

AIR
PRODUCTS



Hydrogen Fuel Current Activities

Tom Joseph

Air Products and Chemicals, Inc.
Allentown, PA

NGV TF

Washington D.C.

August 4, 2005

Fuel Cell Vehicles



Hydride applications

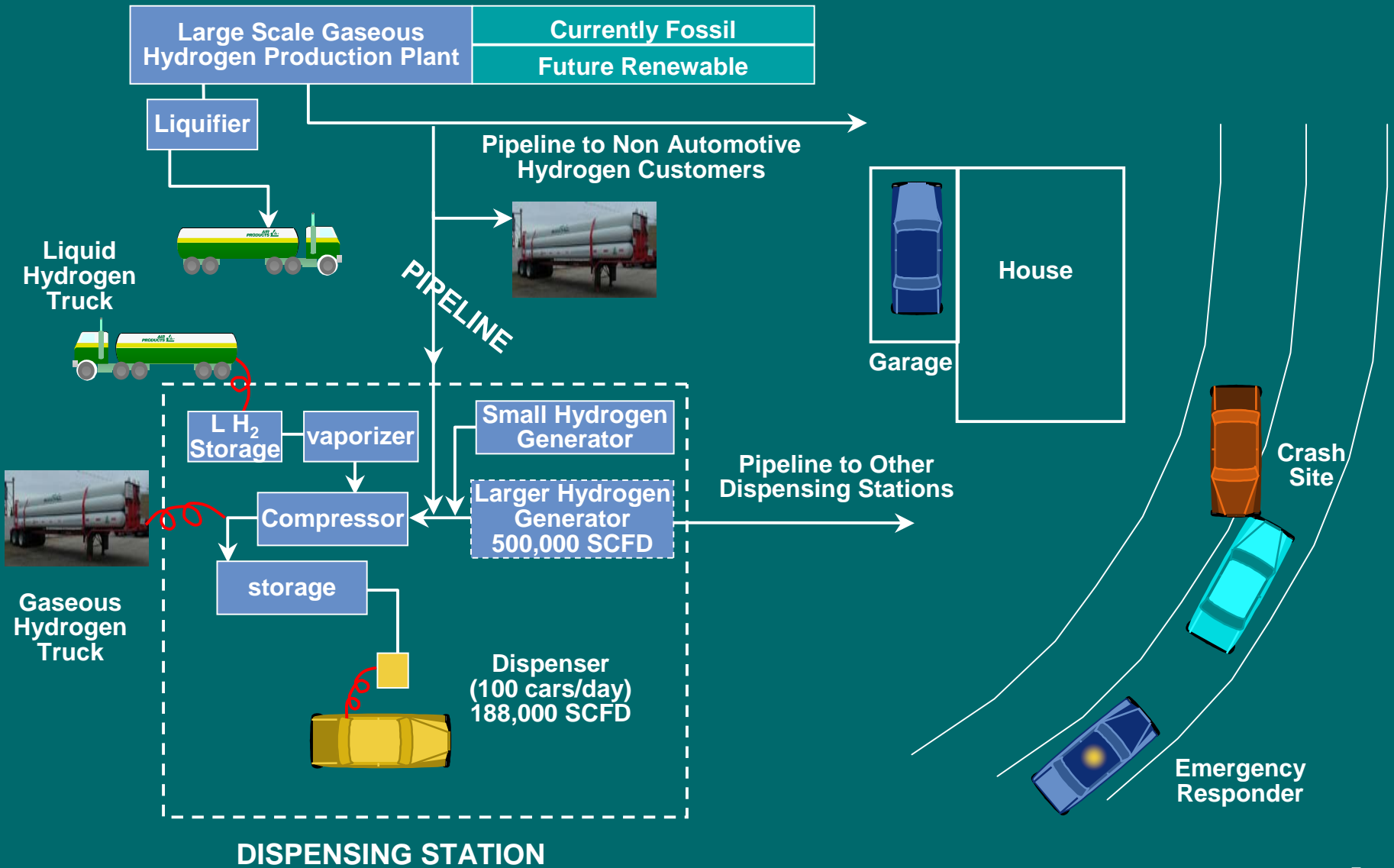


Confidential

3



Hydrogen to the Public



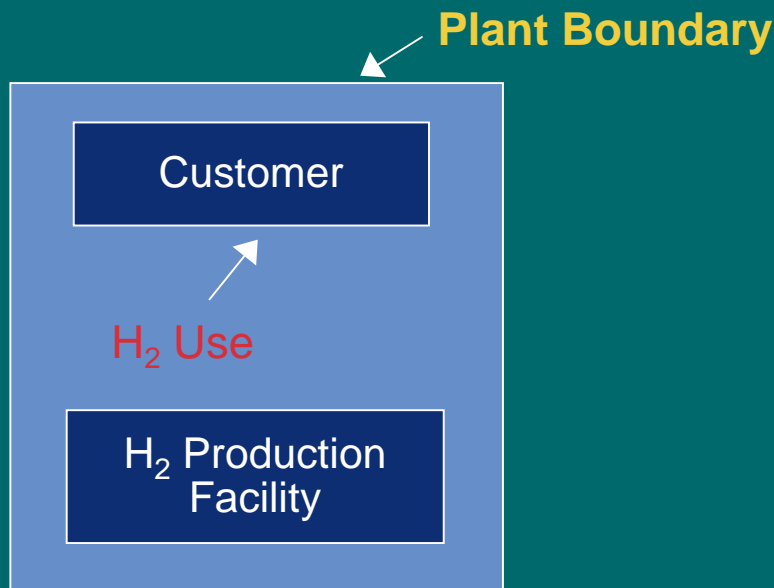
Hydrogen Production - SMR



Capacity: 100 Million SCFD of Hydrogen.
If Used for Automobiles Only this Plant Could Supply
