

AIRCRAFT HYDROGEN LEAK DETECTION SOLUTION

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CEO

20th Sep 2022



Protium
Technologies

 **Hydrogen Showcase**

20 September 2022
Aerospace Integration
Research Centre (AIRC),
Cranfield campus

- Introduction
- Hydrogen leak
- Detection methods
- Aviation legislation and recommendations
- Importance of visual inspection on aircraft
- Hydrogen detection tape is a solution
- Case study

Protium Technologies has been appointed as a distributor for Nitto's Hydrogen and Ammonia detection tapes for the UK and the Middle East region, bringing NASA's developed technology to the world.

Nitto

Innovation for Customers



Protium

Technologies

Global reach, Local presence

THE NITTO GROUP

founded
1918

29,019
employees
worldwide

92
companies
worldwide

806,495
million yen
turnover
worldwide

6988:JP
listed on the
Tokyo Stock
Exchange



13,500 NITTO PRODUCTS

70+ INDUSTRIES

Hydrogen Leak – Safety Concerns

- Hydrogen has the lowest volumetric energy density: **Compressed to high pressure (350/700 BAR) or Liquefied (-253° C).**
- Leaks are Hard to Detect: **Hydrogen is odourless, colourless and tasteless!**
- Highly flammable range: **Ignition can occur at a volumetric ratio of hydrogen to air between 4%-75%**
- Low ignition energy: **Hydrogen-air mixtures can ignite with 1/10 the effort of igniting gasoline-air mixtures.**
- First element of the periodic table: **Extremely light and very buoyant**





U.S. DEPARTMENT OF
ENERGY

... adequate ventilation and leak detection are important elements in the design of safe hydrogen systems.

[Safe Use of Hydrogen | Department of Energy](#)

Hydrogen Leak – Financial and Operational losses

- Revenue losses
- Shutdown losses
- Incidents damage losses
- Performance losses



Hydrogen Leak - Environmental Damage

Hydrogen is a potent indirect greenhouse gas, its leakages could undermine the climate benefits of decarbonisation efforts.

1 kg of leaked hydrogen has an greenhouse gas effect equivalent to 15 – 37 kg of CO₂

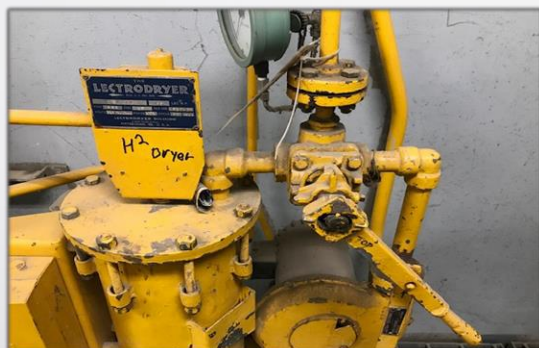


Where is the Problem?

Many potential leak points → Hard to find the exact location of the leak



Unloading Area



Dryer



Cooler



Generator Belly



Gas Manifold



Spool



Bulk Storage

Robust sensors for hydrogen leak detection is very important

Key challenges associated with hydrogen sensors are:

- Response time
- Sensitivity
- Localization
- Functionality
- Durability
- Accuracy
- Cost

Common Hydrogen Leak Detection Methods

Soapy Water Test – “Snoop”



Portable Sensors – “Sniffers”



