

# H<sub>2</sub> and Fuel Cells for Maritime and Port Application

Workshop 15. - 16. June 2017, València, España

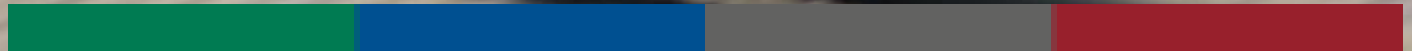


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2. Our Activities / Product Portfolio / References
3. Maritime Application – the FCS Alsterwasser
  - Concept
  - Planning & Realisation
  - Fuel Cell & H<sub>2</sub>-Components
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# Proton Motor at a glance...

## PM staff & infrastructure:

- Currently >70 Employees  
*(40 % Development/Engineering, 25 % Production, 25 % Sales and Service, 10 % IT & Administration)*
- Total Area: > 6'000 m<sup>2</sup> in 3 buildings
- Hydrogen Infrastructure: 75 m<sup>3</sup> / 40 bar storage tank
- Capability to feed-in produced power into the grid
- Charging station for electric vehicles (powered by own test facility)

## Manufacturing capacity:

- 300 Stacks p.a.
- 200 Systems p.a.
- Commissioning and FAT infrastructure for 4 stacks
- Commissioning and FAT infrastructure for 2 systems
- Mechanical workshop / Prototype construction

## Testing capacity (24/7):

- 8 Stack test benches (proprietary)
- 6 Outdoor system test facilities
- 3 Component test benches
- Cooling chamber for frost testing
- Test lab for material testing / AST



# Milestones at Proton Motor



Start of first fuel cell development activities at Magnet Motor



World's first 'Triple Hybrid Fork Lift



EPS System in Bachhausen



Surf'n'Turf Container at the Orkneys, Scotland



Bayernbus in Operation



World's first 'Triple Hybrid City Bus'

Cooperation with the  
**DB**  
*Bahnau Gruppe*

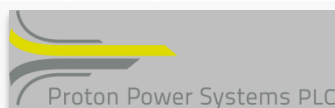
1994 1998 2004 2006 2007 2008 2009 2010 2011 2012 2015 2016 2017

Foundation of



ZEMShip 'Alsterwasser' in Operation (HH)

Merger with



Launch of *Proton Power Systems PLC* at the LSE



Street approval of Newton with HyRange®



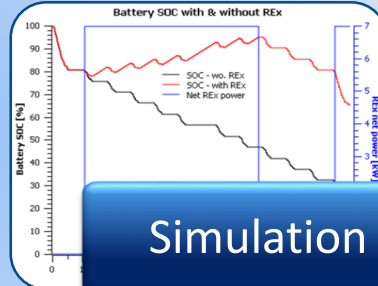
Presentation of the FCREEV van

# PM Core Competences

## Feasibility studies



Development



Simulation



Engineering

## (Serial-)Manufacturing



Stack Production



System Production



FAT



Integration



Comissioning



Service

# CLEANTECH Power Supply



**CLEANTECH COMPETENCE**

## Stack Technology

### LT-PEM Stacks

- PM200
- PM400

Power ranges:  
2 ... 30 kW<sub>elect</sub>

## Fuel Cell Systems

### PM Module

- 19" Rack
- S5-Family: 2 ... 6 kW
- S25: 10 ... 25 kW

### PM Cube

Cabinet solution for one or more 19" Modules  
(for both stack formats)

### HyRange®

Mobile Systems  
Power range:  
9 ... 30 kW

## Energy Solutions

### Containerized stationary Solutions

- Indoor & Outdoor

### Energy supply / Drive trains

for:

- City busses
- LCV
- Boats and Ships

# Product HyRange<sup>®</sup>25

## HyRange<sup>®</sup>25 (powered by PM400)

### Stack Module



Weight: 95 kg  
Volume: 167 L

### Air Module



Weight: 44 kg  
Volume: 163 L

### Cooling Module



Weight: 15 kg  
Volume: 58 L

Nominal power	25 kW
Power Range	4 ... 30 kW
Output current	50 ... 500 A DC

Output voltage	50 ... 110 V DC
Ambient Temperature	-30 °C ... + 55 °C
Common Interface	CAN v2.0A



## Reference II - Stationary Maritime Application



### Surf'n'Turf project at the Orkney's (UK)

- Clean Energy solution with wind and tidal power combined with FC and electrolyser
- Electrical energy supply on demand for ships and load at Kirkwall Harbour facilities
- Additionally designated as training center for maritime fuel cell applications
- PM Container with 75 kW net FC power output (powered by three HyRange®25 systems)
- Utilisation of FC exhaust heat for building heating
- Partners: OIC, EMEC, EDAY RE, ITM Power, Arcola Energy, Proton Motor



