Hydrogen:
Basics and Use

U.S. Department of Energy

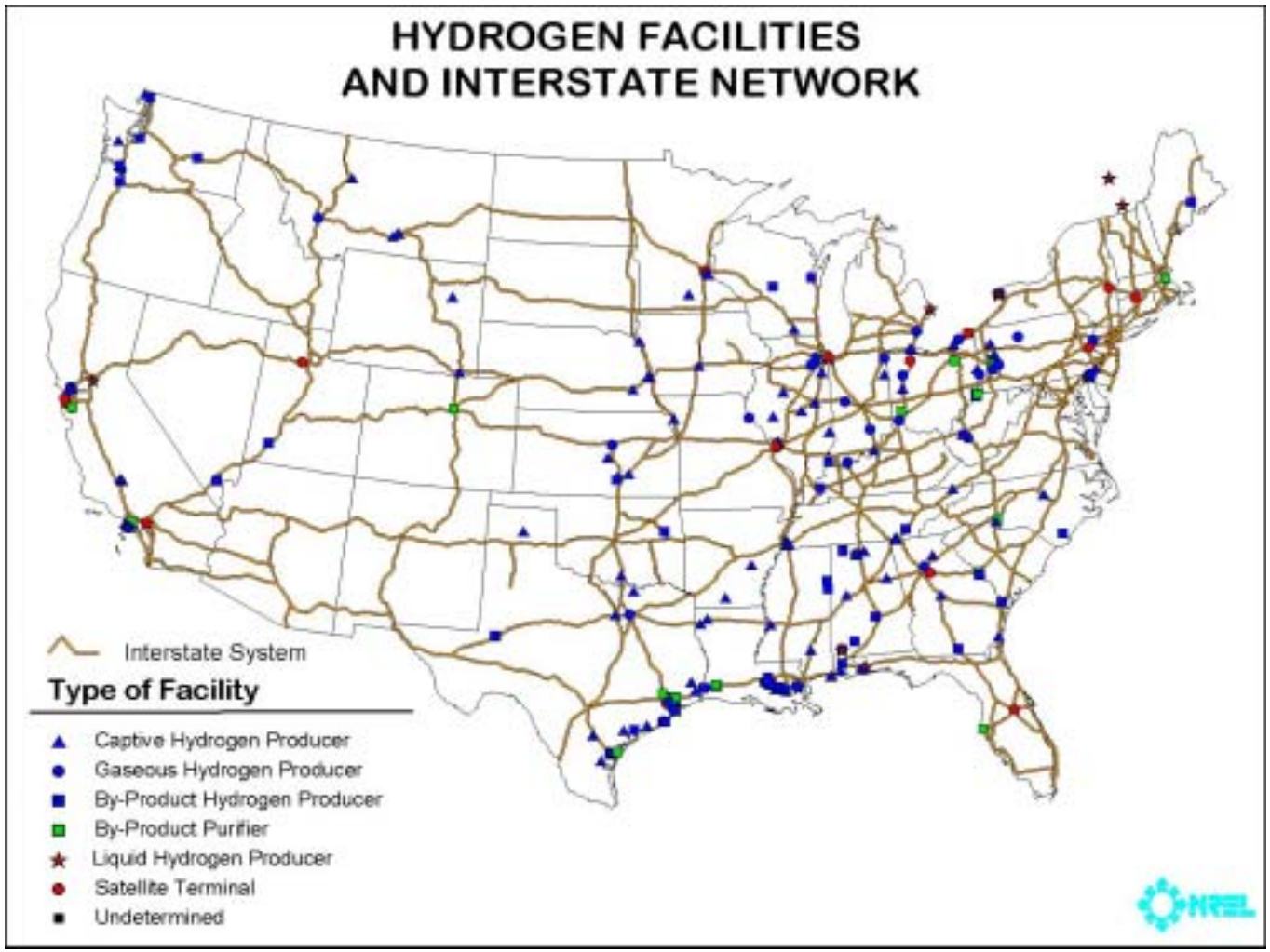
Hydrogen Fundamentals

- Energy Content: 60,958 Btu/lb – highest energy content of all fuels on a **weight** basis
  - This is why NASA uses hydrogen – they care a lot more about weight than volume)
  - Energy content is about three times higher than gasoline, natural gas, and propane on a **weight** basis
  - Energy content is only about one third that of natural gas and about an eighth that of propane on a **volume** basis
- Flammability limits (in air): 4.1 v% - 74 v%
- Explosion limits (in air): 18.3 v% - 59 v%