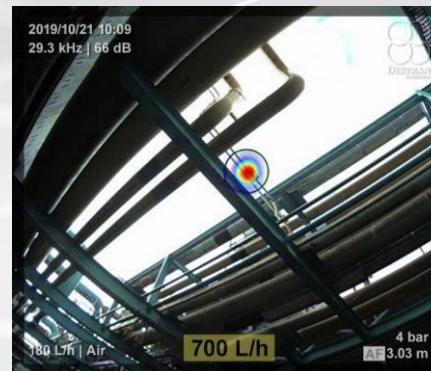
Fixed Area Sensors



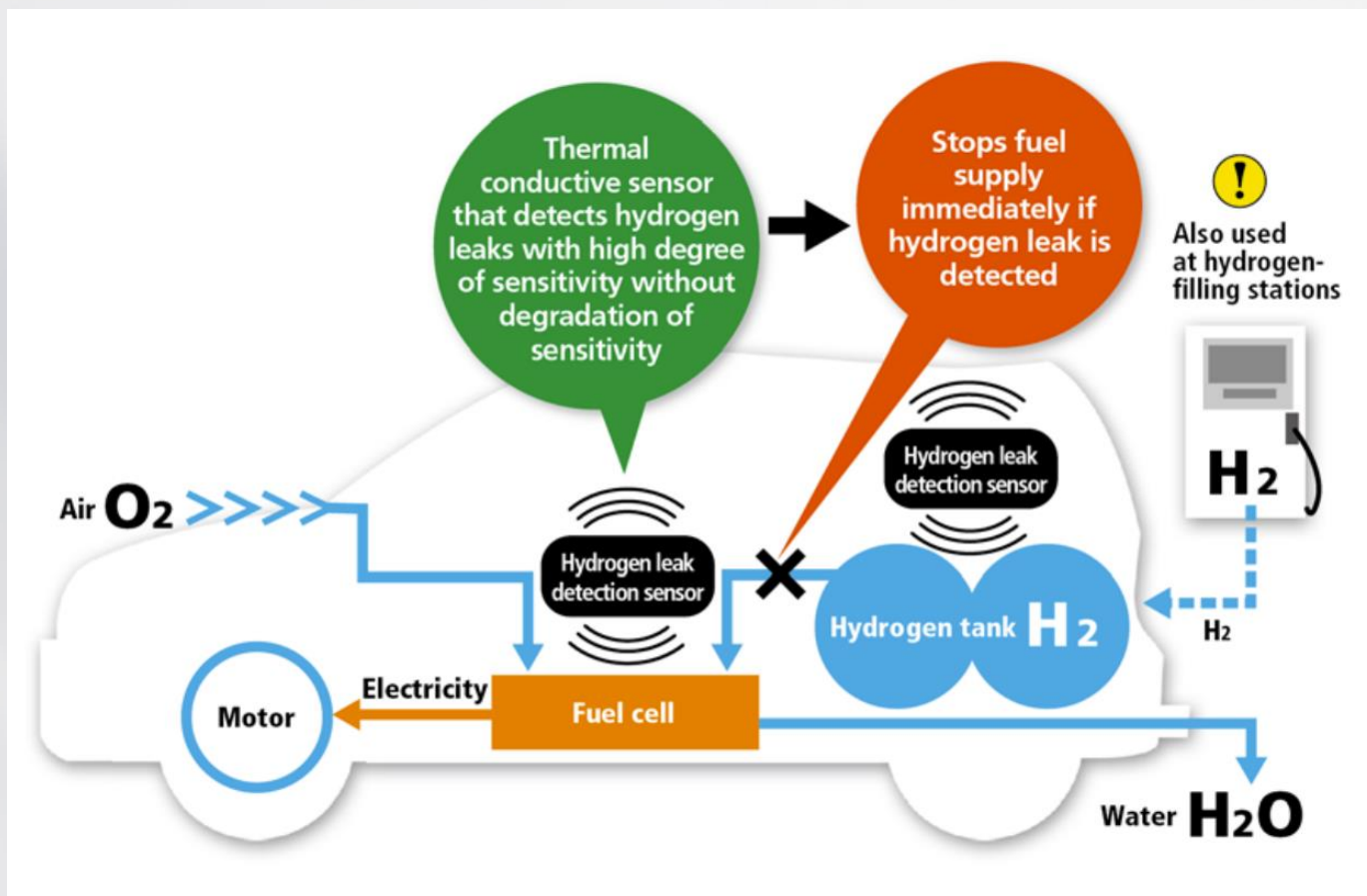
Listening for high-pressure gas leaking

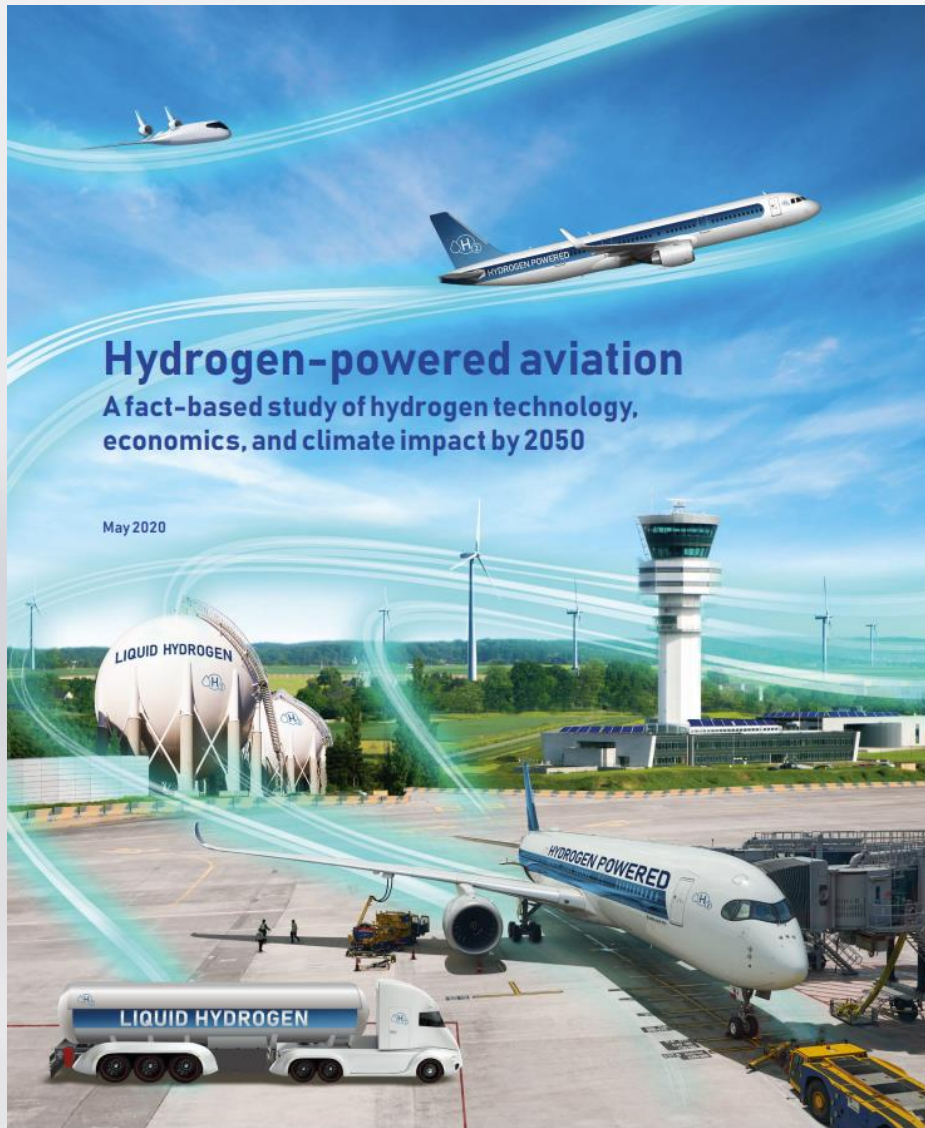
Ultrasonic leak Imaging

Thermal / Infrared Cameras



Leak Detection Sensor for Fuel Cell Vehicles





Hydrogen-powered aviation

A fact-based study of hydrogen technology, economics, and climate impact by 2050

May 2020

The most important components in a hydrogen aircraft are: A LH2 fuel system for the distribution, vaporization, and feeding of LH2 to the fuel cells or turbines: LH2 requires cryogenic cooling down to 20 degrees Kelvin. These temperatures must be handled by pipes, valves, and compressors; boil-off needs to be kept low; and leakage and embrittlement of material avoided.

