



Learning from Recent Hydrogen Incidents

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Modular Transport Leak and Fire

Event Summary

- ▶ Multiple element hydrogen gas module suddenly leaked and caught fire while the transport truck was stopped at a traffic light

Cause

- ▶ Incorrectly rated and incompatible pressure relief devices (PRD) installed during maintenance activity
- ▶ PRD vent tubing compression fittings to some of the gas cylinders had not been sufficiently secured

Lessons Learned

- ▶ Implement rigorous double-witness verification, and documentation/marketing procedures for hydrogen containing equipment during assembly and maintenance inspections



Event Impact

- No injuries
- 1,400 people evacuated

Tank Explosion at Research Facility

Event Summary

- ▶ An outdoor hydrogen tank exploded at a research and development complex during test of a water electrolyzer

Cause

- ▶ Autoignition of a hydrogen-oxygen gas mixture within the tank resulting
 - Potential electrolyzer cell membrane degradation may have permitted excessive oxygen gas crossover rate through the electrolyzer cell membranes into the product hydrogen gas

Lessons Learned

- ▶ Understand interrelation of electrolyzer membrane gas permeability, membrane degradation, and dynamic operating range when establishing process safety controls
- ▶ Consider automatic gas storage isolation and stopping gas generation when safety limits are exceeded



Event Impact

- Two fatalities
- Six injuries
- \$30 million damage

Hydrogen Plant Truck Fueling Deflagration and Fire

Event Summary

- ▶ A gaseous hydrogen leak, fire, and deflagration occurred at a hydrogen production and trailer loading station during a filling operation

Cause

- ▶ Unauthorized repair and failure to follow procedures during a minor leak resulted in more severe consequences

Lessons Learned

- ▶ Repairs must be performed by authorized, trained maintenance personnel following valid procedures
- ▶ When two persons are utilized for transfer operations, ensure that equipment configuration is verified before performing critical actions
- ▶ Hydrogen deflagration overpressures may cause secondary system leaks and degrade integrity



Event Impact

- No injuries
- Equipment damage
- Four tankers damaged

Fueling Station Tank Leak, Fire and Explosion

Event Summary

- ▶ A leak from one tank within a high-pressure hydrogen storage unit serving a hydrogen vehicle fueling station resulted in a jet fire and an open-air deflagration

Cause

- ▶ An assembly error of a specific sealing end plug for the high-pressure hydrogen tank
 - The inner bolts of the plug had not been adequately torqued, allowing seal failures to progress into an explosion and subsequent jet fire

Lessons Learned

- ▶ Implement rigorous assembly, double-witness verification, and documentation/marketing procedures for hydrogen containing equipment



Event Impact

- No injuries
- Station damage
- Airbag activated in nearby vehicle

Bus Fueling Station Fire

Event Summary

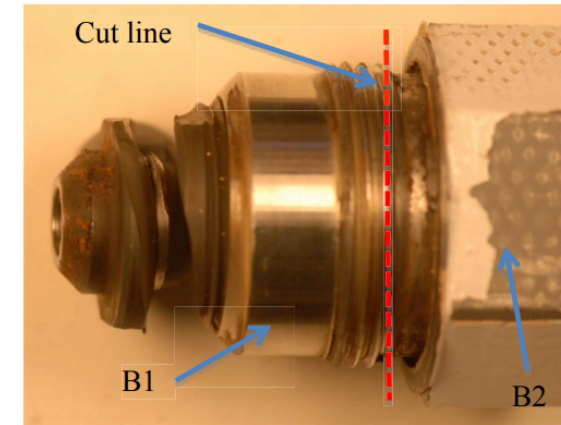
- ▶ A pressure relief valve failed causing the release of approximately 300 kg (660 lbs.) of hydrogen over approximately 2.5 hours

Cause

- ▶ Incompatible pressure relief device installed

Lessons Learned

- ▶ Prior to reopening the station, physical changes were made using the correct PRD valves and higher vent stacks
- ▶ New and modified procedures were instituted to improve the timely communication of station status during emergency events
- ▶ Additional training of personnel focused on improving the response time and effective communication between employees, first responders, and the hydrogen equipment supplier



Approximate location of cut line to separate nozzle subassembly from inlet base

Event Impact

- No injuries
- Very minor equipment damage
- Extensive evacuation of residents and businesses

Summary of Hydrogen Incidents... A Common Thread

- ▶ Electrolyzer
 - Personnel did not fully understand the interrelation of electrolyzer membrane gas permeability, membrane degradation, and dynamic operating range
- ▶ Hydrogen Vehicle Fueling Station
 - Assembly error of an end plug for the high-pressure hydrogen tank
- ▶ Hydrogen Transport
 - Incorrect pressure relief devices installed during maintenance
- ▶ Hydrogen Tanker Loading
 - Unauthorized repair and failure to follow procedures
- ▶ Hydrogen Bus Fueling Station
 - Incompatible pressure relief device installed



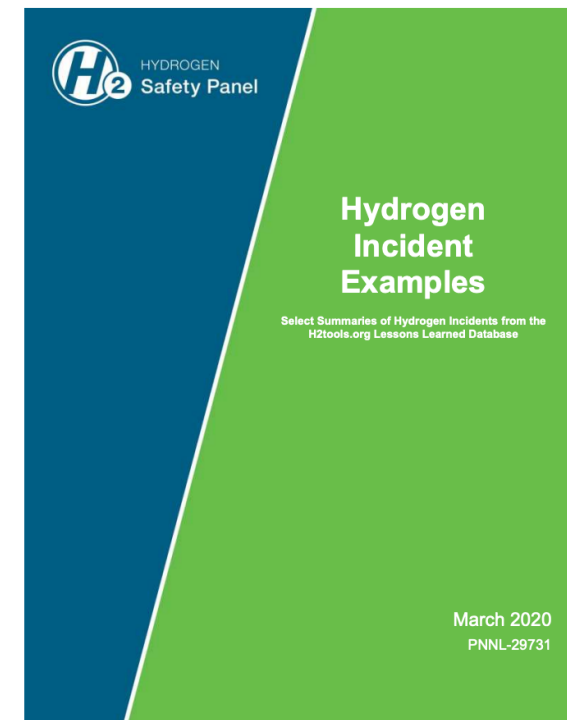
Courtesy of Gangwon Fire HeadQuarter

Damage from Electrolyzer Incident

New Resource... Hydrogen Incident Examples

- ▶ Tables, links and summaries of select incidents from H2Tools.org Lessons Learned resource
- ▶ The listing is intended to enable readers to find incidents in a document form that are most pertinent to their materials, equipment, and activities

Category	No. of Incidents
Pressure Relief Device Incidents	4
Hydrogen Cylinder Incidents	7
Piping Incidents	11
Liquid Hydrogen Incidents	6
Hydrogen Instrument Incidents	3
Industrial Truck Incidents	3
Hydrogen Compressor Incidents	2
System Design, Operation and Maintenance Incidents	9
Laboratory Incidents	10
Fueling Station Incidents	12



Thanks for Your Attention!



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<http://www.aiiche.org/chs>

<http://h2tools.org>

Bringing together individuals and organizations to develop and share best safety practices and learnings