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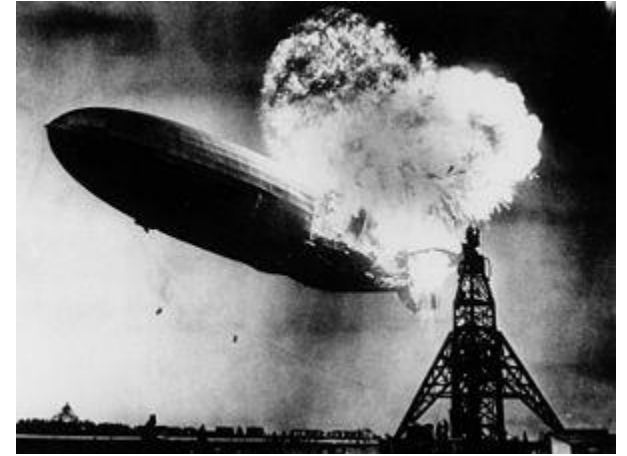
## Is hydrogen safe?

**Rafael Ortiz Cebolla**

*H2 and Fuel Cells in maritime applications  
15-16 June 2017, Valencia - SPAIN*



# Hydrogen perception



# Hydrogen facts

- Millions of tons used annually in Industry since decades
- Infrastructure developed to produce, transport and utilize hydrogen safely
- Like gasoline and natural gas, hydrogen is flammable and can pose a danger under specific conditions
- Hydrogen can be handled safely when simple guidelines are observed and the user has an understanding of its behaviour.

# Hydrogen properties

- *Low ignition energy*
- *High flammability range (4-74% in air)*
- *Wide explosive range (18.3-59% in air)*
- *High stoichiometric mixture (29% in air)*
- *Less radiant heat (compare to hydrocarbons)*
- *Non-toxic and non-poisonous*
- *Odourless, colourless and tasteless*
- *Lowest density and molecular size*
- *High diffusivity*

# Hydrogen properties



*- Low ignition energy*

*It needs ten times less energy to ignite than gasoline or natural gas*

*At low concentrations (<10%) this energy is equal or higher than gasoline or NG*

*- High flammability range (4-74% in air)*

*Much wider range than gasoline or natural gas*

# Hydrogen properties



*- Explosive range (18.3-59% in air)*

*Gasoline can present more potential for danger than hydrogen since the potential for explosion occurs with gasoline at much lower concentrations (1.1-3.3%)*

*- Low density and molecular size and high diffusivity*

*Leaks easily but may also prevent the formation of hydrogen flammable/explosives concentration.*

*Difficult to confine → unless there are ceilings, poor ventilation, structures confining the gas*

*Proper structural design could be enough to have a safe environment*

# Hydrogen properties



*- Odourless, colourless and tasteless*

*Non detectable by human senses*

*Hydrogen sensors to detect leaks*

*Natural gas → Odorants added (typically sulphur based)*

*New methods: tracers, new odorant technology, advanced sensors and others*

# Hydrogen properties



*- High stoichiometric mixture (29% in air)*

*Stoichiometric mixture → easily ignited*

*Difficult to reach such concentration*

*Gasoline 2% and NG 9%*

*- Less radiant heat (compare to hydrocarbons)*

*Less probability of secondary fires*

*Significant impact for the public and rescue workers*

*- Non-toxic and non-poisonous*



# When using hydrogen you want to avoid

## Guidelines in RCS

1- Leak

2- Ignition

3- Explosion

4- Excessive damage



*Prevention:*

- *Materials selection*
- *Sensors location*
- *Ventilation*

*Mitigation:*

- *Structural design*
- *First responders*

# Current RCS could not be sufficient

- *New applications of hydrogen technologies (road transport, maritime applications, power-to-gas) bring new scenarios*
- *RCS need to be updated to include guidelines for these new scenarios*
- *Several regulatory gaps identified in RCS for maritime applications*

# Hydrogen incidents/accidents databases

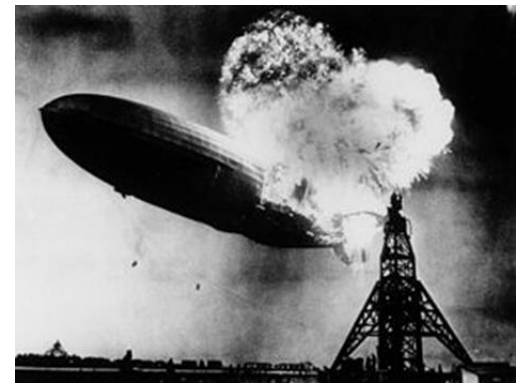
*Databases where events of different severity involving hydrogen are reported*

*They help to understand potential dangers in many different scenarios*

*DOE - <https://h2tools.org/>*

*JRC (HySafe)- <https://odin.jrc.ec.europa.eu/giada/>*

# Hindenburg Facts



- *Zeppelin designed for Helium*
- *US stopped Helium supply to Germany → Hydrogen*
- *Hydrogen was blamed for the disaster*
- *Fabric envelope was coated with reactive chemicals, similar to rocket fuel. Easily ignitable by an electrical discharge (mooring rope)*

# Alsterwasser Facts



- *Fire on on-board batteries due to overheating*
- *Vessel heavily damaged*
- *Bad reputation for hydrogen technologies ?*