Hydrogen Today

- Production (9 million tons per year)
  - Steam methane reforming
  - Electrolysis
  - Byproduct
- Uses – largely in industrial settings
  - Petroleum upgrading
  - Food processing (hydrogenation)
  - Semiconductor processing
  - NASA (only large-scale fuel use)
- Transporting/Delivery
  - Pipeline
  - Liquid tanker
  - Tube trailer (compressed gas)

Hydrogen Facilities in the US



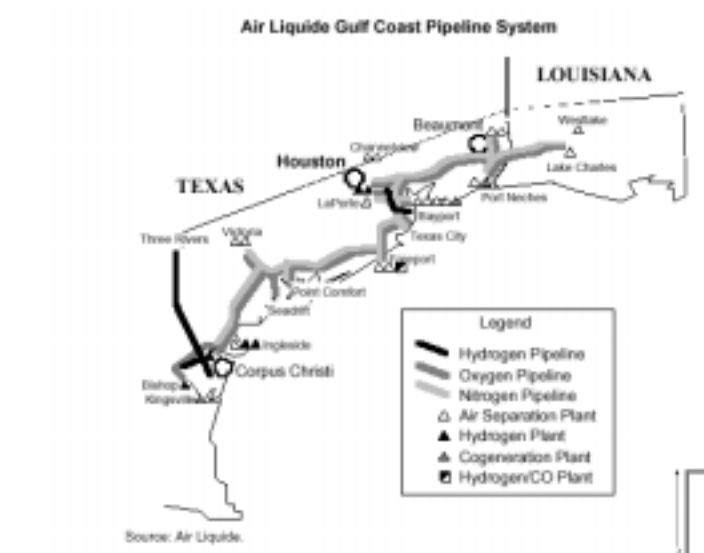
NASA's Hydrogen Facilities

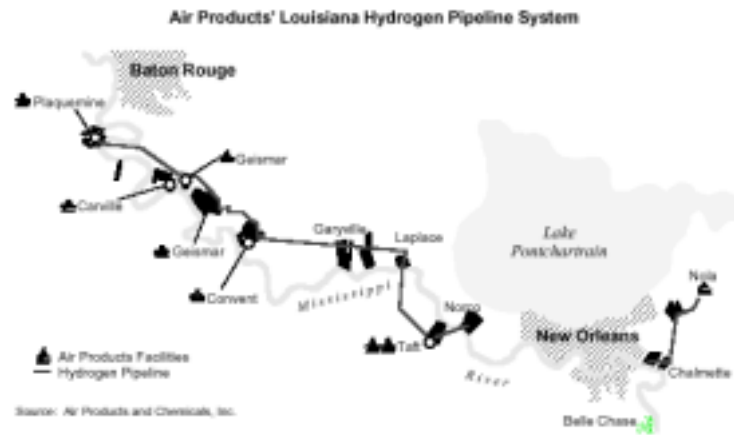
Single largest user of hydrogen for fuel

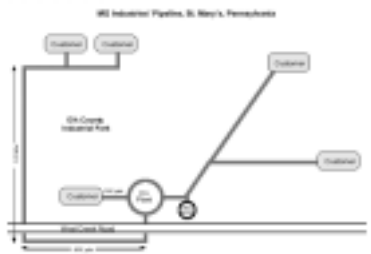
Kennedy Space Center 850,000 gallon liquid storage

Approximately 20 tank trucks driven in from Louisiana for each shuttle launch

Hydrogen Pipelines







Codes and Standards

- Code-making bodies in the US
  - About 20 major developers (excluding federal agencies such as EPA and DOT)
  - Nearly all is done using a consensus process
- Must be adopted by each jurisdiction to be "legal" and binding
  - Approximately 44,000 jurisdictions in the US
  - Federal, state, county, city or town