~50,000 Fuelings/Day or
~400,000 Automobiles on Road

Total U.S. Hydrogen Production: Approx. 35 Billion SCFD

**Most of the Hydrogen Consumed Where Produced
~ 33 billion SCFD**



Major Uses

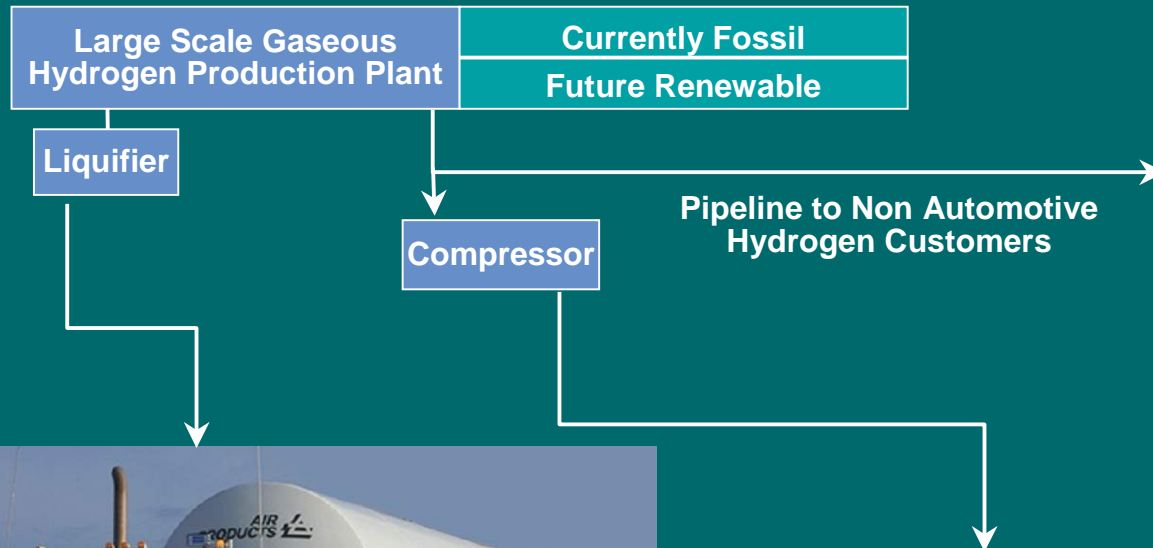
- Ammonia
- Petroleum refining
- Food Industries
- Metals Treatment
- Petrochemicals

Hydrogen production (on-site)

- Generation of *Gaseous* Hydrogen at Fueling Site or Station
 - Large Area in Station Needed
 - Vertical Stacking?



