Introduction to Hydrogen Technology

SAND2011-0837C

Lennie Klebanoff, Joe Pratt, Terry Johnson, Marcina Moreno

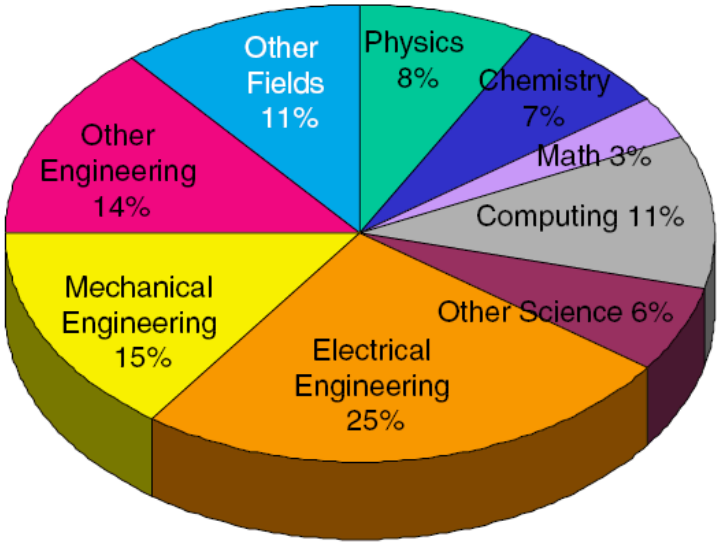
Sandia National Laboratories
Livermore, CA 94551 USA

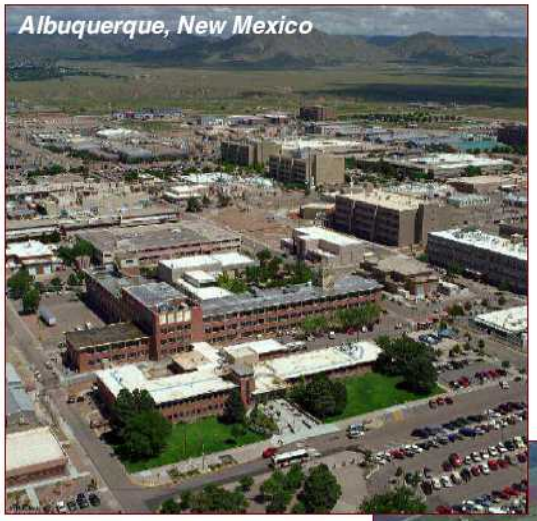
February 8, 2011

End User Workshop on Needs of Non-Motive Power Technology

Sandia National Laboratories

Sandia is a government-owned/contractor operated (GOCO) facility. Sandia Corporation, a Lockheed Martin company, manages Sandia for the U.S. Department of Energy's National Nuclear Security Administration.





- ~ 8,300 employees
- ~ 1,500 PhDs; ~2800 MS/MA
- ~ 700 on-site contractors

Annual Budget ~ $ 2.4 Billion

(~ $1.45 B DOE, ~ $0.95 B work for others)

