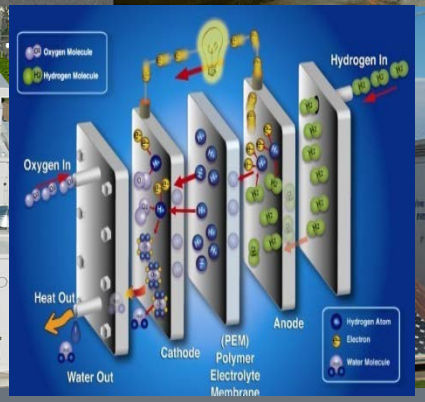
DETECTAPE - Visual Leak Detectors for Hydrogen Equipment

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



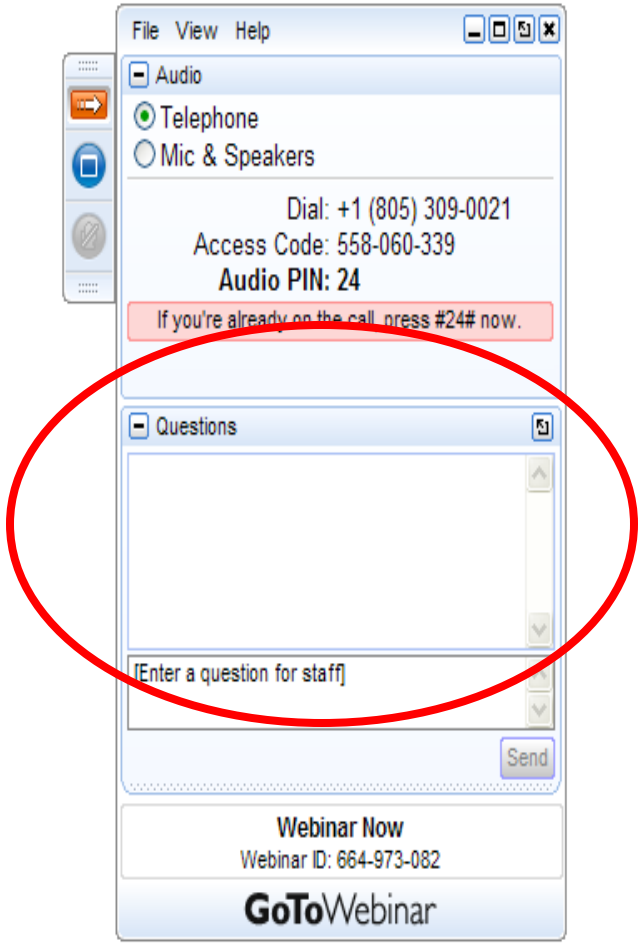
Presenter:
Bill Hoagland – Element One
John Poplawski – Midsun Specialty Products

DOE Host:
Will James – Safety, Codes , and Standards Program Manager

U.S. Department of Energy
Fuel Cell Technologies Office
March 14th, 2016

Question and Answer

- Please type your questions into the question box



Safety, Codes and Standards Overview

Emphasis

- **R&D Activities:** H_2 Behavior, Risk Assessment/Mitigation, Materials Compatibility, H_2 Fuel Quality, Metering, Sensors, Component Testing
- **Safety Management & Resources:** Hydrogen Safety Panel, Databases, and Training Props
- **Outreach:** Codes & Standards and Permitting, Continuous Codes and Standards Improvement, Resource Dissemination

Enable the widespread commercialization of hydrogen and fuel cell technologies through the timely development of codes and standards and dissemination of safety information

NREL Sensor Testing Laboratory

- Provide independent assessment of hydrogen sensor performance
- Interact with manufacturers to improve sensor performance to meet DOE 2012 targets
- Support deployment with information and expertise on sensor use and performance
- Test/validate new sensor R&D
- Support hydrogen sensor codes and standards development (national and international)
- Outreach and Education
  - Publications, presentations, consultations
  - Student Internships
- Client confidentiality

The ultimate goal of the Hydrogen Sensor Testing Laboratory is to ensure that end-users get the sensing technology they need

DETECTAPE™ H_2

Hydrogen Leak Detection

Visual Leak Detectors for Hydrogen Equipment

Presented by

ELEMENT ONE

MSP

MIDSUN SPECIALTY PRODUCTS

DETECTAPE
Hydrogen Leak Detection

PRESENTERS

Bill Hoagland | *Element One*

20+ Years in Hydrogen Research

John Poplawski | *MSP*

12+ Years in Silicone Manufacturing

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DETECTAPE H_2
Hydrogen Leak Detection

WEBINAR SUMMARY

- Company Backgrounds
- Leak Detection Summary
- Benefits of Low-Cost Visual Leak Detectors
- DetecTape™ H_2 Technology and Performance
- Applications and Markets
- Availability and Upcoming Developments

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Hydrogen Leak Detection

ELEMENT ONE BACKGROUND

- Incorporated in 2005 and began R&D of products based on core patent (U.S. Patent #6,895,805).
- Key members are veterans of NREL. Collaboration with NREL 2005 - present.
- Conduct thin film research in NREL's Hydrogen Sensor Laboratory.
- Funded contracts with DOE/NREL, NASA, Industry. Licensing agreements with industry. One technology license with NREL.
- Four patents, three pending.
- In 2015, partnered with MSP to create and market DetecTape™.

www.elem1.com

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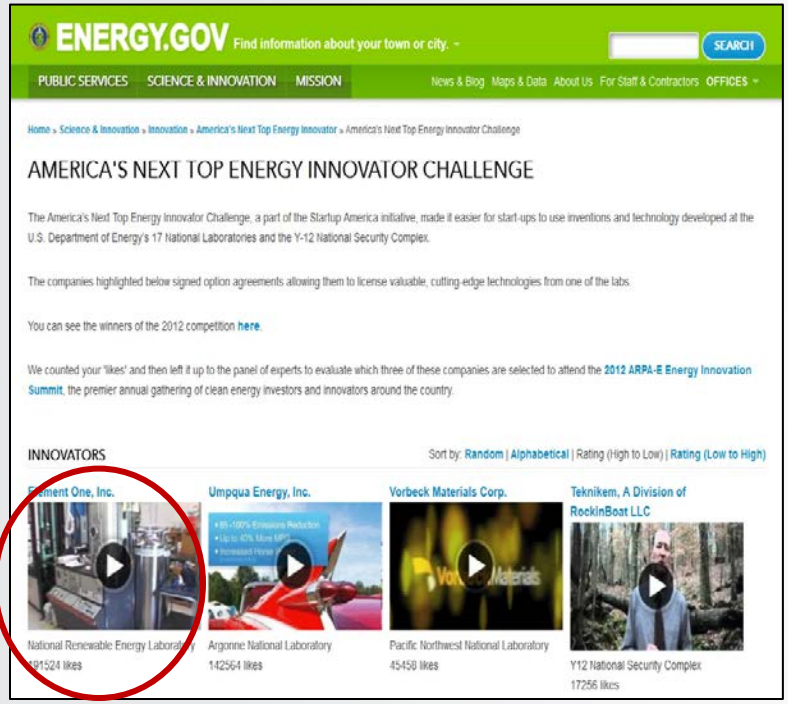
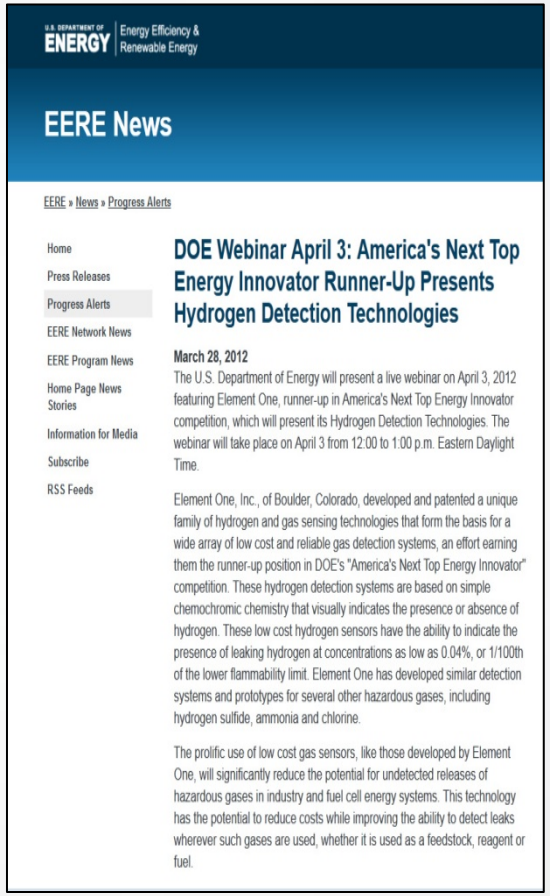
DOE Recognition

