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Panel Forum

Challenges of Hydrogen Pipeline Transmission

International Pipeline Conference and Exposition

Calgary, Alberta Canada

October 5, 2004

Development of US-DOT Regulations for Hydrogen Transportation Systems

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US DOT MISSION

Strategic Transportation Goals

- ◆ Public Safety
- ◆ Security
- ◆ Mobility (people and commerce)
- ◆ Global Connectivity (economic growth)
- ◆ International Co-operation for Codes and Standards, economic development and reserach



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DOT Administrations

All have significant roles in hydrogen economy

- Federal Aviation Administration (FAA)
- Federal Highway Administration (FHWA)
- Federal Motor Carrier Safety (FMCSA)
- Federal Railroad Administration (FRA)
- Federal Transit Administration (FTA)
- Maritime Administration (MARAD)
- National Highway Traffic Safety Administration (NHTSA)
- Research & Special Programs Administration (RSPA)
- StLawrence Seaway Development Corporation



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Hazardous Materials Transportation and Vehicle Safety Regulations

Responsible Administrations

Research & Special Programs
Administration (RSPA)

*Public Safety-Transportation in
Commerce*

National Highway Traffic Safety
Administration (NHTSA)

Design, Safety, CAFA' Standards



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Core Responsibilities

Code of Federal Regulations Title 49

Hazardous Materials Safety

- ◆ Regulatory authority and responsibility for safe hazmat transportation/packaging/inspection
50,000 shippers/800,000 shipments/day- Over 4700 items come under RSPA regulations (40CFR§172.101)
- ◆ State programs for hazmat training to state regulators and public

Pipeline Safety

- ◆ Regulatory authority and responsibility for public safety for over 2 million miles of inter-state pipelines for hazardous liquids, natural gas, and other flammable, corrosive and toxic gases. Over 300,000 miles of pipelines transport a variety of compressed gases (49CFR Part 192).



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Hydrogen Transportation

As of To-day Hydrogen can be shipped in commerce under DOT regulations (US DOT 49 CFR) in a variety of containers and pipelines.



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DOT Specification Packagings Compressed Hydrogen

Cylinders

DOT Specifications 3, 3A, 3AA (steel) and 3AL (aluminum): water capacity not over 1,000 Lbs.; *service pressure* typically 2,000 to 3,600 psig.

DOT Specification 4B, 4BA and 4BW (steel): water capacity not over 1,000 Lbs.; *service pressure* 150 to 500 psig (typically 240 psig) (No Hydrogen)





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DOT Specification Packagings Compressed Hydrogen

Composites



Composite cylinders (steel and aluminum liners wrapped with fiberglass or carbon) manufactured under DOT exemptions: water capacity not over 200 Lbs; Design *service pressure* 900 to 5,000 psig (typically 2,000 to 4,500 psig). DOT FRP-1, DOT-CFFC Standards



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DOT Specification Packagings Liquid Hydrogen

Cylinders

DOT Specification 4L (steel):
water capacity not over 1,000 Lbs.
service pressure 40 to 500 psig.

