Network Fuel Cells

International Telecommunications Safety Conference

The Evolution of Telecom Standby Power

From coal & dry cell To diesel & flooded cell To H2- battery free

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In The Beginning There Were Batteries

1844 *Morse Telegraph Connects Washington and Baltimore*

1876 *Alexander Graham Bell Demonstrates the Telephone*

1885 *American Telephone and Telegraph Formed AT&T*

1898 *C.L. Brown Organized The Brown Telephone Company which Becomes United Telephone and Now Known as* ***Sprint***

First *Telephones Equipped with Dry Cells*

Batteries *Move from Phones to Switchboards*

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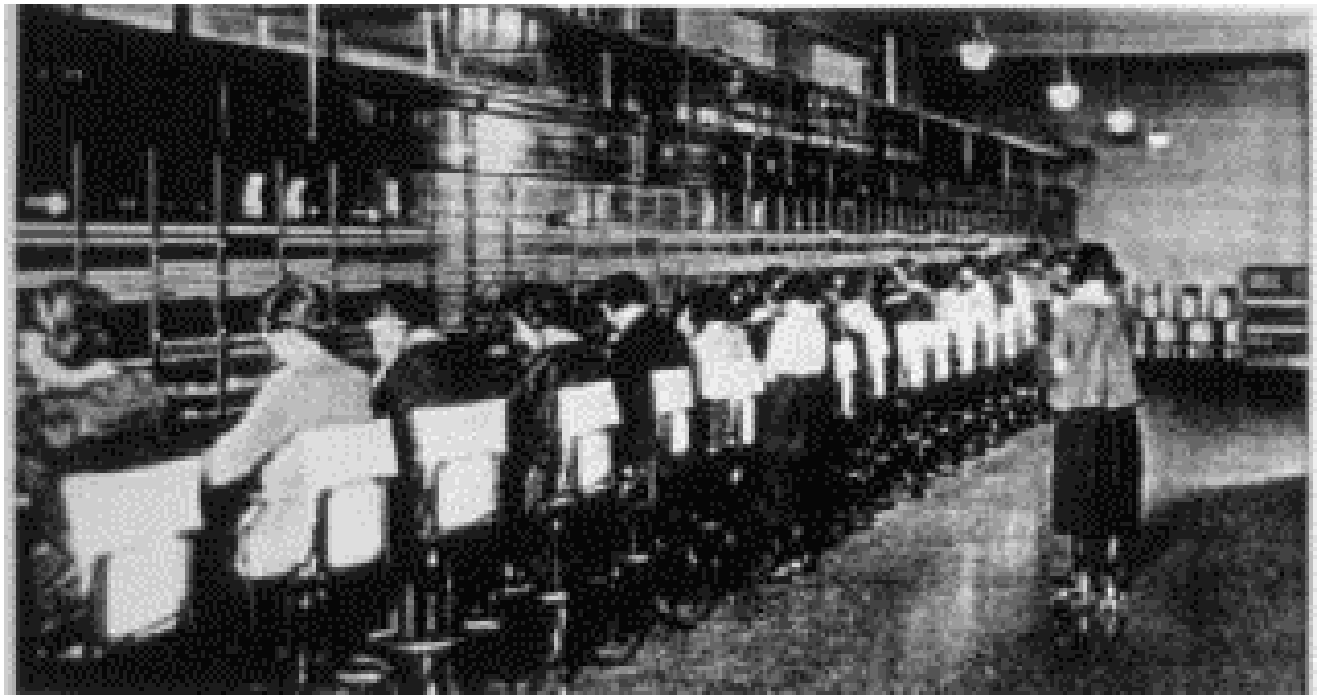
Telecom Batteries - Turn of the Century

1900 Batteries Moved from Switchboard to Local Telecom Central Office



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Telecom Batteries - Turn of the Century

The Telecom Battery Evolution

About the same time batteries migrated to the Central Office from local switchboards, Philadelphia Bell experimented with a Ring Generator which came close to electrocuting several of their employees

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Telecom Transition from Analog to Digital Technology & the Resultant Effect on Site Backup Power

Our older analog switches would survive almost anything:

****Heat *Low Voltage Dips***
****Cold *High Voltage Spikes***
****Dust *High Humidity***
****Dirt *Dry Air***

And all but the most direct transient surge (Lightning) !

<u>Modern switch buildings need maintained air conditioning</u>

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Utility Outage Support for Batteries

1

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Why Replace Flooded Cell & VR Batteries?

- *Battery Technology not Keeping Pace with Telecom Advances*
- *EPA Issue Involving Disposal & Acid*
- *Thermo Runaway*
- *Maintenance Issues*
- *Floor Space Consumption*
- *Not Able to Support New Loads*
- *Can't Keep Bldg Cool*

