Improving FF Health and Safety – Real-Time Personal IDLH Sensor

David Cyganski, Jim Duckworth
Electrical and Computer Engineering Department

Kathy Notarianni
Fire Protection Engineering Department
Worcester Polytechnic Institute
Worcester, Massachusetts

Primary Project Challenge

- Develop toxic gas sensors that:
  - Can be worn by any firefighter on the fire ground
    - From supervisors to fire attack team
  - Reports correct toxic gas concentrations
    - Not overwhelmed by cross-sensitivity to other gases
    - Does not separate toxin from gas flow
  - Does not fail due to sensor or filter saturation, heat or humidity

Additional Contributions

- Continuously collect real-time information
  - about toxic gas levels and
  - SCBA mask status
  - from arrival to departure
- Enable immediate review
  - Immediate medical diagnostic information
- Enable later data mining
  - Role related exposure profiles
  - N-gas modeling
  - Mapping toxic gas distributions

Demonstration and Precursor

- Demonstration that
  - fundamental problems that plague current toxic gas sensors can be overcome
- Precursor to
  - Continuously functioning, personal, situational awareness for a suite of toxic hazards
  - Real time mapping of combustion products
    - For potential exploitation in resource allocation
    - Structure, region and role specific longitudinal studies of combustion product exposures

Available Portable Sensor Problems

- Sensor limitations:
  - False alarms and failures due to high temperature, humidity, cross contamination, or oversaturation
    - Cannot follow the FF into fire attack
    - Can only spot check (time and area)
    - False readings and even depressed readings
    - Sensor damaged at 120 F (high repair burden)
    - Invisible failure modes

Project Summary

- Two year project funded by FEMA AFG (R&D)
- Develop a toxic gas sensor for CO and HCN for use by <u>all</u> FFs on/near the fire ground
  - Will warn FFs of these hazardous gases during all aspects of firefighting
  - Work continuously from arrival to departure
  - No false alarms due to high temperature, humidity, saturation
- Evaluate sensor in fire operations
- Demonstrate potential for ongoing data collection to characterize CO and HCN hazards in operations

The Team (1)

- Worcester Polytechnic Institute (WPI)
  David Cyganski, ECE
  Jim Duckworth, ECE
  Kathy Notarianni, FPE
  - Ray Ranellone, Rob Capizzio, Nick Nava (research assistants).
- Fire Protection Research Foundation
  - Casey Grant (Director)
  - Provide guidance and organize and administer Technical Advisory Panel

The Team (2)

- MFA – Ed Walker
  - Evaluate and provide feedback on prototype sensor during regular training exercises conducted in year one
- WFD – John Sullivan
  - Provide guidance during prototype development
  - Use sensor during year two activities to evaluate operation and effect on FF behavior during operations
- Globe Manufacturing – Mark Mordecai
  - Provide VOC and help with dissemination

Project Technical Panel

- Bob Athanas, Chair NFPA TC on Electronic Safety Equip & FDNY (NY)
- Christina Baxter, DOD / TSWG (VA)
- Dawn Bolstad-Johnson, City of Phoenix (AZ)
- Kevin Courtney, NVFC Rep & Star FD (ID)
- Sean DeCrane, Cleveland FD & IAFF Local 93 (OH)
- Kenney Fent, CDC/NIOSH (OH)
- Michael Grant, Metro Chiefs Rep & New Haven FD (CT)
- John Sullivan, IAFC SHS Section Rep, & Worcester FD (MA)
- Dave Trebisacci, Staff Liaison NFPA TC on Elect Safety Equip (MA)
- Ed Walker, MA Fire Academy (MA)
- Doug Wolfe, IAB Rep & Sarasota County Fire Rescue (FL)

Alternates

- Bill Haskell, NIOSH NPPTL (Alt to Kenney Fent)
- Nancy Pearce, NFPA (MA) (alt to D. Trebisacci)
- Bruce Varner, PastChair NFPA TC on ESE (Alt to Bob Athanas) (AZ)

Project Timeline

- Sep 2012 – Feb 2013
  - Form technical advisory panel
  - Construct Alpha prototypes for lab testing
  - Gather opinions about alarm and readout technology for Beta sensors
- Mar – July 2013
  - Design and construct 4 Beta device prototypes
- August 2013
  - Evaluation by MFA during regular training exercises
- Sep 2013 – Mar 2014
  - Design and construct 10 improved ruggedized devices
- Apr – June 2014
  - Evaluation by WFD during actual incident responses
- July – August 2014
  - Analysis of data, final report, dissemination

Why a new sensor?