Component engineering: Safe and reliable LH2 storage, distribution, and propulsion

Reliable and optimized LH2 system layout with redundancy, highly durable components, leakage and venting management, and optimized point of vaporization – including certification procedures adapted to LH2 equipment standards.



FACT SHEET 7:

Liquid hydrogen as a potential low-carbon fuel for aviation

The hydrogen flame is invisible, and the gas is odorless making it difficult to detect leaks or to fight a hydrogen fire if it that cannot be seen. Since H₂ is such a small molecule, leaking through cracks or pores is a possibility if the tank is not properly insulated, and this is associated to a higher risk due to the reasons outlined before, demonstrating that proper insulation is fundamental.

Aerospace & Defence [+ Add to myFT](#)

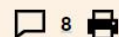
Planemakers step up hydrogen tests in push to clean aviation

Investment in sustainable fuel technology will be critical to achieving zero-emissions by 2050, say executives



US carrier United is trialling sustainable aviation fuels on its Boeing fleet © United Airlines Creative Services

Sylvia Pfeifer JULY 20 2022



Mathias Andriamisaina, head of the zero emission demonstrator programme at Airbus:

“The first big challenge, will be storing the hydrogen inside the aircraft. “We need to demonstrate it is possible to safely transport hydrogen on an aeroplane. **We need to be able to manage things like leaks or a fire.**”

Energy Supply Device Aviation Rulemaking Committee

April 2019
 Final Report

This document is available to the U.S. public through the National Technical Information Services (NTIS), Springfield, Virginia 22161.

This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.



U.S. Department of Transportation
 Federal Aviation Administration

E.5.1 Emergency Power System Aircraft Interfaces

All the interfaces to the aircraft are summarized in Table 15. This system is classified as Critical to the aircraft, but the overall level of integration is probably less than an APU, depending on the oxygen supply and the heat rejection.

Table 15. Emergency Power Interface Descriptions and Applicable Standards

Interface Type	Interface Description	Applicable Standards*, 25.XXXX
Electrical System	Emergency bus 115V AC, 28V DC Batteries on emergency power bus used for starting and recharged when operational	1351, 1353, 1357, 1431, 1301, 1309, 17xx, 1355, 1362
Controls Indicators	Cockpit interface control and monitoring to include power On/Off/Standby and Warnings of H ₂ leaks, fuel capacity (calculated and reported by system)	1302, 1322, 1357(f),

Interface Type	Interface Description	Applicable Standards*, 25.XXXX
	Maintenance computers, bit, health monitoring	
External Safety	External low pressure H ₂ vent, external drain (ODA with water vapor), Box surround system Venting may occur after use on ground Hydrogen leak detection/monitoring Fire detection and suppression	1301, 1309, 899, 1316, 1317, 851, 831, 869 modified, 1183, 1185, 1187, 863 modified, 865, 17xx, fire detection and suppression regs, looking at new regs for H ₂ leak detection on aircraft, H ₂ explosion reg,
Maintenance	Periodic coolant checks and replacement, air filter, maintenance log for bit Refueling total 100lb approx., may need tooling or split to smaller canisters External H ₂ input for system test	1529, 1729, 21.50,

E.3.2.3 Medevac Aircraft Interfaces

Table 13. Medevac Interface Description Summary (example of stand-alone power)

Interface Type	Interface Description Summary	Applicable Standards* § 25.XXXX
Electrical System	Dedicated wire harness, routed through the aircraft. Subject to applicable CFR/CS part 25 EWIS regulations, with no other connection to any other electrical system on the aircraft. Internal battery for self-starting and monitoring.	1301, 1309, 1351, 1353, 1357, 1360, 1365, 17XX
Controls Indicators	System health indicator and emergency shutoff needed on flight deck. Medical crew will operate the fuel cell system from a control panel located on the fuel cell in the cabin.	1322
External Safety	System is contained within an enclosure. H ₂ leakage monitoring in enclosure. H ₂ venting line from system needs accommodation to outside of aircraft.	1309, 1316, 581 or 954 (for the venting outside), 899, 17XX, 851, 831, 1183, 1185, 863, 865

Quantifying the Hazard

Leak: Refers to a leak in the hydrogen system. The consequences of a high pressure leak are more hazardous than a low pressure leak.

Low Leakage (0 to 25% LFL): (1% volumetric H₂ concentration

Medium Leakage (25 to 50% LFL): (1 to 2% volumetric H₂ concentration).

High Leakage (>50% LFL): (>2%) volumetric H₂ concentration).

F.2.2.2 Microflames

A small leak in a hydrogen system could ignite, burn undetected for a long time, and potentially degrade surrounding materials or ignite any hydrogen release that may occur nearby (*Butler et al., 2009*). Hydrogen leaks can support combustion at flow rates much lower than leaks of other gaseous fuels.



Mitigating the Leak Hazard

F.6 OPERATIONAL AND MAINTENANCE HAZARDS

Maintenance procedures should also be developed according to §§ 25.1529 and 25.1729 to ensure proper maintenance for safe continued operation of the FCS.

For instance, in these maintenance procedures could be included

- **Periodically check all connections in the hydrogen fuel system for leaks.**
- **Leak checks should also be conducted after repair or replacement of any fuel system lines or valves.**



Mitigating the Leak Hazard

F.2.2.6 Hydrogen Detonation Mitigation

As a good practice, the high-pressure line should be minimized. **The release duration, due to the time required to detect the leak and operate the valve should be reduced as much as possible. The leak detection time and time of shutting down hydrogen supply line is therefore a critical parameter for safety.**

Hazardous Area: Defined as an area or space in which a hazardous condition, such as an explosive gas atmosphere, may be present in such quantities as to require precautions for the construction, installation and use of apparatus, in order to comply with the intended applications for civil aircraft. Refer to IEC 60079 Standards family.