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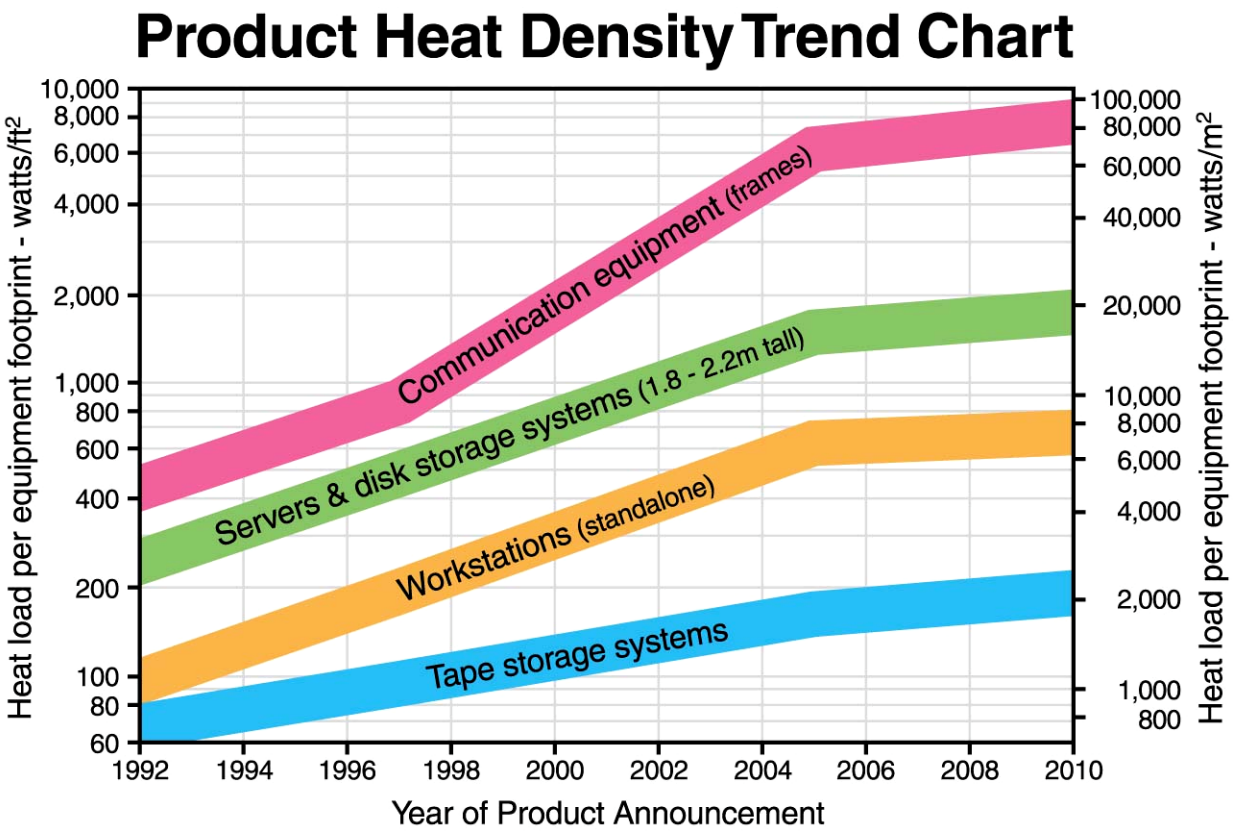
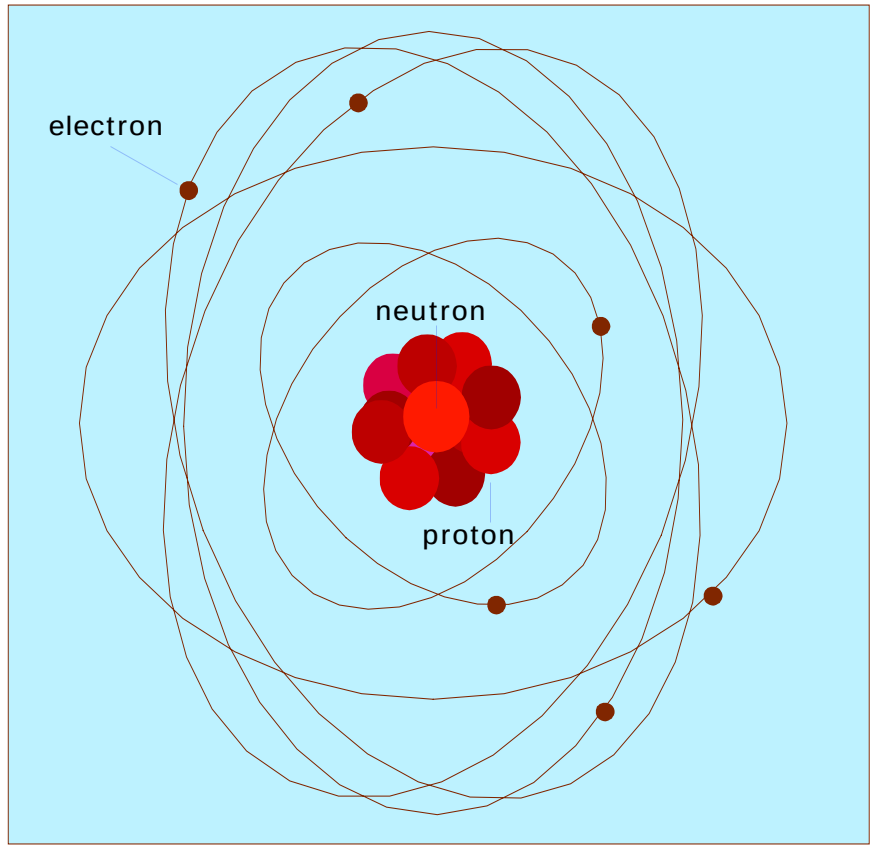
Telecom Anticipated Load Growth



Types of Fuel Cells & Continuous Flywheels

- **Bridge or No Break*
- **Phosphoric Acid*
- **Proton Exchange Membrane*
- **Molten Carbonate*
- **Solid Oxide*
- **Alkaline*
- **Direct Methanol*
- **Regenerative Fuel Cells*
- **Zinc Air*
- **Polybromide Zinc*
- **Aluminum Air*
- **Protonic Ceramic*



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What is a Fuel Cell

Device in which the energy of a chemical reaction is converted directly into electricity. Unlike a battery fuel cell does not run down; it operates as long as fuel and an oxidant are supplied continuously from outside the cell.

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Alternatives to Batteries – Small Flywheels

Stored energy units or flywheels provide continuous ride through AC power during genset start up.

There are a number of configurations with sizes ranging from 0.5kVA to to over 2000kVA.

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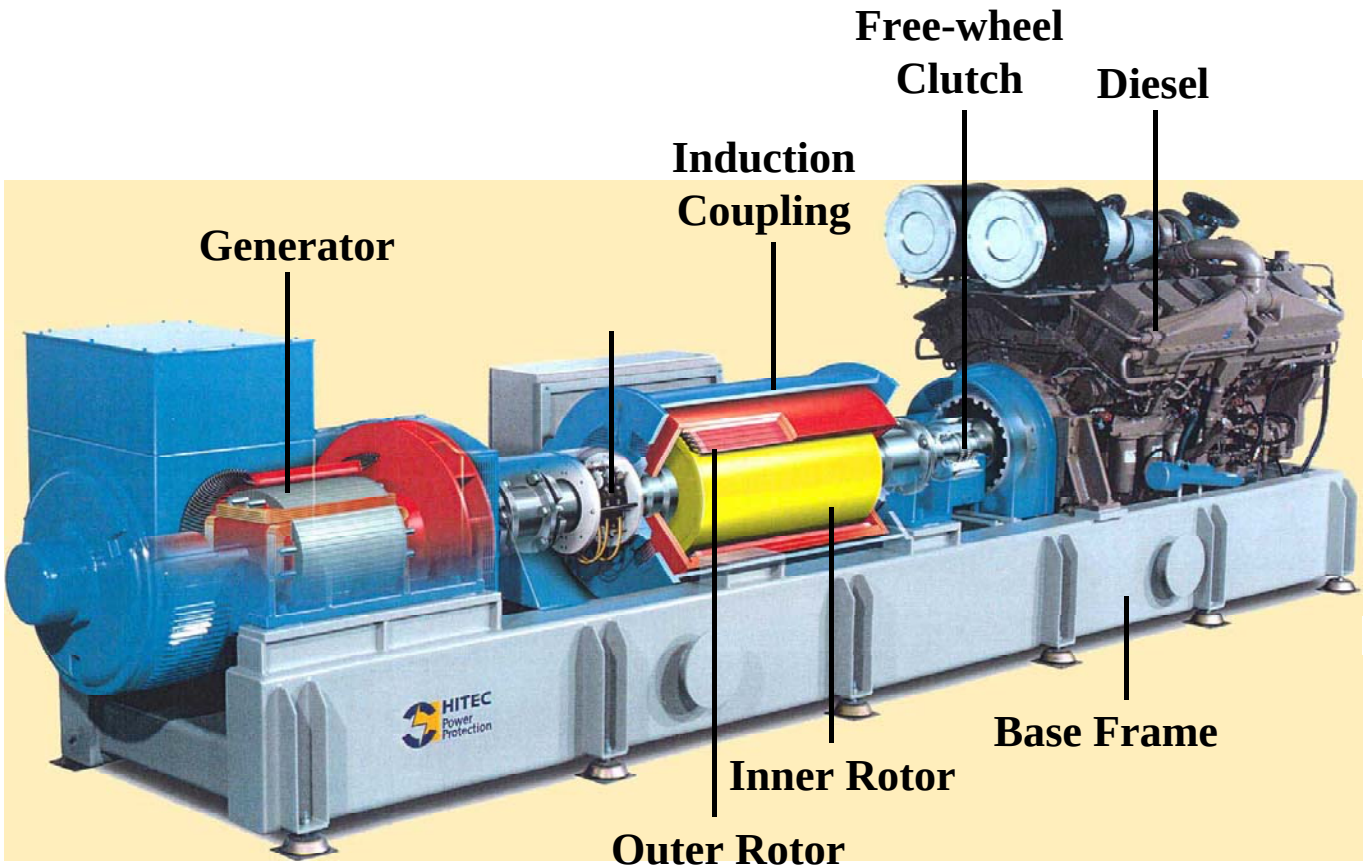
Alternatives to Batteries – 2000kVA No Break



