



ludwig bolkow
systemtechnik



Deutscher Wasserstoff- und
Brennstoffzellen-Verband

Ludwig-Bölkow-Systemtechnik GmbH (LBST)

DWV Hydrogen Safety Compendium

Reinhold Wurster, LBST

Dr. Ulrich Schmidtchen, DWV

19th World Hydrogen Energy Conference
Toronto, 07 June 2012

How the issue of hydrogen safety moves people



ludwig bolkow
systemtechnik



Deutscher Wasserstoff- und
Brennstoffzellen-Verband

- General distrust of the unknown and of things not accessible to sensual perception
 - Hydrogen was an important constituent of town gas in the 19th and 20th century
 - Then in Europe town gas was first replaced by natural gas
 - Both gas and electricity cannot be perceived by the human senses, but we use electricity on a daily basis, we do not use gas on a daily basis in Germany anymore
 - Most people ‘know’ gas from hearsay – not from practical use – or at best from reports in newspapers, television, internet or other media → due to the lack of practical experience the benchmark for personal judgment is missing

How the issue of hydrogen safety moves people (2)



ludwig bolkow
systemtechnik



- Does Hydrogen Explode ?
 - By many hydrogen is associated with **explosiveness** (maybe this comes from the school experiments on the hydrogen-oxygen reaction or from the misperception of accidents in which H₂ was involved at a secondary level)
 - **To burn H₂ you need oxygen**, at least 4%-vol H₂ in air and an activation energy (e.g. a spark, electrostatic charge or 560°C as self-ignition temperature)
 - **Hydrogen itself is not self-igniting** – its only safety-relevant characteristic is that it is flammable (and it can be suffocating if it replaces oxygen, but is not toxic)
 - **In a hydrogen tank under pressure, oxygen is never present** – this is the main difference to gasoline, diesel or kerosene tanks (and constitutes a safety advantage)

How the issue of hydrogen safety moves people (3)



ludwig bolkow
systemtechnik



Deutscher Wasserstoff- und
Brennstoffzellen-Verband

■ Diffusion of hydrogen

- **Hydrogen has been contained in steel cylinders at a pressure of 20 MPa for at least 70 years.** In metallic vessels the diffusion velocity is so small that it is not of practical importance (100 years)
- Full composite plastic vessels at 70 MPa pressure have diffusion or permeation rates which are much higher than for steel vessels or composite vessels with steel liners, but still the amount of hydrogen passing the walls is not relevant for causing explosions and thus poses no safety risk.



Picture:
BAM

How the issue of hydrogen safety moves people (4)



ludwig bolkow
systemtechnik



Deutscher Wasserstoff- und
Brennstoffzellen-Verband

- Potential to cause embrittlement (in metals)
 - The embrittlement of metals by ionized hydrogen is a **phenomenon which is well known since more than 100 years**
 - Especially at locations of high tension embrittlement can lead to accelerated fracture growth and finally to material failure
 - Hydrogen induced corrosion can have several reasons: type of crystal lattice, surface finish, load (pressure, tension, temperature, stress variation/ pulsating stress) and can get more critical above pressure of more than 50 MPa
 - **Appropriate choice of materials and of suitable operational conditions** can avoid these effects

How the issue of hydrogen safety moves people (5)



ludwig bolkow
systemtechnik



- Safe use of hydrogen vehicles in garages
 - Compressed hydrogen vehicle storage tanks are designed as intrinsically tight → **vehicles in regular use can drive into garages or through tunnels**
 - **In Germany none of the federal state garage laws prohibits the entry of hydrogen vehicles into garages** (only for gases heavier than air as e.g. LPG such limitation exist in some cases)
 - **In the case of fire, pressure relief devices release hydrogen towards the ground** (below the vehicle) where it can immediately be burned in a surrounding fire



Pictures:
Daimler AG
2011

How the issue of hydrogen safety moves people (6)



ludwig bolkow
systemtechnik



- Safety of compressed hydrogen storage vehicle tanks
 - Due to their rigidity filament wound composite materials storage tanks have high safety margins
 - Compressed H₂ tanks at 70 MPa typically have integrated pressure reduction valves reducing the storage pressure down to a supply pressure of about 0.3 MPa
 - This concept has been proven suitable in case of accidents to date



