# Hydrogen Safety Workshop
# An Overview of Sensor Metrics


W.J. Buttner,

M. Post, R. Burgess and C. Rivkin

Codes and Standards Group

Hydrogen Technology and Systems Center

National Renewable Energy Laboratory

Golden, CO 80401


**DOE-NREL**

**Hydrogen Sensor Workshop**

**June 8, 2011**

**Chicago, IL**

# Hydrogen Sensor Standards and Codes

- NFPA 2
  - Hydrogen Technology Code (Mandates use of hydrogen detectors)
- UL 2075 U
  - *UL Standard for Safety for Gas and Vapor Detectors and Sensors*)
- ISO/DIS 26142
  - (*Hydrogen Detection Apparatus for Stationary Applications*)
- FM Global
  - Approval Standard for Combustible Gas Sensors (6310 & 6320)
  - Approval Standard for combustible open path gas monitors (6325)
- DOE Target Sensor Performance
  - 2007 year plan (Table 3.8.2)

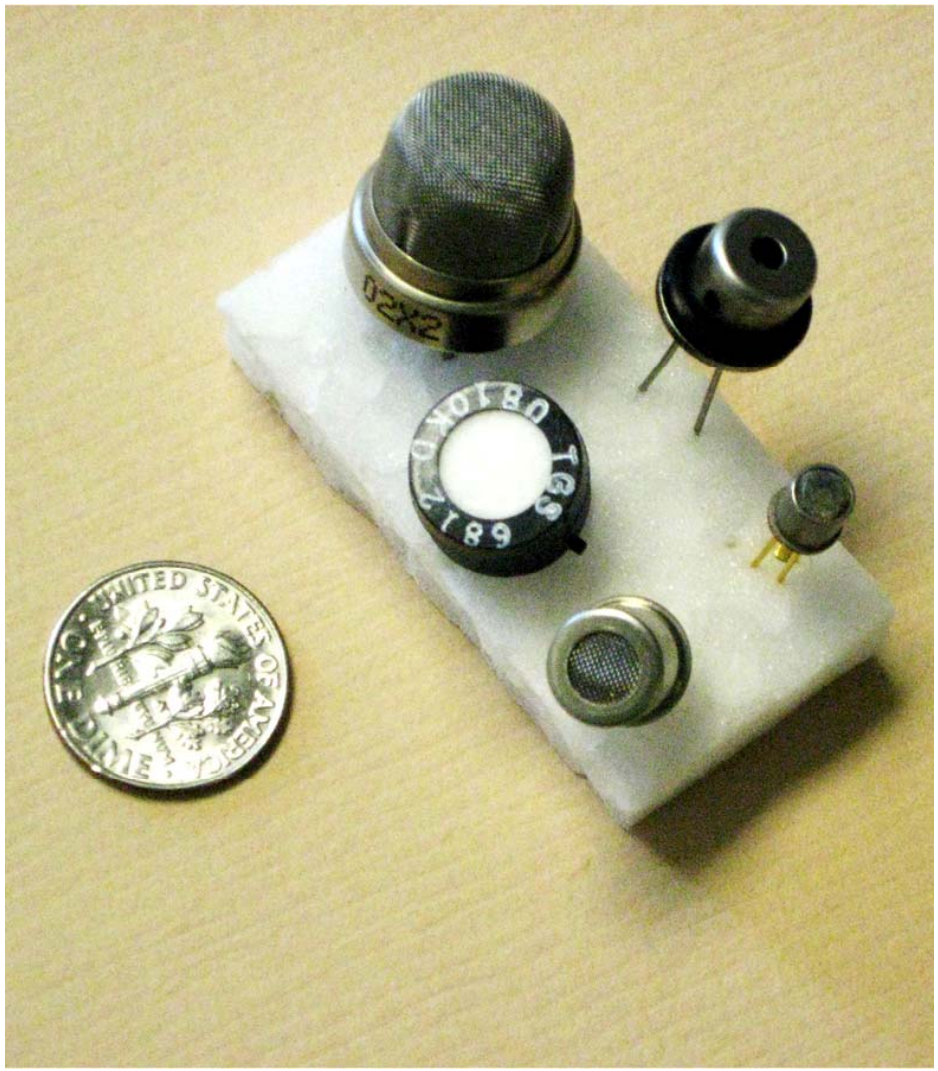
# Hydrogen Sensor Types

- Electrochemical
  - Amperometric, potentiometric [low T and high T]; solid/liquid electrolyte
- Metal Oxide (MOX sensors)
- Pellistor (combustible gas sensors)
- Thermal conductivity
- Optical Devices
  - Colorimetric and indicator dyes
  - Evanescent wave – with film of Pd or other material
- Pd-film and Pd-alloy films
  - Conductivity
  - Potentiometric
  - Mechanical [SAW, cantilever, Quartz]

