U.S. Department of Transportation
Research and Special Programs Administration

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

Gopala Krishna Vinjamuri
Research & Special Programs Administration
U.S Department of Transportation
Washington DC 20590

U.S. Department of Transportation
Research and Special Programs Administration

U.S 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 research

U.S. Department of Transportation
Research and Special Programs Administration

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

U.S. Department of Transportation
Research and Special Programs Administration

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

U.S. Department of Transportation
Research and Special Programs Administration

Research & Special Programs Administration

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).

U.S. Department of Transportation
Research and Special Programs Administration

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.

U.S. Department of Transportation
Research and Special Programs Administration

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)

U.S. Department of Transportation
Research and Special Programs Administration

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

U.S. Department of Transportation
Research and Special Programs Administration

DOT Specification Packagings Liquid Hydrogen

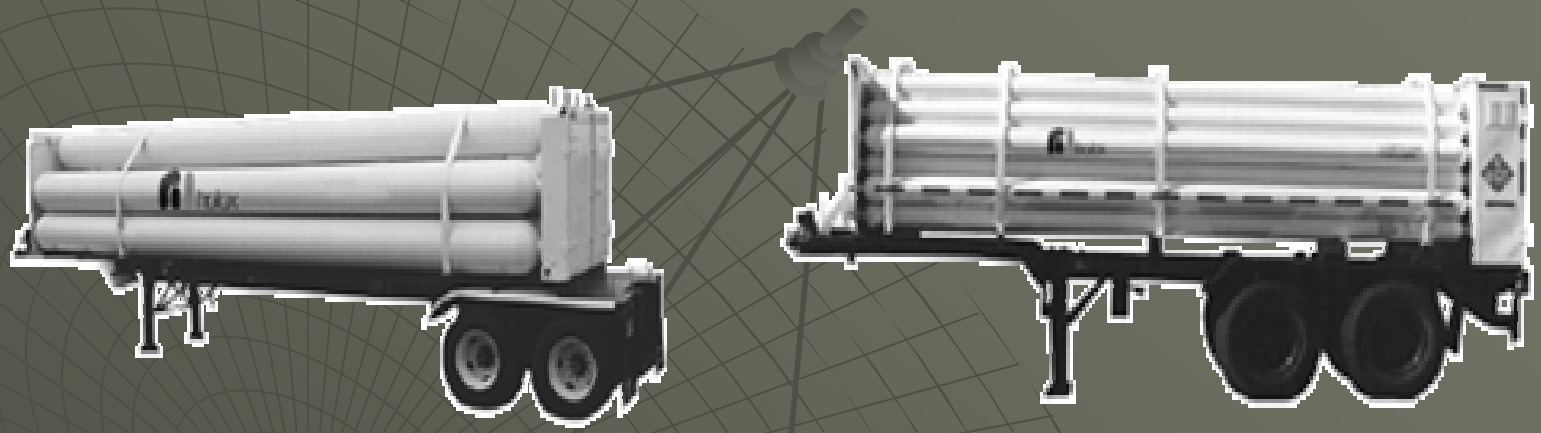
Cylinders

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

U.S. Department of Transportation
Research and Special Programs Administration

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.

