# Measurement of Gas Dispersion in the Anode Feed Stream of a 47 Cell PEM Stack

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## Abstract

A 47-cell Ballard Nexa™ PEM stack was used to investigate the relationship between cell voltage and the concentration of impurities in the feed stream at each individual cell in the stack. Separate voltage taps were applied to each MEA in the stack to measure the time-dependent potential and concentration of impurities. Feeds containing 5% inert gas were used for comparison with feeds of less than .01% inert. AC impedance measurements were also recorded to establish a relationship between impedance, impurity concentration, and diagnosis/ mechanistic discrimination as to the nature of the impurity affect on the stack behavior. The above noted techniques are useful for performing cell diagnostics and understanding gas distribution within the feed manifold and on the catalyst surface of each MEA.

Gas prices continue to rise while its supply and the health of the environment continue to deteriorate prompting researchers to explore alternate means of energy including the PEM fuel cell. Proton exchange membrane (PEM) fuel cells have attracted wide interest for use in vehicular and stationary energy supplies due to their high efficiency and low environmental impact. Safety concerns about hydrogen storage, especially in mobile power sources, and the existing gasoline infrastructure have most speculating that the gas will have to be formed onboard from a safer liquid hydrocarbon. Producing hydrogen with such a method will also yield impurities; thus, it is imperative to understand the manner in which impurities flow through the feed manifold and the degree to which impurity concentration affects the electrical output.

The Nexa™ PEM stack is a stack of 47 individual membrane electrode assemblies (MEAs) producing 1200 W of unregulated DC power at a nominal voltage output of 26 VDC with a maximum current of 44 A and a maximum potential of 50 VDC. The stack was connected to a TDI electrical load set to a constant current to maintain the desired power output. Gas feeds of hydrogen and nitrogen were mixed in the lab to yield a composition of 95% pure hydrogen, which was confirmed using the Agilent 6890 gas chromatography system with enhanced integrator. The prepared tank of gas was connected to the stack inlet in conjunction with a tank of 99.99% pure hydrogen, such that feed compositions could be changed without having to shut-down the stack. The system was then run at the desired power output with pure feed until the stack temperature remained constant. Once a steady-state was reached, the system was ready for voltage measurements across each MEA and for impedance measurements.

## Voltage Measurements

The experimental set-up for the voltage measurements consisted of a Ballard PEM stack connected to 47 separate pairs of voltage taps applied to each MEA in the stack, which communicated to a LabView digital interface through data acquisition hardware by National Instruments. Once the stack had achieved a steady-state with the pure feed, data began to be measured. The feed was switched to the impure after the anode gas was first purged, and the stack was run for several minutes. Changing the feed back to pure and resetting the load value, the experiment was repeated at steady-state.

Voltage data are plotted as a function

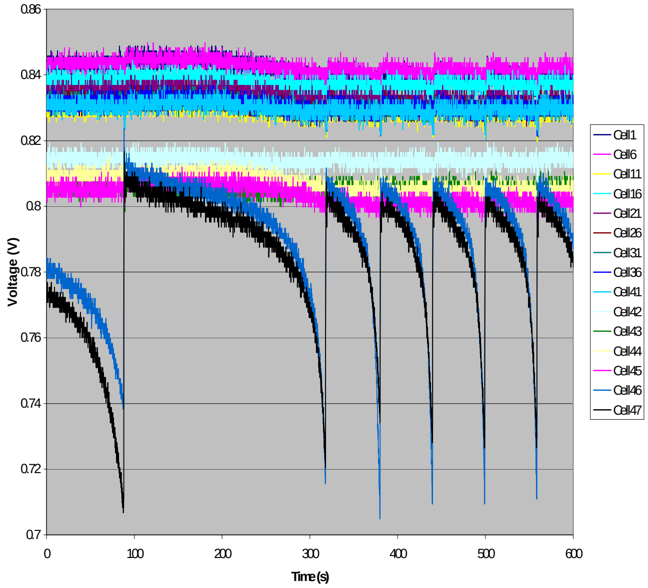


**Figure 1**. Voltage data as a function of time for 50 W stack output.

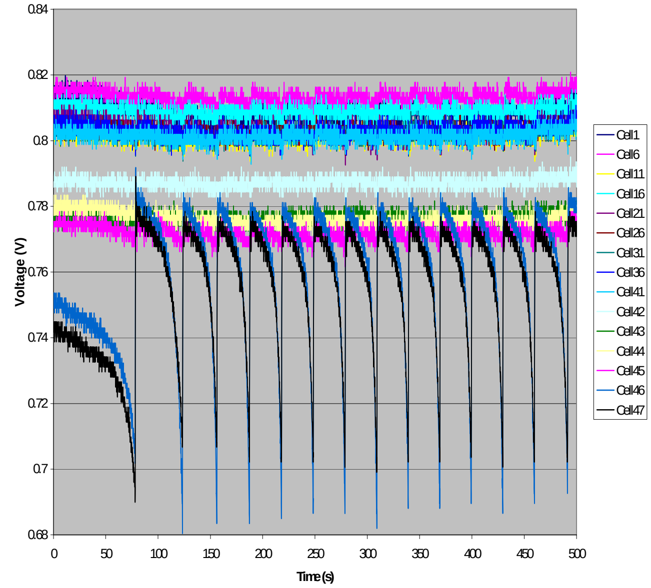


**Figure 2**. Voltage data as a function of time for 100 W stack output.

of time for 50 W and 100 W stack power output in Figures 1 and 2, respectively. The figures show as expected that inert feed concentration has a negative affect on cell potential as indicated by cell numbers 42-47. The cells are numbered such that cell 47 is the closest to the anode feed outlet, where the inert gas molecules collect after flowing past each electrode without reaction. In order to maintain safe operating conditions, the control system purges the anode feed when cell 47 reaches some threshold potential difference. The purge rate varies with time after the feeds have been switched until a steady-state has been achieved, after which the purges are periodic. Comparing the two figures, the purge period for the 50 W is exactly twice that of the 100 W, about 1 min and 30 sec, respectively. This shows that stack power is governed directly by the rate of reaction inside the cells, causing the feed stream to dilute quicker at higher electrical currents. Eventually, plans are to input a pulse of inert gas into the feed stream to calculate the residence time distribution at different loads.