Which are ideal for all applications: **NONE**

Which are good: **ALL**

Which are best for application: **TBD**



# Sensor Performance Metrics
## (may be required by Codes and Standards or by application)

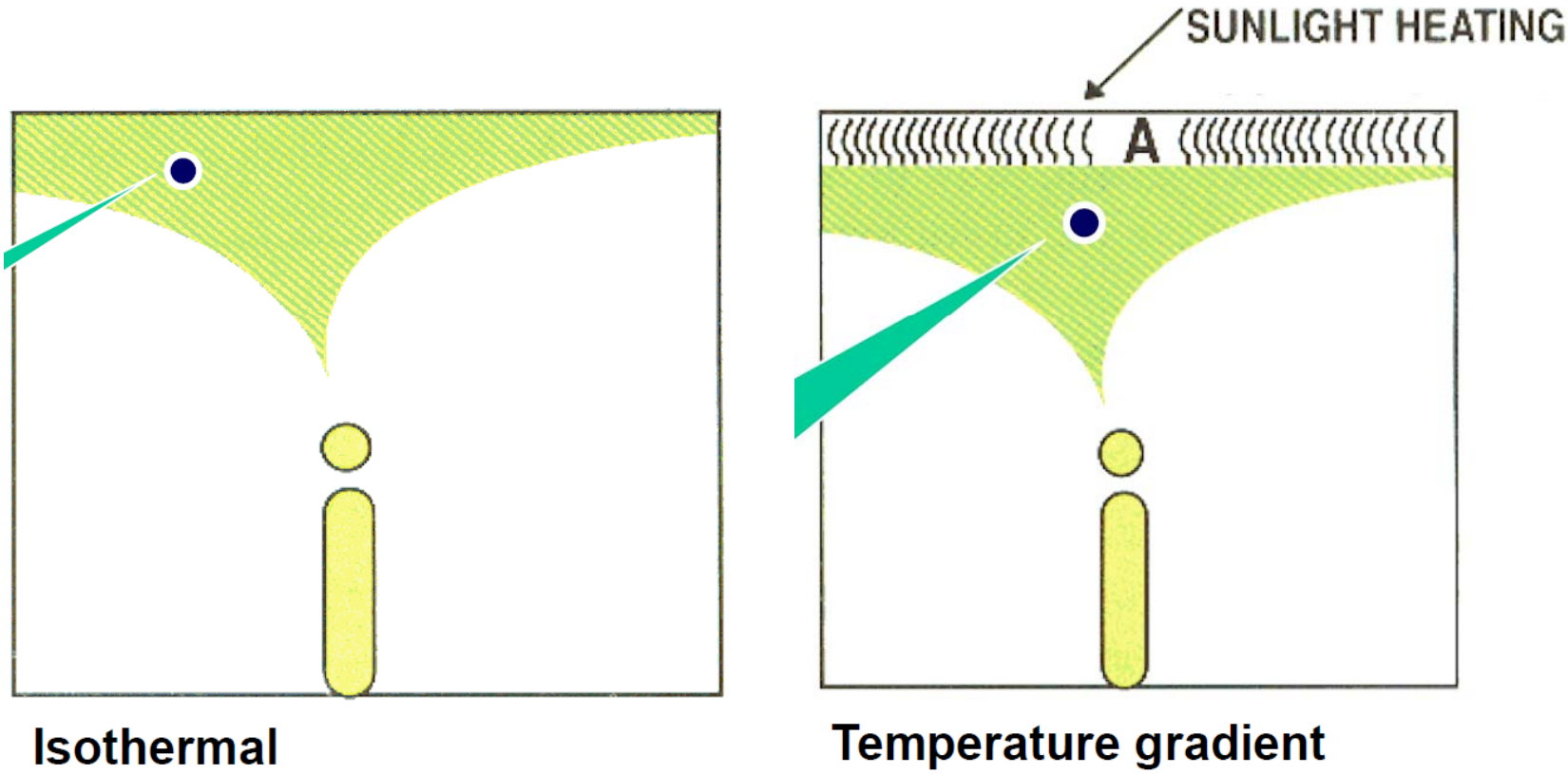
### ANALTYICAL

- Analytical Characteristics
  - Selectivity, Lower Detection Limit, Analytical Resolution, Linear Range (and Dynamic Range), Response Time, Recovery Time, Repeatability, Signal Drift, Environmental Effects (e.g., P, T, and RH), Reversibility, Limits of Quantization (Limits of determination), Saturation Stability, *Sensitivity* (slope of calibration curve)

### LOGISTICAL

- Deployment Parameters
  - Capital Cost, Installation Costs, Location, Physical Size, Control Circuitry, Power Requirement, Electronic Interface, Pneumatic Connections, Shelf life, Maturity/availability, Government Regulations (Codes)
- Operational Parameters
  - Operational Lifetime, Consumables, Calibration and Maintenance Requirements [frequency and complexity], Sample size, Matrix requirements, Signal Management, Orientation Effect, Device to device Repeatability, Warm Up Time, Alarm Set Points

# Sensor Deployment Considerations (isothermal vs. temperature gradients)




- A temperature difference of 3 K corresponds to about 1% H2 in density
- Warrants further investigation/modeling

# Alarm requirements for CO detectors

- Tiered response
  - Minimizes false alarms
  - Notifies when abnormal but low levels are present
  - Fast Alarms in situations dangerous to humans

**Table 39.1 UL 2034 Single and Multiple Station Carbon Monoxide Alarms**

| A. Carbon monoxide concentration and response time | |
|---|---|
| **Concentration, ppm** | **Response time, minutes** |
| 70 ±5 | 60 – 240 |
| 150 ±5 | 10 – 50 |
| 400 ±10 | 4 – 15 |
| **B. False alarm – carbon monoxide concentration resistance specifications** | |
| **Concentration, ppm** | **Exposure time, (no alarm)** |
| 30 ±3 | 30 days |
| 70 ±5 | 60 minutes |

# Comparison of Two Applications

## Residential Garage

- Analytical
  - Selectivity (gasoline vapors)
  - Temperature and RH (broad)
  - Moderate response time
- Operational
  - 5 year maintenance free
- Deployment
  - <0.1$K
  - Audible alarm
  - Passive (no active feedback)