March 2013



March 2012



August 2014

NREL: 2012 Industrial Growth Forum Presenting Company
2014 NREL Commercialization Assistance Program
2016 Small Business Voucher Award

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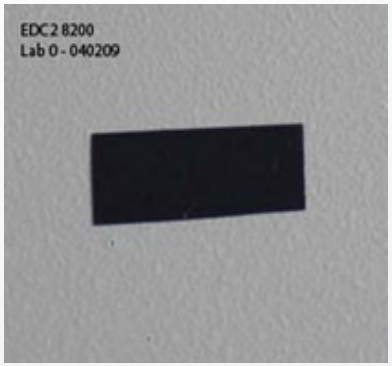
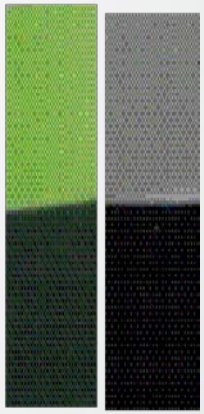
DETECTAPE
Hydrogen Leak Detection

DETECOAT® AND DETECTAPE™

Thin films and "Smart" coatings for the detection of leaked or leaking hydrogen to achieve a **new level of reliability** and make possible a wide array of **very low cost** gas detection products.





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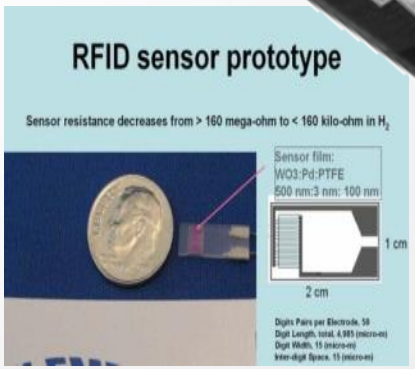
Hydrogen Leak Detection

APPLICATIONS

- ✓ *Tapes and wraps*
- ✓ *Leak detecting pipe covers*
- ✓ *Safety badges and warning s*
- ✓ *Leak detection coatings*
- ✓ *Pressure/reaction vessels and storage containers*
- ✓ *Sensors*



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Hydrogen Leak Detection

HYDROGEN CHARACTERISTICS

- Odorless and colorless
- High propensity to leak
- Low ignition energy
- Invisible flame
- High energy content
- Lighter than air - diffuses rapidly

Difficult to Detect Leaks

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DETECTAPE Hydrogen Leak Detection H_2

IMPORTANCE OF GAS LEAK DETECTION

- Gas detection is a **critical element** of the safe manufacture, handling and use of many industrial gases.
- The **$700+ million gas detection market**, served by more than twenty-five OEMs and hundreds of maintenance contractors, is mature and stable with a projected annual **growth in the 3 to 6% range**.
- The **global hydrogen market** in 2015 was estimated at **53 million metric tons** with 12% in the merchant hydrogen market with a **growth rate of 5-6% per year**.

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DETECTAPE Hydrogen Leak Detection

CURRENT LEAK DETECTION METHODS

- **Bubble Testing** – Simple spot test method with no continuous monitoring at low pressures.
- **Thermal Conductivity** – Works well in stable environments with minimal temperature change, background gas must have conductivity very different from hydrogen.
- **Catalytic Combustion** – Detects heat of combustion, works well for low concentrations. Not for pure hydrogen.
- **Electrochemical** – Sensors use a liquid electrolyte, but varying temperature affects gas diffusion making the sensor unreliable.
- **Mass Spectrometers** – Extremely sensitive, expensive, require skilled operators and may have long response times.
- **Gas Chromatographs** – Similar to mass spectrometers and have the same disadvantages.
- **Ultrasonic** – Technology improving, but cannot determine exact location or whether combustible mixture is present.
- **Semi-Conducting Oxide** – Sensor relies on surface effects with a minimum oxygen concentration. Performance degrades at lower temperatures.

DETECTAPE
Hydrogen Leak Detection

THE IDEAL LEAK DETECTOR

- ✓ **Very Low-cost** – affordably used prolifically at potential leak sites;
- ✓ **Positive Indication** of **both** the **presence** and the **absence** of hydrogen;
- ✓ **Simple, reliable, easily incorporated** into the system, no power source;
- ✓ **Hydrogen specific and sensitive**;
- ✓ **Quick response, but no false indications**;
- ✓ **Durable, long useful life requiring little or no maintenance**; and
- ✓ **Detectable by one or more of the human senses** (sight, smell, sound).

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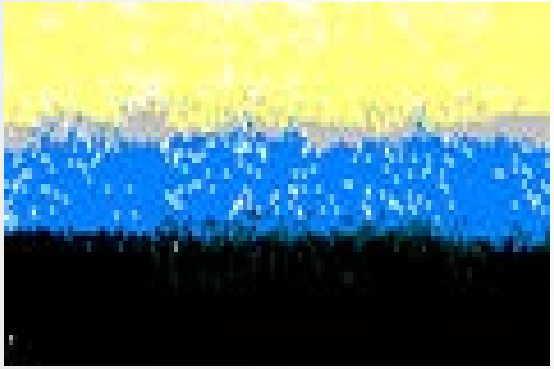
DETECTAPE Hydrogen Leak Detection H_2

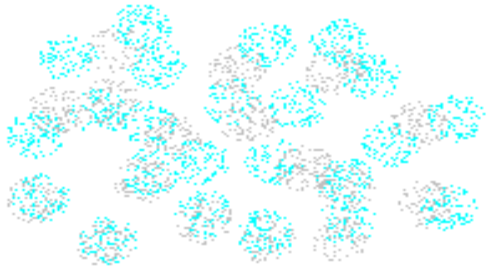
TECHNICAL APPROACHES

To meet varying requirements, Element One's research has taken two directions:

1. **Thin films** that both change color and resistance for use in low cost wireless sensors; and
2. **Color changing pigments** for coatings for visual indication.



Vacuum deposited multi-layer thin film



Synthesized nano-particles

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DETECTAPE Hydrogen Leak Detection H_2

PIGMENTS VS. THIN FILMS

	Pigments	Thin Films
Response Speed	Slower	Faster
Manufacture	Easier to produce	Vacuum deposition process
Detection method	Visual only	Both visual and resistance change
Physical Structure	Incorporated into carriers	Multi-layer thin-film devices
Material required	More pigment per unit area	Less pigment per unit area
Durability	Extremely durable, resistant to contamination, sunlight (UV), acids, bases, moisture.	Less durable, requires selectively permeable protective coating.
Applications	Thick coatings, paints, inks, wraps, molded	Resistive/wireless H2 sensors, detection of

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Chemo-chromic chemical reactions: result of a partial reduction of a transition metal oxide

a partial oxidation of a catalyzed transition metal oxide pigment of < 20% effects a readily visible color change from light gray to virtually black.