U.S. Department of Transportation
Research and Special Programs Administration

DOT Specification Packagings Liquid Hydrogen

Cargo Tanks

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

U.S. Department of Transportation
Research and Special Programs Administration

DOT Specification Packagings Liquid Hydrogen

Tank Car Tanks

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

U.S. Department of Transportation
Research and Special Programs Administration

DOT Specification Packagings Liquid Hydrogen

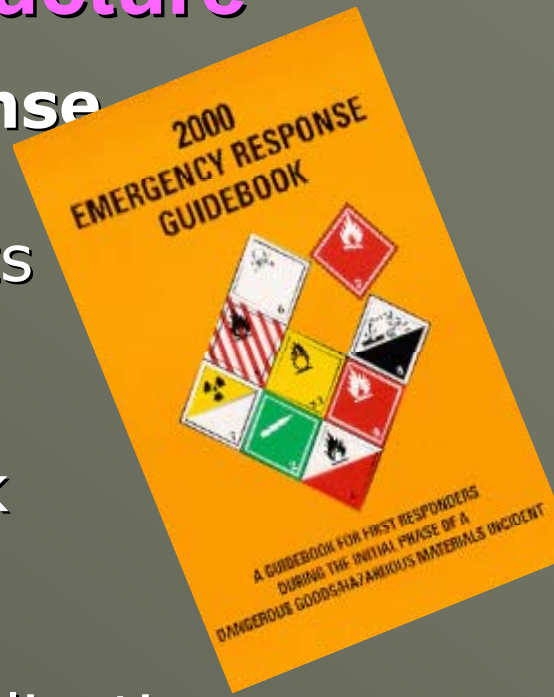
Portable Tanks

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

U.S. Department of Transportation
Research and Special Programs Administration

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

Hydrogen emergency safety publications

U.S. Department of Transportation

Research and Special Programs Administration

Pipeline Safety

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

U.S. Department of Transportation
Research and Special Programs Administration

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…

U.S. Department of Transportation
Research and Special Programs Administration

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.

U.S. Department of Transportation
Research and Special Programs Administration

Operation and Maintenance

Corrosion Control
In-service Inspection and Repair
Integrity management
Operator Qualification
Reporting Requirements

U.S. Department of Transportation
Research and Special Programs Administration

So what is the issue ?

- There is a definite need for alternate energy sources to meet the ever increasing demand for energy worldwide.
- US alone uses over 8 million barrels of oil to fuel over 150 million automobiles. Total consumption is much greater. By 2015 or so 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 even for 20% change.
- Hydrogen properties are unique including flammability, and handling difficulties. Safety considerations and public acceptance must be addressed upfront.
- Codes and Standards and Government Regulations are key to safe and successful use of Hydrogen.

U.S. Department of Transportation
Research and Special Programs Administration

World Pipeline Experience

(Source: Mohitpour et.el 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/Louisina, 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 H2)	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 H2	Yes	Oper.
Air Products, Texas	Steel, schedule 40	Before 1996	**219.0**	**19**	1.400 kPA– Pure H2	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 H2	No	Standby
Gulf Petroleum Cnd, (Petromont- Varnnes)	Carbon Steel, seamless, Sch. 40	--	**168.3**	**16**	93.5% H2; 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 H2	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 H2 (500 MSCFD)		Oper.
Rockwell International S.	SS-116	Before 1994	**250**	**-**	>100,000 kPa; ultra pure	No	-
South Africa				**80**			?

U.S. Department of Transportation
Research and Special Programs Administration

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.