- Commercial, portable, real-time monitors–
  - Subject to prolonged sensor incapacitation after high toxin levels or levels, high temperatures and/or excessive humidity
  - Scrubber filters can deplete rapidly leading to false readings and need for rapid replacement
  - These failures were easily replicated in our lab
    - Even when not permanently incapacitated, recovery time was on the order of tens of minutes
  - Only appropriate for spot checks outside of a building fire, or during overhaul,
    - not for continuous monitoring even outdoors and post fire

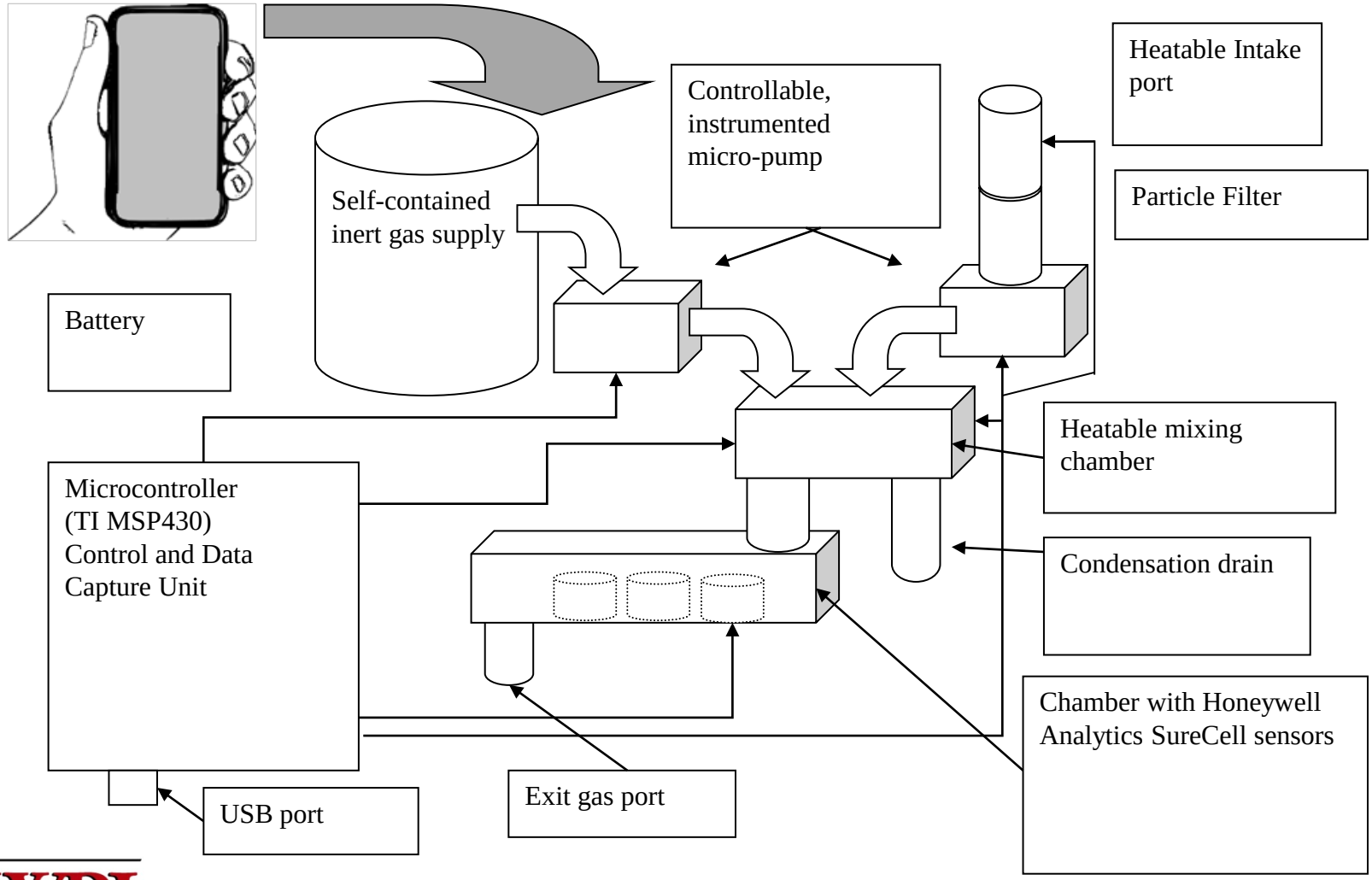
Sensor review

- We have conducted a review of sensor technologies seeking best basis for real time, portable, multi-gas capable measurement
  - Electrochemical
  - Chemo-FET
  - Optical (IR) absorption
  - FTIR
  - NMR
  - Fiber optic (surface effect)
  - Photo-acoustical (broad band and laser)
  - Etc.

The sensor selection problem

- Portable multi-gas sensors are based on electrochemical cells
  - The root of temperature, saturation, contamination and humidity issues
- No other current technology offers:
  - Small size, low cost
  - Rapid response
