Wide Area Sensor Needs

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Identifying the Need


Hydrogen Research Advisory Council

Research Needs in Support of Hydrogen Safety Standards

2009 Activities of the Hydrogen Research Advisory Council

THE FIRE PROTECTION RESEARCH FOUNDATION

Research in support of the NFPA mission

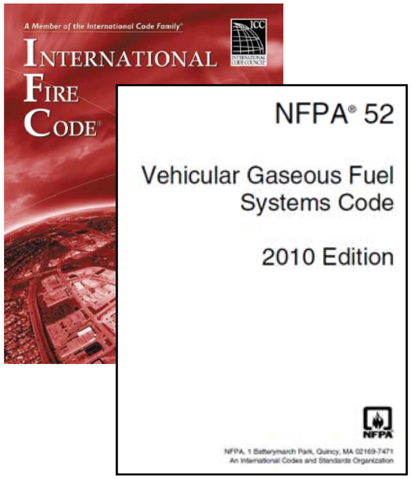
FIRE RESEARCH

In 2007, the National Renewable Energy Laboratory of the Department of Energy contracted with the National Fire Protection Association to establish a Hydrogen Research Advisory Council (HRAC) under the umbrella of the Fire Protection Research Foundation to assist NFPA technical committees in establishing research needs to inform the technical bases for the safety requirements in NFPA 2, *Hydrogen Technologies Code*, NFPA 52, *Vehicular Gaseous Fuel Systems Code*, NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, and other relevant standards. The purpose of the group was to: (i) identify and evaluate research needed to support the development of hydrogen safety requirements in the NFPA codes; and (ii) make recommendations on research projects that need to be completed to support these code changes. A report presenting the results of the Council's work was published in 2009.[1]

Current Requirements/HRAC Conclusions

Requirements

NFPA 52 requires hydrogen detectors to be installed at refueling stations and be capable of detecting hydrogen “at any point on the equipment” (other codes and standards have similar requirements). The installation of spot sensors in outdoor or partially enclosed facilities becomes problematic at best, such that many facilities cannot comply with the codes and standards requirements for hydrogen detection using conventional spot sensors. There is a need for detectors that do not need to be physically distributed throughout the equipment.



HRAC Conclusions

Considering the above, the HRAC identified the development of wide area and distributed detection methods for outdoor compression, storage, and refueling facilities, and large indoor facilities as a **priority research need**. While workshops and industry focus on spot detectors in support of fuel cell applications continues to be important, **wide area detector development is receiving little attention**.

Paper Outlines Need

A great variety of hydrogen sensors using metal semiconductor, catalytic combustion temperature rise, gas sensitive field effect transistor, thermoelectric device, optical method, etc. have been proposed and practically applied. Many exhibited excellent sensitivity and are widely used. Most of them, however, can only sense the leakage at a particular spatial point.

Some indoor facilities with dedicated high point air exhausts are well suited for conventional spot type hydrogen detectors since there are well defined locations to place the sensors. However, many other hydrogen facilities are either outdoors or are only partially enclosed without any clear location for hydrogen accumulation or exhaust. The installation of spot sensors in these outdoor or partially enclosed facilities becomes problematic at best, such that they are often not used. Other indoor facilities may either be so large or have complex partitioned ceilings so as to require an excessive and unachievable number of spot detectors.[2]

Hydrogen Detection Methods
Advantages/Disadvantages

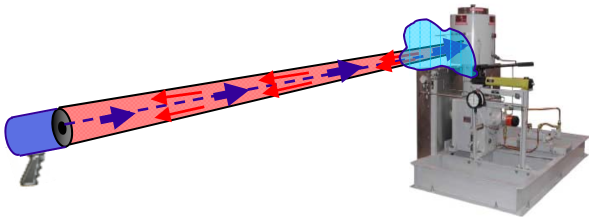
- Point Sensors
  - Detect and measure gas at a single location
    - Advantages:
      - Currently available
    - Disadvantages:
      - Requires precise positioning or a collection system (roof, canopy, etc.)
      - Must deploy a large number of devices or be confident of where the leak will occur
      - Expensive for large area deployment
- Wide Area Sensors
  - Detect and measure gas throughout an area
    - Advantages
      - Wide areas can be covered by minimal number of devices
      - Need not know where the leak will occur
    - Disadvantages
      - Additional research is needed for development and production of reliable systems