## Impedance Measurements

Impedance data were measured for af Nexa™ fuel cell stack using Gamry's FC350™ monitor and the TDI electric load from earlier. The electrochemical impedance spectroscopy (EIS) technique used to acquire these data is discussed in detail elsewhere on this cd-rom (Zhu et al.). Data were taken for the whole stack at varied power outputs for pure and 5 % nitrogen feeds.

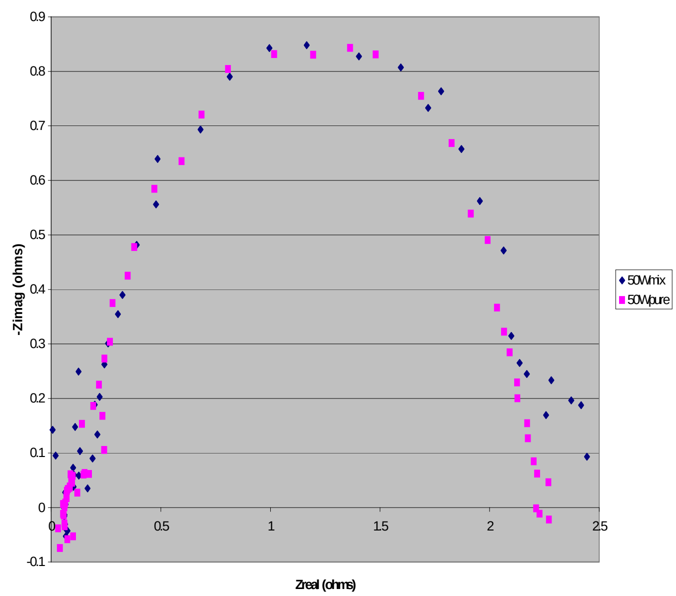


**Figure 3**. Nyquist plot for 50 W stack output.

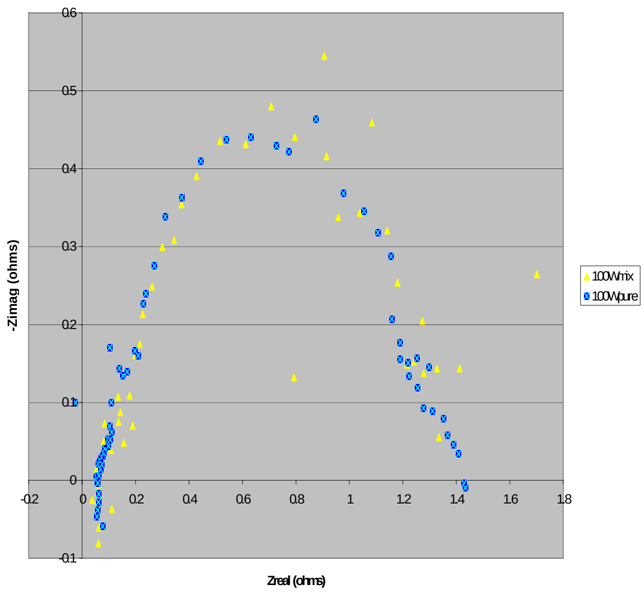


**Figure 4**. Nyquist plot for 100 W stack output.

Nyquist plots are excellent tools in evaluating an equivalent circuit model for an electrochemical power source such as a fuel cell. Comparing the overlaid Nyquist curves (Figures 3 and 4) reveals that pure and mixed gases do not affect the $Z_{re}$-intercept nearest the origin. Assuming Randle's equivalent circuit, the point represents the ohmic solution resistance, indicating that such resistance is not dependent on feed composition regardless of the power output. The opposite $Z_{re}$-intercept, however, does change depending on feed composition. The diameter of the semi-circle corresponds to the charge transfer resistance, which is observed at low frequencies. A problem arises in interpreting the data at this point, because the resistance due to mass transfer by diffusion can dominate the kinetic control of the cell reaction. Other tests reveal that mass transport effects are only observed in the last cells for a pure feed (Zhu et al.). The diffusion resistance is described by Bard as the Warburg impedance, which appears as a straight line of positive slope. This effect can only be observed in limited frequencies depending in the kinetics. Reactant concentration is well known to affect kinetics; therefore, the mixed feed should exhibit a differing charge transfer resistances, especially in cells 42-47. Since the contribution of each element in each individual cell in the stack is so different in mixed feeds, apprehensions arise about the dependability of modeling 47 equivalent circuits in series by a similar circuit with different parameter values. Another problem arises in that the data were taken with the control system intact, which can cause significant noise. The significant purge rate for mixed feeds (as seen in the voltage measurement section) could also affect the plots. Work is in progress to evaluate to what degree each of these problems is affecting the current data, so that better data can be acquired to accurately model the entire PEM stack with an equivalent circuit.

## Conclusion

Understanding the manner in which impurities flow through the anode feed manifold and its affect on stack impedance is crucial for implementing fuel cells into real systems. Once the project is complete, the results should prove useful to engineers designing electrical equipment to be powered by PEM stacks and to those designing anode feed gas filters/separators.

## Acknowledgements

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