  - Multi-gas and open cell operation
  - Freedom from H_20 sensitivity
  - Low/no cross-sensitivity

Sensor concept diagram

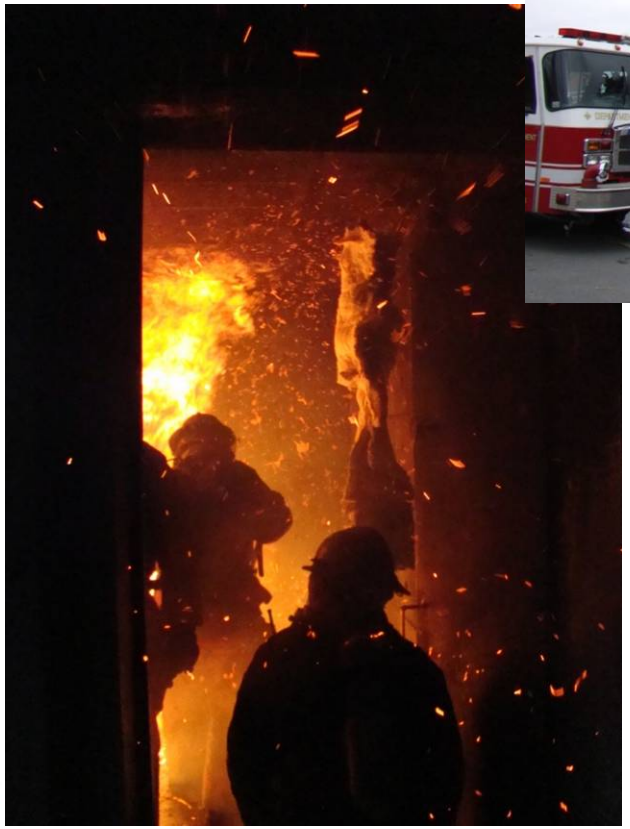


Initial tests: New WPI FPE Fire Lab

- State of the art large oxygen depletion system, and additional state-of-the-art measurement devices
- Allows for large-scale (5 MW) fire experiments on a <u>real-life scale</u>, up to two residential stories in height
- Fundamentals lab for controlled bench scale experiments

Evaluation with/by firefighters

- Phase 2: MFA
- Phase 3: WFD



Firefighter evaluation

- Evaluation by the MFA during training exercises, followed by questionnaire based data collection from the trainees and the instructors, focus groups and discussion with the Project Technical Panel.
- Evaluation by WFD during actual incident responses, followed by questionnaire based data collection from the firefighters and the incident commanders, and focus group discussion.

Thank you

Thank you for requesting our presence at this meeting and allowing us to tell you about our project

David Cyganski,
Jim Duckworth,
Kathy Notarianni

Worcester Polytechnic Institute
Worcester, Massachusetts