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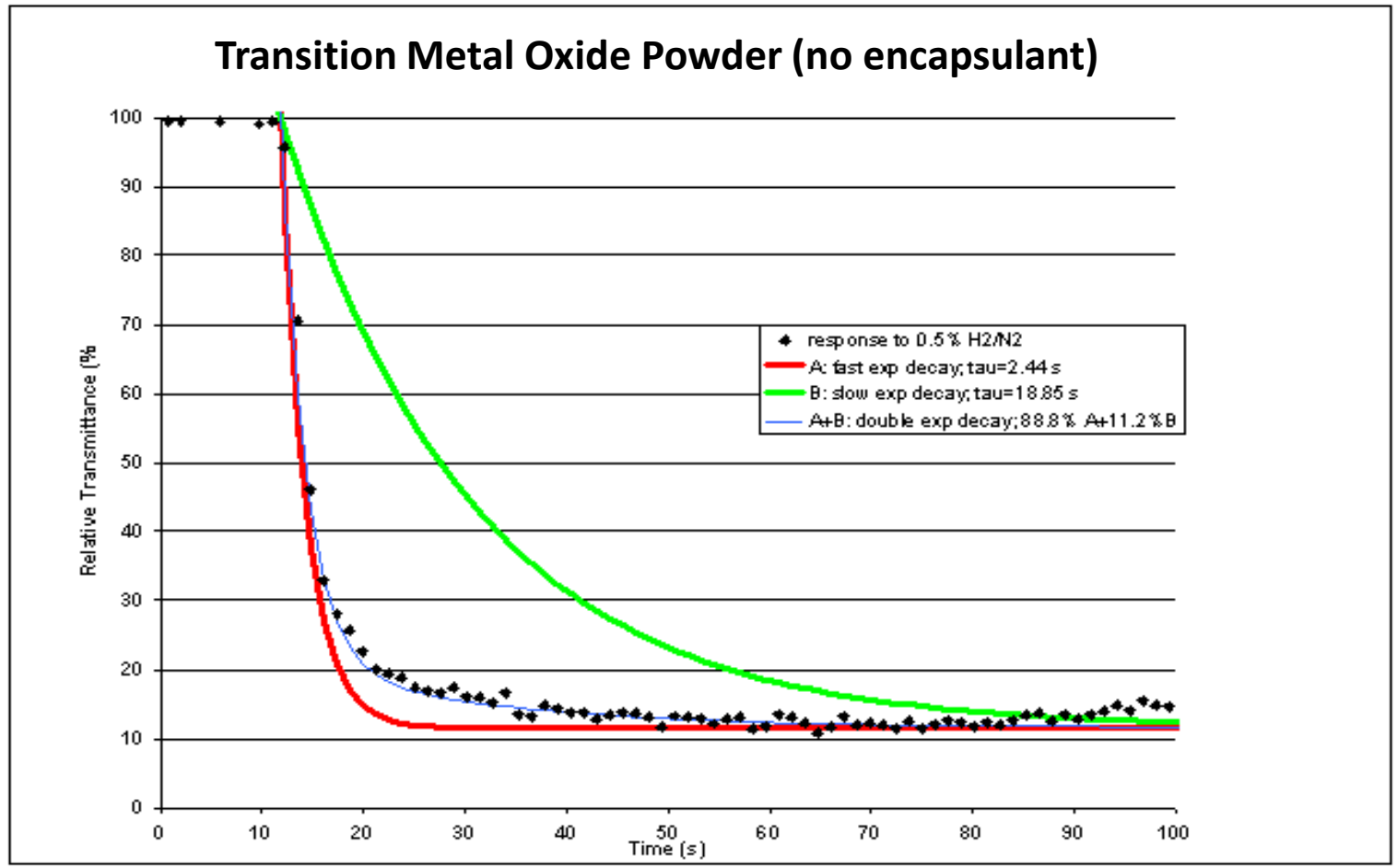
Hydrogen Leak Detection

CHEMO-CHROMIC RESPONSE



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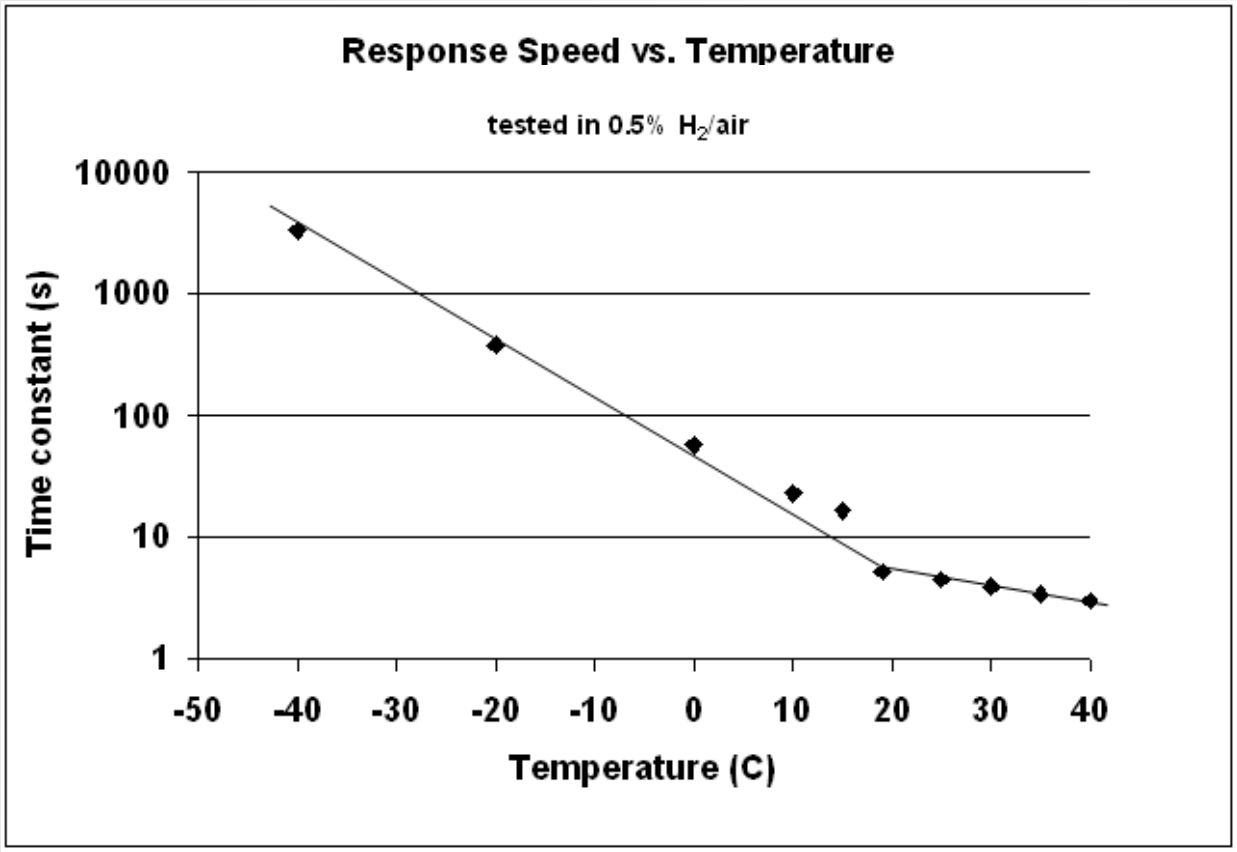
Hydrogen Leak Detection

RESPONSE VS. TEMPERATURE



- ✓ Responds more quickly at higher temperatures.

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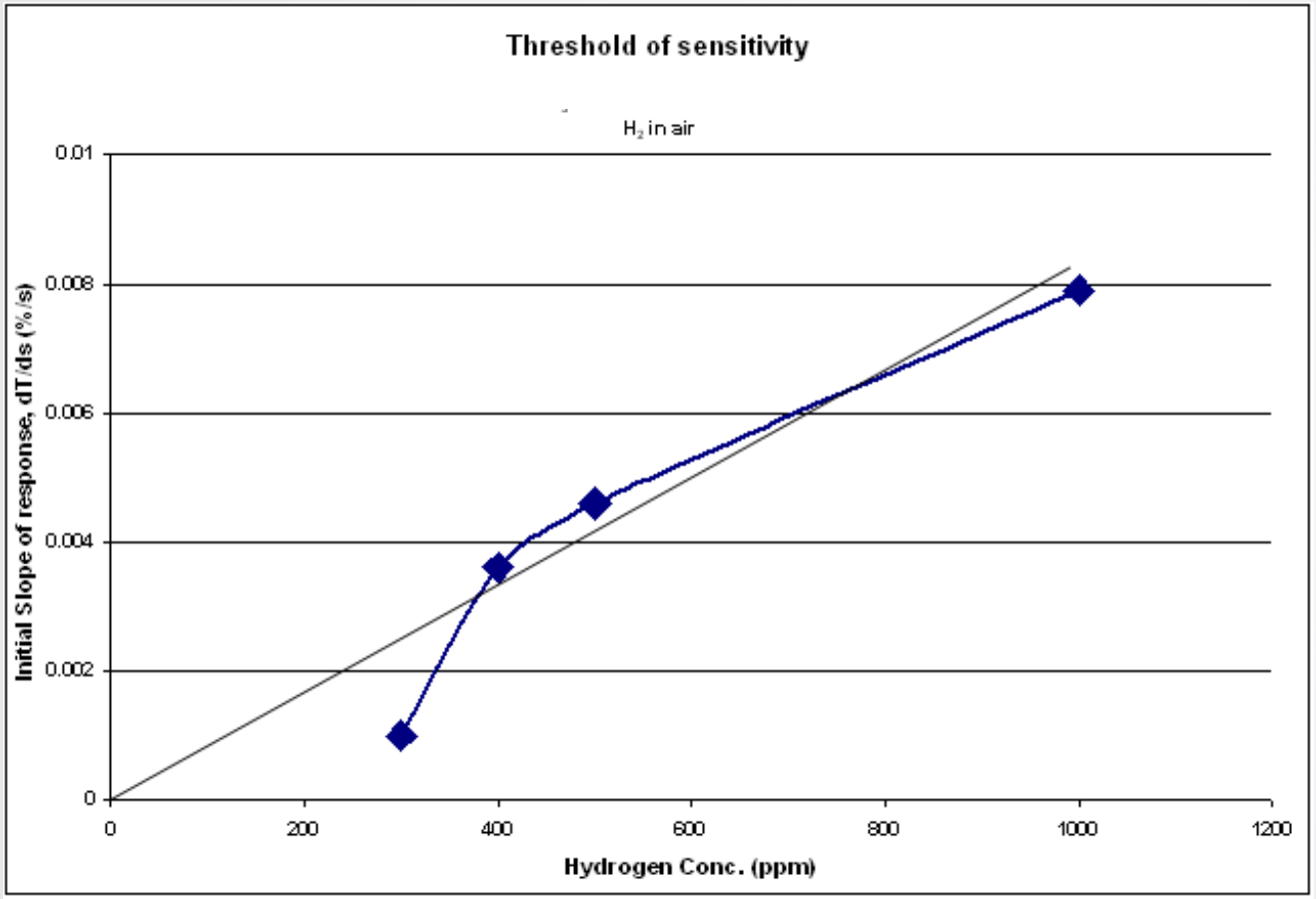
DETECTAPE H_2
Hydrogen Leak Detection