Wide Area Detector Approaches

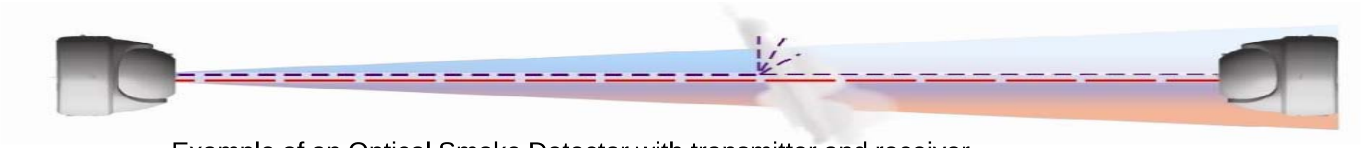
- Standoff Detectors
- Fiber/Cable Detectors
- Aspirating Detectors

Standoff Detectors

Standoff detectors could include those optical technologies which utilize a single device to scan an entire area. The concept has been incorporated into devices used for large area smoke detection and by natural gas industry for hand held devices. **These detectors offer great promise as they could provide detection over a large open or enclosed area.** Additionally, the detectors would not need to be mounted under covers or on equipment.



Example of Natural Gas Handheld Standoff Detector

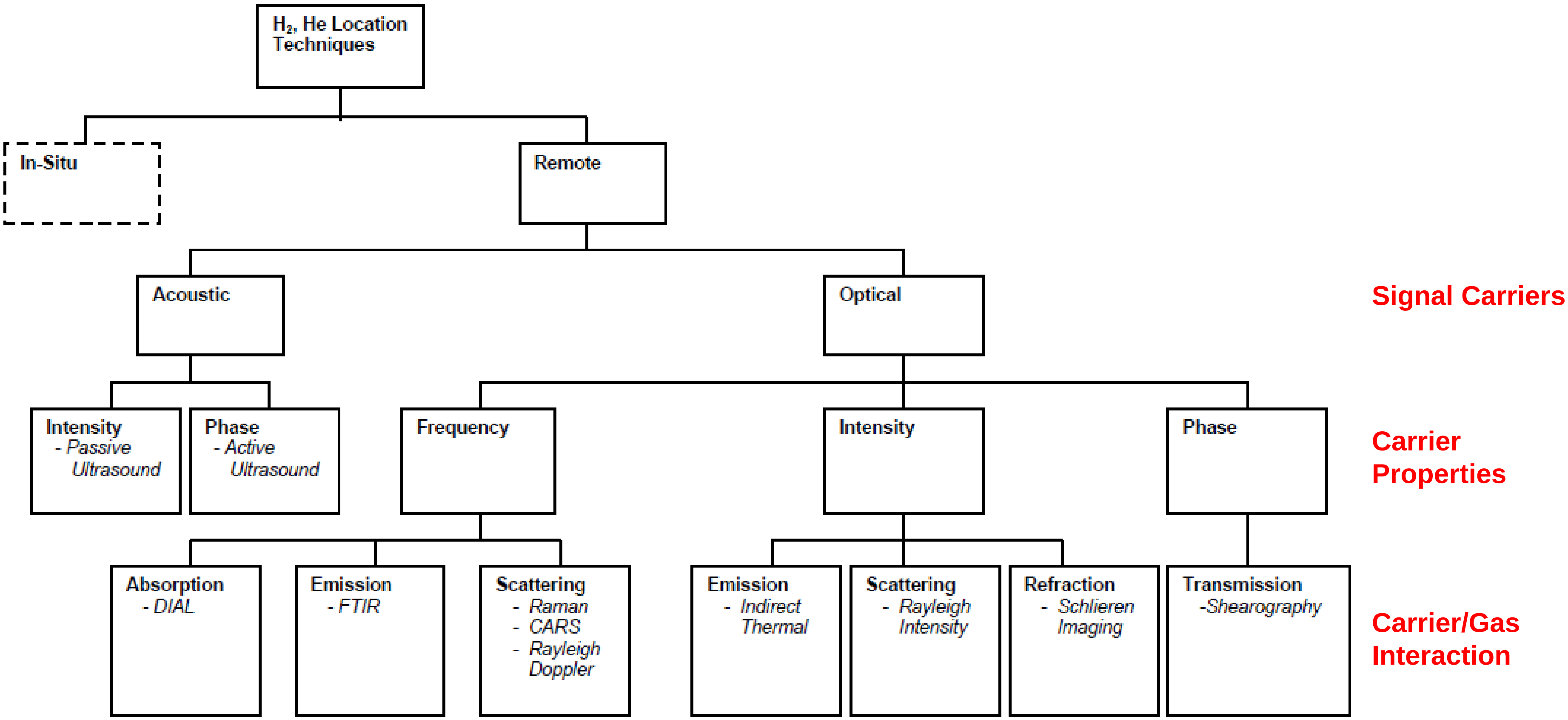


Example of an Optical Smoke Detector with transmitter and receiver

DEVELOPMENT OBSTACLE

"Optical detection of H_2 gas is difficult because H_2 has no absorption bands from the near ultraviolet to the near infrared. The principal electronic transitions of H_2 originating from the ground state ($X^1\Sigma_g^+$-$B^1\Sigma_u^+$ Lyman bands, $X^1\Sigma_g^+$- C $^2\Pi_u$ Werner bands) lie in the vacuum ultraviolet[3] and cannot be used for remote detection because light of such wavelengths does not transmit through air. The absence of accessible absorption bands makes conventional optical detection methods that rely on absorption (laser induced fluorescence, differential absorption lidar, absorption spectroscopy, Fourier transform infrared spectroscopy) inapplicable." [4]

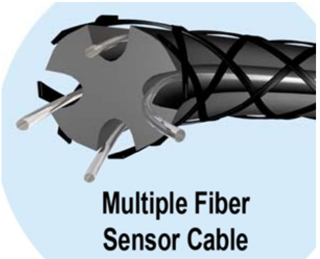
Standoff Detectors – H_2 Detection Techniques[5]



Standoff Detectors – Potential Technologies[5]

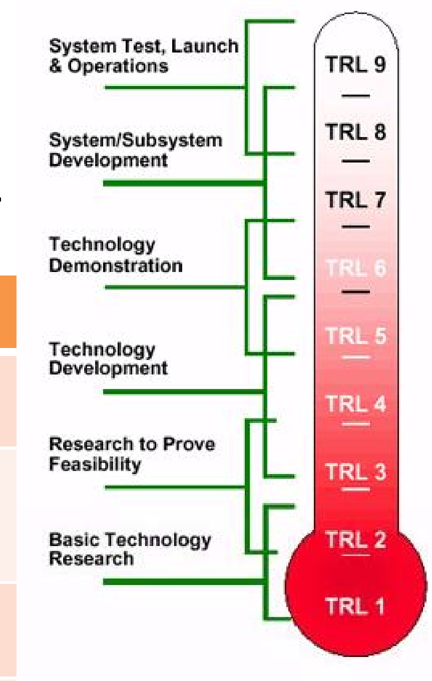
Technique	Distinguishing Characteristic	Measurement	Applicability	TRL
