Setting-up a Fuel Cell Testing Facility – A Primer

Introduction

This document covers the basics of what is required to set-up a fuel cell test lab. A checklist of suggested items that will assist in setting up and operating the facility are provided. Safety precautions common to fuel cell testing are provided.

WARNING

Use of Hydrogen or other combustible reactants, and Oxygen or other strong oxidants, can result in **extreme hazard of fire and explosion** including **injury or death to the operator** and **severe property damage**. These reactants should be used **only by qualified personnel.** All responsibility for the correctness of connections, installation and use of these products is assumed by the user. Scribner Associates, Inc. specifically disclaims any and all responsibility and/or liability for injury, death or property damage associated with improper installation or use of these products. This disclaimer applies to both direct and consequential damages.

Checklist of Facilities

- ☐ Venting for flammable/combustible gases—exhaust lines that terminate in a hood or other type of building exhaust
- ☐ High purity de-ionized water (*e.g.*, ASTM Grade I, 18 MΩ-cm). This supply must be from a source pressurized to 30-65 PSI (210-240 kPa). If a pressurized source is not available, Scribner Associates does sell tanks that may be safely pressurized
- ☐ Fuel supply: pressure regulated compressed gases – hydrogen, air, oxygen – 99.999% purity, generally. It is crucial to use contaminant free gasses, because impurities can damage the system and fuel cell.
- ☐ Gas regulators with CGA fittings; hydrogen gas supply must use a regulator specifically designed for hydrogen use. Outside of North America, it may be necessary to have adaptors to ensure proper fit.
- ☐ Nitrogen gas supply for purging the system and fuel cell
- ☐ Sufficient tubing to install gas supply lines to unit. Stainless steel or steel braided gas lines should be used for hydrogen and oxygen supply lines. Rigid polypropylene (PP) or high-density polyethylene (HDPE) tubing is acceptable for plumbing air and nitrogen.
- ☐ Gasses should be distributed with a CGA regulator on the tanks, fed immediately to a cut off valve. From there, the gasses should be distributed to various test stations, with valves at both the source the test system connects to, and a main cutoff for each general area, such as at each lab bench, or in each laboratory should there be a multi-room system. Remember that all tubing, valves, and regulators must conform to each gas's handling requirements, such as stainless tubing for hydrogen.
- ☐ Ensure that the electrical outlets have enough circuit amperage capacity and the proper voltage for the instruments used (check instrument AC line voltage and current markings; Scribner Associates units typically require 10A each).

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- ☐ An Uninterruptable Power Supply (UPS) should also be used to safeguard the system and your collected data on both the test system and the host computer. This should also meet the power requirements of the system.
- ☐ Given a 3 ft deep bench, for each test station, a roughly 5 ft bench space would be more than sufficient to accommodate the unit. For deeper benches, or islands, it may be possible to use a more compact configuration.
- ☐ A typical fuel cell test facility (Figure 1) includes provisions for storage and delivery of compressed gas, a high purity, deionized (DI) water source, sink and bench space for the test stand, single cell fuel cell, and PC computer. The fuel cell test stand and/or fuel cell may be located inside a fume hood.