U.S. Department of Transportation
Research and Special Programs Administration

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**

U.S. Department of Transportation
Research and Special Programs Administration

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

U.S. Department of Transportation
Research and Special Programs Administration

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

U.S. Department of Transportation
Research and Special Programs Administration

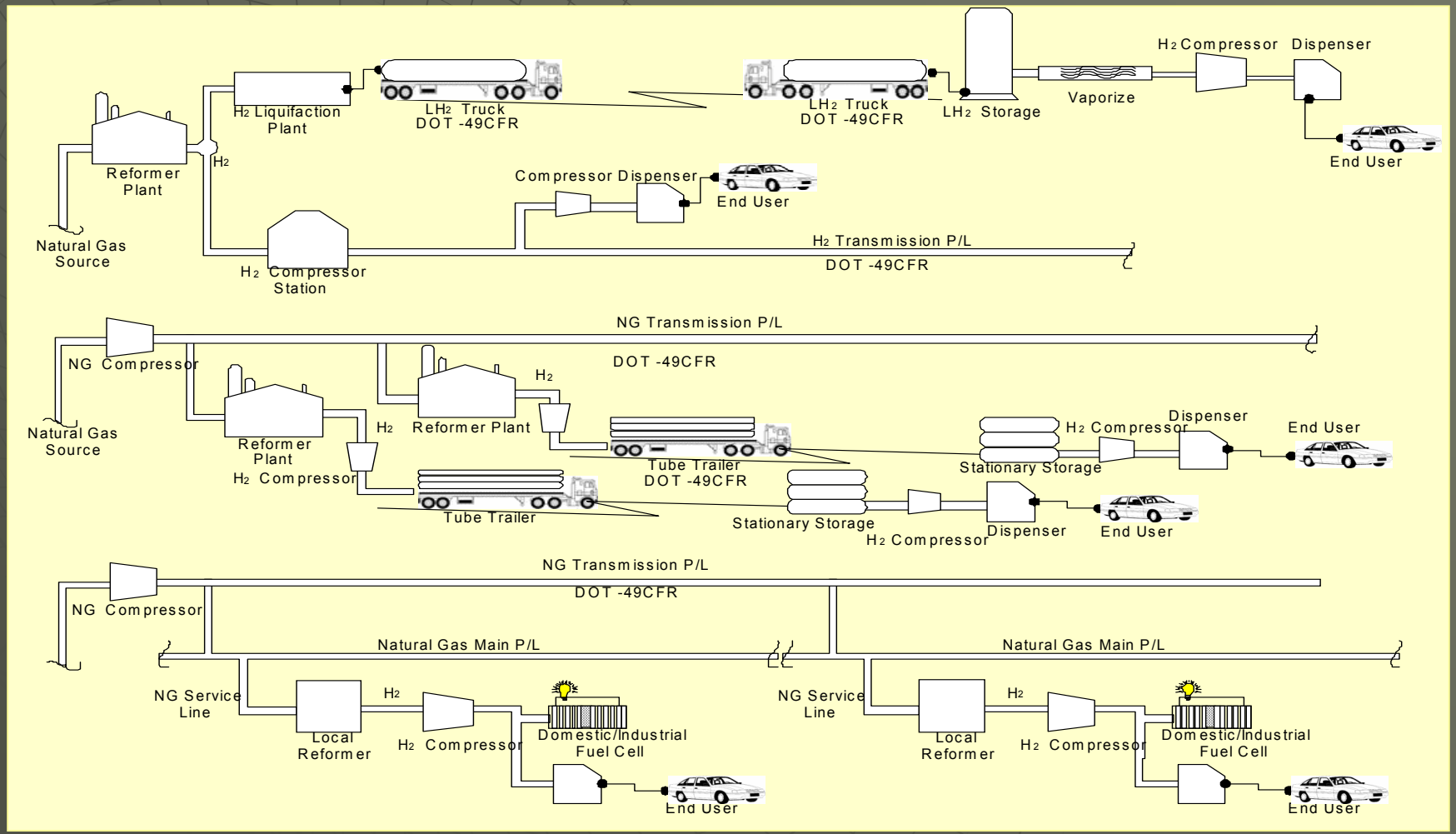
Hydrogen Storage

The three basic methods are:

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

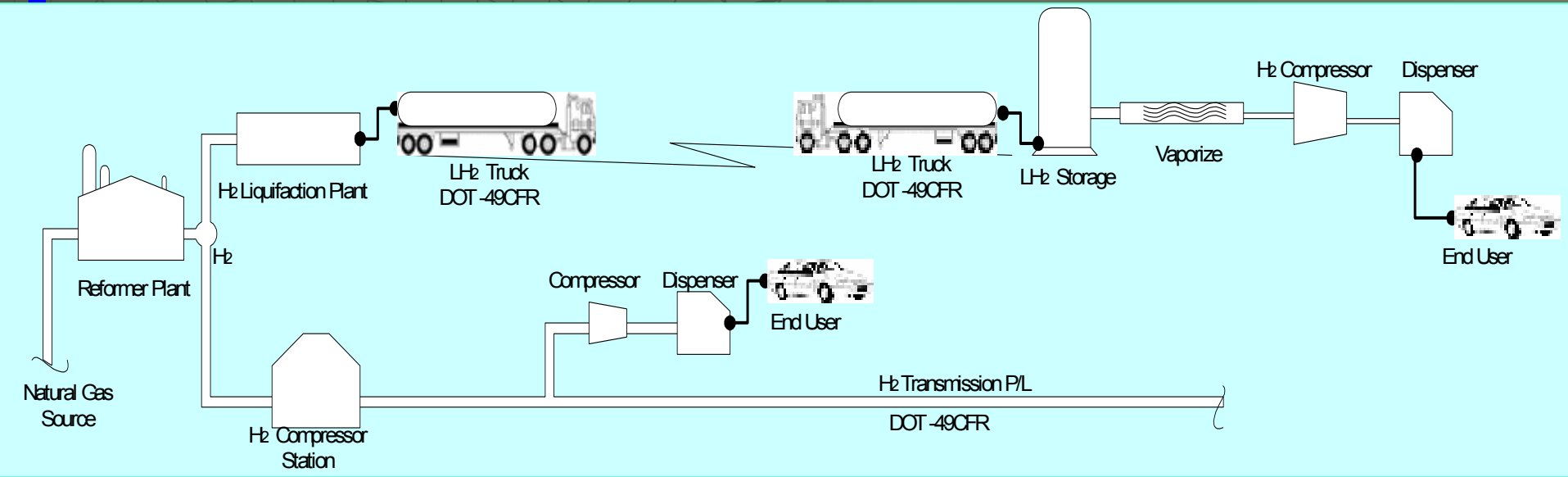
U.S. Department of Transportation
Research and Special Programs Administration

Hydrogen Economy Infrastructure Options



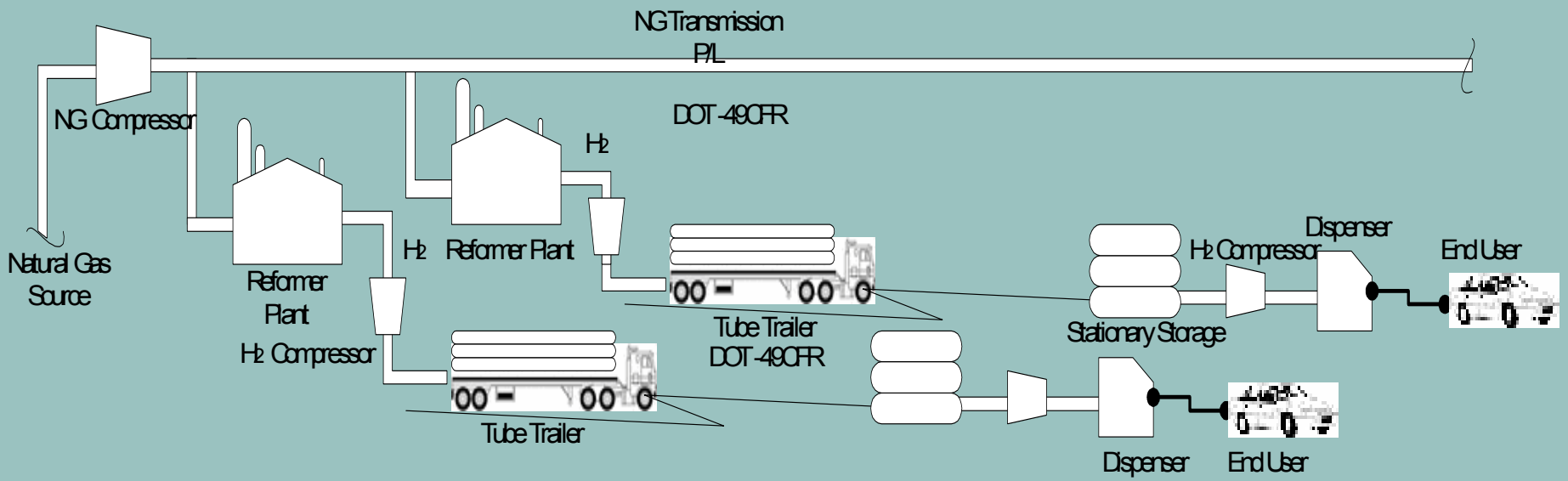
U.S. Department of Transportation
Research and Special Programs Administration