Picture: GM/USA Today 2010

Advantages of hydrogen regarding safety

- **High diffusion coefficient**, fast mixing with air and therefore rapid dilution to non-critical mixture levels and short lifetime of mixture
- In case of fire hydrogen **burns rapidly** – much faster than liquid hydrocarbons
- Hydrogen does not contain carbon and therefore **heat carrying infrared radiation is much lower** than for hydrocarbon containing fuels



ludwig bolkow
systemtechnik



Deutscher Wasserstoff- und
Brennstoffzellen-Verband

Appropriate measures in case of traffic accidents



ludwig bolkow
systemtechnik



Deutscher Wasserstoff- und
Brennstoffzellen-Verband

- Rescue teams of first responders have to learn how to deal with hydrogen fuel cell vehicles. i.e. to deal with **high voltage** (up to 500V) and **high gas pressures** (up to an slightly above 70 MPa)
- The higher pressure level of hydrogen fuel cell electric vehicles does not change these requirements in principle
- For road vehicles regulation EC79/2009 in junction with EC406/2010 requires **labeling of hydrogen** vehicles; for cars and light duty vehicles this has to be visibly placed near the filler receptacle (another sticker inside the engine compartment)
- **Rescue Data Sheets** are available for all H₂ FCEVs and should be carried onboard the vehicle (fire brigades usually have access to this information via communication links)

Existing regulations for the daily safe use of Hydrogen



ludwig bolkow
systemtechnik



- The **Pressure Equipment Directive** for stationary and portable use of hydrogen equipment (PED: 97/23/EU and TPED: 2010/35/EU)
 - ADR (European Agreement Concerning the International **Carriage of Dangerous Goods by Road**) [ECE/TRANS/215, 01JAN2011] rules also the transport of hydrogen on European roads
 - **ATEX – Directive** 94/9/EU (Products) and 1992/92/EU (Operation) for equipment and protective systems which should be applied in explosive environment
 - Regulation EU 79/2009 of the European Parliament and the European Council in conjunction with regulation EU 406/2010 of the European Commission regulate the **whole vehicle type approval** of hydrogen road vehicles in EU27
- ➔ Regulations and Directives are law and thus mandatory

Conclusions (1)

- Hydrogen can be stored safely under high pressures, in metal hydrides, as cryogenic liquid and in underground salt caverns
- Diffusion, permeation and embrittlement effects of hydrogen in metallic materials are **known since decades** and can be managed by **proper design and materials choice**.
- For composite materials as well practical experience is growing and **allows safe use** of these materials for pressurized hydrogen as well.
- Due to very **stringent approval procedures**, the safe use of hydrogen vehicles in garages and tunnels is regarded as feasible. Ventilation systems for regular use conditions are sufficient. If ventilation systems have to be defined explosion-proof is not finally clear and highly depends on assumed accident scenarios.



ludwig bolkow
systemtechnik



Deutscher Wasserstoff- und
Brennstoffzellen-Verband

Conclusions (2)

- Accident scenarios for hydrogen vehicles (cars, buses) are **not regarded to be more critical than those of conventionally fueled vehicles** (gasoline, LPG, CNG)
- Accident scenarios for hydrogen transport trailers are regarded to be **not more critical** than for other fuels transported, in some aspects they are even less critical
- **More than 200 HRSs** are in use globally with so far excellent safety records
- Continuous scientific research and technical development as well as growing **international harmonization** of regulations and standards simplify, harmonize and adapt the use of hydrogen and fuel cell technologies to every day needs and **enhance overall safety**.
- Finally society decides on the acceptability of risks of a given technology



ludwig bolkow
systemtechnik



Deutscher Wasserstoff- und
Brennstoffzellen-Verband



ludwig bolkow
systemtechnik



Reinhold Wurster Senior Consultant

Ludwig-Bölkow-Systemtechnik GmbH
Daimlerstr. 15
85521 München/Ottobrunn

Tel.: +49/89/608110-31
e-Mail: reinhold.wurster@lbst.de
Web: <http://www.lbst.de>

Dr. Ulrich Schmidtchen Member of the Board

Deutscher Wasserstoff- und
Brennstoffzellen-Verband e.V. (DWV)
Tietzenweg 85/87
12203 Berlin

Tel.: +49/30/398 209 946-0
e-Mail: h2@dwv-info.de
Web: <http://www.h2de.de>

Overview



ludwig bolkow
systemtechnik



Deutscher Wasserstoff- und
Brennstoffzellen-Verband

- Why is Hydrogen Important?
- Part I: How the issue of hydrogen safety moves people
 - General distrust of the unknown and of the not perceptible by the senses
 - Does hydrogen explode?
 - Oxo-hydrogen gas
 - Diffusion of hydrogen
 - Potential to cause embrittlement
 - Safe use of hydrogen vehicles in garages
 - Safety of compressed hydrogen storage vehicle tanks
 - Behavior of hydrogen vehicles in regular use and in accident situations
 - Findings from historical accidents with hydrogen involvement
 - Examples for the safe use of hydrogen in today's life



- Part II: Hydrogen safety – an in depth overview
 - Explosion protection
 - Hydrogen release, diffusion, and permeation
 - Advantages of hydrogen regarding safety
 - Appropriate measures to be taken in case of traffic accidents or in case of hydrogen releases in buildings
 - Role of regulations and standards for the safe everyday use of hydrogen is explained

- Part III: Assessment and Conclusions