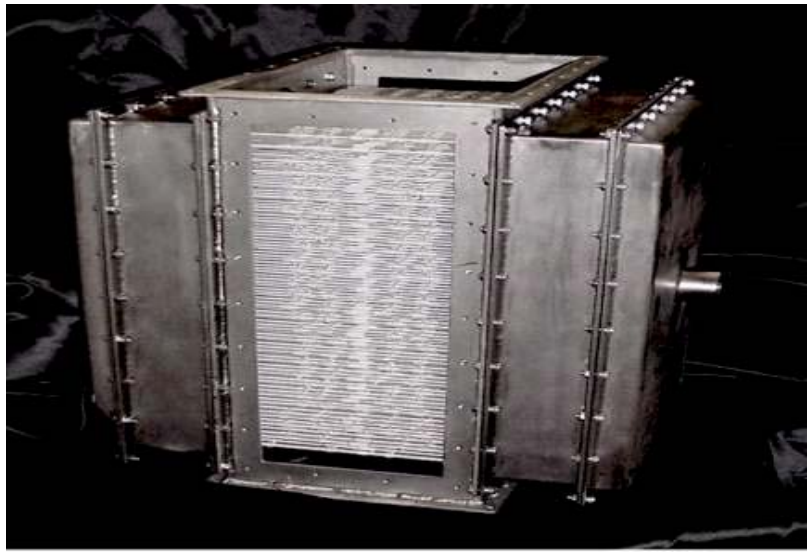
Alternatives to Batteries – ZAFC

Zinc/Air Fuel Cell

120VAC, 208VAC or 48VDC with an 8hr running time

The zinc/air fuel cell delivers up to ten times more energy per volume and mass than lead-acid batteries … But do they work?

Alternatives to Batteries – SOFC



SOLID OXIDE FUEL CELL (SOFC)

Electrolyte	***Solid Zirconium Oxide + Ytrria***
Temperature	***1000°C***
Capacity	***25 kW to 220 kW***
Efficiency	***60 -85 %***

Alternatives to Batteries - MCFC

MOLTEN CARBONATE (MCFC)

Electrolyte : ***Liquid solution of Lithium, Sodium &/or Potassium Carbonate***

Temperature: ***650°C***

Catalyst: ***Inexpensive***

Fuel: ***Hydrogen, Methane, Landfill gas***

Capacity: ***10 kW to 2 mW***

Efficiency: ***60- 85 %***

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Alternatives to Batteries – PAFC

PHOSPHORIC ACID FUEL CELL (PAFC)

Electrolyte	***Phosphoric Acid***
Temperature	***150- 200°C***
Electro-catalyst	***Platinum (Sulfur & CO above 1.5% is objectionable)***
Fuel	***Hydrogen (Impurities acceptable)***
Max Capacity	***200 KW (1 MW under testing)***
Size	***Generally large.***
Power Density	***Low***

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Alternatives to Batteries – PAFC

PROTON EXCHANGE MEMBRANE (PEM)

Electrolyte:	***Solid Organic Polymer poly***
Temperature:	***80°C***
Electro-catalyst:	***Plastic membrane coated with Platinum***
Fuel:	***Hydrogen (sensitive to impurities)***
Capacity:	***50-250 kW***
Size:	***Compact***
Power Density:	***High***
Response:	***Quick (14sec Start)***

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PEM Electrical Design Considerations

Battery Replacement Requirement

48VDC Output ……54.6VDC
Suitable Rating…….....40A
Size……...19”x25”x9”
Rackible ……....Yes
Run time……..48m/200A
Outdoor WP Housing……Yes
4 – 9s H_2……...LH_2
Floor Loading……..150#/Sqft

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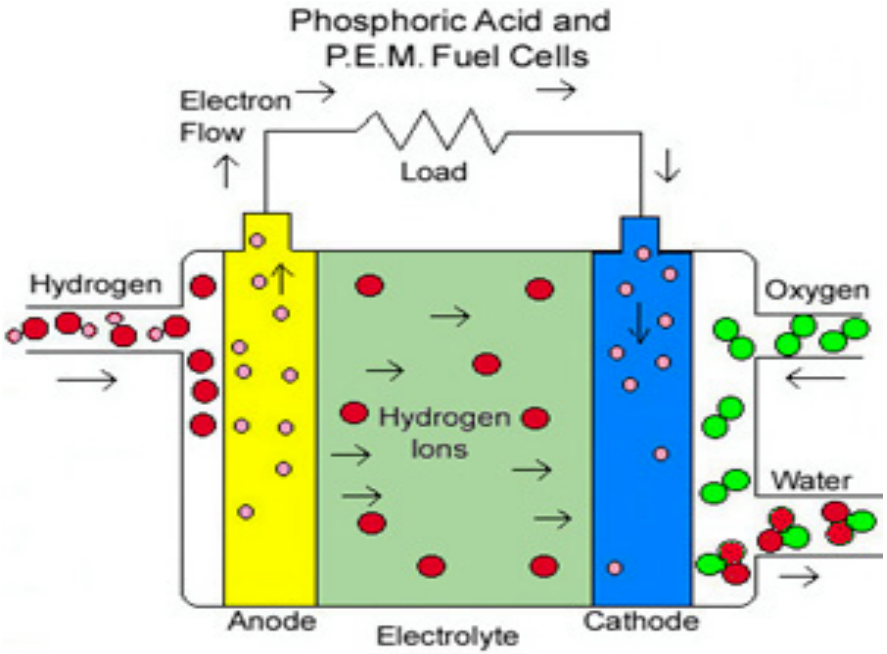
Hydrogen Proton Exchange Membrane