Passive Sonar	Turbulent airflow (ultrasound)	Acoustic intensity (passive)	Demonstrated Low spatial resolution Sensitivity depends on pressure and aperture	4
Active Sonar	Speed of sound	Phase of acoustic waves (active)	Low spatial resolution Sensitivity limited by clutter	3
Differential Absorption Lidar (DIAL)	Allowable energy levels	Absorption of radiation at characteristic wavelengths (active)	None – absorption lines only in vacuum UV	-
Fourier Transform Infrared (FTIR)	Allowable energy levels	Emission of radiation at characteristic wavelength (passive)	None – absorption lines only in vacuum UV	-
Raman-spontaneous	Allowable energy levels	Shift in wavelength of inelastically scattered radiation (active)	H_2: Sensitivity of 2% demonstrated *He*: None – monatomic therefore no vibration	5
Raman – CARS (Coherent Anti-Stokes Raman Scattering)	Allowable energy levels	Shift in wavelength of inelastically scattered radiation (active)	H_2: Sensitivity of 10 ppm demonstrated *He*: None – monatomic therefore no vibration	3
Rayleigh Doppler	Molecular/atomic velocities	Shift in wavelength of elastically scattered radiation (active)	Theoretically applicable for both H_2 and He	1
Indirect Thermal	Temperature	Variation in temperature of solids caused by nearby cryogenic gas or expanding gas (passive)	Clutter limited?	3
Rayleigh Intensity	Molecular/atomic cross-section	Intensity of elastically scattered radiation (active)	Limited by Mie scattering (particles) Clutter limited?	3
Shlieren	Index of refraction	Refraction of radiation caused by spatial variations in index of refraction (active)	Sensitivity limited by clutter: 1^{o} ~ 346 ppm H_2 1^{o} ~ 461 ppm He	4
Shearography	Index of refraction	Phase (path length) of transmitted radiation (active)	Sensitivity limited by clutter: 1^{o} ~ 346 ppm H_2 1^{o} ~ 461 ppm He	5