Website: www.sandia.gov

Project Goals

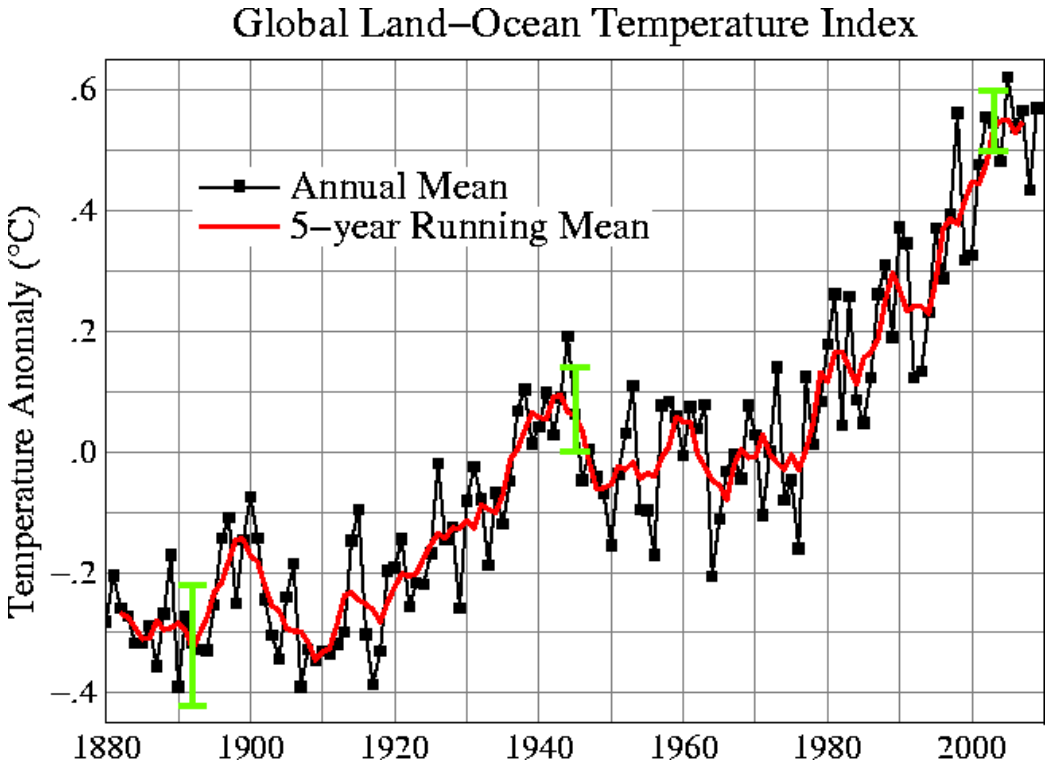
Our purpose is to understand:

1. What would the operational requirements be for using fuel cells in non-motive portable power equipment, aviation ground support equipment, construction equipment, back-up power and other non-vehicle pieces of equipment? **(Today's Workshop)**

2. Based on these applications and requirements, Sandia will identify for the DOE the most significant performance gaps in hydrogen storage technology that hinder using fuel cells in these applications. **(After the Workshop)**

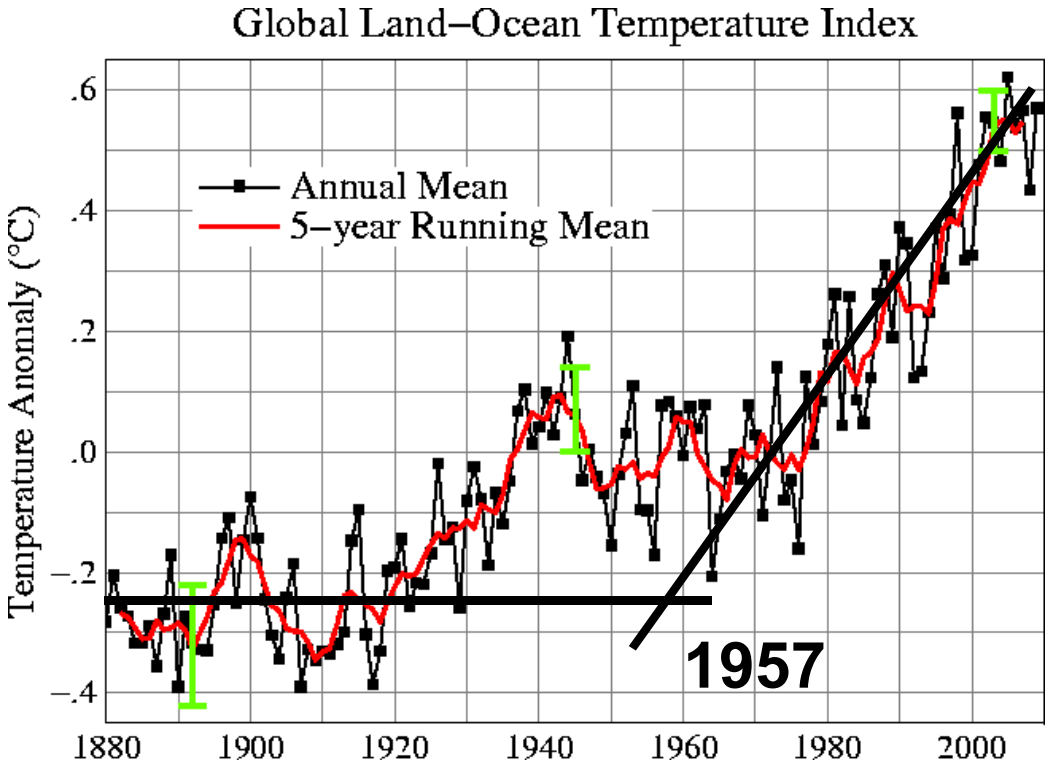
Why Hydrogen?