Anode side:

$2H_2 \Rightarrow 4H^+ + 4e^-$

Cathode side:

$O2 + 4H^+ + 4e^- \Rightarrow 2H_2O$

Net reaction:

$2H_2 + O2 \Rightarrow 2H_2O$

Pressurized hydrogen gas (H2) entering the fuel cell on the anode side. This gas is forced through the catalyst by the pressure. When an H2 molecule comes in contact with the platinum on the catalyst, it splits into two H+ ions and two electrons (e-). The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as powering DC loads) and return to the cathode side of the fuel cell. Meanwhile, on the cathode side of the fuel cell, oxygen gas (O2) is being forced through the catalyst, where it forms two oxygen atoms. Each of these atoms has a strong negative charge. This negative charge attracts the two H+ ions through the membrane, where they combine with an oxygen atom and two of the electrons from the external circuit to form a water molecule (H2O).

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Proton Exchange Membrane Fuel Cells

PEMs Make Electricity From Bottled Hydrogen and Exhaust Clean Safe Water

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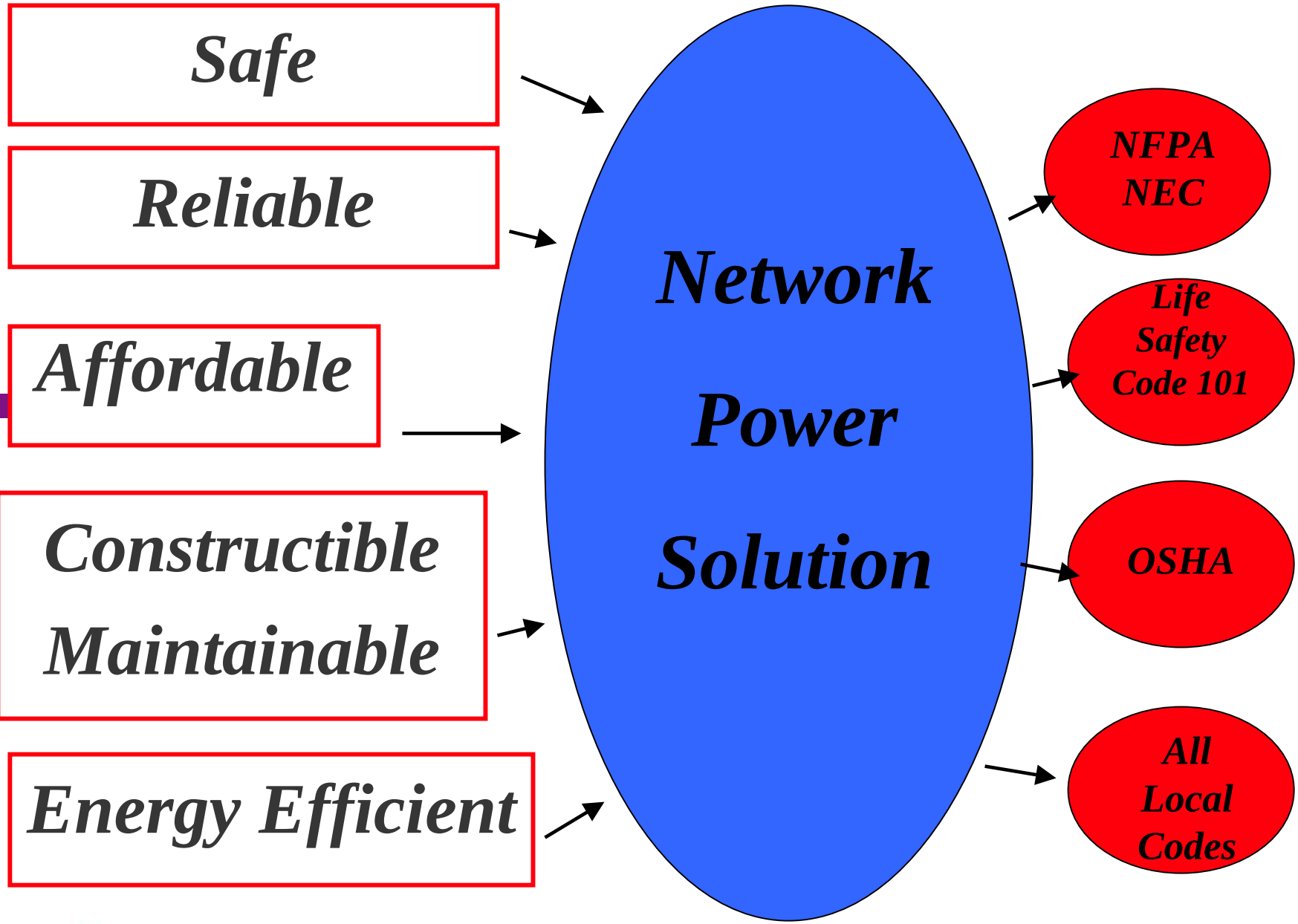
Safe
Reliable
Affordable
Constructible
Maintainable
Energy Efficient
Network
Power
Solution
NFPA
NEC
Life
Safety
Code 101
OSHA
All
Local
Codes

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Major Electrical Design Considerations

On-Site Gaseous Hydrogen:

Concerns

- *Design of System (Containers, Pressure, Volume)*
- *Location (Inside Buildings or Outdoor Only)*
- *Operation & Maintenance (Sprint or Outside Contractors)*
- *Life Safety Codes (On-Site H2 - New Direction for Sprint)*
- *Fire Protection (NEC Area Classification)*
- *Cost (Ground Breaking Technology)*

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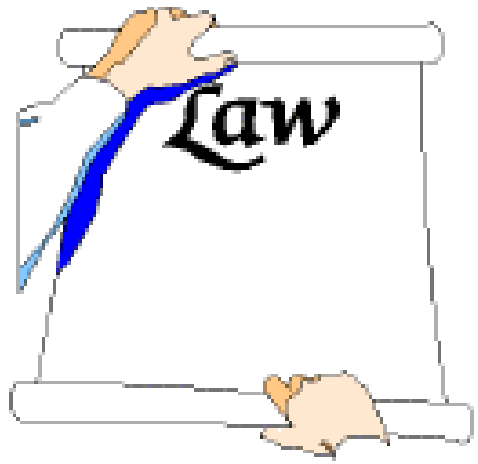
Code Considerations

Electrical Fuel Cell Design is Safe When:

Hold paramount the life safety employees and general public involved in the use our equipment and facilities and we closely adhere to all electrical codes.