Safety – Hydrogen Leak Check

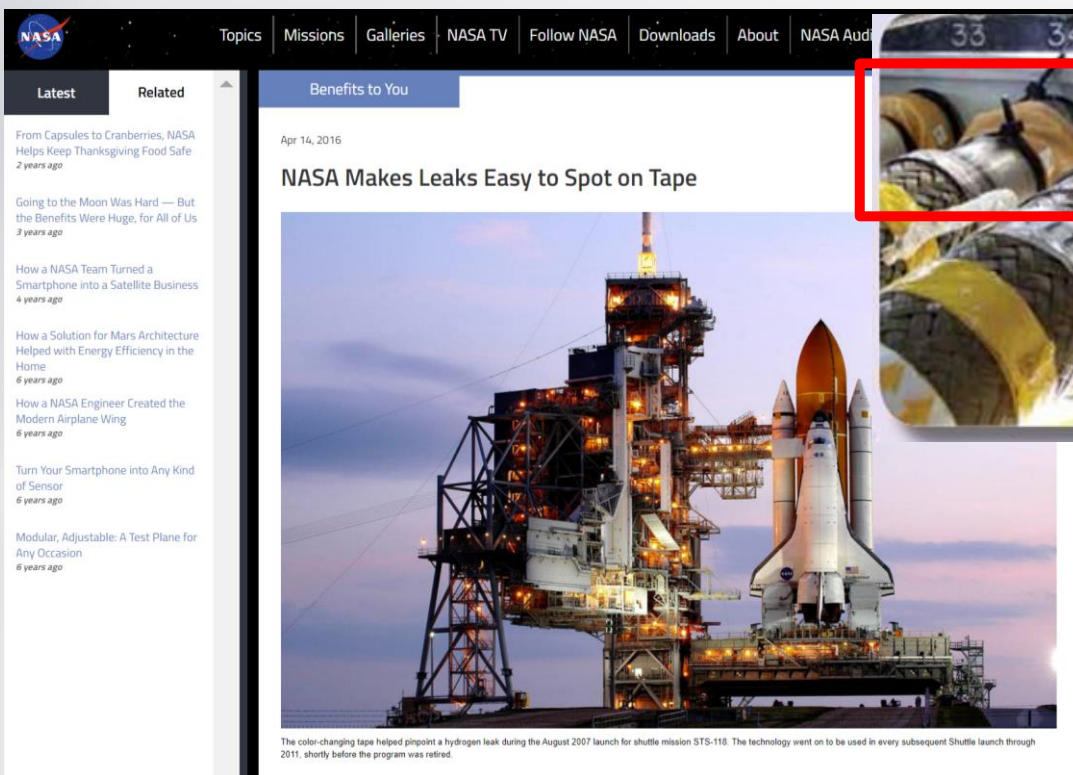
- **Periodically check all connections in the hydrogen fuel system for leaks.**
- **Leak checks to be conducted after repair or replacement of any fuel system lines or valves.**
- **Leak identification after positive gas leakage warning**

System must be active and hydrogen is flowing

This increases the operator's exposure to gas hazardous area!

Launch of NASA's Hydrogen Detection Tape

Advancing *Safety* with Color-Change *Hydrogen Detection Tape*



Space Shuttle Endeavor arrives at launch pad 39A on August 9, 2007 in preparation for mission STS-118. A leak developed in the Orbiter Midbody Umbilical Unit, or OMBUU (inset), which loads liquid hydrogen and liquid oxygen into the spacecraft's fuel cells.

A color-changing hydrogen-detection tape, seen in beige, which was developed by Kennedy Space Center and the University of Central Florida in the mid-2000s, was applied to the OMBUU and helped to detect the leak's source. The technology went on to be used for every subsequent Shuttle launch up until STS-134, the program's penultimate mission.

2022: NASA's ARTEMIS Hydrogen Leak

The Telegraph

World News > World News

Artemis I launch: Nasa bungles second attempt at groundbreaking mission to Moon



CNBC

NASA working to repair fuel leak on moon rocket and plans to launch Artemis mission later this month

PUBLISHED THU, SEP 8 2022 1:08 PM EDT | UPDATED THU, SEP 8 2022 3:47 PM EDT



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KEY POINTS

- NASA hopes to make another attempt at launching the lunar Artemis I mission later this month, but needs to clear a series of obstacles.
- The agency's team aims to complete the removal and replacement of faulty seals on the rocket's fueling system by the end of Thursday.
- NASA needs a waiver from the U.S. Space Force in order to launch on its requested next target dates of Sept. 23 and Sept. 27.



TV **Closing Bell: Overtime** WATCH LATER

UP NEXT: Fast Money 10:30 pm ET Likes

TRENDING NOW

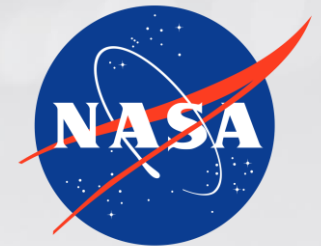
- Here are the side effects to expect from your omicron-specific Covid booster shot
- Ukraine moving 'towards victory,' Zelensky says; troops root out 'collaborators' in reclaimed territory
- Nasdaq closes higher on Wednesday as stocks stabilize following massive sell-off

sky NEWS

Artemis 1: NASA moon launch postponed after hydrogen leak

Its first mission, a 42-day uncrewed flight around the moon, will test the huge rocket and the Orion spacecraft that astronauts will eventually travel in.