Hydrogen Economy Infrastructure Options



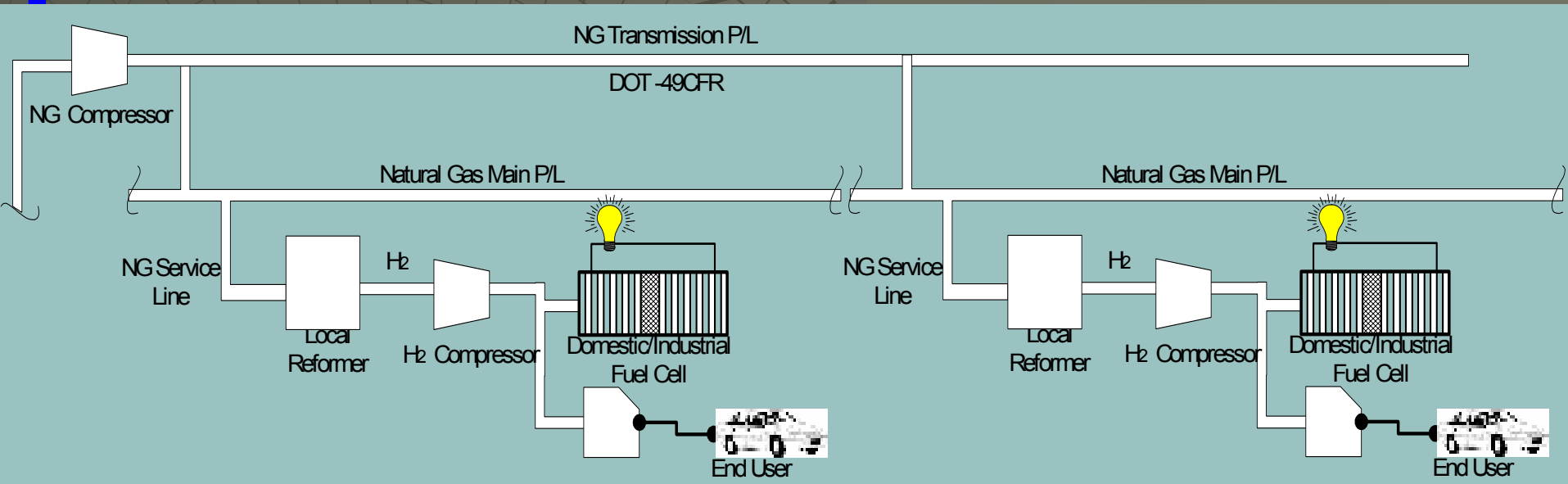
U.S. Department of Transportation
Research and Special Programs Administration

Hydrogen Economy Infrastructure Options



U.S. Department of Transportation
Research and Special Programs Administration

Hydrogen Economy Infrastructure Options



U.S. Department of Transportation
Research and Special Programs Administration

Exmptions, 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

U.S. Department of Transportation
Research and Special Programs Administration

Rulemaking Procedures

- Study the issue on hand
  (Public meetings, Industry Input and R&D)
- Notice of Proposed Rulemaking
  (30/60-day comment period)
- Proposed Rulemaking
  (30-day comment period)
- Final Rule
  30-comment period for corrections

U.S. Department of Transportation
Research and Special Programs Administration

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.