THRESHOLD of SENSITIVITY



- ✓ Thin film indication threshold in air is less than 400 ppm H_2

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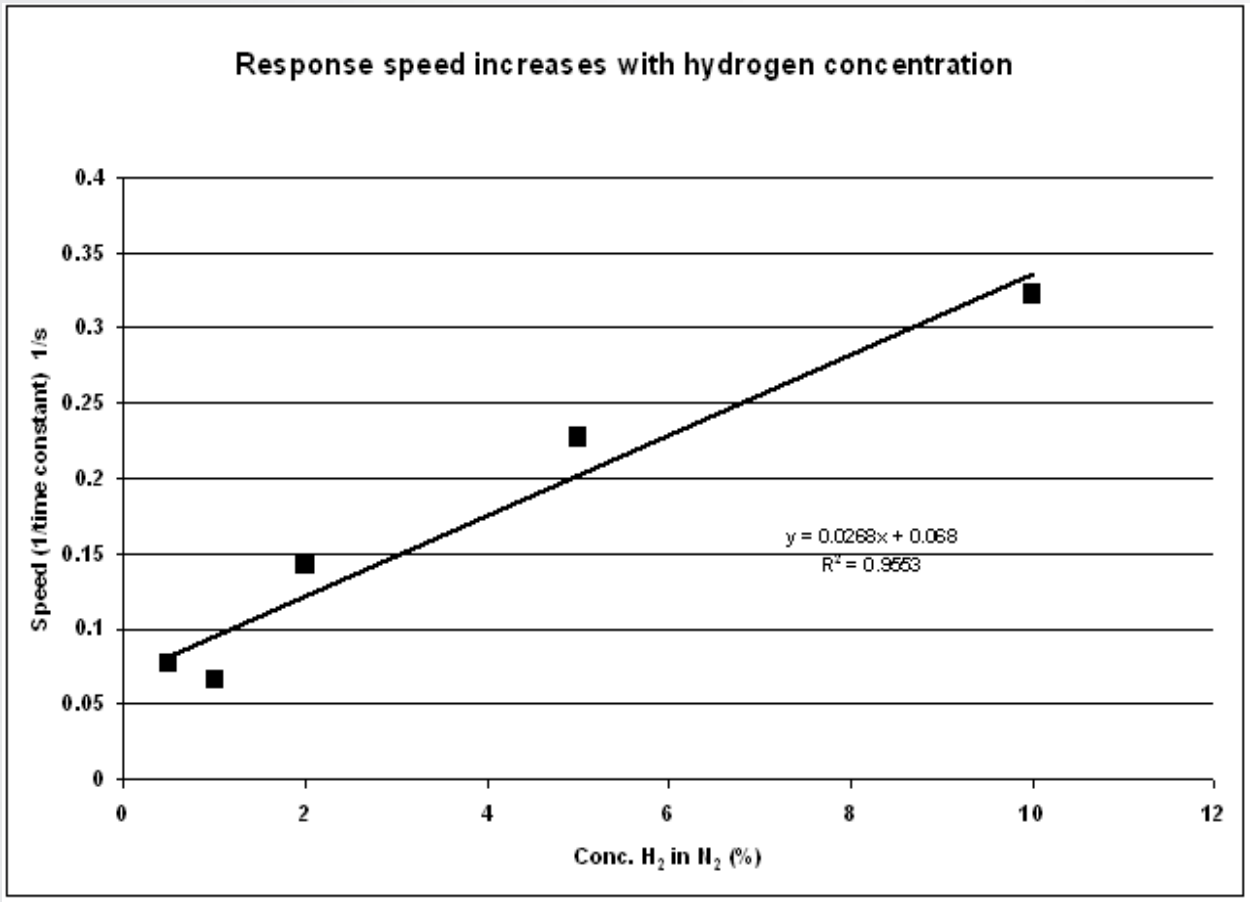
Hydrogen Leak Detection

RESPONSE VS. CONCENTRATION



- ✓ Speed of Response is proportional to Hydrogen concentration.

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DETECTAPE Hydrogen Leak Detection H_2

DETECTAPE™ H_2

(patent pending)

A chemo-chromic (color changing), self-fusing silicone tape designed to detect hydrogen gas (H_2) leaks in storage, transmission and generation facilities.

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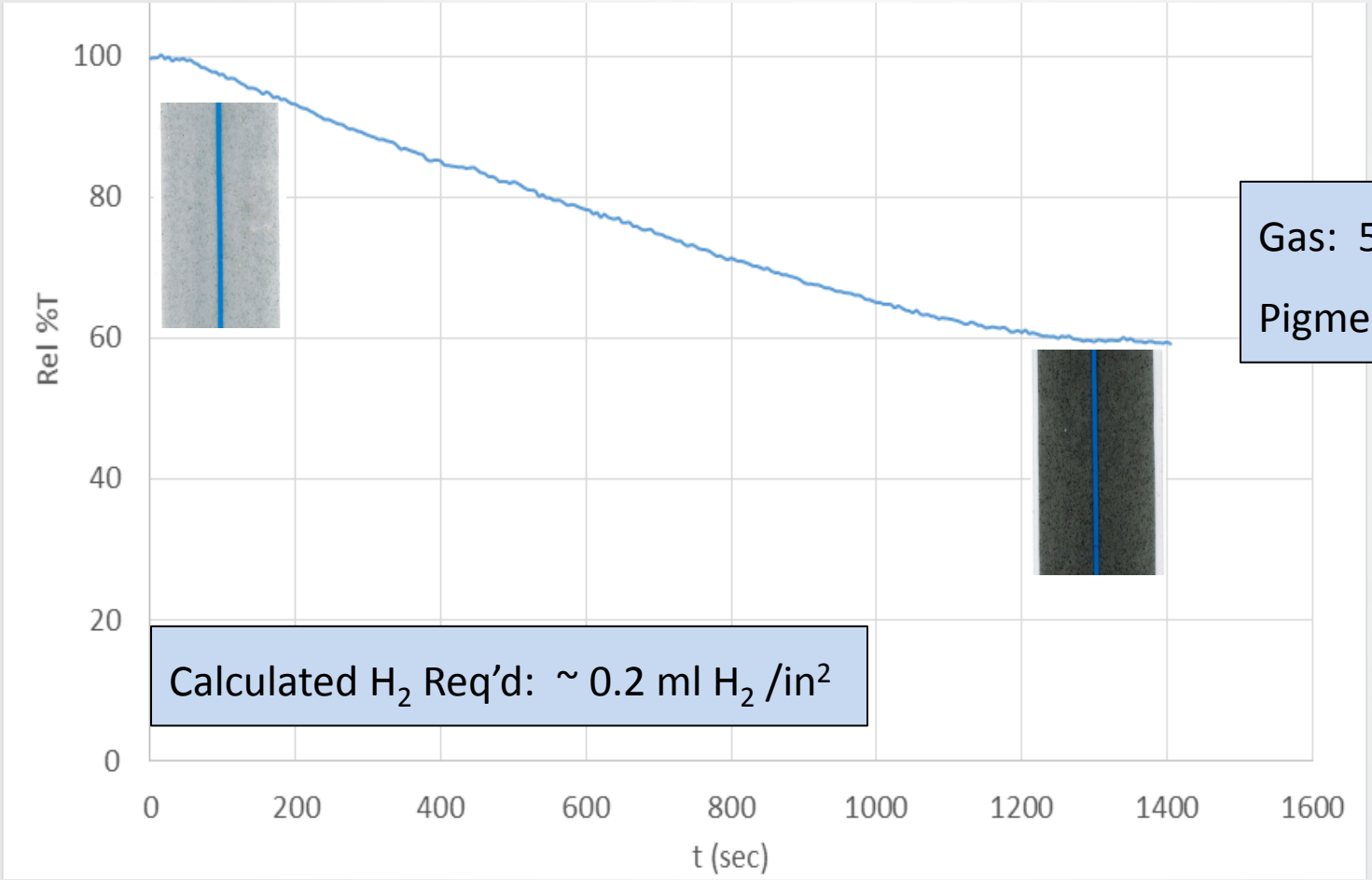
DETECTAPE Hydrogen Leak Detection H_2