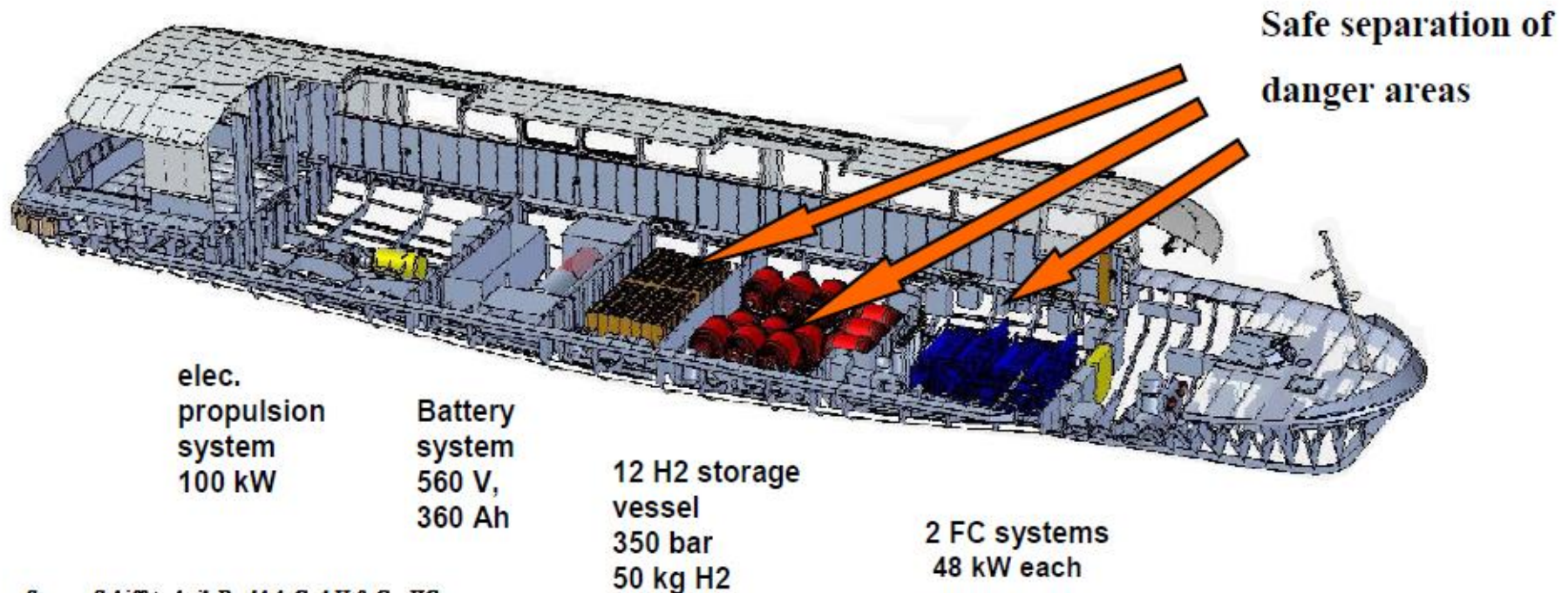


# Alsterwasser Facts

- *No people were endangered or injured*
- *Neither the fuel cell nor the hydrogen caused the incident*
- *The safety system puts the fuel cell and the hydrogen storage vessel in a safe state before the fire developed,*
- *Neither the fuel cell system nor the hydrogen storage was damaged or endangered*

# Alsterwasser Facts

- *Safety concept based on guidelines of Germanischer Lloyd*
- *Fire temperatures melted aluminium furniture in passenger area, but in H2 storage room temperatures where not higher than in a warm summer day*



# Conclusions

## **Fact:**

*Hydrogen technologies, as any other technology using combustible gas or liquid/solid fuels, are potentially dangerous*

## **But:**

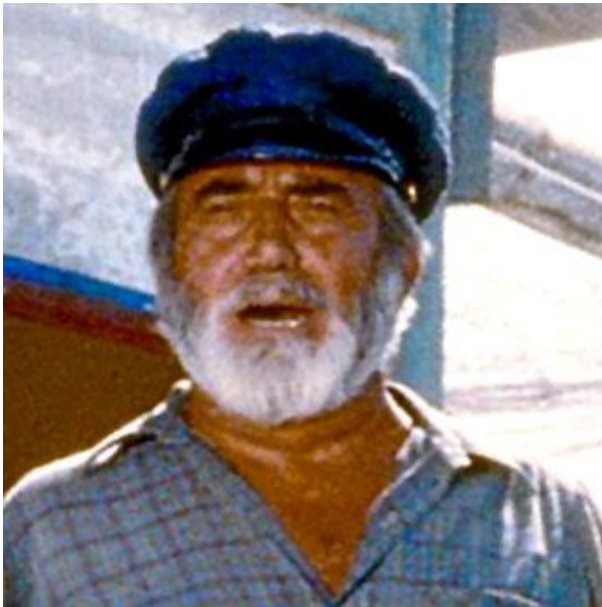
*Guidelines given by RCS have proven that increase their safety*

## **However:**

*New applications bring new scenarios that require specific guidelines*



# Thank you very much for your attention



**4 out of 4 sailors feel safe using H2 for maritime applications  
(after this presentation)**

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