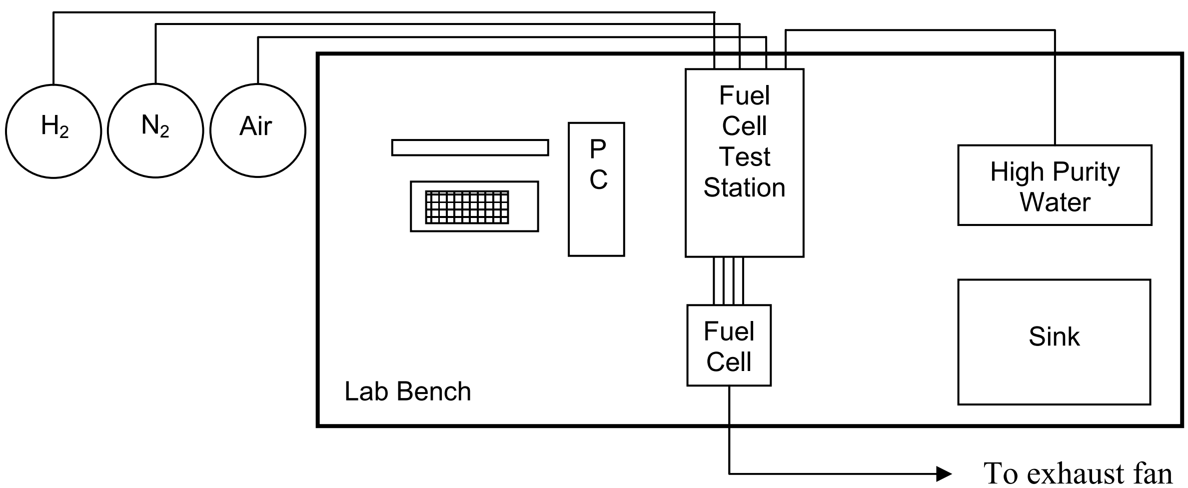

Figure 1. Sample layout of a fuel cell laboratory

Suggested Tools

- ☐ An assortment of hand tools.
- ☐ screwdrivers, standard sizes
- ☐ adjustable wrenches
- ☐ channel locks
- ☐ Tubing cutter – metal and plastic
- ☐ Open end spanner wrenches appropriate for fittings and load-cable fasteners – common imperial sizes required are 3/8”, 7/16”, 1/2 ”, 9/16”, 5/8”.

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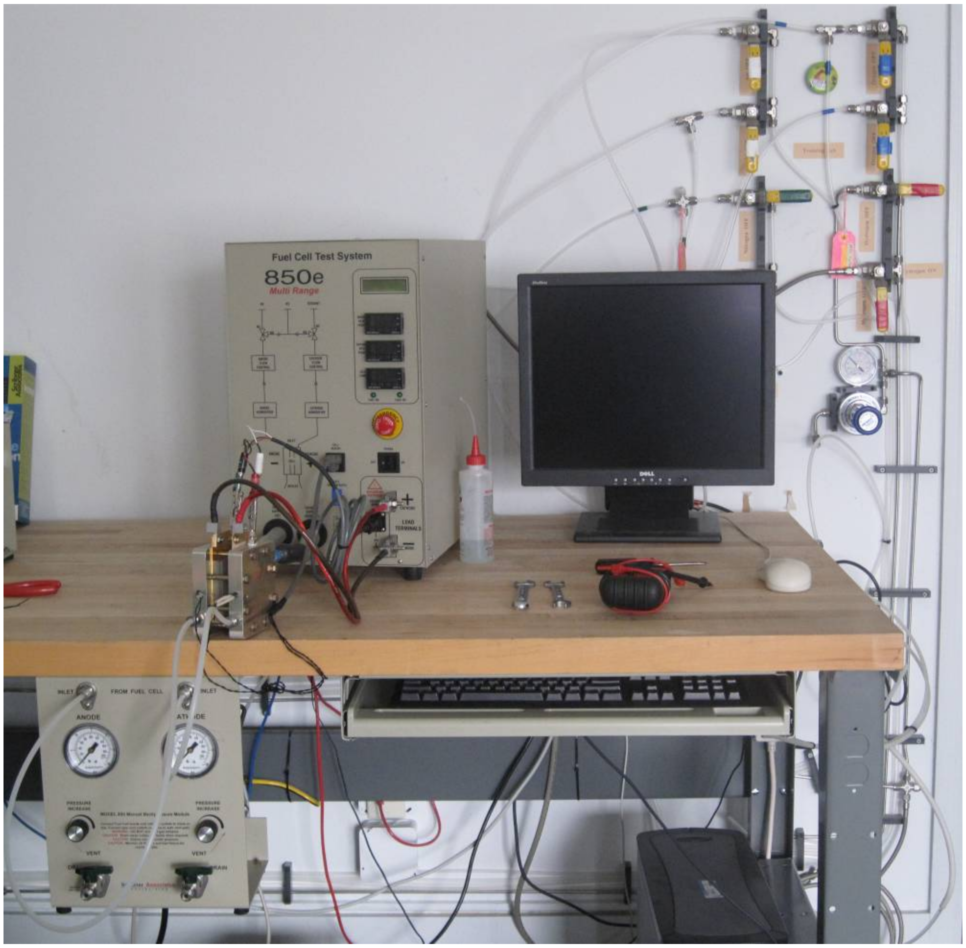

Figure 2. Sample setup of a Scribner Associates 850e Fuel Cell Test System, single cell fuel cell and standard Back Pressure Unit. Locating the back pressure unit below the exit port of the fuel cell facilitates draining of liquid water that accumulates in the exhaust lines. Accumulation of liquid water leading to slug formation causes pressure fluctuations in the system leading to unstable cell performance. Not shown are exit lines from the back pressure unit to a forced-air exhaust vent. To the right is a pressurized gas and water distribution manifold and valve system for reactant delivery to multiple locations, all of which is fed off a common source located elsewhere in the facility.

Equipment and Materials

- ☐ Swagelok® fittings – (www.swagelok.com) – the ferrule and tubing material should be the same, *e.g.*, metal-on-metal (stainless steel) or plastic-on-plastic (nylon, PTFE); do not combine dissimilar materials, all gas supply fittings on the test unit are stainless steel.
- ☐ GPIB to USB cable (for sale through Scribner Associates)
- ☐ GPIB IEEE-488 daisy chain cable to permit connection to a potentiostat or other GPIB-based instruments as desired (Figure 3)
- ☐ Load cables and hardware to connect them, *i.e.*

Figure 3. GPIB-to-USB converter (National Instruments).