DETECTAPE™ H_2 RESPONSE TEST



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DETECTAPE H_2
Hydrogen Leak Detection

E1 DETECTAPE H_2 TESTS

- Controlled leak at ~ 0.5 ml/sec, 15 psi

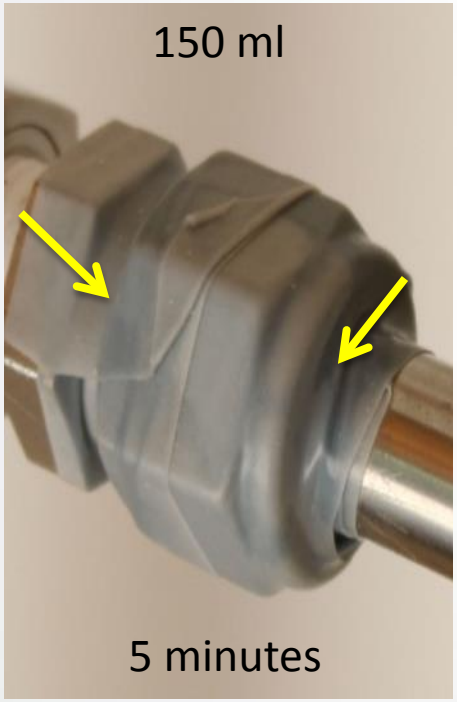

Photo credits: Element One, Inc.

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So…

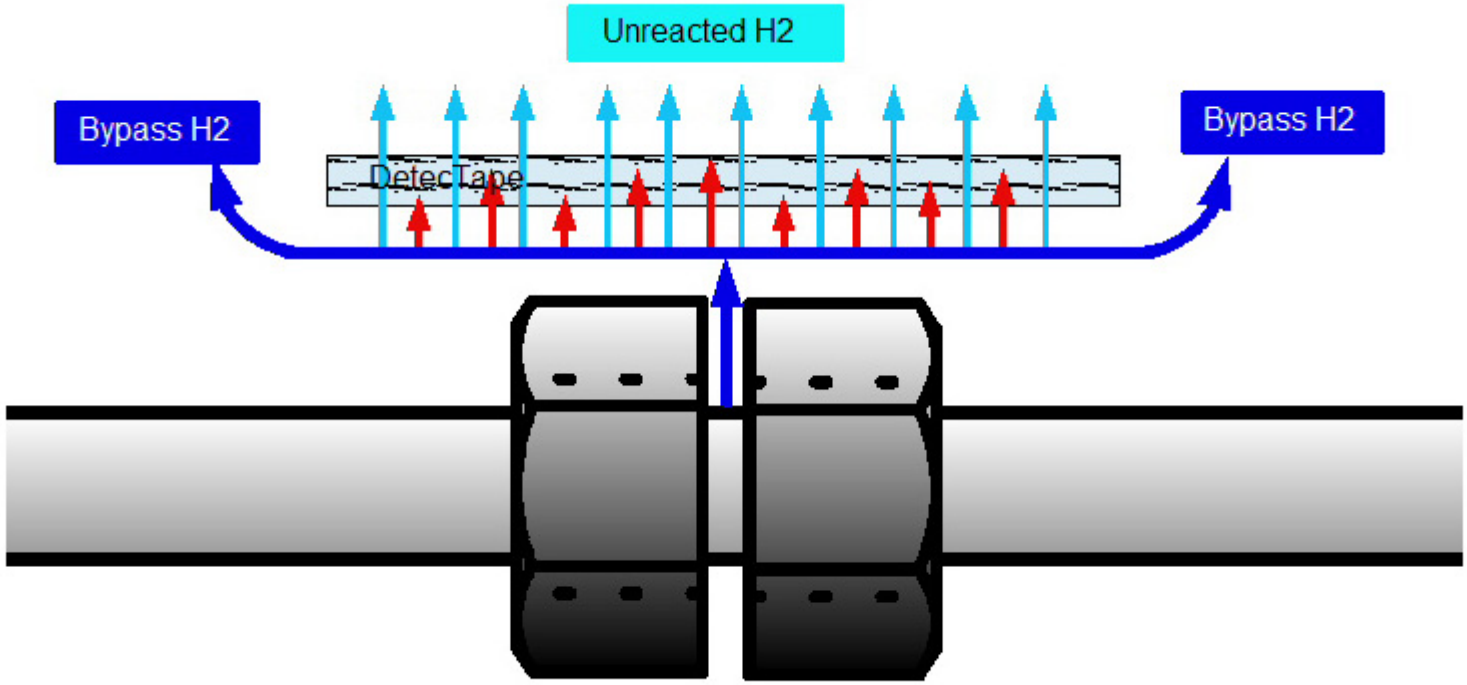
If a typical wrap of DetecTape™ H_2 is 6 in^2;

and if it takes only .2 ml to change 1-in^2….

Why does it take a leak of >300ml to completely change color?

DETECTAPE H_2
Hydrogen Leak Detection

Not all leaked gas reacts with the DetecTape™ H_2 pigment



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DETECTAPE Hydrogen Leak Detection H_2

E1 DETECTAPE EXPOSURE TESTS (60 days and counting)

- ✓ 67º C under water
- ✓ 113º C in air
- ✓ 126º C in air
- ? 195º C in air
- ✓ south-facing outdoors (sun)
- ✓ south-facing outdoors (shade)
- ✓ under NaOH solution pH 10
- ✓ under HCl solution pH 2

When exposed to hydrogen, all samples except the one exposed to 195º +/-5º C turned dark within 2 minutes. A significant darkening was apparent within 1 minute.

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NREL TESTING OF DETECTAPE™ H_2

- Test duration: 8 months (on-going)
- 55 applications of DetecTape™ H_2 at NREL H_2 compressor and dispensing station
- Nine clear and verified leaks were indicated
- Four were “out-of-normal” requiring repair; four were “normal” (e.g., valve weep holes); one was noted for further monitoring

DETECTAPE H_2 Hydrogen Leak Detection

NREL TESTING OF DETECTAPE™ H_2

The deployment study was initiated with laboratory exposure testing

- Temperature cycling (-7° C to 44° C)
- Humidity cycling at ambient temperature (dry to 94% rh)
- Humidity cycling at elevated temperatures (56% and 75% relative humidity at 43° C)
- Hydrogen exposures - after the temperature and humidity cycling, the indicator response was verified using 5.7 vol.% H_2 in N_2. ***Result: Temperature and humidity cycling did not affect the functionality of the indicators.***