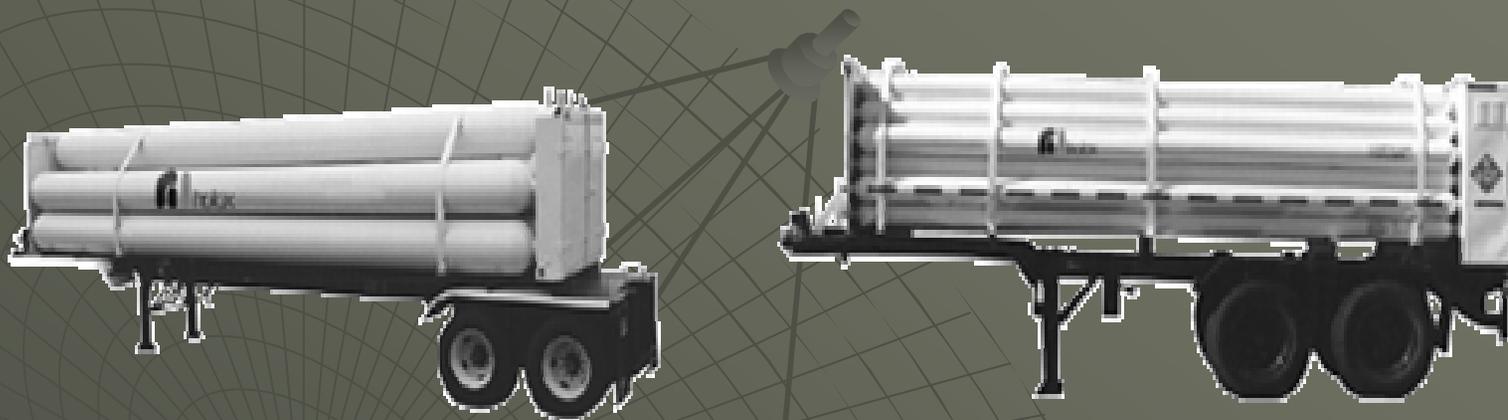




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DOT Specification Packagings Compressed Hydrogen

Tube Trailers



DOT specifications 3AX and 3AAX (steel):
water capacity greater than 1,000 Lbs. Typical
design pressure 2,000 to 3,600 psig.



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DOT Specification Packagings Liquid Hydrogen

Cargo Tanks



DOT Specification MC-338 (steel):
maximum allowable working pressure
100 to 500 psig.



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DOT Specification Packagings Liquid Hydrogen

Tank Car Tanks



DOT Specification 113A (steel):
Test pressure 175 psig



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DOT Specification Packagings Liquid Hydrogen

Portable Tanks



DOT Specification UN Portable Tanks &
Exemption Portable Tanks based on
DOT Specification MC-338 (steel):
maximum allowable working pressure
100 to 500 psig.



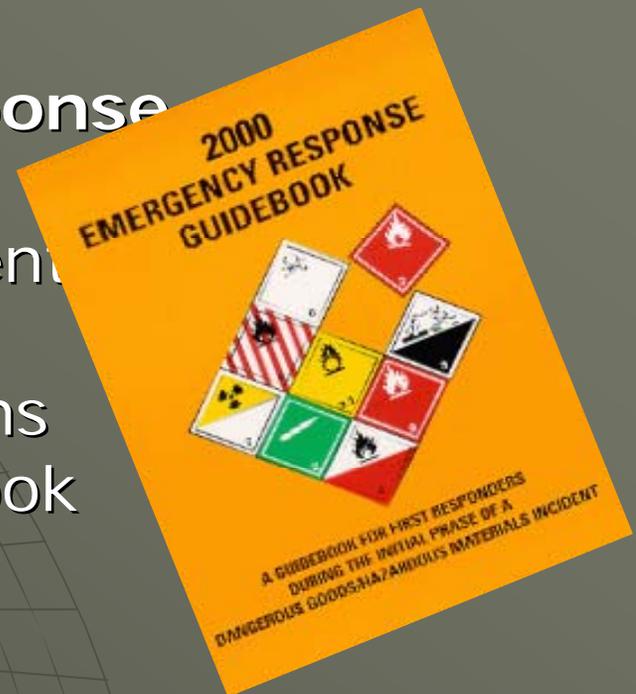
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Hydrogen Fuel Infrastructure

Emergency Preparedness/Response

- Higher risk of transport accidents
Catastrophic potential
- Reflect first responder concerns
- Emergency Response Guidebook
Nearly 2,000,000 distributed

Coordinate hydrogen emergency
safety publications with RSPA's Office of
Hazardous Materials Safety





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Pipeline Safety

**49 CFR parts 190-199.
Part 192 for Gas
Transmission and
Distribution Systems**



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Material Qualification

49CFR §192.53 Materials.