Code Developers

- International Code Council, Inc. (ICC)
  - Building Officials and Code Administrators International (BOCA)
  - International Conference of Building Officials (ICBO)
  - Southern Building Code Congress International, Inc. (SBCC)
- Underwriters Laboratories (UL)
- National Fire Protection Association (NFPA)
- CSA International
- Society of Automotive Engineers (SAE)
- Institute of Electrical and Electronic Engineers (IEEE)
- American Society of Mechanical Engineers (ASME)
- International Electrotechnical Commission (IEC)
- International Organization for Standards (ISO)
- Compressed Gas Association (CGA)
- Natural Gas Institute (NGI)
- US Department of Transportation
- Occupational Health and Safety Administration (OHSA)

Issues

- Codes & standards are being developed in advance of, or in parallel with, hydrogen-fueled systems
  - Codes & standards development must be coordinated with technology development
  - Efforts should be devoted to R&D efforts to validate proposed standards (i.e., need data to support or validate proposed requirements)
- Coordination is vital
  - All applications involve production, transportation, storage, dispensing, and use of hydrogen
  - A large number of organizations are involved in generating codes & standards

Key Codes

Component Technology	Codes	Status
Production	NFPA 70/ NEC/CEC ASME Boiler-Pressure Vessel Sec. VIII	mature mature
Transportation:	DOT 49 CFR	mature mature
Pipeline	NEC/CEC ANSI/ASME B31.1, B31.8	mature mature
Storage	NFPA 50 A: Gaseous Hydrogen NFPA 50 B: Liquid Hydrogen ASME Boiler-Pressure Vessel Sec. VIII	mature (1994) mature (1994) mature
Vehicle Refueling Stations	HV-3: Hydrogen Vehicle Fuel NFPA 52: CNG Vehicle Fuel HV-1: Hydrogen Vehicle Connector NGV1: NGV connectors	being developed base for HV-3 being developed base for HV-1
Hydrogen Vehicles	HV-3: Hydrogen Vehicle Fuel NFPA 52: CNG Vehicle Fuel HV-2: Gaseous Hydrogen Tanks NGV2: CNG Storage Tanks	being developed base for HV-3 being developed base for HV-2

ISO-TC197

Identification Number	Title	Working Group	Convener (Country)
DIS 13984	Liquid H_2 - Land Vehicle Fueling System Interface	WG 1	SCC (Canada)
DIS 14687	H_2 Fuel-Product Specification	WG 3	ANSI (USA)
NP 15594	Airport H_2 Fueling Facility	WG 4	DIN (Germany)
NP 15866	Gaseous H_2 and H_2 Blends--Vehicular Fuel Systems	WG 5	ANSI (USA)
NP 15869	Gaseous H_2 - Vehicle fuel tanks	WG 6	ANSI (USA)
NP 15916	Basic requirements for safety of H_2 systems	WG 7	DIN (Germany)
WD 13985	Liquid H_2 - Land vehicle fuel tank		SCC (Canada)
WD 13986	Tank containers for multimodal transport of liquid H_2		SCC (Canada)

ANSI/CSA NGV2[1]
Fuel Containers
(CNG only)

ASME
Boiler & Pressure Vessels
(Published)

SAE J2600
Fueling Connectors
(Published)

ICC Family Codes
Fire,Fuel,Mechanical
Electrical
(Approved)

NFPA Codes
Fuel,Electrical,Storage
(Under review for H2)

ISO TC197 WG5
H2& H2 Blends
Refueling
(Requested)

SAE J2601
Vehicle Communication
(In Progress)

UL 2264
Gaseous H2 generation
(To be developed)

ANSI/CSA NGV 4[2]
Dispensing Systems
(CNG only)

ISO TC197 WG8
Water Electrolysis
(Requested)

SAE J1616
Recommended Practice
(CNG only)

CGA G-5.3 Hydrogen
Commercial Specification
(Published)

CGA P-6 Hydrogen
Standard Density Data
(Published)

CGA G-5 Hydrogen
Commercial H2
(Published)

CGA G-5.4 Hydrogen
Piping Systems
(Published)

ISO TC-197 WG2
Tank Containers
(Requested)

CSA FC-4
Fuel Cell Modules
(Proposed)

ANSI Z21.83/CSA FC-1
Fuel Cell Powerplants
(Under revision)

IEC TC 105 WG5
FC Installation
(Initiated)

IEC TC105 WG1
Terminology
(Under review)

ICC Family Codes
Fire,Fuel,Mechanical
Electrical
(Approved)

NFPA Codes
Fuel,Electrical,Storage
(Under review for H2)