1/4" hex bolts and nuts

- ☐ Voltage sense leads
- ☐ Thermocouple
- ☐ Non-corrosive, non-flammable liquid leak detector, *e.g.*, Snoop®, to check for gas leaks
- ☐ http://www.swagelok.com/leak_detectors_lubricants_sealants/liquid_leak_detectors.htm
- ☐ Military-grade Teflon Sealing Tape (MIL-T-27730A, A-A-58092) is suitable for H_2, regular white Teflon tape is acceptable for other gases (McMaster-Carr P/N 44945K12)
- ☐ Should the test station's humidifier tanks need to be drained, it is advisable to use a length of polypropylene tubing attached to the drain port to direct water into a bucket or a sink.

Safety

- ☐ Use only stainless steel, or stainless steel braided plastic, tubing for plumbing hydrogen
- ☐ Ensure that the gasses from the exhaust port of the fuel cell are properly ventilated
- ☐ Install a combustible gas detector in the laboratory with alarm setting less than the explosive limit for H_2 in air (~4%). Periodically check proper functioning of the combustible gas detector.
- ☐ Hand held combustible sniffer to isolate hydrogen leaks is recommended.
- ☐ Verify that potential ignition hazards are not present in the laboratory given the combustible nature of hydrogen and oxygen.
- ☐ The facility should also have good circulation of outside air, as nitrogen can become a severe asphyxiant if not vented. In most cases this is not an issue, but should an instrument, or multiple instruments have a high cumulative flow rate, it is an important consideration.

Gas Hazards

What are the fire and explosion hazards associated with compressed gases?

Flammable Gases

Flammable gases can burn or explode under certain conditions. Flammable gases include **hydrogen**, acetylene, butane, ethylene, methylamine and vinyl chloride.

Gas Concentration within the Flammable Range

In order to be flammable, the concentration of the flammable gas in air (or in contact with an oxidizing gas) must be between its lower flammable limit (LFL) and upper flammable limit (UFL). The LFL and UFL are sometimes called the lower and upper explosive limits (LEL and UEL), respectively. The LFL of hydrogen gas in air is 4% and its UFL is 75% at atmospheric pressure and temperature. This means that hydrogen can be ignited when its concentration in the air is between 4% and 75%. A hydrogen concentration below 4% is too lean to combust whereas above 75% it is too rich to combust.

The flammable range of a gas includes all of its concentrations in air between the LFL and UFL. The flammable range of a gas widens in the presence of oxidizing gases such as oxygen or chlorine, and by higher temperatures or pressures. For example, the flammable range of hydrogen in pure oxygen gas is 4% to 85% and the flammable range of hydrogen in chlorine gas is 4% to 89%.

Ignition Source

For a flammable gas within its flammable limits in air or another oxidizing gas to ignite, an ignition source must be present. There are many possible ignition sources in most workplaces including open flames, sparks and hot surfaces.

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The auto-ignition or ignition temperature of a gas is the minimum temperature at which the gas self-ignites without any obvious ignition sources. Some gases have very low auto-ignition temperatures. For example, phosphine's auto-ignition temperature of 100 °C (212 °F) is low enough that it could be ignited by a steam pipe or a warm light bulb.

Flash-back can occur with flammable gases. Many flammable compressed gases are heavier than air. If a cylinder leaks in a poorly ventilated area, these gases can settle and collect in sewers, pits, trenches, basements or other low areas. The gas trail can spread far from the cylinder. If the gas trail contacts an ignition source, the fire produced can flash back to the cylinder.

Oxidizing Gases

Oxidizing gases include any gases containing oxygen at higher than atmospheric concentrations (above 23% to 25%), nitrogen oxides, and halogen gases such as chlorine and fluorine. These gases can react rapidly and violently with combustible materials such as,

- organic (carbon-containing) substances such as most flammable gases, flammable and combustible liquids, oils, greases, many plastics and fabrics
- finely-divided metals
- other oxidizable substances such as hydrazine, hydrogen, hydrides, sulphur ,or sulphur compounds, silicon and ammonia or ammonia compounds.

Fires or explosions can result.

The normal oxygen content in air is approximately 21%. At slightly higher oxygen concentrations, for example 25%, combustible materials, including clothing fabrics, ignite more easily and burn much faster. Fires in atmospheres enriched with oxidizing gases are very hard to extinguish and can spread rapidly.

Oxygen itself is not flammable but strongly increases the combustion of flammable materials.

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