Hydrogen Distribution



Liquid hydrogen delivered at about -425°F and 100 psig.



Gaseous hydrogen delivered at ~2600 psig

Pipelines

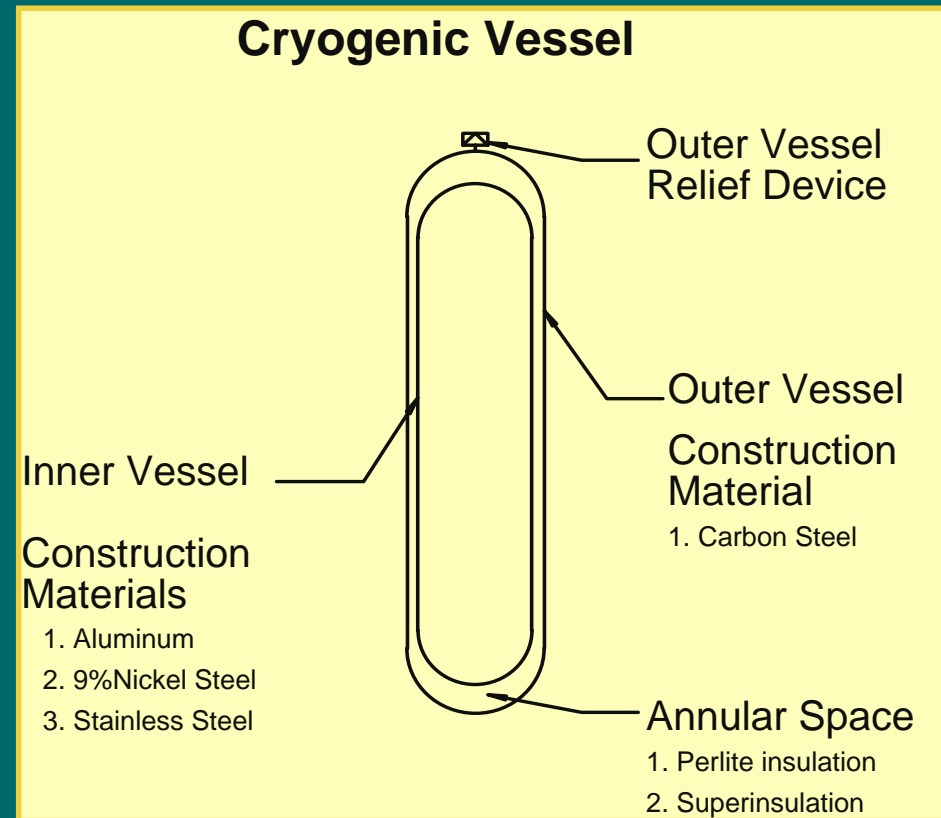
- **Hydrogen Industry Has 500 Miles of Pipelines in U.S.**
- **Air Products Hydrogen Pipelines Exceed DOT Requirements**
 - Use of Automatic Excess Flow Valves in Populated Areas
 - Significantly Limit Amount of Release
- **No Fires at Hydrogen Pipelines in 35 Years**

Liquid Hydrogen Trailer

- **75 Trailers With Armored Type construction**
 - Inner Tank With Outer Thick Steel Jacket
- **70 Million Gallons of Liquid H₂ / Year**
- **8 Million Miles / Year**
- **160 Million Miles Since Inception Without Loss of Liquid Hydrogen onto the Road**
- **1996 NASA Safety Award Winner**
 - 200 Million Pounds of Liquid H₂ Over 25 Year Period Without a Significant Incident
- **Vehicle Accidents Do Occur**

Cryogenic Tanks for Liquid Hydrogen

- Typically 50 psig and -425°F
- Dual Vessel construction
 - Giant “Thermos Bottle”
- Convection
 - Annular Space Vacuum
- Conduction
 - Suspend vessel
- Radiation
 - Super Insulation



We do have less than our share on the road . . .



But the difference is . . .



