per PA utility companies
- Identified a preliminary list of COTS sensors



Future H₂ Delivery Work

- Refine production scenarios
- Develop/modify existing models and tools to determine required fueling stations and best means for H₂ delivery to the stations
 - Model potential delivery scenarios
 - Pipeline
 - Tanker
 - Rail
- Perform sensitivity analysis
 - Consider % differences in estimated H₂ use and that based on gas usage



Future Materials Work

- Quantify effects/issues of H₂ and gas blends on infrastructure materials (including new H₂ pipeline)
 - Prioritize issues based on occurrence, relative cost, and safety
 - Examine issues in context of pure H₂ or gas blend delivery
 - Benchmark current H₂ delivery materials
 - Identify material/performance cost trade-off for replacement in existing natural gas infrastructure or incorporation into new infrastructure (as in tanks, pipelines, etc.)
- Select materials for investigation based on priority
- Evaluate effects of H₂ and H₂/natural gas mixtures on infrastructure materials
 - Feed data into lifing/survivability model for lifecycle safety and durability prediction
- Construct and test prototype tank



Future Sensor Work

- Evaluate and modify an ambient H₂ sensor for hydrogen transportation and delivery applications
 - Review prototypes or near-commercial H₂ sensors
 - Conduct testing on three sensors that show the greatest commercial viability
 - Focus on detecting and quantifying H₂ gas leakage into ambient environments in the following priority:
 - Natural gas pipelines with H₂, H₂ gas pipelines, and process gas pipelines with H₂
 - H₂ transfer (transfer lines and storage containers)
 - H₂-managed environments (near H₂ storage tanks, along transfer lines, within personnel zones, around combustion zones)
 - Other areas where H₂ is stored, transferred, and consumed



Supplemental Slides



Hydrogen Safety

The most significant hydrogen hazard associated with this project is:

- Testing materials in a high pressure hydrogen environment
 - Activity has not yet been initiated



Hydrogen Safety

Our approach to deal with this hazard is:

 Subcontract high-pressure hydrogen test work to laboratories accustomed to dealing with the hazard and experienced in the test activity