Materials for pipe and components must be

- (a) Able to maintain structural integrity of the pipeline...
- (b) Chemically compatible with any gas that they transport..., and
- (c) Qualified in accordance with the applicable requirements of this subpart...



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Design Requirements

$$P = (2 S t / D) F E T$$

P = Design Pressure

S = Specified Minimum Yield Stress

t = Nominal wall thickness

D = Nominal outside Diameter

F, E, T = Design, weld joint &
temperature derating factors.



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Operation and Maintenance

Corrosion Control

In-service Inspection and Repair

Integrity management

Operator Qualification

Reporting Requirements



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So what is the issue ?

- ◆ There is a definite need for alternate energy sources to meet the ever increasing demand for energy worldwide.
- ◆ Current conventional energy sources may not be adequate
- ◆ Increased use of oil and natural gas increases global pollution and global warming.
- ◆ Considering Hydrogen is a viable choice, issues related to production, transportation and delivery to end user pose technological and economic and social issues.
- ◆ Current infrastructure is not adequate to handle the hydrogen transportation needs.
- ◆ Hydrogen properties are unique including flammability, and handling difficulties. Safety considerations need be addressed upfront.
- ◆ Codes and Standards and Government Regulations are key to safe and successful use of Hydrogen.



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World Pipeline Experience

(Source: Mohitpour et.al ASME Paper '2004)

Location	Pipeline Material	Years of Operation	Diameter (mm)	Length (km)	Pressure (kPa) and Gas Purity (%)	Exp	Status
AGEC, Alberta, Canada	Gr. 290 (5LX X42)	Since 1987	273 x 4.8 WT	3.7	3.790 kPa– 99.9%	No	Oper.
American Air Liquide Texas/Louisiana, USA	API 5LX42, X52, X60 and others	?	3" to 14"	390	5100 kPa (740 PSI)	Yes	Oper.
Air Products, Houston area, USA		Since 1969	114.3 – 324	100	345 kPa– 5.516 (Pure H ₂)	No	Oper.
Air Products, Louisiana	ASTM 106	1999 ?	101.6 – 304.8	48.3	3.447kPa	Yes	Oper.
Air Products, Sarnia (Dow to Dome plant)				3 app.		No	Oper.
Air Products, Texas	Conv. natural gas line (steel)	Before 1994	114.3	8	5,500 kPa – Pure H ₂	Yes	Oper.
Air Products, Texas	Steel, schedule 40	Before 1996	219.0	19	1.400 kPa– Pure H ₂	Yes	Oper.
Air products, Nether lands				45	(throughput = 50 tons/day)		Oper.
Chemische Werke Huis AG- Marl., Germany	Seamless equipment to SAE 1016 Steel	Since 1938	168.3 – 273	215	to 2,500: raw gas (throughput = 300 x 106 m ³)	Yes	Oper.
Cominco B.C., Canada	Carbon Steel (ASTM 210 seamless)	Since 1964	5 x 0.8125 WT	06	Greater than 30,000 kPa, 62 to 100% pure H ₂	No	Standby
Gulf Petroleum Cnd, (Petromont- Varnnes)	Carbon Steel, seamless, Sch. 40	--	168.3	16	93.5% H ₂ ; 7.5% methane	No	Oper.
Hawkeye Chemical, Iowa	ASTM A53 Gr. B	3	152.4	3.2	2.757.6 kPa	Yes	Oper.
ICI Billingham, UK	Carbon Steel	-	-	15	30,000 kPa, pure H ₂	No	Oper.
L'Air Liquide, France, Netherland, Belgium	Carbon Steel, seamless,	Since 1966	sizes up to 12"	879	6,484 – 10,000 kPa; pure and raw	No	Oper.
LASL, N.M.	ASME A357-Gr.5	-	25.4	6.4	13,788 kPa	Yes	Abandoned
Los Alamos, N.M.	5 Cr. – Mo (ASME A357 Gr. 5)	Before 1996	30	6	13.790 kPa; pure	Yes	Abandoned
Linde, Germany	-	-	-	1.6 – 3.2	-	-	-
NASA-KSC, Fla	316 SS (austinitic)	Before 1988	50	1.6-2	42,000 kPa	No	Oper.
NSA-MSFC, Ala	ASTM A106-B	-	76.2	0.091	34470 kPa	Yes	Oper.
Phillips Petroleum	ASTM A524	4	203.2	20.9	12,133-12,822 kPa	Yes	Oper.
Praxair, 6 states	Carbon Steel			450	Commercial Purity H ₂ (500 MSCFD)		Oper.
Rockwell International S.	SS-116	Before 1994	250	-	>100,000 kPa; ultra pure	No	-
South Africa				80			?