National Electrical Code
Life Safety Codes Code 101
OSHA
Local Codes and Regulations
Sprint Network Practices



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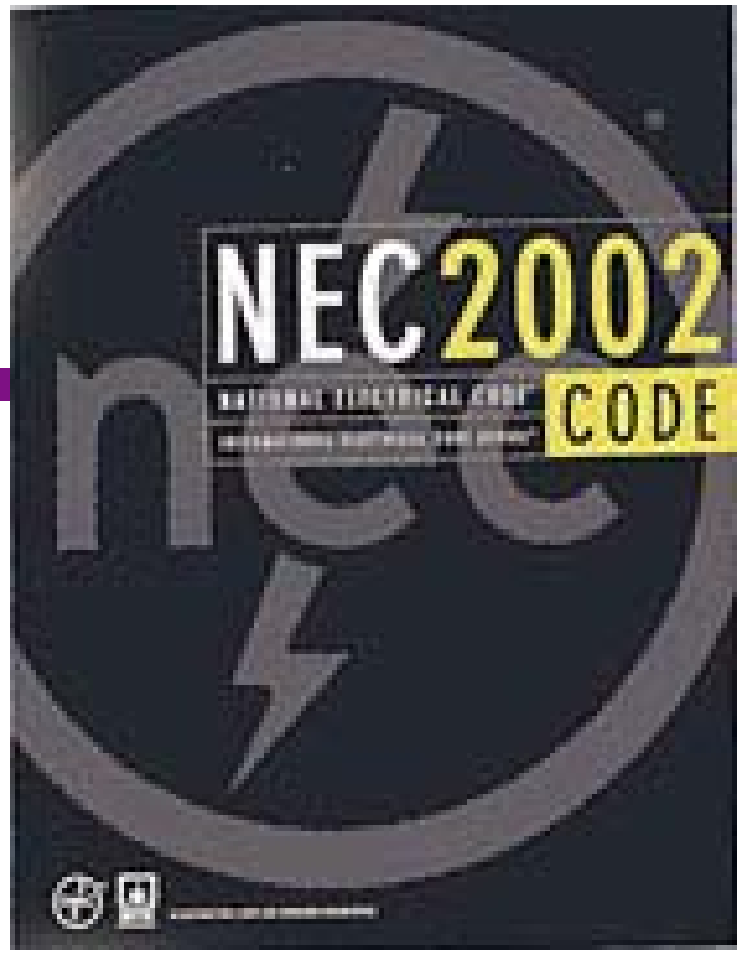

Article 692
"Fuel Cell Systems"

I General
II Circuit Requirement
III Disconnecting Means
IV Wiring Methods
V Grounding
VI Marking
VII Connection to Other Circuits
VIII Output Voltage Over 600V

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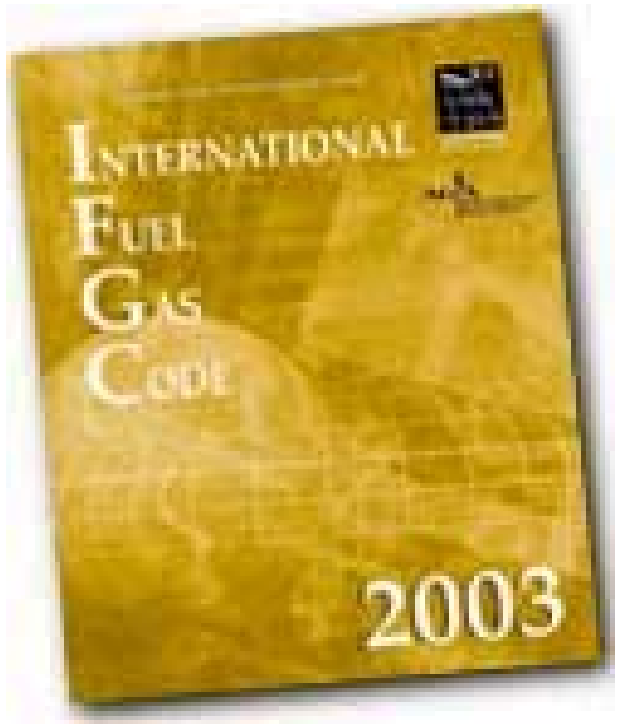
Current Model Codes for Hydrogen Storage and Distribution - NFPA 50A and IFGC



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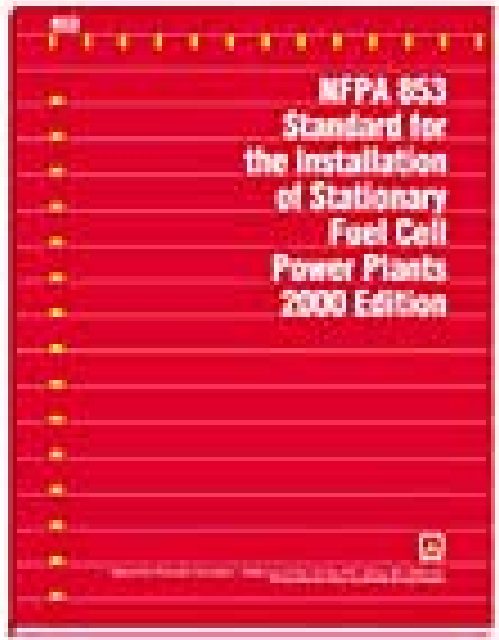
Current Model Codes for the Installation of Fuel Cell Power Plants

- *Electrical Classification*
- *Ventilation*
- *Siting*
- *Fuel Connection*
- *Fire Protection*
- *Detection*