# Maritime Customer Application: FCS Alsterwasser



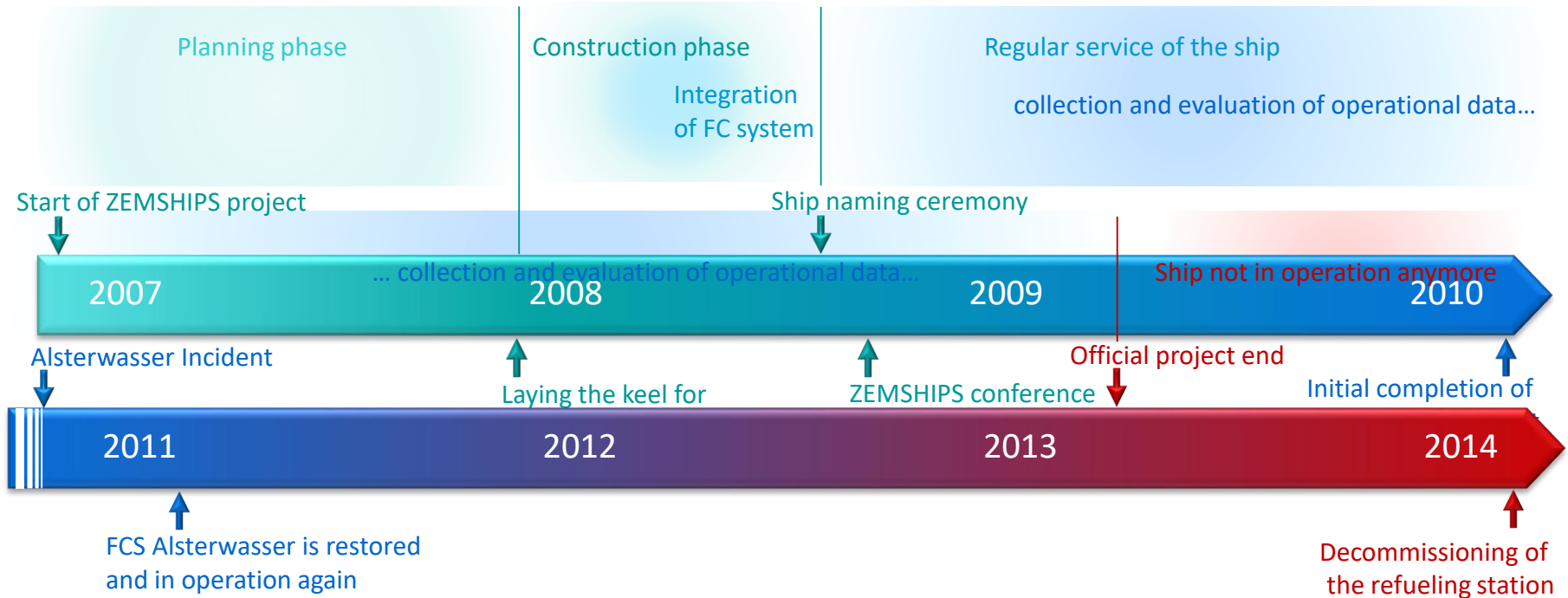
## ZEMSHIPS Project, Hamburg

- Zero Emission Fuel Cell Ship
- Capacity for approx. 100 passengers
- ZEMSHIPS project partner: ATG, Linde, German Lloyd, Stadt Hamburg, Proton Motor
- Proton Motor was responsible for the complete propulsion system of the ship
- In use since summer 2008 → in approx. 4'000 operating hours more than 50'000 passengers were transported (01/2014)
- 1.7 kg hydrogen consumption per operation hour