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Hydrogen Pipeline Infrastructure (United States)

- 900 miles of relatively low pressure and short intra-state hydrogen pipelines
- There are high pressure pipeline systems but these are for very specialized applications, very small diameters and using expensive steels.



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National Highway Traffic safety Administration (NHTSA)

Core Responsibility

Federal Motor Vehicle Safety Standards (FMVSS) 49 CFR Part 571

- ◆ FMVSS 100 Series- Crash Avoidance
- ◆ FMVSS 200 Series -Crashworthiness
- ◆ FMVSS 300 Series - Post Crash Standards



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Requirements for NHTSA-FMVSS

Must meet a safety need

Performance Based Standards

Be practicable (technology & economics)

Objectively measurable compliance

Appropriate for each type motor vehicle



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Hydrogen Use

- ◆ Produce Ammonia
- ◆ Hydrogenation of fats & oils
- ◆ Convert low grade crude oils into transport fuels
- ◆ Rocket fuel
- ◆ Alternative fuel to hydrocarbon used for Aviation
- ◆ Fuel Cells/ Automobile & Energy



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Hydrogen Storage

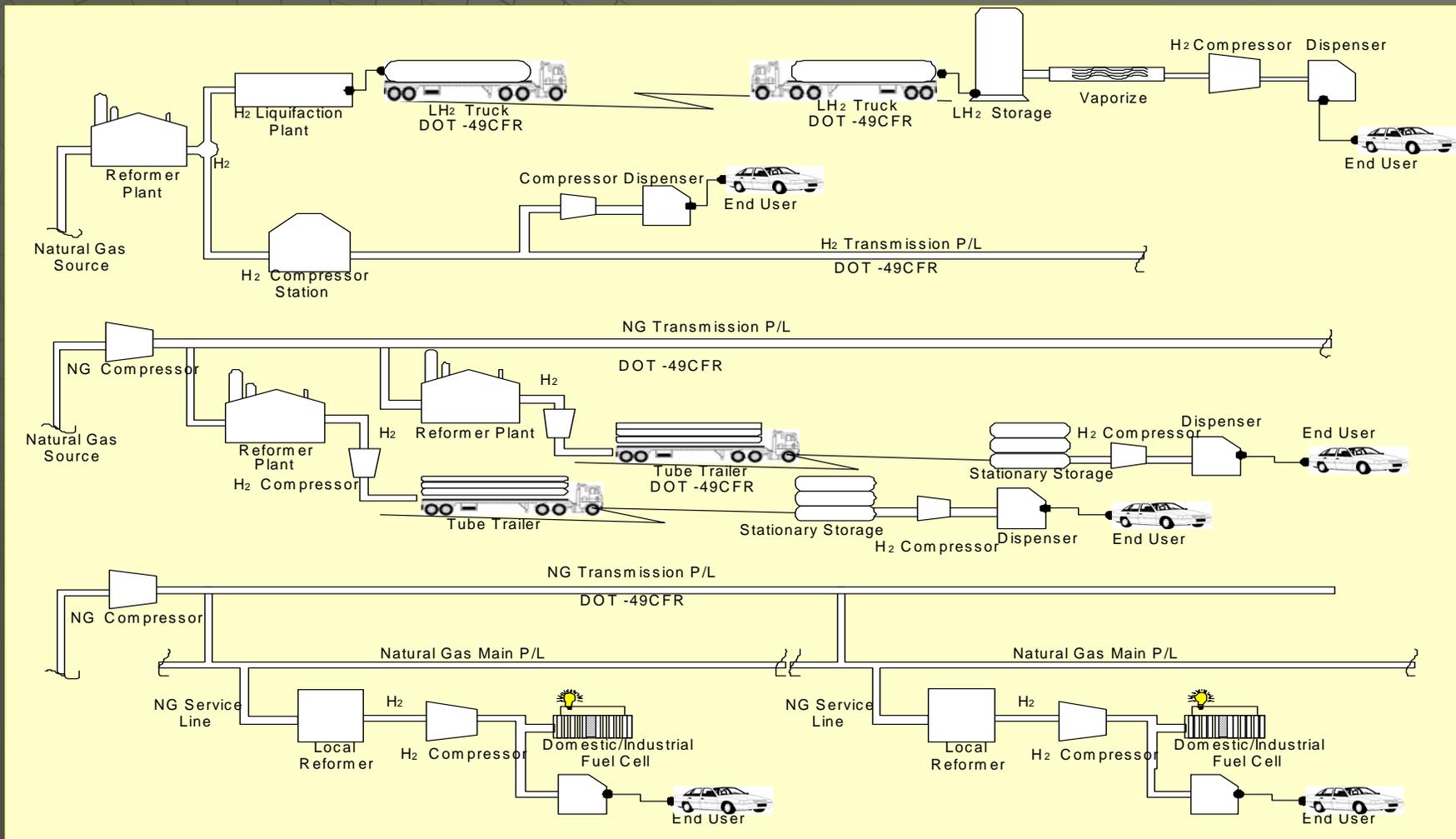
The three basic methods are:

- ◆ Compressed gas in pressure vessels / pipelines
- ◆ Liquid hydrogen stored in insulated tanks and dewars
- ◆ hydrogen stored in a solid compound (metal and ceramic hydrides)



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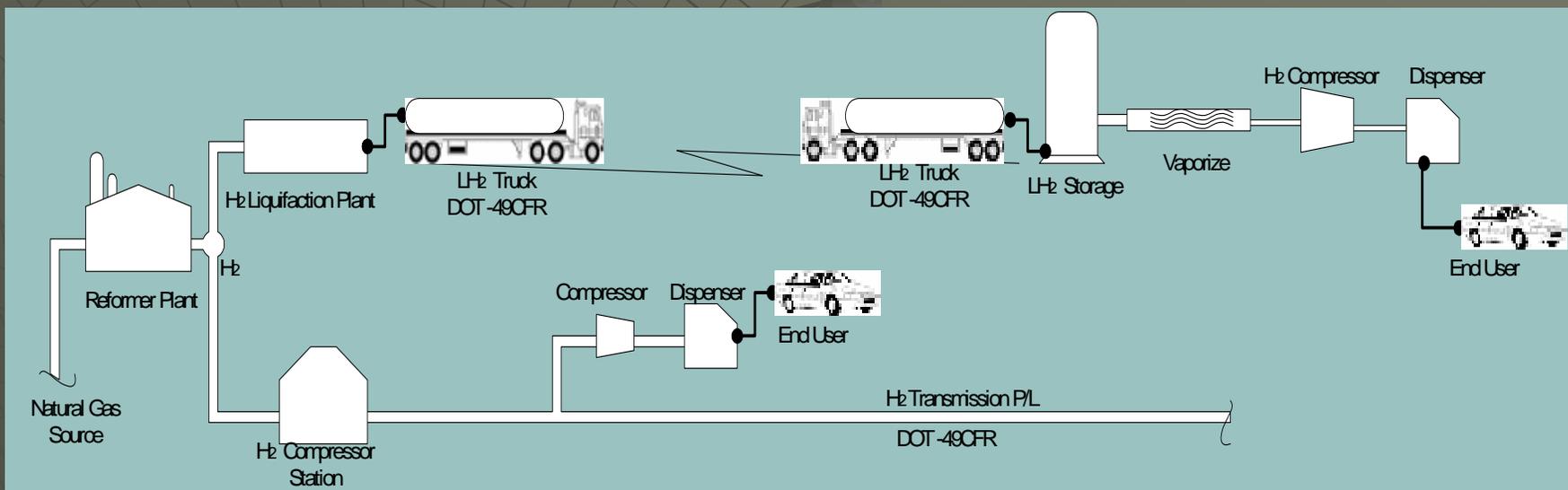
Hydrogen Economy Infrastructure Options