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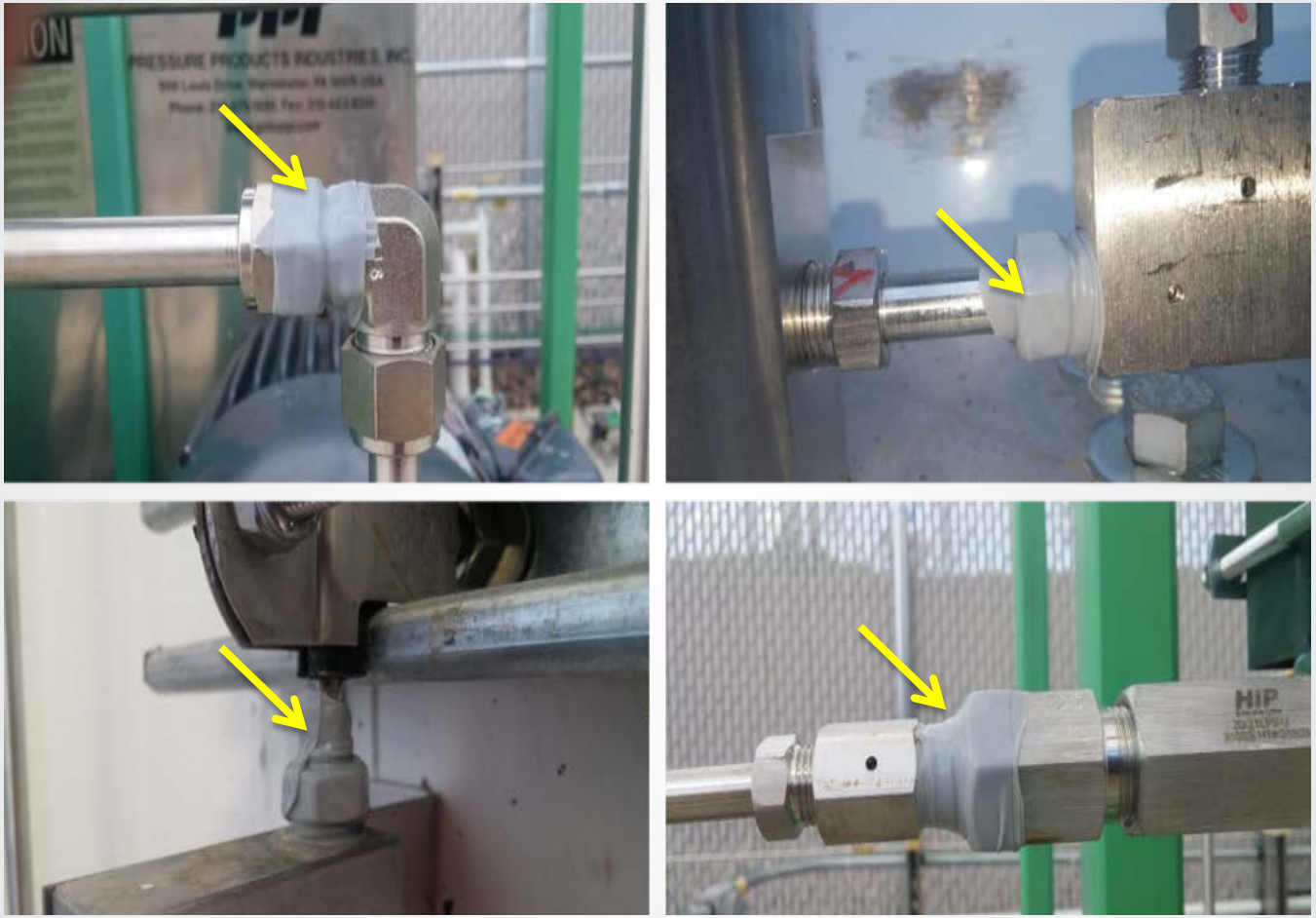
DETECTAPE
Hydrogen Leak Detection

NREL DEPLOYMENT STUDY



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DETECTAPE H_2
Hydrogen Leak Detection

NREL Deployment tests: Clear indication of a leak

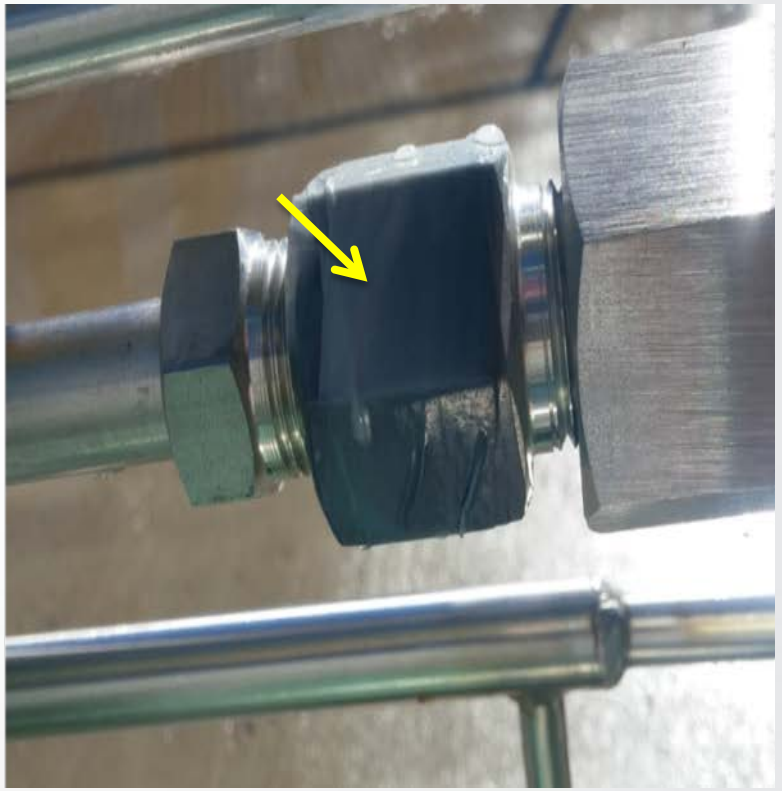

Photo credits: K. Hartman/W. Buttner, NREL

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DETECTAPE H_2
Hydrogen Leak Detection

NREL TESTING DATA

Photo credits: K. Hartman/W. Buttner, NREL

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NREL TESTING DATA

- This indication was seen as the initiation of a slight darkening of the pigment. Since the color change was not as obvious as other indications, this indicator will continue to be monitored.

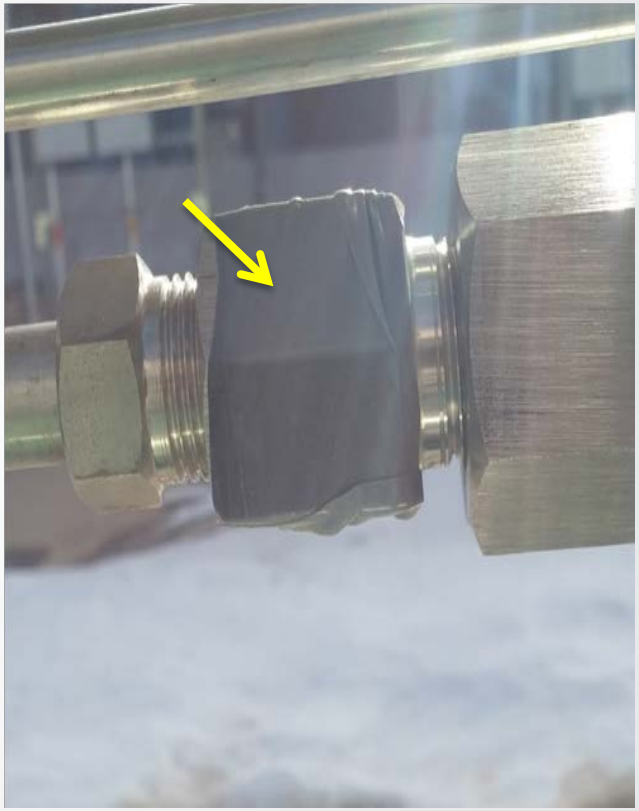

Photo credits: K. Hartman/W. Buttner, NREL

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DETECTAPE H_2
Hydrogen Leak Detection

Conclusions drawn from data by Element One

1. *DetecTape™ H_2 was shown to reliably identify unintended hydrogen releases from complex pneumatic systems.*
2. *DetecTape™ H_2 was verified as a viable technology to identify small hydrogen leaks which would otherwise go undetected. The identification of such leaks facilitates implementation of appropriate corrective action before the potential occurrence of major adverse events.*

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DETECTAPE Hydrogen Leak Detection H_2

DETECTAPE™ H_2 PRODUCTION AND MARKETING

MSP, Inc.

John Poplawski

Executive VP / COO

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DETECTAPE Hydrogen Leak Detection H_2

MSP BACKGROUND

- **1997** – Established as “Tommy Tape Manufacturing”
- **2000** – Acquired by Midsun Group (est. 1992 Southington, CT), a leading provider of animal mitigation and corrosion coating products designed for electric utilities
- **2006** – Renamed to Midsun Specialty Products, Inc.
- **2009** – Moved operations to Berlin, CT
- **40** employees
- Manufacturer and distributor of self-fusing silicone tapes, corrosion protection, and specialty products worldwide

http://www.midsunsp.com

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DETECTAPE
Hydrogen Leak Detection

CHANGES COLOR UPON DETECTION

Upon hydrogen detection, tape changes color from light grey to dark black.

- Noticeable change within 3 minutes.
- Significant change within 30 minutes.

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DETECTAPE
Hydrogen Leak Detection

SELF-FUSING SILICONE

- Cross-linking silicone **bonds to itself** on contact.
- Does not use adhesives, leaves **no residue** on substrate.
- Naturally **resists UV** and most corrosive chemicals.
- Protected by a special removable liner before installation.
- Potential for vibration dampening.
- Conforms smoothly when wrapped around **irregular shapes**.