Tuesday 30 August 2022 16:21, UK



Nitto

Innovation for Customers

Nitto DX-2106H Hydrogen Detection Tape



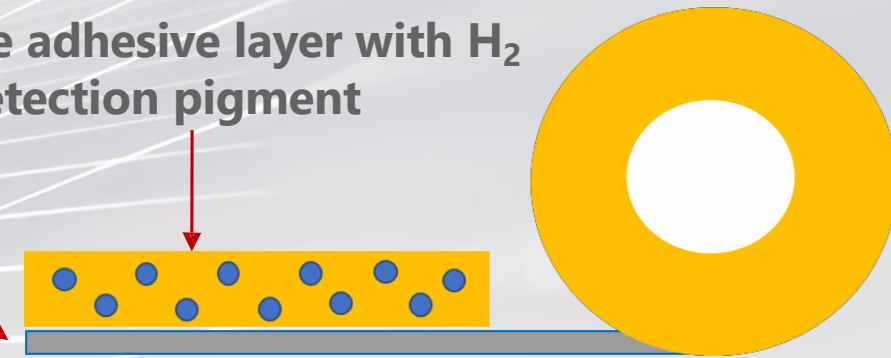
Innovative Hydrogen Leak Location Detector

- ✓ Identifies the leak's location with a visible and permanent color change.
- ✓ Proactively detects hydrogen leaks
- ✓ Easy to check vertical and bottom faces
- ✓ Safer to detect leak

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Silicone adhesive layer with H₂ detection pigment

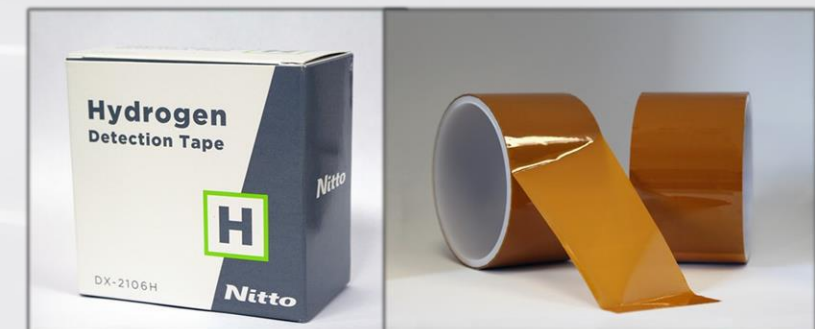
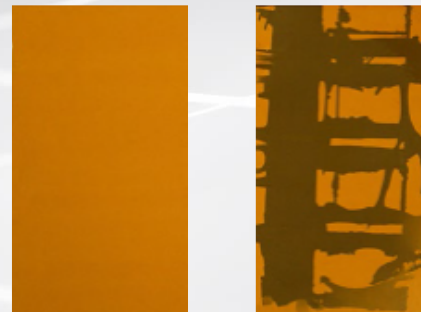
1mil Polyimide backing



Hydrogen Detection Tape will permanently change color, even when the flow of hydrogen gas has stopped.



Before After

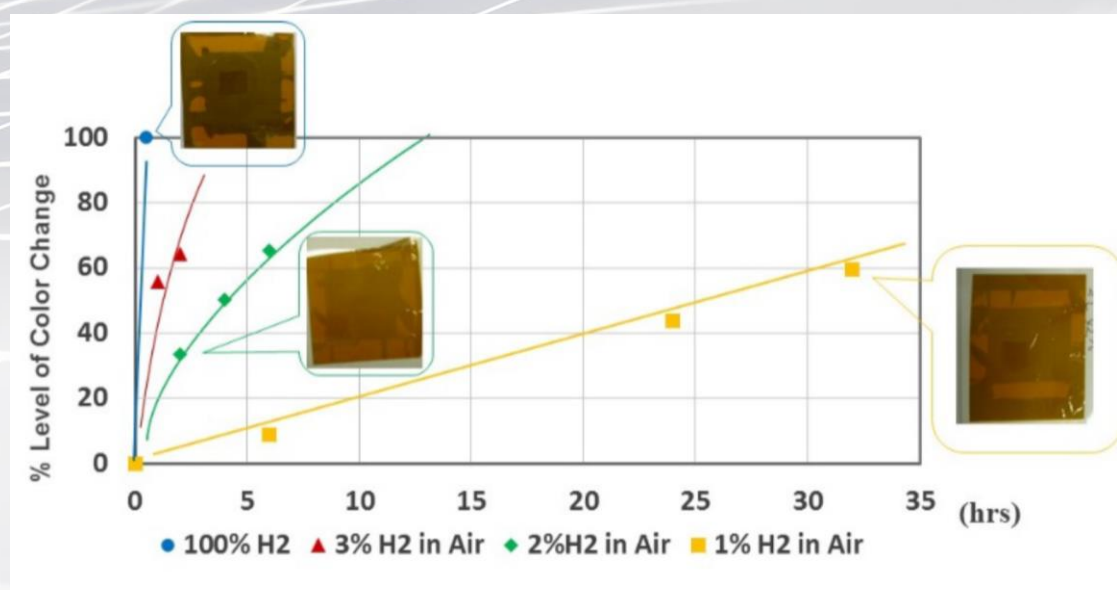
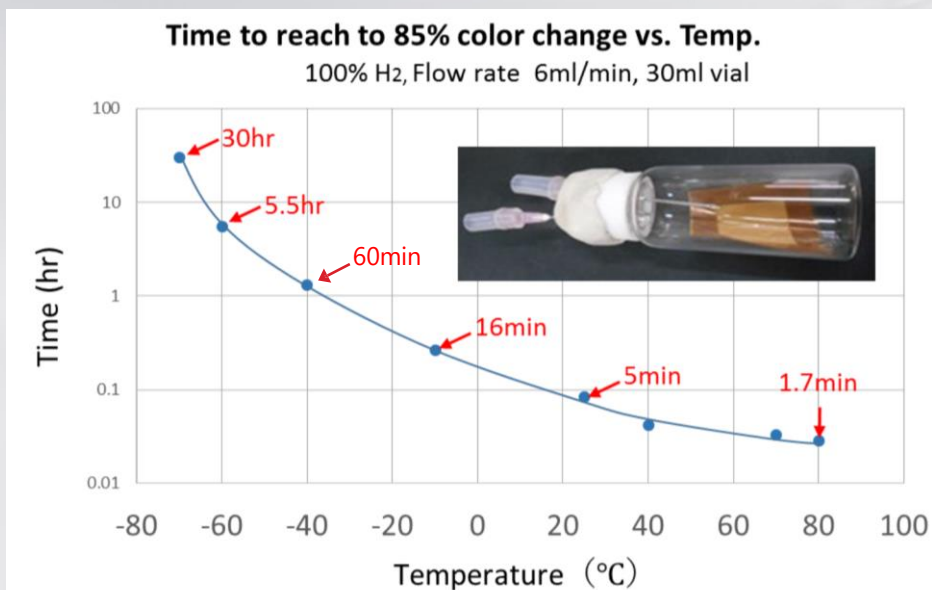