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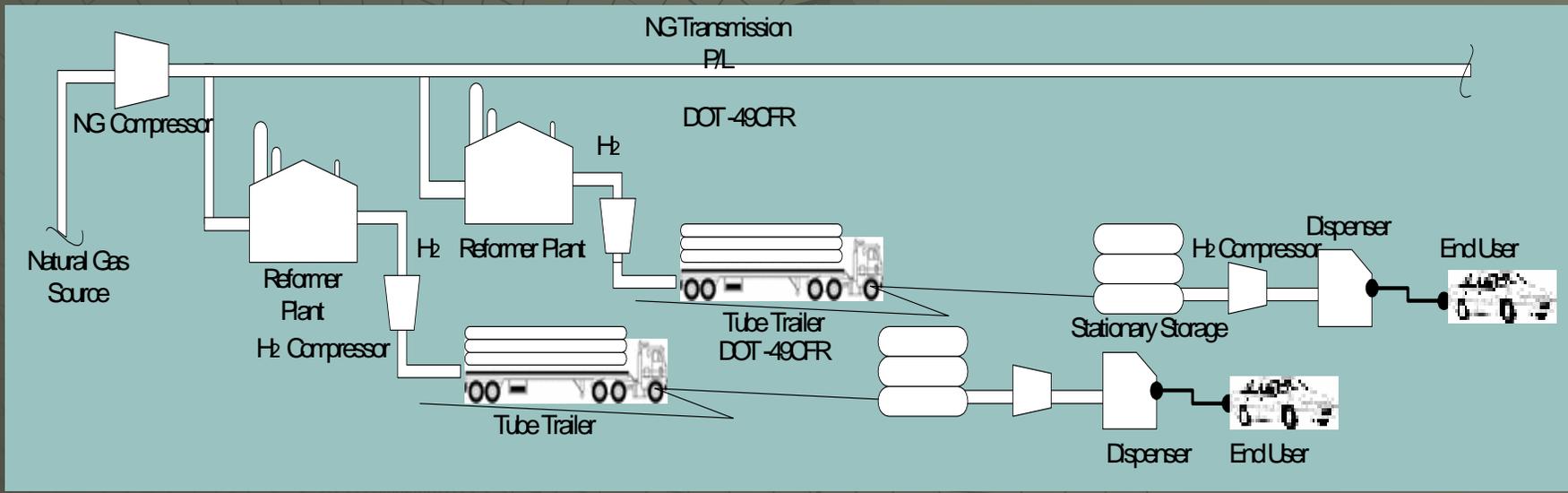
Hydrogen Economy Infrastructure Options