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Hydrogen Leak Detection

FEATURED IN

sensors ONLINE
Your Technical Resource for Sensing Communication, & Control

HARTFORD BUSINESS.com
A PUBLICATION OF THE HARTFORD BUSINESS JOURNAL

gasworld magazine

INNOVATION DESTINATION HARTFORD

Laboratory EQUIPMENT.

altenergymag.com

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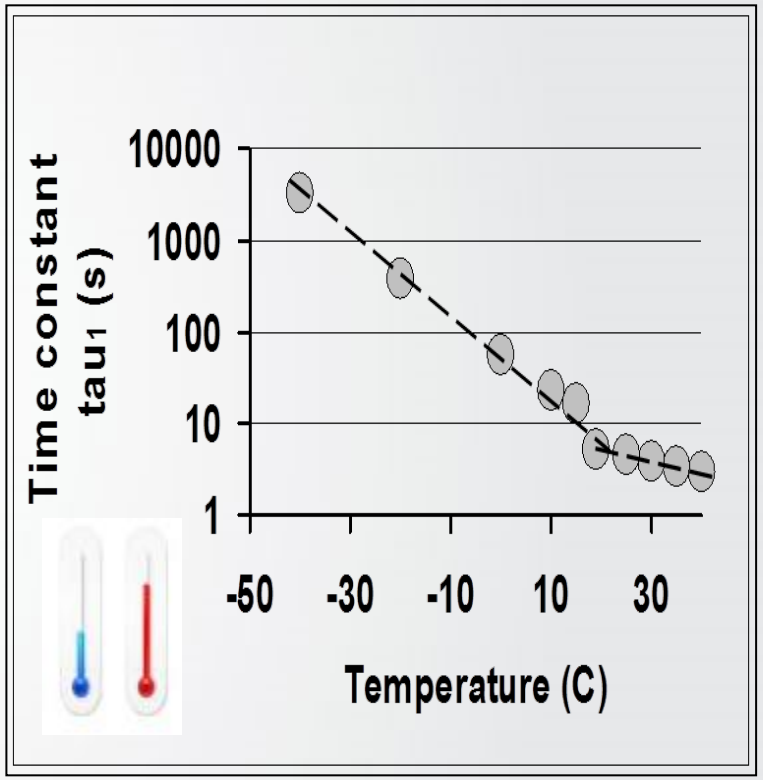
DETECTAPE Hydrogen Leak Detection H_2

TEMPERATURE RANGE

- Extreme Temperature Range
- As low as 0°F (-17°C)
- As high as 350°F (176°C)
- Detection reaction time may be reduced or improved depending on temperature.

*** Temperature data still being collected. Subject to change ***



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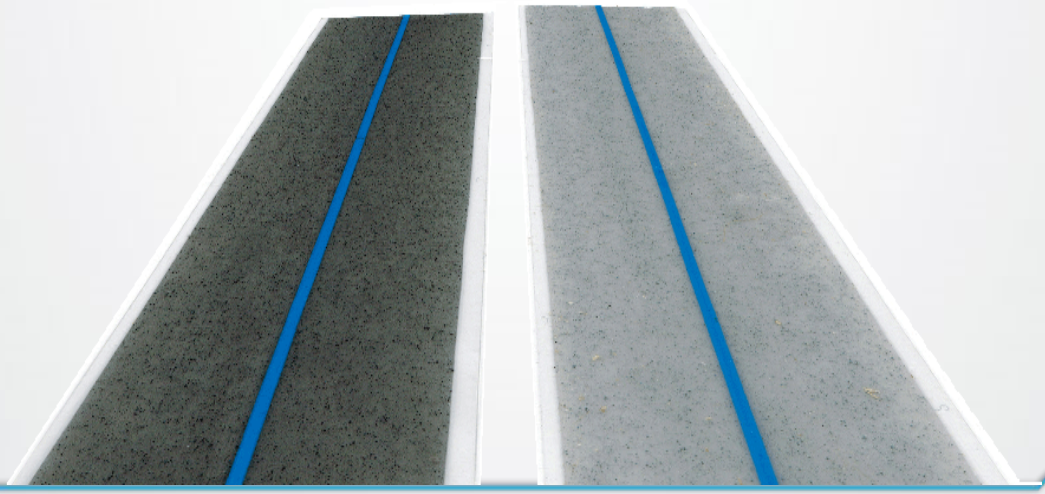
HYDROGEN REACTION

- Silicone is a hydrogen permeable carrier for chemo-chromic pigment that changes color when exposed to hydrogen.



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HYDROGEN SAFETY INTEREST

- Very large quantities of hydrogen are safely used in industry today, but it's hard to contain and difficult to detect leaks.
- Hydrogen is a very large industrial commodity with a growing market.
- The introduction of hydrogen as a consumer fuel has caused heightened concerns over its safety with a corresponding increased interest in hydrogen sensors.

DETECTAPE H_2
Hydrogen Leak Detection

HYDROGEN REACTION

- **Leak Rate** and **Concentration**
  Determine Speed of Color Change.
  Formula in Development
- **Cumulative Effect** –
  Slow or small leaks can lead to significant color change over a long period of time.
- Reaction is **permanent** after hydrogen is detected, tape replacement is recommended after repair.

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DETECTAPE H_2
Hydrogen Leak Detection

EASY TO USE

- Can be easily installed by on-site maintenance, inspection teams or equipment operators.
  No certified training required.
- Does not require power to operate.
- **Can be used in unison with existing leak detection tools** including sniffers and ultrasonic detectors.

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DETECTAPE H_2
Hydrogen Leak Detection

INTENDED USAGE

DetecTape™ H_2 can be wrapped on **most objects** including:

- Connections, Fittings and Reducers
- Swagelok and NPT
- Rigid Pipeline
- Flexible Tubing
- Flanges
- Welded Seams and Joints

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Hydrogen Leak Detection

INTENDED USAGE

- Initially wrap DetecTape™ H_2 on all hydrogen connections that may be leak prone or susceptible to vibration damage.
- Leave DetecTape™ H_2 on connections permanently or until a leak is detected and a repair needs to be made.
- Can be easily removed with a blade or scissor.
- Once repair is complete and connection is in working order, wrap with DetecTape™ H_2 to monitor for future leaks.

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DETECTAPE H_2 Hydrogen Leak Detection

USAGE LIMITATIONS

DetecTape™ H_2 is **not** intended to:

- be used to stop nor slow down a leak.
- be used to detect anything other than hydrogen gas.
- prevent other gases from mixing with hydrogen.

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DETECTAPE H_2
Hydrogen Leak Detection

COUNTRY OF ORIGIN

- All components of DetecTape™ H_2 are manufactured in the United States.
- Tape core denotes Country of Origin.
- Hydrogen reactive pigment synthesized in Boulder, Colorado USA.
- Tape manufactured in Berlin, Connecticut USA.

MADE IN USA

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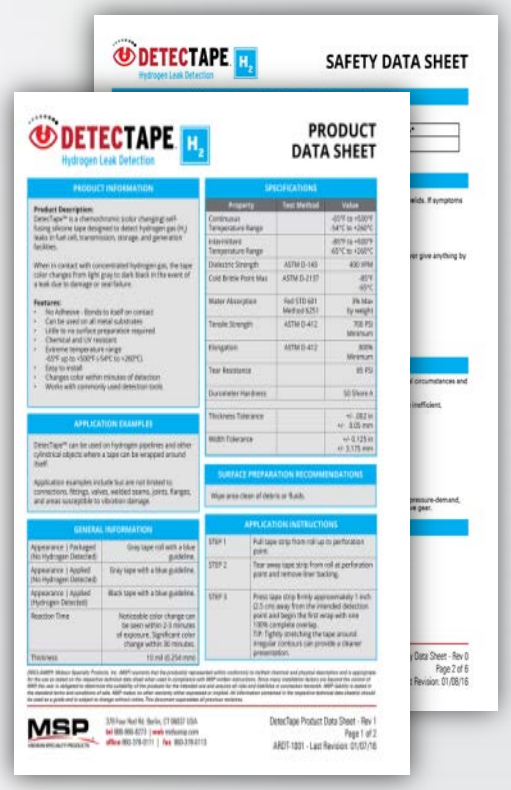
DETECTAPE H_2
Hydrogen Leak Detection

DOCUMENTATION

- New Product Announcement Sheet
- Product Data Sheet
- Safety Data Sheet
- Instruction Sheet
- Videos (Coming Soon)
- NREL Deployment Study Coming Soon



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DETECTAPE
Hydrogen Leak Detection

TAPE ROLL SPEC

- **Thickness** – 10 mil (0.01 inch / 0.254mm) thick
- **Profile** – Rectangular / 10 mil across
- **Width** – 1 inch (25mm) wide
- **Length** – 15 feet (4.57m) long
- **Color** – No leak detected : Light grey
  Leak Detected : Cumulative dark black blotches
- **Guideline** – Blue to denote Hydrogen Gas Detector
- ***Current* Perforation** – 4 inch (10cm) strips