ISO TC 197 WG2
Containers & Hydrides
(In Progress)

CSA CAS No. 33
Component Acceptance
Service
(Published)

ASME PTC 50
Performance Test
(Approved)

UL 2265
Replacement FC units
(Under development)

ISO TC 58
Tanks & Embrittlement
(Requested)

IEC TC105 WG2
FC Modules
(Under review)

IEC TC 105 WG3
FC Safety
(Draft in progress)

CSA US Requirements 1.01
FC supplimental
(Published)

UL 1741
Inverters & Converters
(Under draft)

CGA G-5.4
H2 Piping at Consumers
(Published)

NFPA 853
FC Installation
(Under revision)

IEEE P1547
Interconnect Standard
(Approved)

ASME B31.4
Pipeline Transportation
(Published)

NFPA 58
Transport of LPG
(Published)

DOT 49 CFR
Transportation of
Hazardous Materials

ASME B31.8
Gas Transmission &
Distribution
(Published)

ISO TC 197 WG2
Containers & Hydrides
(In Progress)

CSA CAS No. 33
Component Acceptance
Service
(Published)

NFPA 55
Combined 50 A&B
(In progress)

Part 1910 29 CFR
OSH Standards
(Published)

ISO TC 58
Tanks & Embrittlement
(Requested)

DOT Guide
First Responders on
Emergencies
(Published)

NFPA 50B
Liquid H2 Systems
(Published)

ASME
Boiler & Pressure Code
(Published)

CGA G-5.4
H2 Piping at Consumers
(Published)

NFPA 50A
Gaseous H2 Systems
(Published)

CSA/NGV2
Fuel Tanks for Hydrogen
(Requested)

SAE J2600
Compressed Hydrogen
Fueling Connectors
(In Progress)

SAE J2594
Fuel Cell Recyclability
Guidelines
(In progress)

SAE J2574
Fuel Cell Vehicle
Terminology
(Published)

SAE J2572
Recommended Practice
Exhaust Emissions
(In Progress)

SAE J2615
Performance Test Procedures
For Fuel Cell Systems
(In progress)

SAE J2601
Compressed Hydrogen
Fueling Communication
(In progress)

SAE J2616
Performance Test Procedures
For Fuel Processor Subsystem
(In progress)

SAE J2578
Recommended Practices
For Vehicle Safety
(Published)

DOT/NHTSA
Vehicle
Regulations

SAE J2579
Recommended Practices
For Hazardous Fluid Systems
(Published)

SAE J2617
Performance Test Procedures
Of PEM FC Stack Subsystem
(In progress)

ISO TC 197
Compressed Hydrogen
Fueling Connectors
(Requested)

Hydrogen Uses - Tomorrow

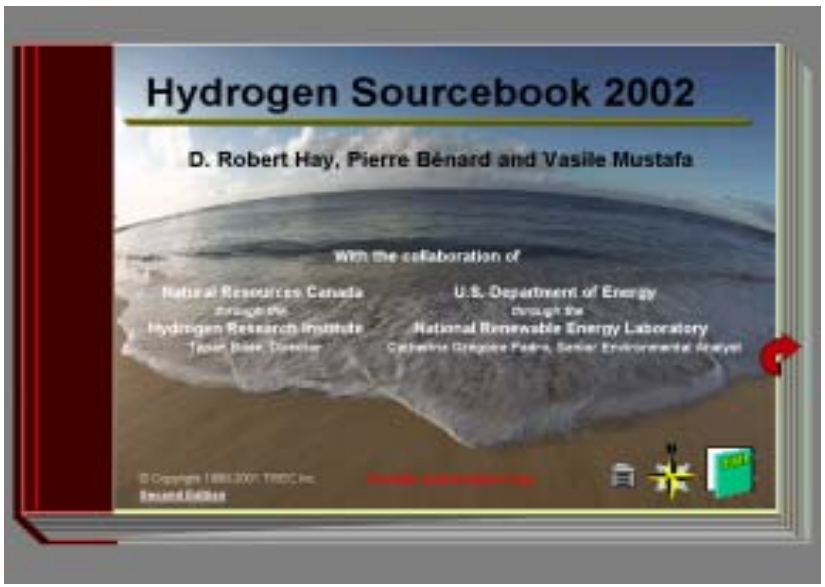
- Mobile Applications
  - Fuel cell vehicles (buses, trucks, passenger)
  - Modified ICEs

