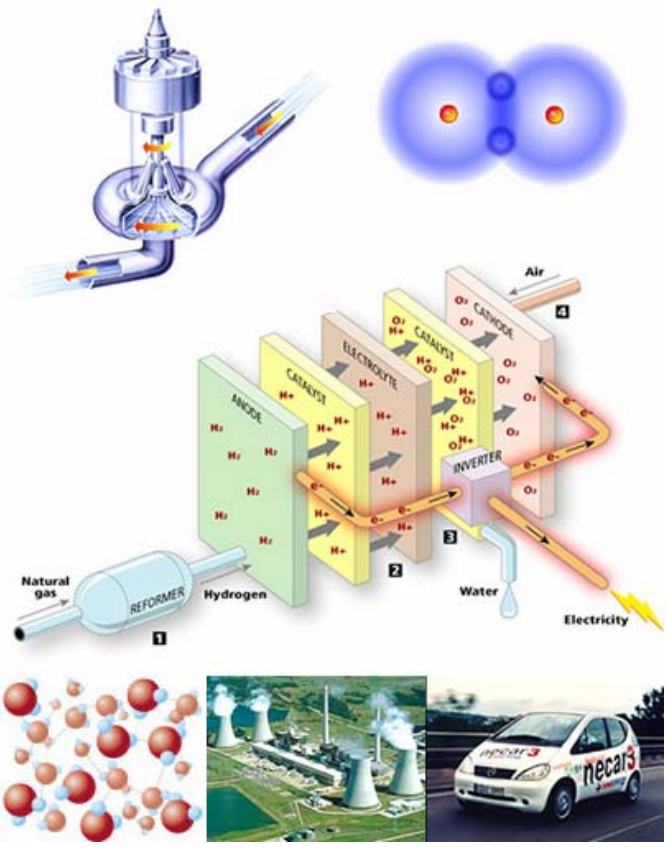
ioMosaic Statement Of Qualification

Hydrogen and Fuel Cells

Overview

The interest in vehicles powered by fuel cells using hydrogen as a fuel has increased after President Bush, in his 2003 State of the Union speech, asked the Congress for $1.5 billion for research and development of fuel cell technology. Additionally, Congress is discussing making hydrogen facilities and hydrogen powered vehicles tax-free.



We Can Help

The founding partners of ioMosaic Corporation have worked on many assignments involving hydrogen and fuel cell technology for vehicles. They continue to be active in both of these areas of technology today. Their work with hydrogen involves its generation, storage and distribution for both local use in a manufacturing facility or the infrastructure to support hydrogen fuel cell based transportation technologies. What follows are some examples of work done by the ioMosaic professional staff.

Hydrogen Fueling Infrastructure Study

ioMosaic conducted a failure modes and effects analysis (FMEA) of four alternative designs currently being operated by the California Fuel Cell Partnership and SunLine Transit District:

- Delivery from compressed hydrogen tube trailers, gas compression, gas storage and dispensing
- Delivery of liquid hydrogen in trucks, liquid storage, vaporization, gas compression, gas storage and dispensing
- Delivery of natural gas by pipeline, steam reforming, gas compression, gas storage and dispensing
- Delivery of electricity, electrolysis of water, gas compression, gas storage and dispensing

In addition, we conducted a similar FMEA on the delivery of natural gas by pipeline, compression, storage and dispensing.

The goal of the FMEAs was to develop specific and useful guidance, to stakeholders involved in developing or installing the infrastructure for hydrogen-fueled vehicles, regarding the safety of hydrogen fueling stations and other infrastructure elements.

The FMEAs considered failures in major equipment components (i.e., vessels, piping, pumps, compressors, valves and associated instrumentation and controls) as well as human errors. The effects of failures were expressed in terms of a range of safety consequences (e.g., local impact to fatalities). Any safeguards that were in place to mitigate potential safety consequences were documented. The resulting likelihood of undesirable impacts were expressed in terms of a range of frequencies. Where the safeguards were not considered adequate, recommendations for additional safeguards were made.

Hydrogen Storage Technologies for Fuel Cell Powered Vechiles

Members of the ioMosaic staff evaluated methods for the storage of hydrogen for use in fuel cell powered vehicles. The study evaluated both hydrogen-only systems and systems that contain hydrogen associated with some other substance within the vessel. Hydrogen-only systems included both compressed hydrogen gas and liquefied hydrogen. Bonded-hydrogen systems included metal hydrides, liquid hydrides, iron and water, dihydrides, and carbon adsorption.

Some of the main conclusions of this study were that:

1. No hydrogen storage technology is best for all applications
2. No hydrogen storage technology is obviously favored for fuel cell powered vehicles
3. The hydrogen industry should address the safety problems (including the public perception thereof) associated with hydrogen storage technologies

Liquid Hydrogen/Ammonia Dissociation Risk Assessment for Supplying Hydrogen

For a large international chemical company our staff conducted a quantitative risk assessment (QRA) of two argon purification processes under consideration. Hydrogen for the purification was supplied in one case by direct receipt, storage and feed of liquid hydrogen and, in the second case, by dissociation of ammonia. The scope-covered potential upsets associated with the unloading, storage, dissociation, feed and purification activities of both approaches for the purpose of evaluating the relative risk levels between the two processes. Results of the QRA were presented in terms of societal risk profiles, risk contours and maximum individual risk estimates.

Liquid Hydrogen Storage and Distribution

A safety survey of an installed liquid hydrogen storage tank and distribution system was performed for a major semiconductor manufacturer. The survey reviewed the management practices for mechanical integrity of the storage and distribution piping, leak prevention and detection, ignition source control and user interface hazards. Deficiencies, such as locating a non-intrinsically safe fire alarm bell inside the main hydrogen manifold room, along with other recommendations were summarized in a written report.

Updating of EPA's Hydrogen Guideline

We reviewed and updated the Environmental Protection Agency's (EPA) Hydrogen Guideline that contains recommendations and instructions that define the criteria for gaseous hydrogen handling and use. This guideline applies to all uses of gaseous hydrogen in EPA-owned and leased facilities, test laboratories, and field operations in quantities greater than standard lecture bottles. The review involved ensuring that the EPA guidelines were consistent with the most recent version of external codes and standards including applicable NFPA, CGA, and BOCA recommended practices. Additions were made to the guidelines to address electrolytic hydrogen generators and fuel cell fuel processors.

Fuel Cell Studies

The ioMosaic Corporation staff has been involved in many fuel cell assessment studies during their careers. A partial list of topics they have studied is provided below:

- A quantitative risk assessment (QRA) of a fuel cell power plant system for a major US fuel cell developer.
- A study of alternative fuel cell feed stocks and price forecasts for EPRI.
- A technical review of the development program of an international fuel cell developer, to assess potential for acquisition.
- Study of system design and economics of fuel cell power generation in most-favorable industrial applications.
- Study of fuel cell propulsion systems for commercial transportation vehicles, excluding automobiles, buses and locomotives.

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