Our C-based fuels such as gasoline, diesel, kerosene, propane will become increasingly unusable due to the contribution of CO_2 to global climate change…



Why Hydrogen?

Our C-based fuels such as gasoline, diesel, kerosene, propane will become increasingly unusable due to the contribution of CO_2 to global climate change…



Global Climate Change is an Old Problem

-- from "Energy Resources", a Report to the Committee on Natural Resources of the US National Academy of Sciences, 1962, page 96

-- M. King Hubbert

"There is evidence that the greatly increasing use of the fossil fuels, whose material contents after combustion are principally H_2O and CO_2, is seriously contaminating the earth's atmosphere with CO_2. Analyses indicate that the CO_2 content of the atmosphere since 1900 has increased 10 percent. Since CO_2 absorbs long-wavelength radiation, it is possible that this is <u>already</u> producing a secular climatic change in the direction of higher average temperatures. This could have profound effects both on the weather and on the ecological balances."

Note: In 1957, World Population = 42% of Current, Number of Cars ~ 1/5 of Current

Hydrogen Technology: Getting the Carbon Out of the Fuel

Fossil Fuels:

$$C + O_2 \rightarrow CO_2$$ (BAD for Global Warming)

Hydrogen Technology:

$$H_2 + 1/2O_2 \rightarrow H_2O$$

But…the H_2 has to come from carbon free sources for H_2 to have the most impact reducing CO_2 emissions

Fuel Cells and internal combustion engines (ICE) can both employ H_2 as a fuel

Some Things about H_2

- Trace amounts (0.5ppm) in atmosphere
- Produced from a variety of sources, but mostly natural gas (CH_4) today. Can be made from H_2O
- Odorless, color-less, nonpolluting, non-toxic flammable gas
- Much lighter than air, leaks tend to go straight up
- Ignites over a wider fuel/air ratio than gasoline or CH_4
- Very good safety record, used safely for over 60 years
- Enables high efficiency devices (fuel cells)
- Promotes high technology new jobs

Being More Quantitative……

	Hydrogen	Natural Gas	Gasoline
Color	No	No	Yes
Toxicity	None	Some	High
Odor	Odorless	Mercaptan	Yes
Buoyancy Relative to Air	14X Lighter	2X Lighter	3.75X Heavier
Energy by Weight	2.8X > Gasoline	~1.2X > Gasoline	43 MJ/kg
Energy by Volume	4X < Gasoline (Liquid H2)	1.5X < Gasoline	120 MJ/Gallon

Storing Hydrogen for Fuel Cells or H_2 ICE

Suppose you want to replace ~ 10 gallons of gasoline with H_2…

Energy in 1 gallon of gasoline = Energy in ~ 1 kg of hydrogen (LHV)

Therefore: We might have to store ~ 10 kg of H_2 for some applications

OPTIONS FOR STORING 10 kg of H_2 :

1. **Compressed Gas (~ 116 gallons at 5000 psi, T = 298K) (large V)**

2. **Liquid H_2 (~ 38 gallons, T = - 424 F) (hard to make something that cold, maybe it evaporates)**