Distribution Challenges

Gaseous H2



- **High Pressure tubes and associated piping**
 - Non-metallic tubes
- **Pressure Relief Devices on metallic tubes**
- **CFR changes**
 - Protection in an accident
 - Rear impact protection
 - Recessed vales

Conventional LH₂ Storage Tanks at Fuel Stations

Chicago (CTA), IL

Santa Clara VTA, CA

City of Las Vegas, NV



CaFCP, CA

Ann Arbor, MI



First Underground Cryogenic Liquid Hydrogen Tank – Washington, DC



Underground Cryogenic Hydrogen Tank

- **Advantages**

- **Reduced Area in Already Tight Fuel Station Layouts**
- **Improved Safety From Fuel Station Incidents**
 - **Vehicle Collisions**
 - **Vehicle Fires**
 - **Convenience Store Related Violence**
- **Improved Protection From Terrorists**

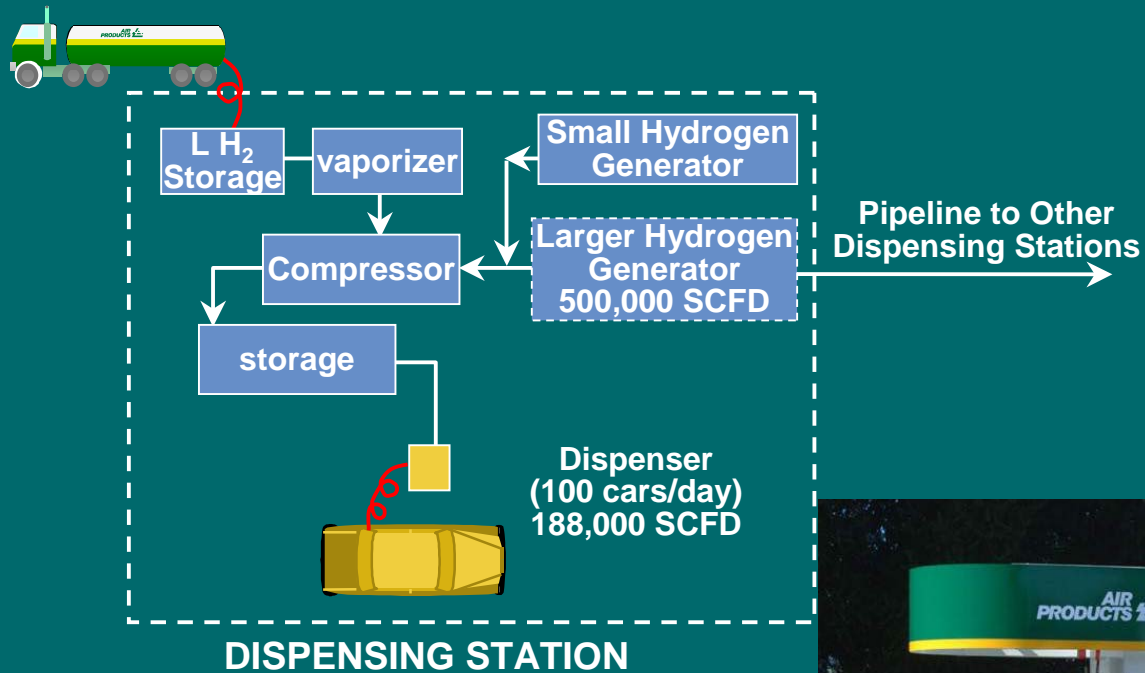
- **High Pressure Gaseous Hydrogen Storage Tubes Could Also Be Placed Underground**

Supplying Hydrogen

- Vaporize *Liquid* Hydrogen, Compress and Store Gaseous Hydrogen, Ready for Dispensing.