U.S. Department of Transportation
Research and Special Programs Administration

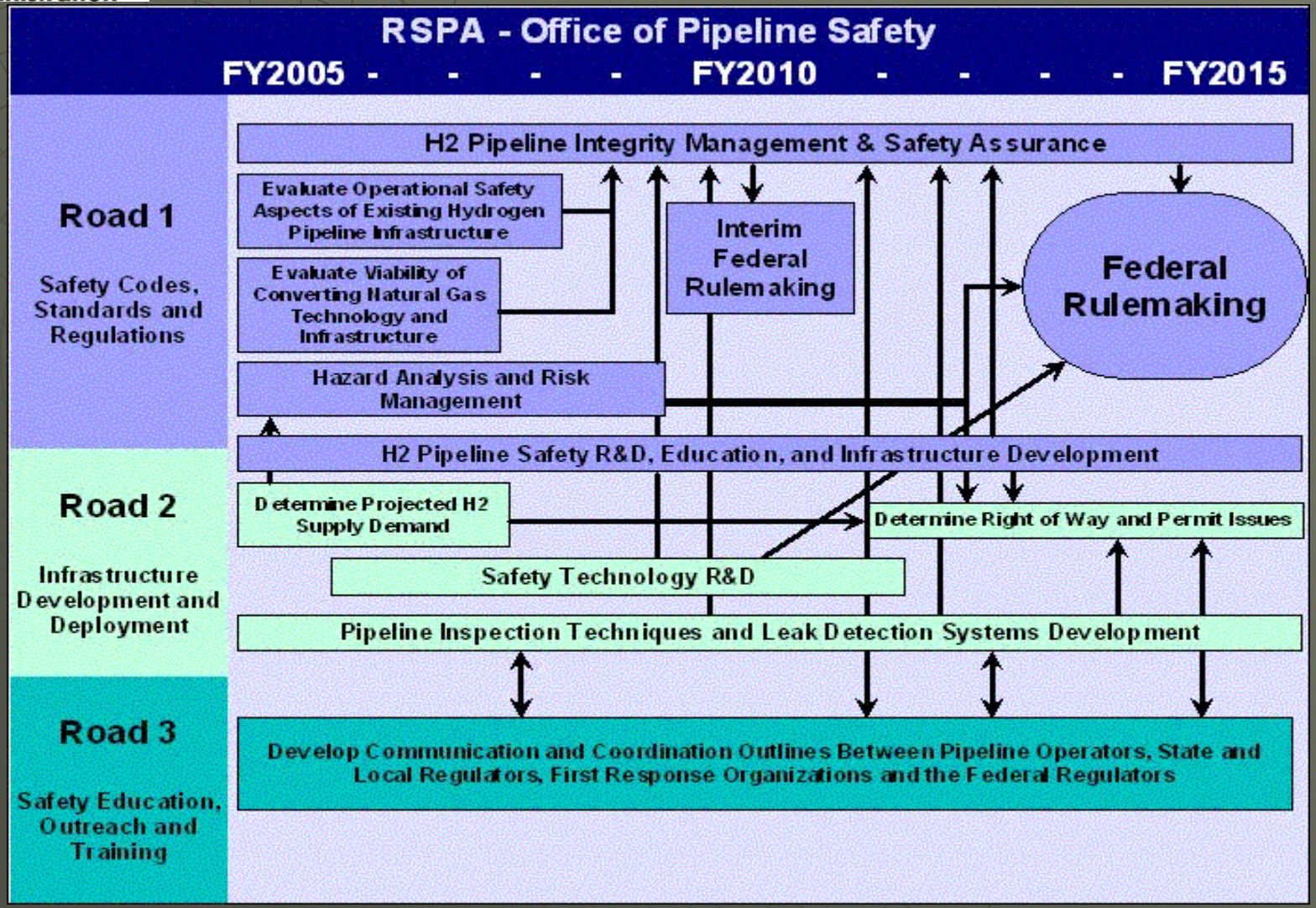
International Partnership for the Hydrogen Economy (IPHE)

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

U.S. Department of Transportation

Research and Special Programs Administration



U.S. Department of Transportation
Research and Special Programs Administration

DOT Hydrogen Web-Site

- http://www.rspa.dot.gov/dra/hydrogen/index.htm
- contact e-mail:
- gopala.vinjamuri@rspa.dot.gov
- stanley.staniszewski@rspa.dot.gov
- William.chernicoff @rspa.dot.gov