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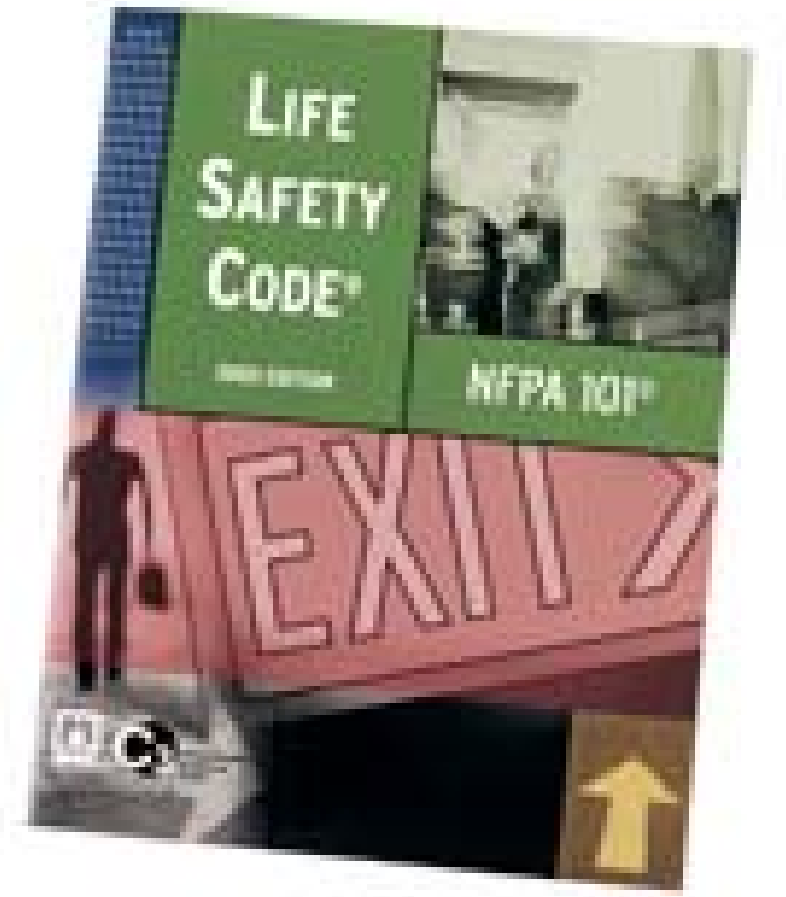
Life Safety Code 101



Chapter 4 (4-1.9) Telephone exchangers listed as an Industrial Buildings

Chapter 7 (7-1.2) Electrical wiring and equipment shall be in accordance with NFPA 70 (NEC)

Chapter 28 (28-5.1) Utilities shall comply with provisions of Section 7-1

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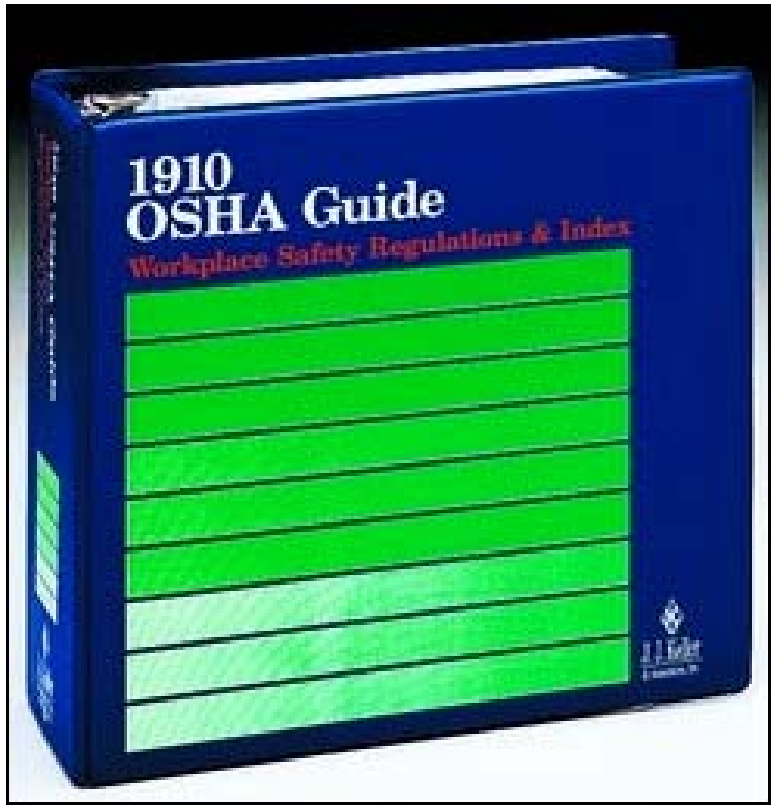
OSHA 1910 & NEC Section 500 - H_2 = IB2

Telecom Fuel Cell Power Plant Hazardous Classified Location

Class I = Flammable Gas May be Present.

Class B = Gaseous Hydrogen Used and Stored.

Division 2 = Hydrogen in Closed Containers & Only Present in Air by Accident



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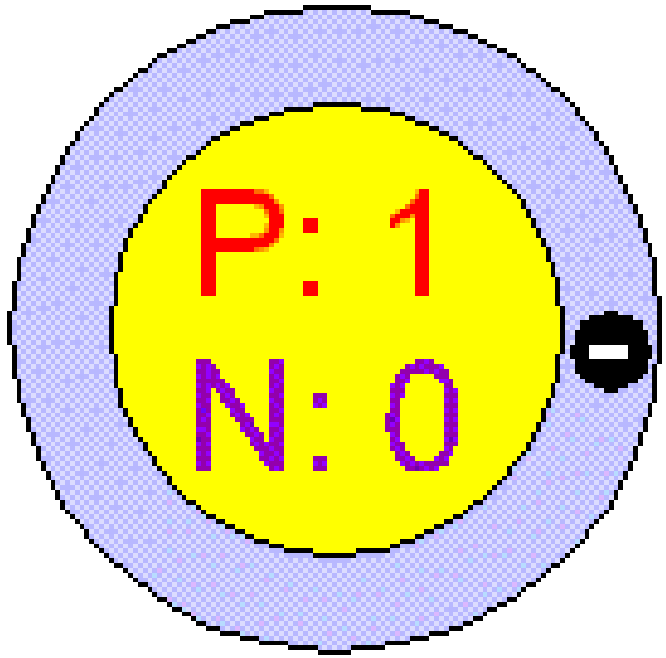
Hydrogen Facts

Symbol: H
Atomic Number: 1
Atomic Mass: 1.00794 amu
Melting Point: -259.14 °C (14.009985 °K, -434.45203 °F)
Boiling Point: -252.87 °C (20.280005 °K, -423.166 °F)
Number of Protons/Electrons: 1
Number of Neutrons: 0
Classification: Crystal Structure: Hexagonal
Density @ 293 K: 0.08988 g/cm3
Color: colorless



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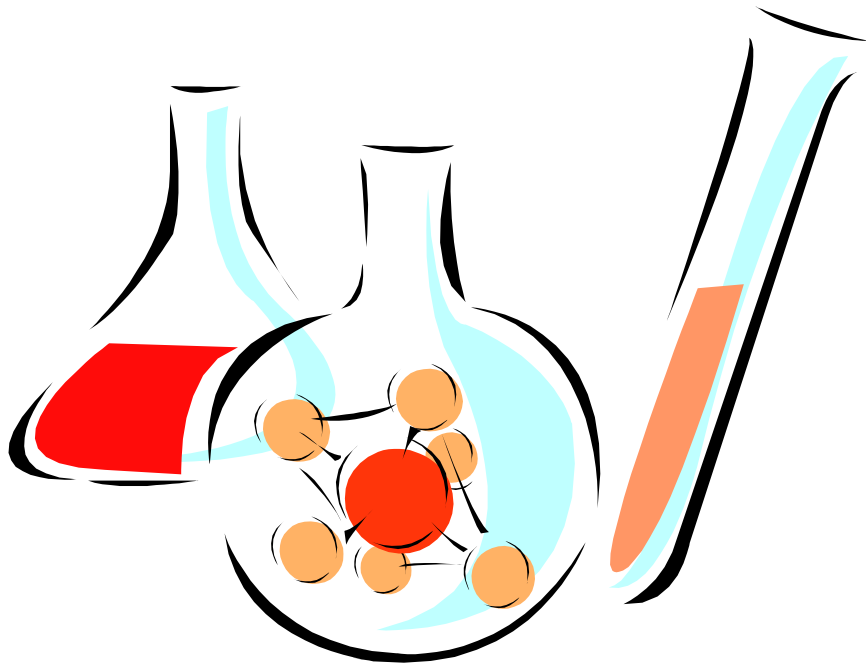
Gaseous Hydrogen