Fiber/Cable Detectors
Description & Potential Technologies



Detectors in this category utilize either a chemically treated solid polymer matrix optical fiber sensor cladding such that the presence of hydrogen can be detected anywhere along the length of the optical fiber, or is a fiber optic network with double fibers that can transmit a laser optical signal and a return signal such that only a single light source and single detector can provide detection over a large obstructed area.

Technique	Research Area	Current Status
Fiber Optic Sensor	DICAST® proprietary fiber design with Palladium Catalyst paired with Tungsten Oxide	TRL5
Fiber Optic Sensor	Optical time domain reflectometry (OTDR) using a silica core fiber coated with platinum-supported tungsten trioxide	TRL5
Fiber Optic Sensor	Magnesium based fiber optic detector using a $Mg_{70}Ti_{30}$ film capped with Pd catalytic layer	TRL5
Fiber Optic Sensor	Raman	TRL2



Aspirating Gas Detection

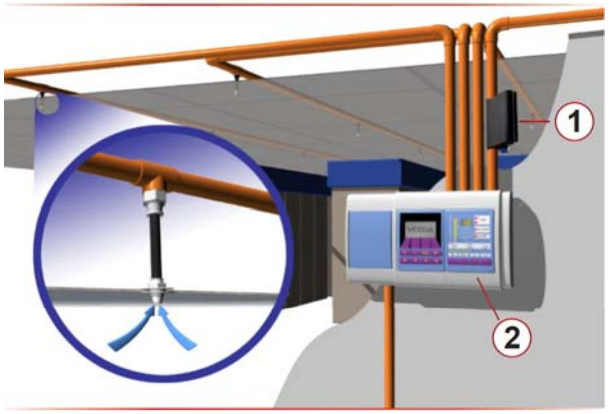
VESDA ECO uses an air sampling pipe network to actively monitor for gas leaks and continuously ensure air quality in occupied areas. The system draws the air through the piping by a remotely located pump.

BENEFITS

- Is available now
- Improved area coverage compared to conventional fixed point gas detectors
- More effective detection in variable air flow conditions than point detectors

DRAWBACKS

- System has not been rigorously tested
- Sampling holes are similar to point detectors and have the same limitations (influenced by ventilation, needs to be be located in close proximity to potential gas release/ingress locations, etc.)
- Response time is greatly dependent on the length of the pipe network and number of holes
- System is best suited to applications where the area to be protected is small and pipe runs have a limited number of sample holes – or additional detectors may be needed for larger areas
- May not be effective in outdoor locations



Air is actively drawn through a series of pipes through multiple sampling holes to the VESDA ECO gas detector (1) in route to the VESDA smoke detection unit (2).

