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

Barriers

- Natural gas pipeline materials and new storage tank materials compatibility with pure H_2 and gas blends at higher pressures
- Long-term material lifecycle
- Cost effective H_2 delivery
- Implementing low cost, innovative H_2 sensors

Budget

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

Partners

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

CTC
Concurrent Technologies Corporation

Objectives

- **Capture data pertinent to H_2 delivery in PA**
- **Establish means for ensuring safe/reliable delivery options**

<u>H_2 Delivery</u>

- Determine the feasibility of co-transporting H_2 and natural gas in existing pipelines
- Determine the feasibility of separating H_2 from H_2/natural gas blends at the point of use
- Perform tradeoff analysis to determine the best H_2 delivery approach(es) in PA

<u>New Material Development</u>

- Evaluate novel material approaches for pipelines and compressed gas storage tanks

<u>Hydrogen Sensor Development</u>

- Establish capability of H_2-specific sensors to determine %H_2 in feed gas (including gas blends) and ppm-level H_2 for leaks

CTC Concurrent Technologies Corporation

H_2 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 H_2 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

Concurrent Technologies Corporation

Materials/Sensors Approach

- Conduct baseline assessment of innovative materials/processes for H_2 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 H_2 sensor requirements
- Assess sensor potential based on requirements
- Test priority sensor technologies in H_2 and gas blends
  - Identify effects of:
    - Contaminants - Pressure
    - Humidity - Temperature
  - Assess calibration, maintenance, and in-field sensing abilities

CTC
Concurrent Technologies Corporation

H_2 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%

CTC Concurrent Technologies Corporation

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%

CTC®
Concurrent
Technologies
Corporation

H_2 Delivery Accomplishments

- Established the H_2 Pipeline Working Group
- Identifying H_2 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 H_2 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 H_2 costs if recovery to H_2 applications is less than 50%
      - *CTC* team aiming to achieve >80% recovery
- Assessed thermodynamic models and property data for methane, H_2, and their mixtures
  - Using NIST software to estimate the thermodynamic properties of H_2-natural gas mixtures

CTC
Concurrent Technologies Corporation

H_2 Delivery Accomplishments

- Performed research* and demographic studies for PA H_2 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 H_2 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

CTC

Concurrent Technologies Corporation

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 H_2 LDVs required for 10% market penetration
  - Assumes 0.78 LDV/person
- 12,938 kg/day H_2 demand
  - Assumes 0.72 kg/vehicle/day
- 12 refueling stations needed
  - Assumes 1,050 kg/day capacity refueling station

CTC Concurrent Technologies Corporation

H_2 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

CTC

Concurrent Technologies Corporation

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

CTC
Concurrent Technologies Corporation

Materials/Sensors Accomplishments

- Creating existing and new infrastructure material issue matrix
  - Separating issues according to:
    - New pure H_2 lines and existing natural gas lines
    - Low and high pressure and pure H_2 and gas blends
  - Found existing H_2 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 H_2 or gas blends is not an option in existing infrastructure
    - Per PA utility companies
- Identified a preliminary list of COTS sensors

CTC
Concurrent Technologies Corporation

Future H_2 Delivery Work

- Refine production scenarios
- Develop/modify existing models and tools to determine required fueling stations and best means for H_2 delivery to the stations
  - Model potential delivery scenarios
    - Pipeline
    - Tanker
    - Rail
- Perform sensitivity analysis
  - Consider % differences in estimated H_2 use and that based on gas usage

CTC
Concurrent Technologies Corporation

Future Materials Work

- Quantify effects/issues of H_2 and gas blends on infrastructure materials (including new H_2 pipeline)
  - Prioritize issues based on occurrence, relative cost, and safety
    - Examine issues in context of pure H_2 or gas blend delivery
    - Benchmark current H_2 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 H_2 and H_2/natural gas mixtures on infrastructure materials
  - Feed data into lifing/survivability model for lifecycle safety and durability prediction
- Construct and test prototype tank

CTC

Concurrent Technologies Corporation

Future Sensor Work

- Evaluate and modify an ambient H_2 sensor for hydrogen transportation and delivery applications
  - Review prototypes or near-commercial H_2 sensors
  - Conduct testing on three sensors that show the greatest commercial viability
    - Focus on detecting and quantifying H_2 gas leakage into ambient environments in the following priority:
      - Natural gas pipelines with H_2, H_2 gas pipelines, and process gas pipelines with H_2
      - H_2 transfer (transfer lines and storage containers)
      - H_2-managed environments (near H_2 storage tanks, along transfer lines, within personnel zones, around combustion zones)
      - Other areas where H_2 is stored, transferred, and consumed

CTC
Concurrent Technologies Corporation

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*

CTC
Concurrent Technologies Corporation

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*

Concurrent Technologies Corporation