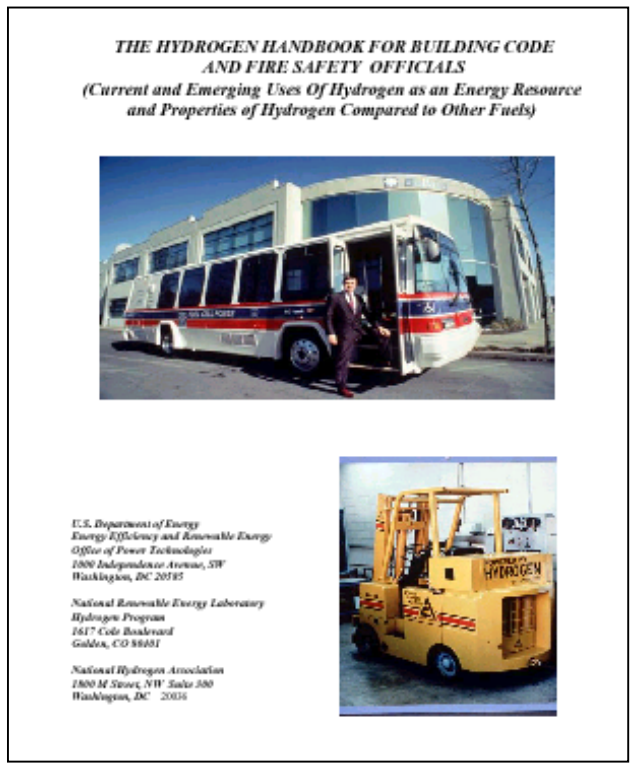
- Stationary Applications
  - Uninterruptible power supplies
  - Backup/premium power
  - CHP

- Portable Applications

Guidelines for Hydrogen Systems

- The Hydrogen Handbook for Building Code and Fire Safety Officials
- The Hydrogen Sourcebook





THE HYDROGEN HANDBOOK FOR BUILDING CODE AND FIRE SAFETY OFFICIALS

(Current and Emerging Uses Of Hydrogen as an Energy Resource and Properties of Hydrogen Compared to Other Fuels)

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Office of Power Technologies
1000 Independence Avenue, SW
Washington, DC 20585

National Renewable Energy Laboratory
Hydrogen Program
1617 Cole Boulevard
Golden, CO 80401

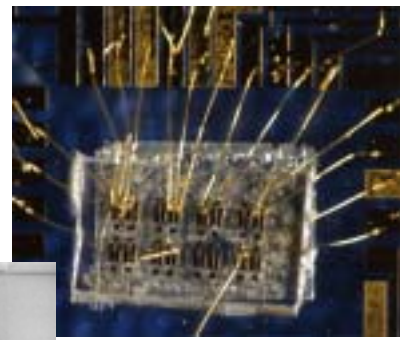
National Hydrogen Association
1800 M Street, NW Suite 300
Washington, DC 20036

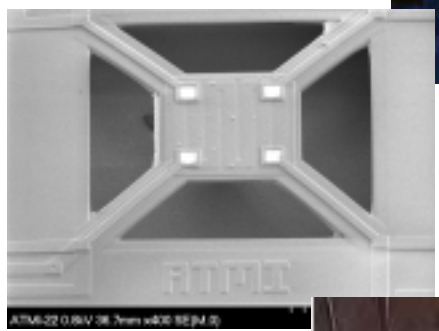
Typical Hydrogen Site Plan Review

- Confinement
- Review Potential for Ignition
- Minimizing Consequences
- Review the Need for Detectors
- Safety Analysis
- Review Site-Specific Factors
- Personal Investigation

Detection

- Sensors
  - Safe, reliable, cheap sensors being developed
  - Placement is important
- Odorants
  - Diffusion/dispersion matching is difficult
  - Poison to fuel cell?





Safe Hydrogen Systems

- Safety issues can be handled through testing, certification, and codes & standards, just like with any other fuel
- Sustained, collaborative government-industry RD&D needed
  - Fuel cell and vehicle systems development are critical
  - Infrastructure and codes & standards development require significant government participation (on all levels)
  - Coordination is key

For more information:

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