# VII.H.6 Hydrogen Program Sensor Development

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## Overall Project Objectives

Identify concepts and barriers leading to the creation of physical sensors (temperature, pressure, airflow, and humidity) suitable for monitoring and controlling a polymer electrolyte membrane (PEM) fuel cell-based power plant, including the fuel reformer, fuel cell stack, and thermal management system.

- 2005 Objectives – Humidity Sensor Effort
- Reduce response time
- Demonstrate long-term stability under PEM conditions
- Demonstrate hydrogen leak-proof design

## Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- H. Sensors

## Technical Targets

This project addresses the following Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan technical targets for fuel cells:

- Relative humidity for cathode and anode gas streams
  - Operating temperature: 0°C to 120°C
  - Relative humidity: 20% – 100%
  - Accuracy: 1% full scale
  - Gas environment: high-humidity reformer/partial oxidation gas: $H_2$ 30%–75%, $CO_2$, $N_2$, $H_2O$, CO at 1–3 atm

## Introduction

This document reports on the work done by Honeywell Sensing and Control to investigate the feasibility of modifying low-cost commercial sensors for use inside a PEM fuel cell environment. Both stationary and automotive systems were considered. The target environment is hotter (100°C) than the typical commercial sensor maximum of 70°C. It is also far more humid [100% relative humidity (RH) condensing] than the more typical 95% RH non-condensing at 40°C (4% RH maximum at 100°C). The work focused on four types of sensors: temperature, pressure, air flow and relative humidity.

As work progressed, requirements changed to where the temperature and pressure sensors were similar to off-the-shelf products and didn't merit separate development. With the elimination of on-board reformers, there was no need for airflow sensors. Work relative to this annual report was exclusively on ruggedizing capacitive membrane humidity sensors. The general and technical barriers specific to humidity sensors include the following:

## General Barriers

- Robust to high humidity and high temperature
- Exposure to DI and hydrogen media
- Automotive grade
- Cost
- Overall package size
- Overall package weight

## Technical Barriers

- Recovery from a condensing environment
- Accuracy at high temperature and high humidity with minimal drift

## Approach

Look at the fuel cell system and establish the requirements for the RH sensor. Deploy existing technologies and develop packaging strategies to minimize sensor cost.

Fuel cell manufacturers now use instrument-grade sensors to accommodate sensing requirements. Due to cost, size, and weight, instrument-grade sensors do not provide a long-term sensing solution for fuel cell applications.

Use a capacitive humidity sensor chip on ceramic with an application-specific integrated circuit (ASIC). The technology is packaged in a heated chamber with a micro-filter and controlled to shift the dew point. The sensor assembly is over-packaged in an automotive-grade housing. The ASIC is not exposed to the wet hydrogen environment.

## Accomplishments

- Micro-filter performance testing in a condensing environment and heated sensor has been completed.
- Condensation tests with heated Alpha 3 sensing technology have been completed.
- Selection of ASIC completed.
- Environmental and stability testing completed with Alpha 3 configuration and ultra-high humidity sense die.
- Follow-on research for RH sensing film material with improved stability initiated at Honeywell Laboratories.
- Testing has confirmed the modeling prediction that temperatures throughout the heated package can be maintained and stable in the Alpha 3 and Beta configurations.
- Alpha 3 and Beta configurations passed gross $H_2$ leakage tests.
- Response time on Alpha 3 sample was 6 seconds, 1 second short of goals.

## Testing Performed on Alpha 3

- 28 sensors per test group for 1,000-hour temperature/humidity/bias testing
- 3 conditions: 85°C/85% RH, 85°C/65% RH, 100°C/65% RH
- All sensors survived
- Virtually all sensors drifted up in sensitivity
- Each sensor drifted unpredictable magnitudes
- Conclusion 1: a kind of burn-in or conditioning may be required
- Passed gross $H_2$ leakage testing
- Response time 6 seconds, not up to desired value (<5 sec)

## Overall Conclusion

Existing capacitive membrane technology is incapable of achieving multi-thousand-hour stability in PEM fuel cell environments. Additional work to develop a more suitable polymer or perhaps even a different sensing technology should be selected.

## Future Directions

Based on test data from the current concept, it was determined by DOE and Honeywell that this project would be terminated. Any future work could look at infrared-based sensors or thermal conductivity sensors.