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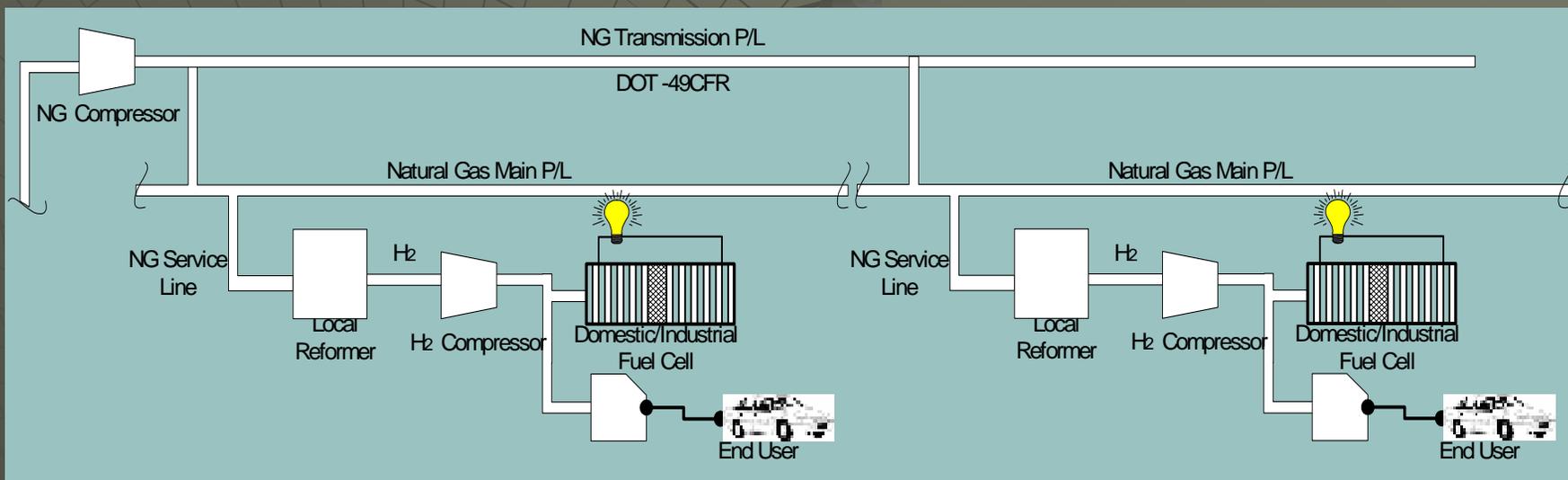
Hydrogen Economy Infrastructure Options





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Hydrogen Economy Infrastructure Options





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Exemptions, Waivers & Rulemaking

For HAZMAT Safety Regulations

Exemption from regulations is a path to introduce new materials and technologies

Waivers from Pipeline Safety regulations generally involve new design criteria and operations (Risk analysis, corrosion monitoring periodic inspection)

Rulemaking is initiated because of Congressional statute, immediate safety concerns, petition for rule making by individuals



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Relevant Codes and standards

Active participation in development of National and international standards:

- ASME, API, ASTM, NACE, NFPA, CGA , SAE Committees
- UN Committee and Sub-Committee of Experts on the Transport of Dangerous Goods
- US Interagency committees
- UN-ICAO Dangerous Goods Panel
- IMO Dangerous Goods, Solid Cargoes and Containers Sub-Committee and its editorial and technical group.
- ISO Technical Committees for Hazmat Transportation Pckagings design and manufacturing
- UNECE WP-29/ Working Group for Hydrogen Vehicle Standards.



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International Partnership for the Hydrogen Economy (IPHE)

An international partnership with currently 16 member countries to leverage R&D efforts and funds by commitment to advance all aspects of Hydrogen Economy.