Color-Changing Adhesive Tape

Product: DX-2106H

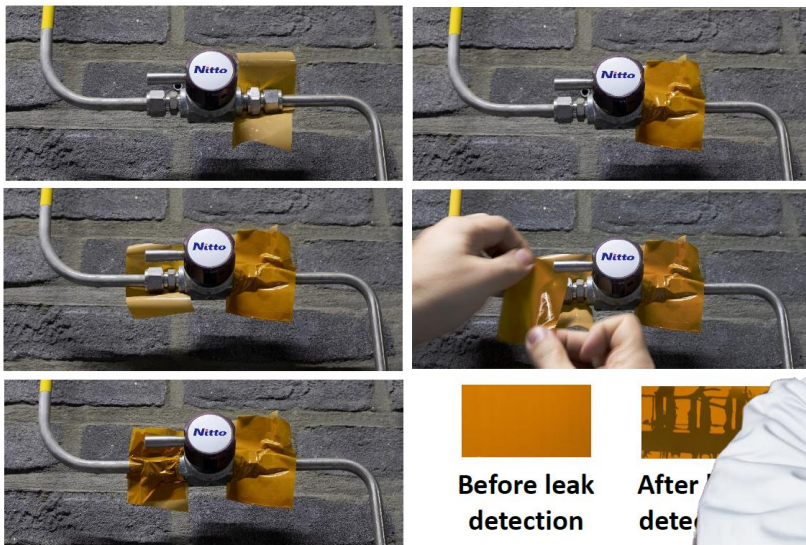
Nitto Hydrogen Detection Tape

- Can detect as little as 1% H₂ (99% Air or N₂)
- Wide operating temperature range (- 70°C to 100°C)



Recommended Usage

Nitto DX-2106H Hydrogen Detection Tape Butterfly application method



Before leak detection



After detection



Nitto

Application Manual

Updated: February 2020 This manual replaces all previous versions

DX-2106H

NITTO HYDROGEN DETECTION TAPE

APPLICATION TECHNIQUES

- Ensure that the substrate surface is clean, dry and free of any debris, oils, loose particles, etc.
- Nitto's hydrogen detection tape is a Pressure Sensitive Adhesive (PSA) tape and requires pressure applied by hand or roller.
- Not every situation will allow for DX-2106H to be easily wrapped around the substrate. In challenging areas, apply DX-2106H using the "Butterfly Wrap" (shown right) method. This not only will help encapsulate the surface, but it also helps with preventing any escape route for hydrogen gas, thereby allowing you to identify a potential leak.
- Wrinkles or pop-ups, when applying the tape, may cause the color-change more easily. This can be recognized because the color-changed area will become irregular, which allows for leaking gas to contact more of the tape.
- To see contrast of the color-changed area versus the non-changed area, apply tape around an area larger than the expected leak location. If the color of the whole tape is changed, it may be difficult to recognize the leak point. It is better to apply the tape over a wider area.



PRECAUTION REMINDER

- This product is intended for use as a localized hydrogen gas indicator and should be used as part of a comprehensive gas detection system. Note: It is not able to prevent gas leaks.
- Color change speed depends on hydrogen gas % concentration, flow rate, and temperature. Higher concentration, flow rate, and temperature cause a faster color-change. 1% hydrogen balance in 99% air may not cause a change in color, depending on the condition.
- Although this tape has been tested for its hydrogen gas detection ability under 60°C, 40°C x 95%RH and -5°C for 3 months or more, the product is only warrantied to conform to specification's defined by Nitto.
- When a color-change is observed, it is highly recommended to recheck for hydrogen gas leak with a hydrogen gas detector.
- Under high temperatures (~ 200°C/ 392°F), organic materials including but not limited to finger prints adsorb on the adhesive surface and can generate gases that may potentially cause the tape to change color.
- "Spot" color-change may be observed under high temperature conditions or after long term outside UV exposure (shown right). A "Spot" color-change is not caused by a hydrogen gas leak. In case of a gas leak, an "area" color-change is observed.

"Spot" color change example





AEP Power Station Field Trial Results

PSO Tulsa Power Station



Objective: Deploy and observe **Nitto DX-2106H Hydrogen Leak Detection Tape** at critical and potential leak locations **for preventative maintenance and continuous monitoring**

Test Period: 90 Days – Active Engagement and Auditing

Initial Tape Installation Date: 04/18/2019

- Number of Applied Locations: 22
- Number of Applied Tape Areas: 44
- Time to Install: 120 minutes

PSO Riverside



An AEP Company

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AEP Field Trial Application Locations

Power Facility Application Areas & Examples:

- H₂ Bulk Storage Area
- Pressure / Purity Monitoring Cabinets
- Inside Distribution and Critical Piping
- H₂ Flow Meters
- Generator Belly
- H₂ Coolers & Dryers
- Various Flange Connections / Valves / Fittings / Etc.

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Inside Distribution



Bulk Storage



Generator Belly



AEP - Location # 2 Hydrogen Purity (Unit 4)



- Location: **UPPER Flange**
 - **Leak Indicated (04/19)**
- Flange tightened and tape reapplied



- Location: **LOWER Flange**
 - **Leak Indicated (04/19)**
- Flange tightened and tape reapplied. >> **Leak indicated at audit (04/22)**

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AEP - Location # 3 Hydrogen Distribution Piping (Unit 4)