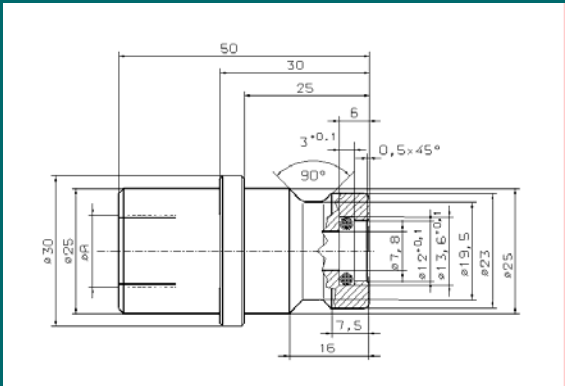


Hydrogen as Fuel

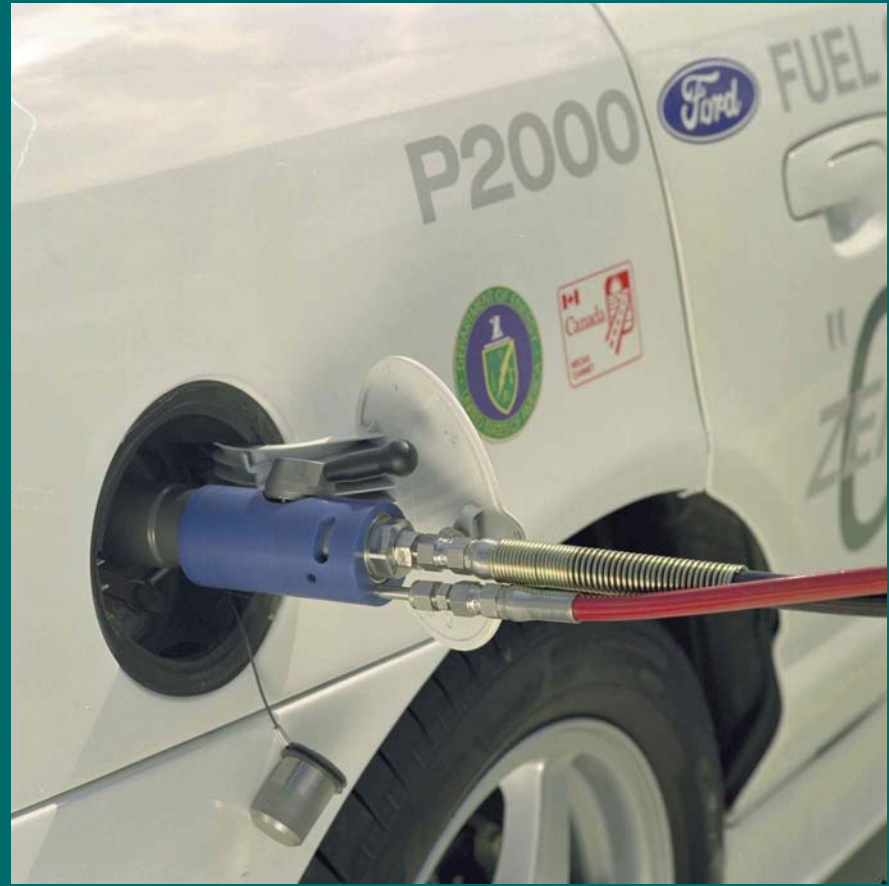
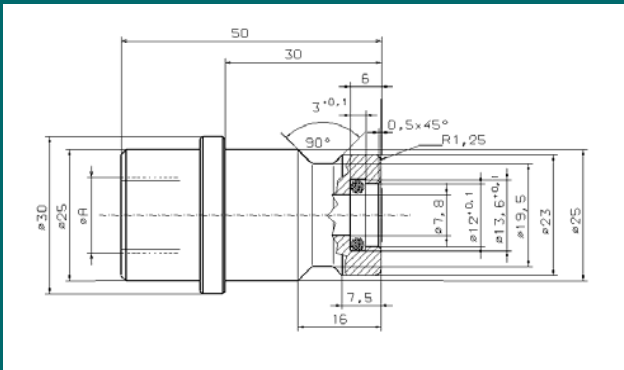


Connector Geometry SAE J2600

250 bar (3600 psig)



350 bar (5000 psig)



Fueling Issues – Best Practices

- **Grounding the Vehicle and the Operator**
 - Transparent to the Operator
- **Wear and Tear**
 - on Nozzles and their Components, Hoses
 - SAE Nozzle Test Cycles
 - Damage to Connector on the Vehicle
- **Fast Fill**
 - can overheat the Tank
 - Telemetry From Vehicle Back to Dispenser for Fast Fill
 - Without Telemetry Fills Will Be Slower and/or Incomplete
- **Over Pressuring a Vehicle During Fueling**
 - Protection must lie with the Dispenser