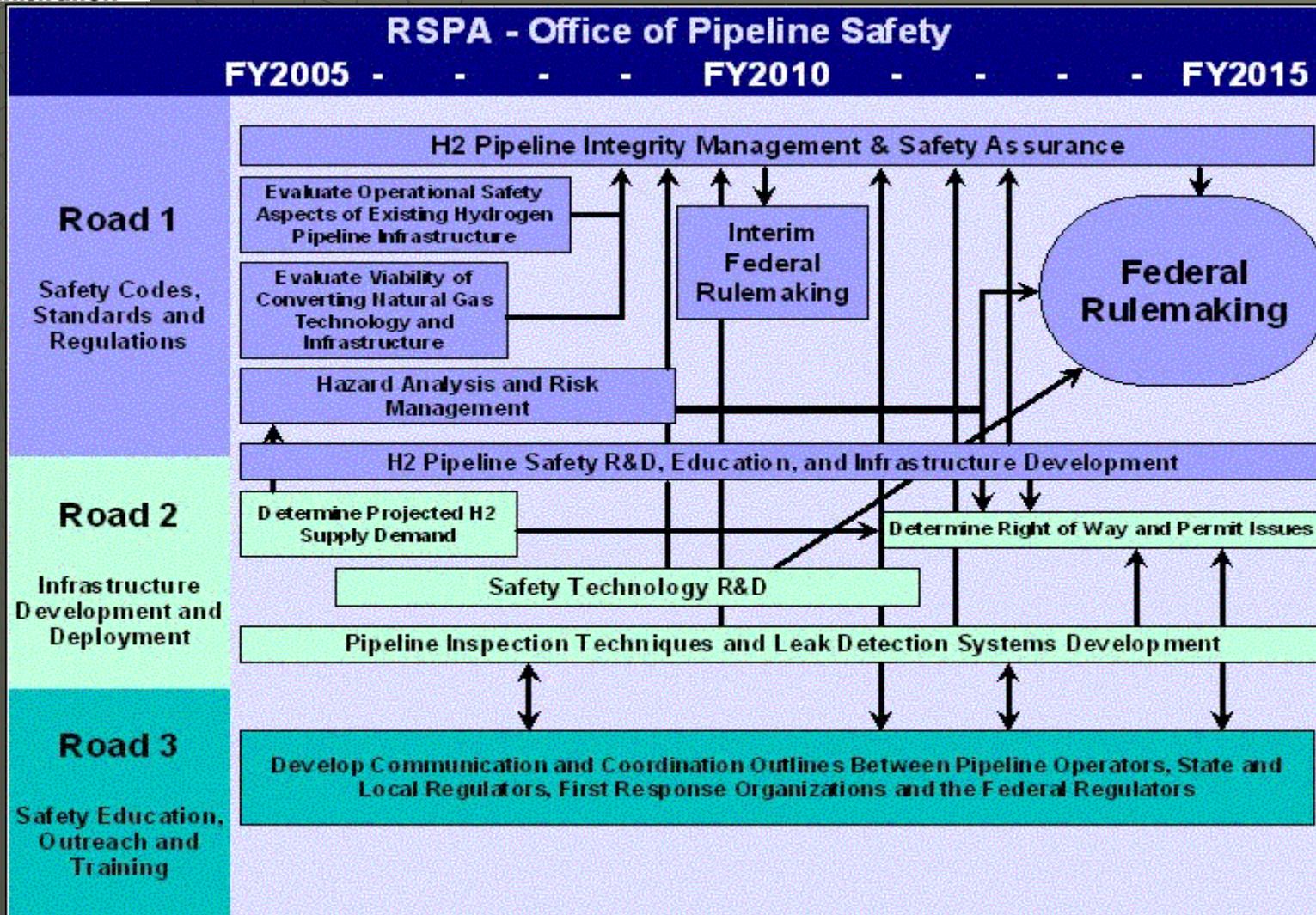
IPHE Website:

www.usea.org/IPHE.htm



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DOT Hydrogen Web-Site

- ◆ <http://www.rspa.dot.gov/dra/hydrogen/index.html>
- ◆ contact e-mail:
- ◆ gopala.vinjamuri@rspa.dot.gov
- ◆ stanley.staniszewski@rspa.dot.gov
- ◆ [William.chernicoff @rspa.dot.gov](mailto:William.chernicoff@rspa.dot.gov)