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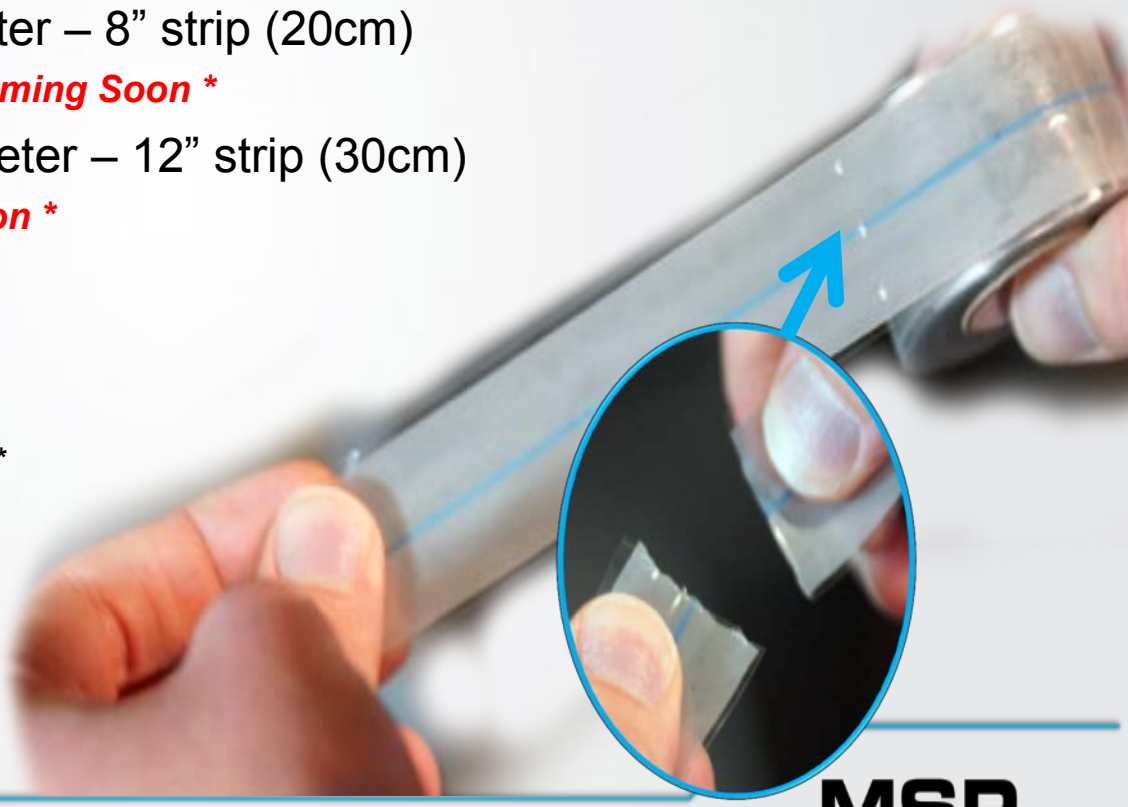
Hydrogen Leak Detection

PERFORATION

Strips **perforated** to specific lengths depending on object diameter.

- 1/16” – 1/8” (1mm - 4mm) diameter – 4” strip (10cm)
  40-45 applications per roll ***NOW AVAILABLE***
- ¼” – ½” (6mm – 12mm) diameter – 8” strip (20cm)
  25-30 applications per roll **** Coming Soon ****
- 1” – 4” (25mm – 100mm) diameter – 12” strip (30cm)
  10-12 applications **** Coming Soon ****
- Multiple strips can be used on large diameters.

***** Configurations still in trial stages. Subject to change based on user feedback *****



ELEMENT ONE

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MIDSUN SPECIALTY PRODUCTS

DETECTAPE H_2
Hydrogen Leak Detection

CONTAINER

- DetecTape™ H_2 15 foot rolls are shipped in a re-usable clarified polypropylene container to keep roll clean and dry while not in use.
- Portable enough to fit a roll in pocket, tool belt or toolbox.

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Hydrogen Leak Detection

USER INSTRUCTIONS

- Every roll comes with user installation and detection instructions.
- More information and documentation (SDS, PDS, FAQ) is available to users on http://www.detectape.com

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DETECTAPE
Hydrogen Leak Detection

APPLICATIONS

Fuel Cell Plant

- Use on connections inside cabinets that are inspected on a routine schedule.
- Quickly identify hydrogen leaks during inspections.

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DETECTAPE
Hydrogen Leak Detection

APPLICATIONS

Fueling Station

- Use on hydrogen supply connection points in fueling stations.
- Attendants and maintenance crews can react quickly with a visual alert that there is a hydrogen leak present.

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DETECTAPE H_2
Hydrogen Leak Detection

APPLICATIONS

- Use on all hydrogen network connections that are within visual range of inspection routes.
- Prioritize leak repair based on quantity of alerts in a zone to maximize efficiency.

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DETECTAPE H_2
Hydrogen Leak Detection

APPLICATIONS

Research Laboratory

- Use on hydrogen-related research equipment to improve laboratory safety.
- Once a leak is detected, equipment operator can safely shut down equipment for repair.

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Hydrogen Leak Detection

APPLICATIONS

Storage Facility

- Useful in conjunction with other gas detection alarm systems.
- Expedite repairs by visually identifying localized connections.

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Hydrogen Leak Detection

OTHER APPLICATIONS

- On-Site Hydrogen Generation
- Manufacturing (Semiconductor, Aerospace, Etc.)
- Power Plants (Using Hydrogen Coolant)
- Gas Processing and Production
- Metallurgy and Welding
- Portable Power Units
- Pharmaceutical
- And More

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DETECTAPE
Hydrogen Leak Detection

AVAILABILITY

- Samples available upon request through website.
- Limited trial rolls available at introductory rate in exchange for user feedback and data.
- Case pack – 36 rolls / case
- Single rolls available with 5 roll MOQ
- Available for Purchase

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MIDSUN SPECIALTY PRODUCTS

DETECTAPE H_2 Hydrogen Leak Detection

UPCOMING DEVELOPMENTS

- **H_2 Reversible Tape** - Hydrogen reaction is reversible. Designed for tightly enclosed spaces where in-air hydrogen may be a concern over time.

- **H_2S Tape** – Hydrogen Sulfide leak detection for use as a marker for natural gas pipeline leaks.

DETECTAPE H_2S Hydrogen Sulfide Leak Detection

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DETECTAPE Hydrogen Leak Detection H_2

ACKNOWLEDGEMENTS

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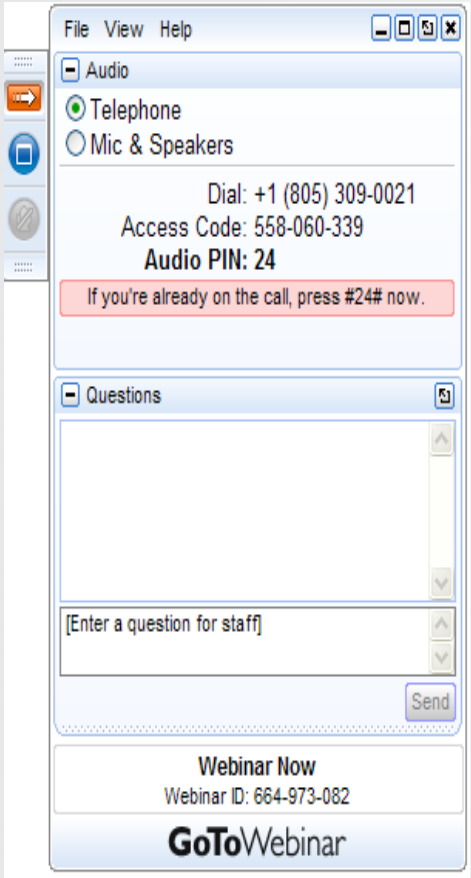
DETECTAPE
Hydrogen Leak Detection

THANK YOU FOR WATCHING



Q & A SESSION

http://www.detectape.com

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Thank You

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Webinar Recording and Slides:
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DETECTAPE
Hydrogen Leak Detection

FREQUENTLY ASKED QUESTIONS

1. What range of hydrogen concentration has the tape been measured / proven with?
2. What other components have been included in the testing for Question 1?
3. What is the repeatability of the tape's performance, i.e. does the same size leak produce color at the same rate?
4. Is there a correlation of leak amount versus color change rate?
5. What is the impact on temperature on the color change?

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FREQUENTLY ASKED QUESTIONS

6. What is the longest that the tape is been in use for any of the tests?
7. How can we tell if the tape is still working after it has been in service for a time? (eliminate false negatives)
8. Are there any other components that may cause false positives?
9. Are there any other components that may interfere with the hydrogen response? (eliminate false negatives)
10. Is the tape sample we received the same as will be sold for commercial use?