- Location: Indoor
- **Leak Indicated (06/14)**

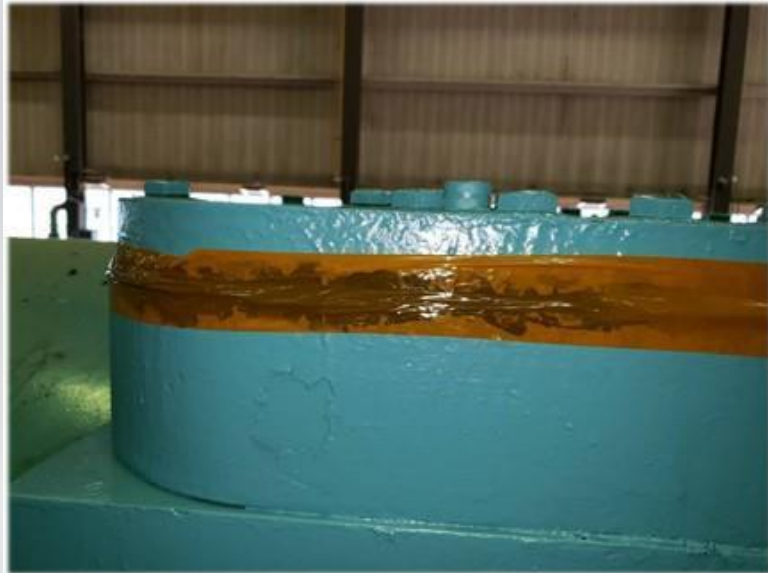
Nitto

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AEP - Location # 9 Unit 1 Hydrogen Cooler



- Location: Indoor
- **Leak Indicated (06/13)**
- Hand held sensors used to verify hydrogen leak

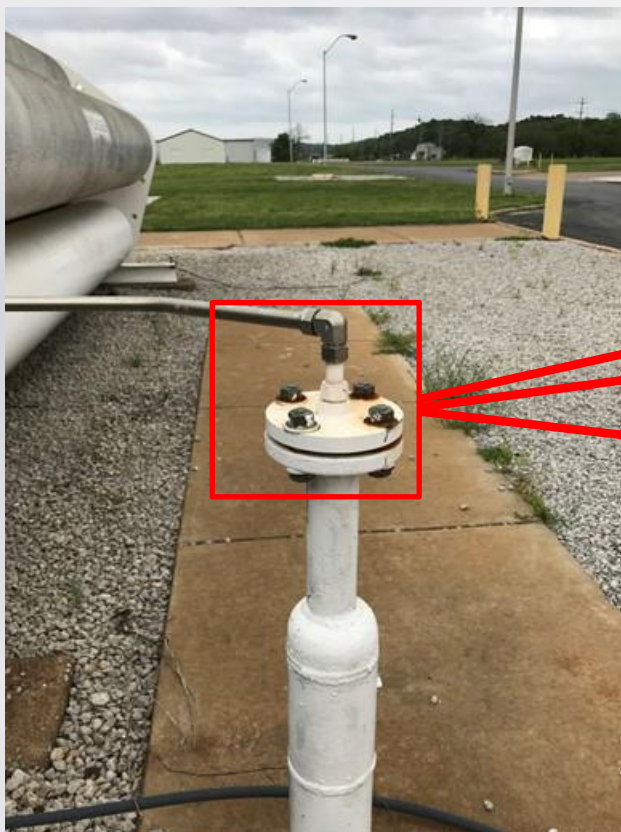
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AEP - Location # 16 Flange to Underground Piping



- **Leak indicated on 05/24**
- Flange addressed and tape reapplied
- Leak source mitigated during 06/14 audit
- Pipe Temp: 77.2 Deg. F

AEP - Location # 16 Flange to Underground Piping



- Date: 05/03
- Moisture bubbles observed following recent **heavy rain storms**

- **Leak Indicated (05/24)**
- Moisture bubbles noticed following recent heavy rain storms (05/03)
- Standing water inside flange (enclosed by tape) – Still effective for H₂ detection

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AEP - Location # 18 Flange from Underground to Feed Generator



- **Leak Indicated (05/31)**

Action:

- Hand held monitor from distance (12") – No indication
- Made hole in tape and monitored again – **Leak Indicated**



Operator Feedback (P. Mendoza – Riverside)

Tape had changed color again. I went around the tape with two different gas detectors and didn't get any alarms. I poked a hole in the tape and checked with both monitors. The yellow monitor is what the operators usually use to look for hydrogen leaks. The monitor didn't alarm when it was a foot or so away from the flange. When I placed the monitor next to the hole I made, it alarmed. When it was away from the flange, there were no alarms. Placed next to the hole I made, it alarmed. **The tape was then removed, and I tried to find a leak with snoop. No bubbles.** Once the testing was completed, new tape was installed.

AEP Field Trial Summary

Initial (90 Day) Results: (44) Locations Applied – (9) with positive Hydrogen leak indication

- **20.45% Positive Hydrogen leak indication**

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DX Tape – Low Temp. Exposure Test

- Location Details: Hydrogen Facility Vent System – The purge connection on vent line. DX-2106H applied directly where no possible leak would occur adjacent to connection. Trailer pressurized to 20 PSIG and vented through line.

Time: 0 min. / 82 Deg. F (28 °C)



Time: 2 min. / 20 Deg. F (-7 °C)



DX Tape – Low Temp. Exposure Test

Temp: - 22 Deg. F (-30°C)



Temp: - 40 Deg. F (-40°C)



DX Tape – Low Temp. Exposure Test

Temp: - 108 Deg. F (-77.77°C)



New Method: Color-Changing Adhesive Patch

Product: DX-2106H-P

- Wide operating temperature range (- 70°C to 100°C)
- Easy to cover and monitor multiple leak ports
- Can deploy in minutes for entire unit

