Fuel Cell Experiment

TO: Engineering Development Branch

FROM: Engineering Division

SUBJECT: Fuel cell performance

The company is considering using a proton exchange membrane (PEM) fuel cell to convert excess hydrogen from our refinery to electricity. Space is at a premium and catalyst costs are very high, so the company seeks a fuel cell that has maximum power density.

A small prototype (16 cm^2) fuel cell provided by the manufacturer in our laboratory is available to estimate the fuel cell power output as a function of reactor conditions within the ranges of 25-75 °C, 0-10 psig, 60-480 mL/min H_2, 200-1600 mL/min air.

The design fuel cell in the refinery must provide a net power output of at least 1 kW. Your assignment is to use the prototype fuel cell to find the optimum operating conditions of pressure, temperature, and fuel flow rate and the optimal current density that minimizes the catalyst area of required (cm^2). A great deal of literature suggests the polarization curve (voltage, V, vs. current density, i) for a fuel cell can be approximated as

$$V(i) = c_5 - c_2 \ln(i) - c_6 i$$

However, we suggest the equation

$$V(i) = c_1 - c_2 \operatorname{arcsinh}\left[c_3^2\, i \left(1 - \frac{i}{c_4}\right)^{-\gamma}\right]$$

where γ should be 1 for a hydrogen PEM fuel cell. If the prototype cannot measure voltages at high current densities, you can assume that c_4 is about 1225 mA/cm^2. The other parameters have typical values of approximately 1 V, 0.1 V, and 0.2 cm/$mA^{1/2}$ for typical PEM fuels cells at optimal operating conditions. This equation has the following significant advantages and no disadvantages compared to the previous equation

1. a stronger theoretical basis (relaxes to a dimensionally correct version of the previous equation in the limit of large current density),
2. finite value at zero current density,
3. includes transport effects
4. transcendental function arguments do not have dimensions

The parameters c_1 and c_4 in this equation are the voltage at zero current density (V) and the maximum current density (mA/cm^2), respectively. The other two parameters should be fit to your data.