Hydrogen (H2) is the lightest of all gases. Commonly found in nature in compounds with other elements, it is the most abundant element in the universe. Hydrogen is a component of water, minerals and acids, as well as an essential part of all hydrocarbons and essentially all other organic substances. In fact, 98 percent of the known universe - most notably the sun and stars - consists of hydrogen.



Hydrogen Facts

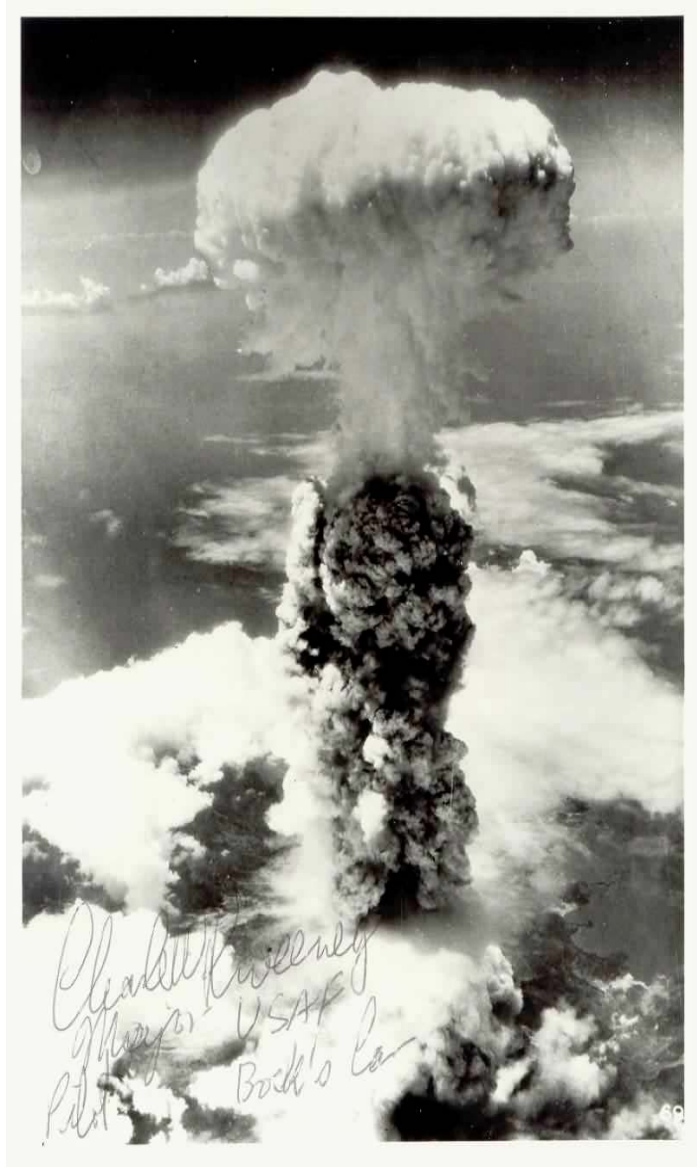
Substance	Molecular Weight	NEC Gas Grp	Ignition Temp (F)	Lower Heating Value (Btu/CF)	Lower Heating Value (Btu/Lb)	Specific Gravity (Air=1)	Lbs per CF	CF per Lb
Hydrogen - H2	2.016	B	1085	274.9	51605	0.0696	0.0053	187.7

Hydrogen is flammable and explosive over a much wider range of mixtures than any conventional fuel, but its lower limits of 4% and 13% respectively in air are better than gasoline (1% and 1.1%) and similar to natural gas (5.3% and 6.3%). Hydrogen does not pool on the ground like gasoline or LPG and is therefore less of a hazard apart from the first few seconds after a spillage. Calculations and experiments involving kerosene (aviation fuel) suggest that a fire in a hydrogen-fuelled aircraft would last a tenth of the time, produce much less heat and spread over a smaller area than a comparable kerosene fire. This would certainly save lives if the fire occurred on the ground.

1

Gaseous Hydrogen

H_2 Fuel Cell Can Not Be Made Into A Hydrogen Bomb!



Gaseous Hydrogen

Observations of the incident show evidence inconsistent with a hydrogen fire: (1) the Hindenburg did not explode, but burned very rapidly in omnidirectional patterns, (2) the 240-ton airship remained aloft and upright many seconds after the fire began, (3) falling pieces of fabric were aflame and not self-extinguishing, and (4) the very bright color of the flames was characteristic of a forest fire, not a hydrogen fire (hydrogen makes no visible flame). Also, no one smelled garlic, the scent of which had been added to the hydrogen to help detect a leak.

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Gaseous Hydrogen – Site Storage

Bumpstop

48ea 2400psi Outdoor WP manifolded "T" tanks will support a 1500A, 54.6VDC PEM power plant for 4.8hrs with no rundown decay in output.

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Sprint's Ten "T" Bottle Hydrogen Chalet

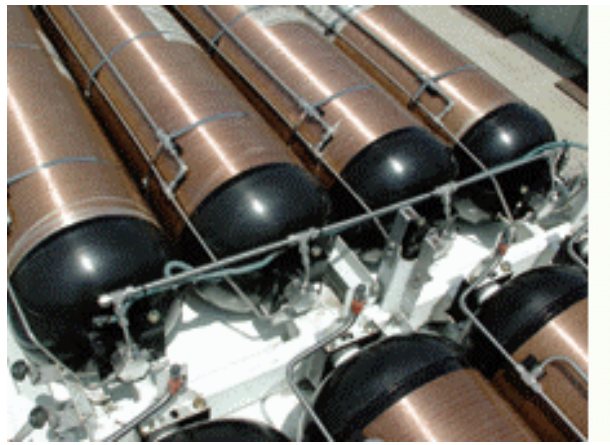
Stores a full 8hr Runtime Backup for a 200A, 48VDC Hydrogen Power Plant. Outdoor Installation with No Air Conditioning Required.