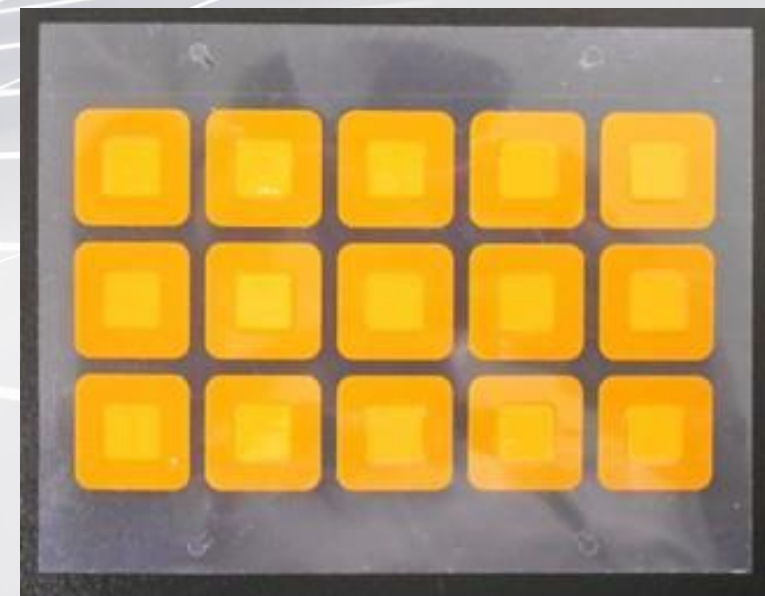
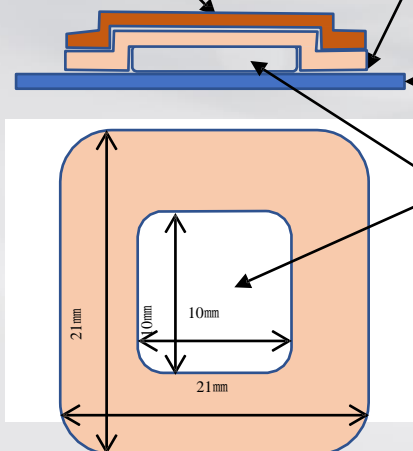
- **Structure**

Polyimide base film

Silicone adhesive layer with H2 detection pigment

Release Liner

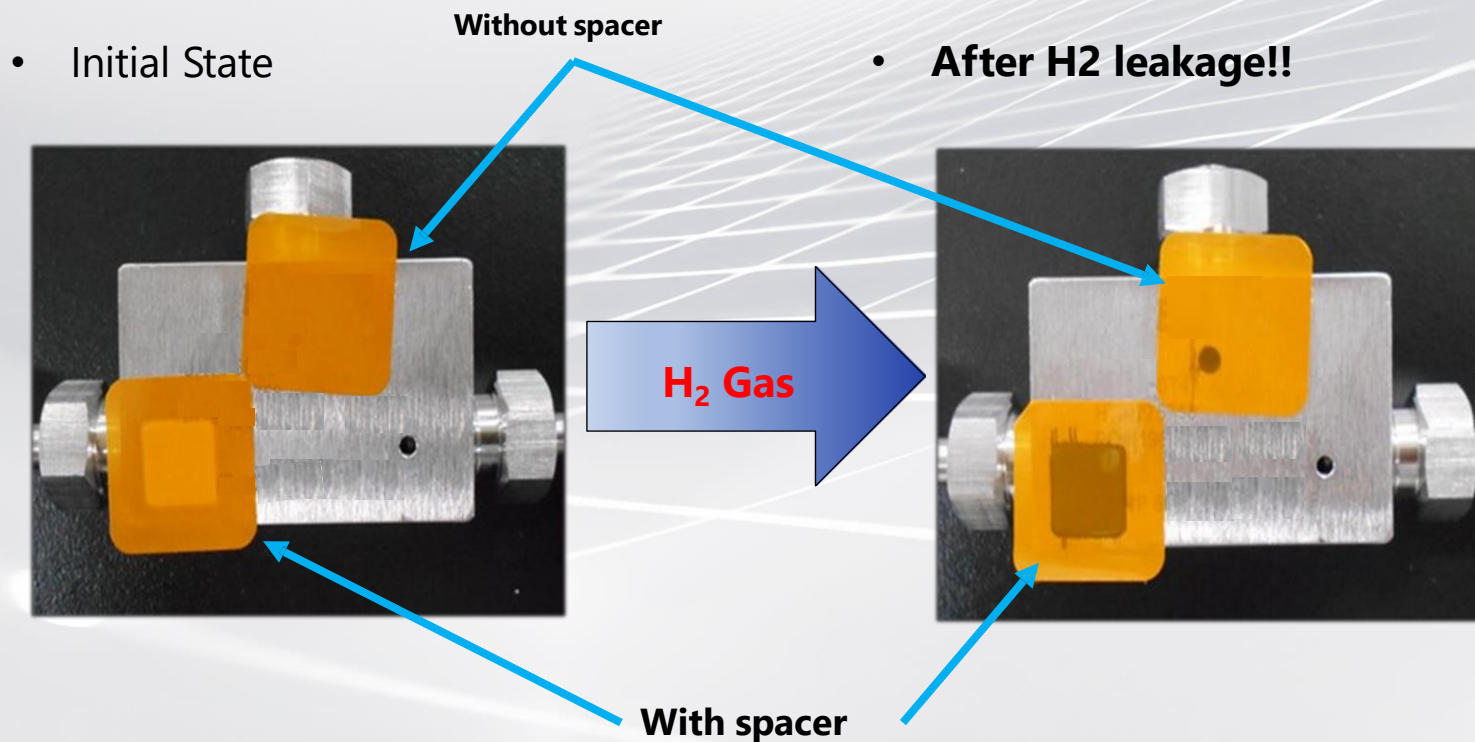
Spacer / PTFE porous membrane



New Method: Color-Changing Adhesive Patch

Product: DX-2106H-P

- Wide operating temperature range
- Easy to cover and monitor multiple leak ports
- Can deploy in minutes for entire unit



Innovative & Award-Winning Technology

Your Benefits of Using Nitto Hydrogen Detection Tape

- Advancing Safety Procedures
- Risk Mitigation & Critical Asset Protection
- Substantial Costs Benefits & Enhanced Labor Efficiencies
- Quickly Get Plant Back to Generating Power & Revenue
- Award Winning & Proven Technology



SEE THE LEAK



2016 Commercial Invention of the Year



2017 National Florida Lab Consortium
Technology Transfer of the Year Award





[\(1004\) Nitto Hydrogen Detection Tape - YouTube](#)



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Thank you!

Any Questions ?



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in the UK and the Middle East**