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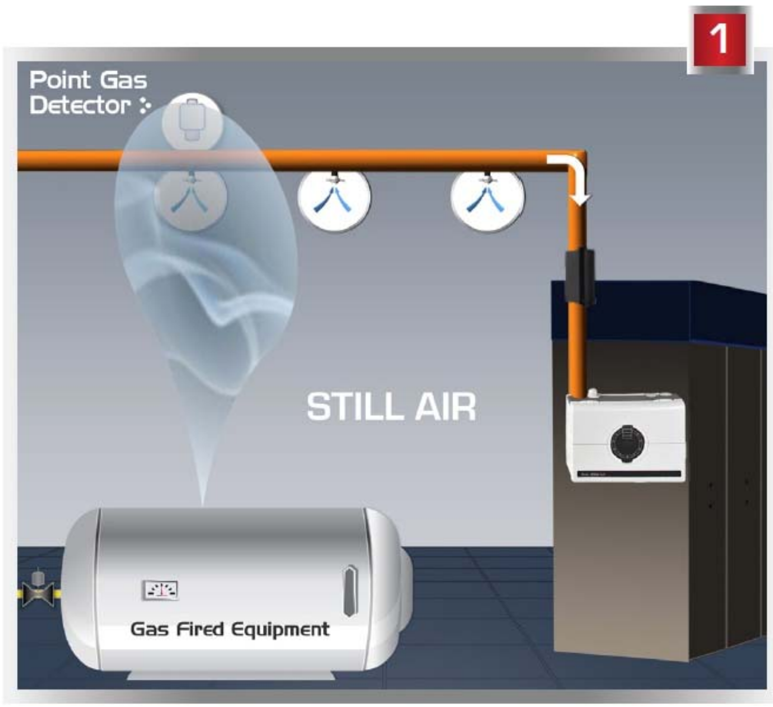
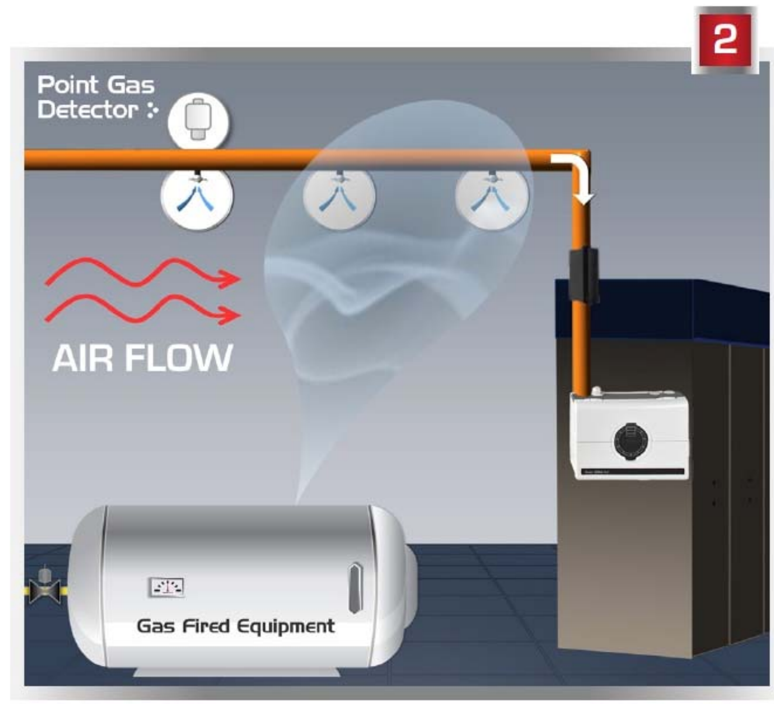
Aspirating Gas Detection





- Increased sampling points provide better area coverage
- Better detection in variable air flow environments

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Comparing the Technologies

Technology	Demonstrated Sensing Length (m)	Lowest H2 Concentration Detected (v%)	Best Response Time (s)	Development Status
Open Path Raman Scattering	50 [4]	0.8 [6]	< 1	Outdoor Demonstration [4]
Distributed Optical Fiber	Sensor: 1 [7] Fiber Length: 880 [8]	0.5 [7]	2 – 5 [7]	Laboratory System
Ultrasonic	8 [9]	NA	< 1	Commercially Available
Imaging	~ 4 [10]	1 [11]	< 1	Components Only
Aspirating	Varies, based on transport times	>0 (can be LFL or PPM measurements)	1-120s (varies with configuration)	Commercially Available

Final Thought

The wide area hydrogen sensor technologies described in this presentation offer the potential to provide detection for facilities where spot detectors are not feasible (there is often difficulty in providing complete coverage and appropriate spot sensor locations). Pursuing the development of these detectors could ultimately help hydrogen facilities better satisfy or exceed the detection requirements of consensus safety codes and government regulations and ensure a safe transition to the widespread use of hydrogen.

Where Do We Need To Go From Here?

- Apply resources to identify and develop technologies for standoff hydrogen detection
- Expand current research on fiber/cable detector research activities
- Perform additional testing of aspirating gas detectors for a variety of leaks and room configurations
- Develop performance criteria for evaluating and installing wide area detectors

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