Sprint®

Gaseous Hydrogen – Site Storage

5000PSI Tanks $$

Quantum Technologies' TriShield composite cylinders can hold up to 3 kilograms of hydrogen at 5,000 psi, which is sufficient fuel for a 200-kilometer journey in a standard sedan.



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Metal Hydrides Used for Fuel Storage

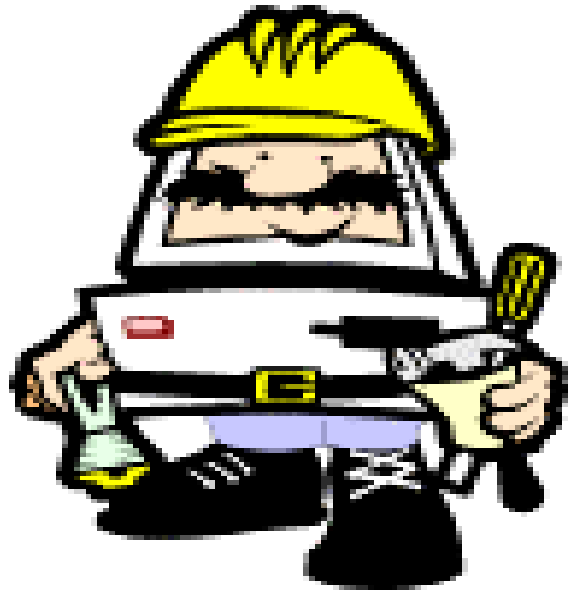
Some metal alloys have the ability to absorb and store hydrogen. The hydrogen can be released (desorbed) as a gas and the alloy is returned to its original state. These "metal hydrides" provide a safe and efficient "solid state" approach to hydrogen energy storage. In addition, the energy implications of this continuously repeatable phenomenon are the basis for a wide range of commercial products.

Hydrogen Fuel Cell Maintenance

Electrical design systems are maintainable when:

**Site design is managed by telecom experienced consultants*

**Maintenance contract is handled by a hydrogen experienced vendor.*



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Gaseous Hydrogen

Hydrogen is flammable and burns in air with a pale blue, almost invisible flame. In its gaseous form, hydrogen dissipates quickly. These unique properties call for strict safety measures in hydrogen use and storage.

Hydrogen is flammable and can act as a simple asphyxiant by displacing the oxygen in the air. In addition, when in its liquid form, it may cause severe frostbite to the eyes and skin. To avoid these harmful effects, it is important follow strict safety guidelines for storage and handling just like any other fuel.

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Telecom Handling of Gaseous Hydrogen

***Receiving Cylinders and Containers** -- Personnel responsible for receiving cylinders and containers should perform an external inspection on all packages before moving them to the point of use or to the storage area.*

***Testing for Leaks** -- After completing the external inspection, you should proceed with testing for leaks.*

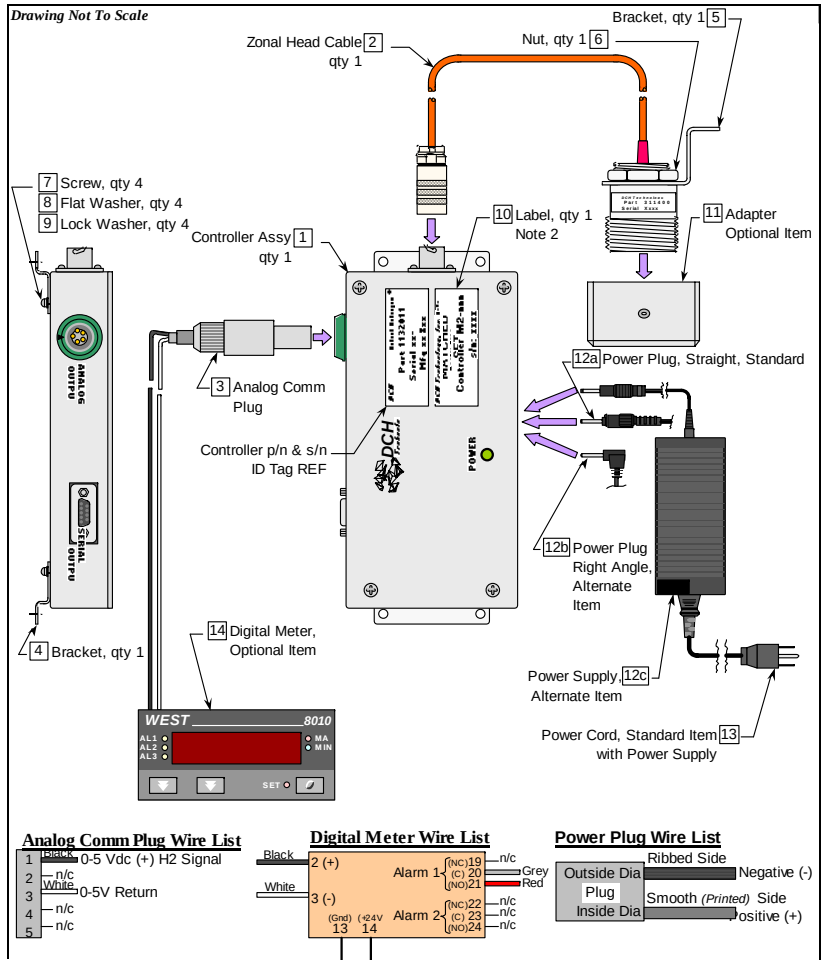
***Moving Cylinders and Containers** -- Cylinders and containers must always be moved carefully. Mishandling that results in a damaged valve or ruptured cylinder can expose personnel to the hazards associated with these gases.*

***Storing Cylinders and Containers** -- Storage of compressed gas cylinders containers is governed by codes of the NFPA. Local codes may also apply. Know and obey codes governing storage at each Sprint location.*

On Site Hydrogen Monitoring & Shut Down

H2Scan

New Hydrogen Monitoring Arrangement

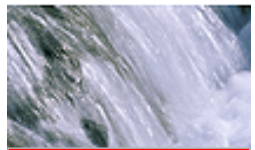


On Site Hydrogen Monitoring & Shut down

Hydrogen moves into a palladium base lattice (PD alloy film).
An equilibrium hydrogen density is reached proportional to gas concentration.
The sensor is housed in a 1B2 approved enclosure.

Hydrogen Liberation


PV Array
~5 kW


Potable Tap Water
45 to 75 psi

Simplified Process Flow
for a

Renewable-Hydrogen
Back-up Power System

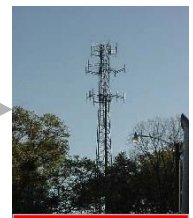
Oxygen


H2 Generation


Booster
Compressor


Hydrogen Storage


NEXA Fuel
Cell Rack


PCS
Tower

Proposed Scope of Supply

- Sprint
- Stuart Energy
- Ballard Power

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