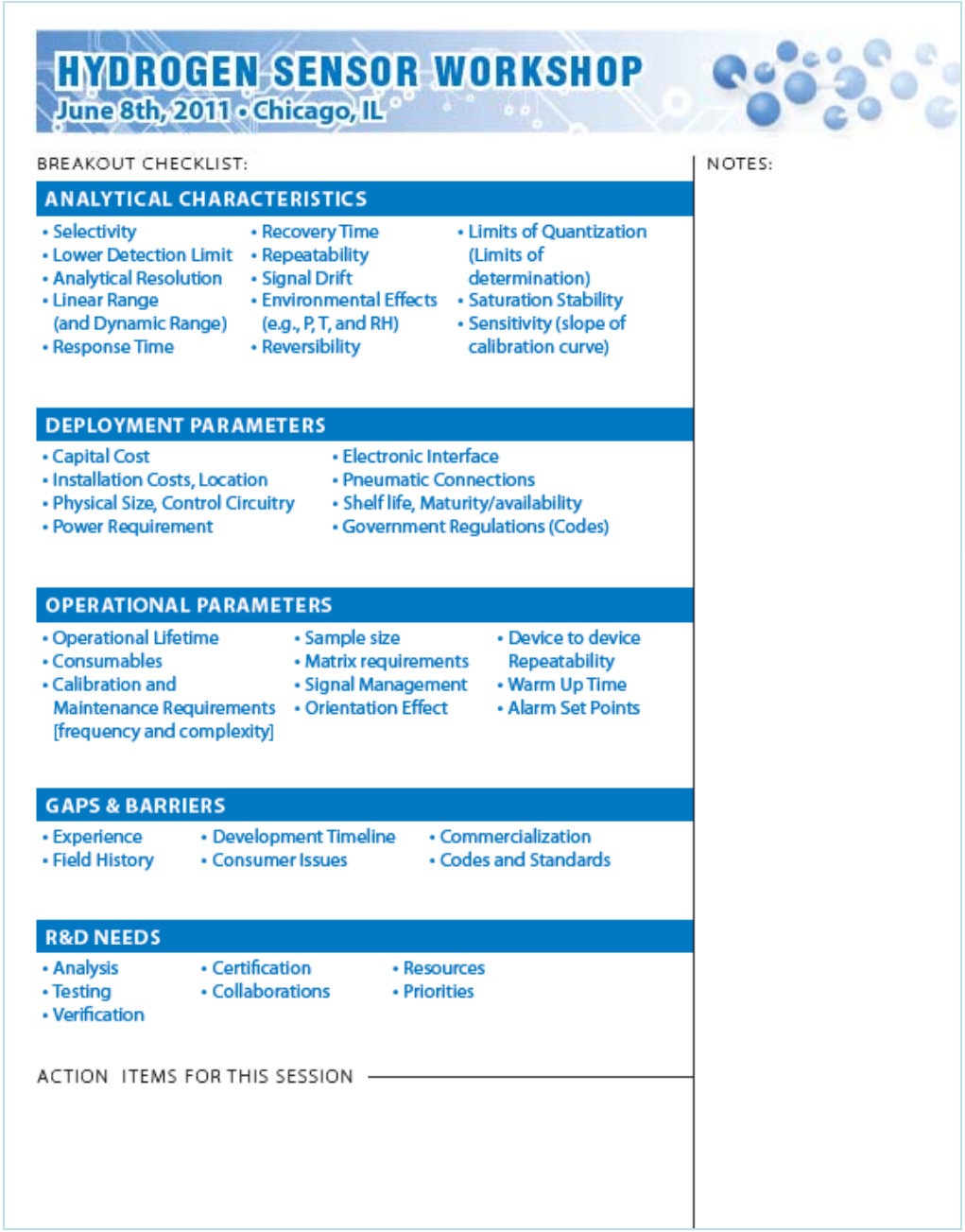
## Indoor Fueling

- Analytical
  - Selectivity (TBD; silicon resistant)
  - Temperature and RH (moderate)
  - Fast response time
- Operational
  - 1 year validation/calibration
- Deployment
  - <10$K
  - Audible alarm (and monitoring)
  - Interface to ventilation

# Sensor Technologies
# (General Issues and Concerns)

- Analytical performance is only one category
  - Cost independent
- Cost of operation (maintenance and calibration)
- Deployment Considerations (point, ventilation)
  - Smart Sensors integrated into networks
- Critical Performance Parameters
  - Application specific (must be identified)
- BREKAOUT Sessions
  - Handout as guide

# Breakout Checklist



## HYDROGEN SENSOR WORKSHOP

June 8th, 2011 • Chicago, IL

BREAKOUT CHECKLIST:

NOTES:

### ANALYTICAL CHARACTERISTICS

- Selectivity
- Lower Detection Limit
- Analytical Resolution
- Linear Range (and Dynamic Range)
- Response Time
- Recovery Time
- Repeatability
- Signal Drift
- Environmental Effects (e.g., P, T, and RH)
- Reversibility
- Limits of Quantization (Limits of determination)
- Saturation Stability
- Sensitivity (slope of calibration curve)

### DEPLOYMENT PARAMETERS

- Capital Cost
- Installation Costs, Location
- Physical Size, Control Circuitry
- Power Requirement
- Electronic Interface
- Pneumatic Connections
- Shelf life, Maturity/availability
- Government Regulations (Codes)

### OPERATIONAL PARAMETERS

- Operational Lifetime
- Consumables
- Calibration and Maintenance Requirements [frequency and complexity]
- Sample size
- Matrix requirements
- Signal Management
- Orientation Effect
- Device to device Repeatability
- Warm Up Time
- Alarm Set Points

### GAPS & BARRIERS

- Experience
- Field History
- Development Timeline
- Consumer Issues
- Commercialization
- Codes and Standards

### R&D NEEDS

- Analysis
- Testing
- Verification
- Certification
- Collaborations
- Resources
- Priorities

ACTION ITEMS FOR THIS SESSION