Fueling Issues – Best Practices

Continued

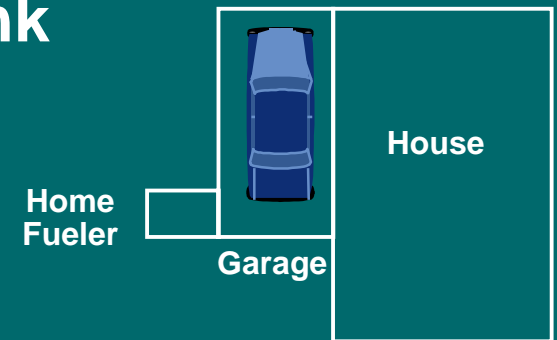
- **Design of Fuel Hose Fittings**
 - Minimization of Public Risk
- **Leak From an Idle Hose**
 - Smart systems to monitor/detect
- **Leak From a Nozzle to Vehicle Connection**
 - Detection before Fueling
- **Significant Leak During Fueling**
 - Monitoring built into Dispensers

Hydrogen Mobile Fueler



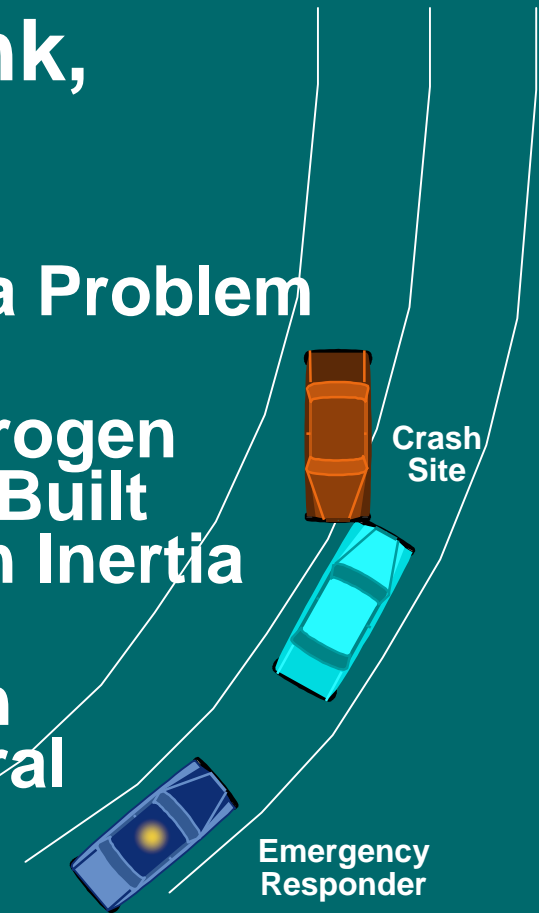
H2 Vehicle in the Home Garage

- Any Leaking Hydrogen Is Buoyancy Driven Toward Ceiling
- ASHRAE Three Sigma Natural Ventilation Rate for Garage
 - Leak Rate May Be Back Calculated
- Auto Manufacturers Design
 - Hydrogen Shut-off in the Tank



H2 Vehicles on the Highway

- Training Emergency Responders
- Compressed Hydrogen Tank, Typically Is Not the Threat
 - CNG Tanks Have Not Posed a Problem at CNG Vehicle Crash Sites
 - Many/Most Compressed Hydrogen Tanks Have Solenoid Valves Built into the Tank – Closed (via an Inertia Switch) in a Crash
 - Only Few Grams of Hydrogen Outside of the Tank vs. Several Hundred Grams of Gasoline



Conclusion

- **The Public Must Gain Confidence That Hydrogen Fueling and Driving Are As Safe (or Safer) As Conventional Fuels**
 - Achieve Thru Demonstrations
 - Improved Design to Make Differences Between Fuels Transparent
- **Safety Risks Must Be Managed**
 - Important Role of Good Engineering Design
 - Important Role of Codes and Standards
 - Important Role of Enforcement

Thank you

tell me more
www.airproducts.com