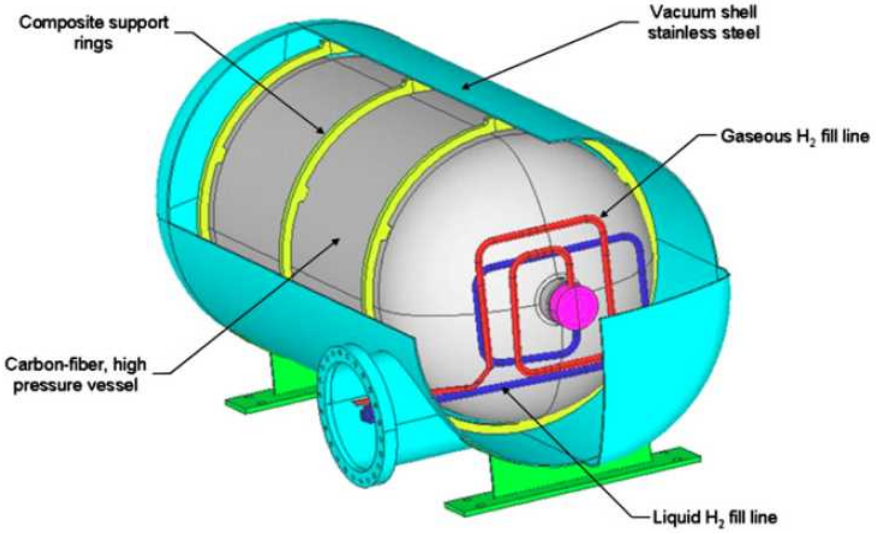
3. **Storing H_2 in a chemical-- a sponge that absorbs and releases H_2:**

Ex. : $NaAlH_4$ (T = 75 F, ~ 57 gallons, wt. = ~ 436 lbs) (addresses V, T problems, but heavy)

Project Goal: Identify the remaining R&D problems in these storage technologies that must be solved to enable widespread use of fuel cells

Examples of Commercially Available Hydrogen Storage Tanks

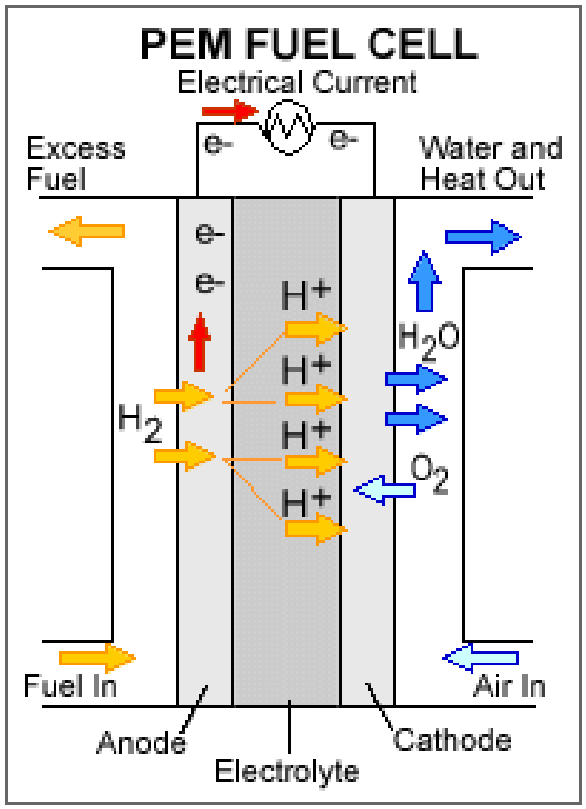
Lincoln Composites High Pressure Tank



"Cryo-compressed"
LH_2 Storage from LLNL

Ovonic Hydrogen Systems
Metal Hydride Tank

Using H_2 to Make Power: Fuel Cells



$H_2 + ½O_2 \rightarrow H_2O$

There are other types of fuel cells, this is one……

Going In: H_2 (stored), and O_2 from the air

Going Out: electricity, waste heat, warm humidified air

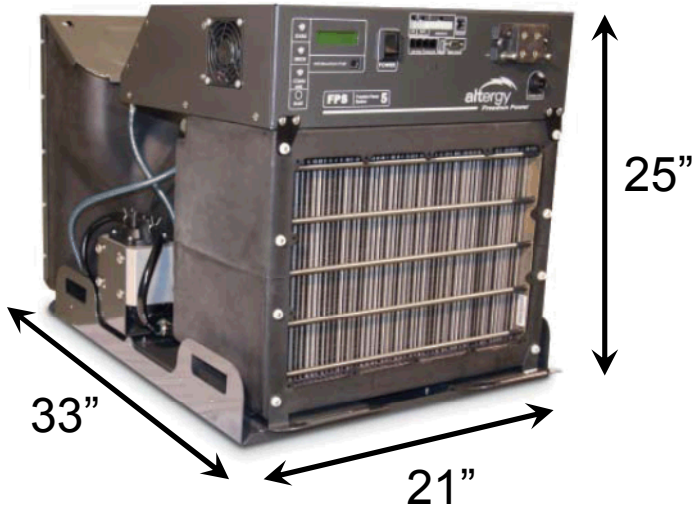
Some things about PEM Fuel Cells:

- 8x higher power density than batteries
- Operates at ~80 ºC; allows for fast start
- Requires pure H_2 from storage system
- Oxygen obtained from ambient air
- ~45% efficiency, better than ~30% efficiency of existing diesel generators
- No CO_2, NO_x or particulates emitted
- No moving parts (reliable, no oil)
- Very quiet operation

Examples of Fuel Cells, ICE Engines

$$H_2 + \tfrac{1}{2}O_2 \rightarrow H_2O$$

Altergy FPS-5 (5kW)



5 kW PEM Fuel Cell

BMW Hydrogen 7 ICE Engine (~ 100 kW)

Commercial H_2LT Fuel Cell Mobile Light

H_2LT product brochure

Commercialized by Multiquip Inc.

Employs four 5000 psi tanks of H_2 (~8kg)

One Altergy 5kW PEM fuel cell

8 Luxim Plasma Lights (~2.0 kW total)

Multiquip Trailer

Performance Benefits:

Greatly reduced noise with PEM fuel cell

No diesel particulate emissions

No CO_2, NO_x emissions

Easier to operate than diesel system

Displaces 900 gallons of diesel/year/unit

Superior lighting to existing systems

Mobile Light Deployments-- DOE Project

We are building 5 units for installation at partner facilities, and to conduct environmental testing, promote H_2 fueling infrastructure:

Caltrans (Sacramento), exposure to snow, cold, road work

Boeing (Washington State), exposure to sleet, ice, rain and fog

Kennedy Space Center (Florida), exposure to heat, humidity, salt air

Paramount Pictures (LA), performance for noise reduction

SFO (Hybrid Unit), performance of Hybrid system (not described)

System Performance Requirements (Fuel Cell + Storage):

Temperature range of operation 140 F to -20F

Noise: < 43 dB at 20 feet

Refueling in < 15 minutes

Emissions: Zero at point of use

Fuel Cell Pallet Lifts and Fork Lifts

Another DOE Project

Plug Power
Gendrive
PEM Fuel Cells

Food distributor Sysco using PEM fuel cell lifts in their 585,000 ft^2 Houston facility. 72 Raymond Pallet trucks, 25 Raymond “Reach Fork” trucks using PEM fuel cells.

Air Products providing two indoor H_2 stations, that can fuel a pallet lift in 2 minutes.

Sysco no longer needs to deal with lead acid batteries (slow charging, toxic waste, spare batteries, wasted space)

Options for Refueling

- H_2 Fueling Stations

There are a number of H_2 refueling stations in the US that dispense 5,000 psi hydrogen

- Mobile H_2 Refueling Stations

Air Products has a “mobile refueler” (150kg capacity, 5,000 psi) that can be placed at work sites. They are also developing a smaller more mobile unit.

Fuel Cell Mobile Light at Burbank H_2 Station

- Refueling from H_2 Cylinders

The unit can be filled to ~2,000 psi using readily available hydrogen cylinders from local gas suppliers

Airgas Locations

Summary

1. Hydrogen Technology (H_2 Storage, Fuel Cells, IC engines) is one approach to dramatically reducing CO_2 emissions.

2. The DOE wants to understand the H_2 storage performance gaps that must be solved to enable wider use of fuel cells.

3. Hydrogen is a flammable gas that can be handled safely, and can be stored in a variety of ways.

4. Fuel Cells convert H_2 to electricity with high efficiency.

5. Mobile Lighting, Lift Trucks are two examples of how fuel cells can be used in non-motive and motive equipment.

6. There are a variety of ways to fuel with hydrogen