# ZEMSHIPS Consortium Partners



# ZEMSHIPS Timeline



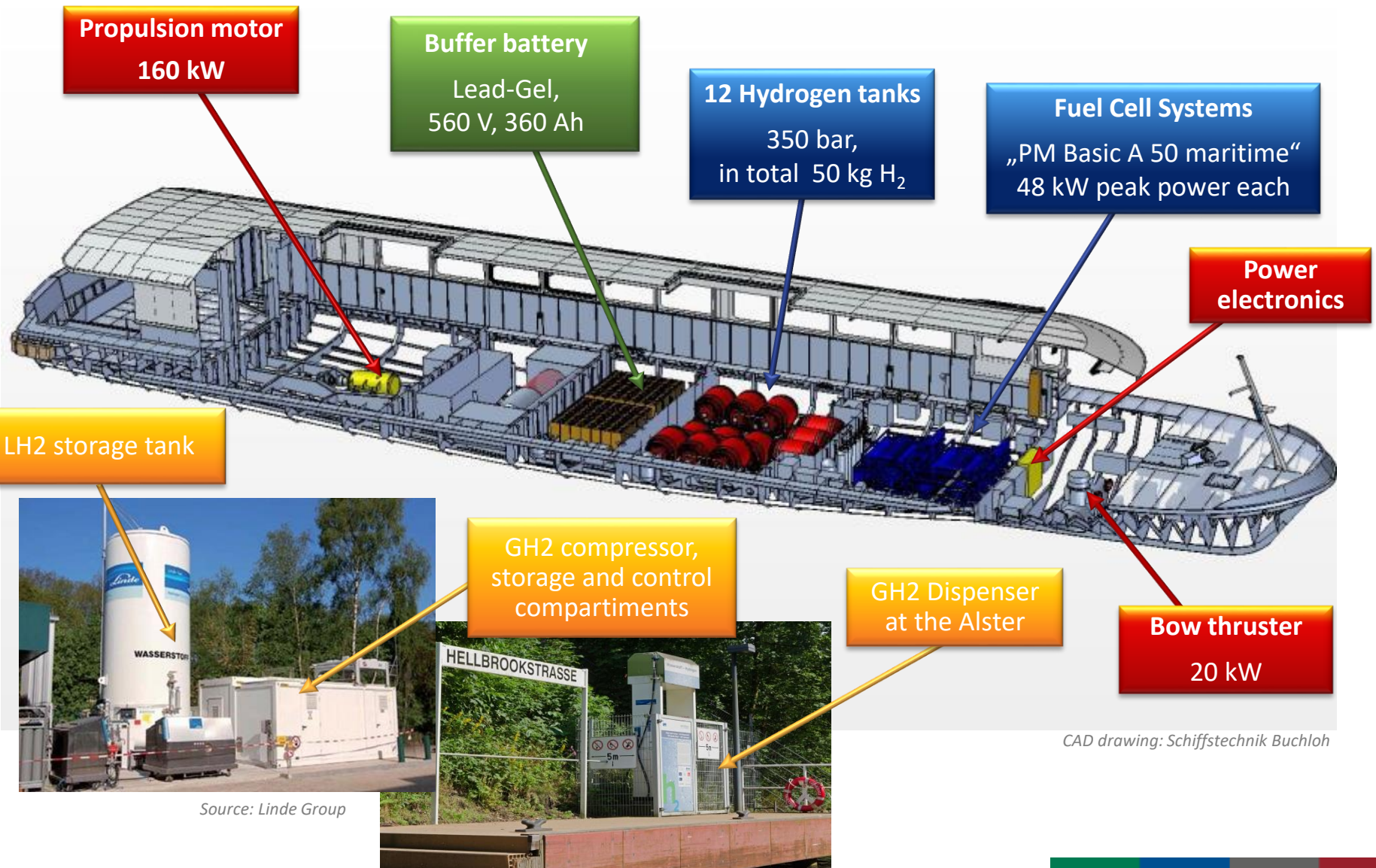


# Alsterwasser Technical Data

Specification of the ship	
Length over all	25.46 m
Width of body	5.36 m
Height over waterline	2.65 m (2.30 m with roof lowering device)
Tonnage displacement	72 to. (fully loaded)
Draft with passengers	1.33 m
Max. cruising speed	15 km/h (8 kn)

Propulsion system	
Fuel cell type	LT-PEM PM Basic
Fuel cell peak power	48 kW
Max. system efficiency	>50 %
FC operating temperature	<70 °C
Total weight of the FC system	Ca. 500
Refuelling intervals	2 to 3 days

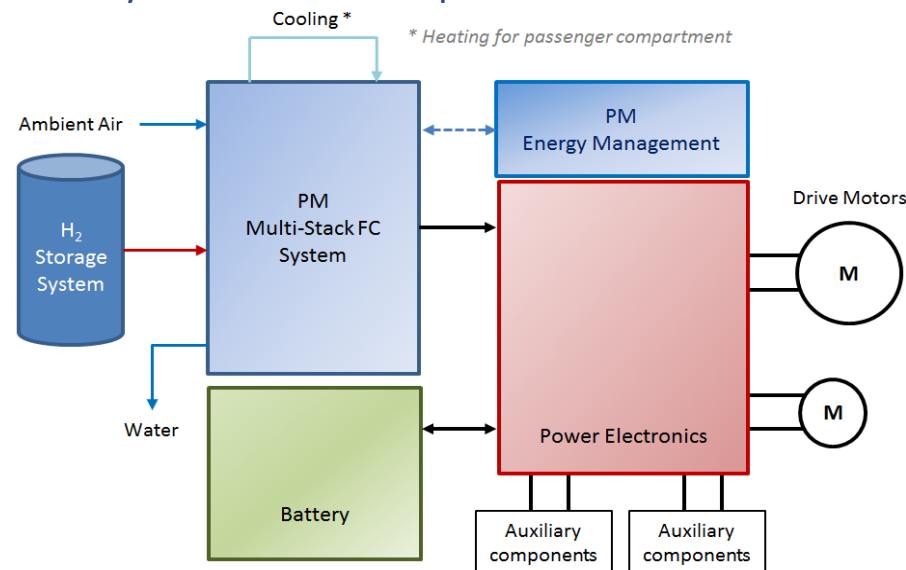
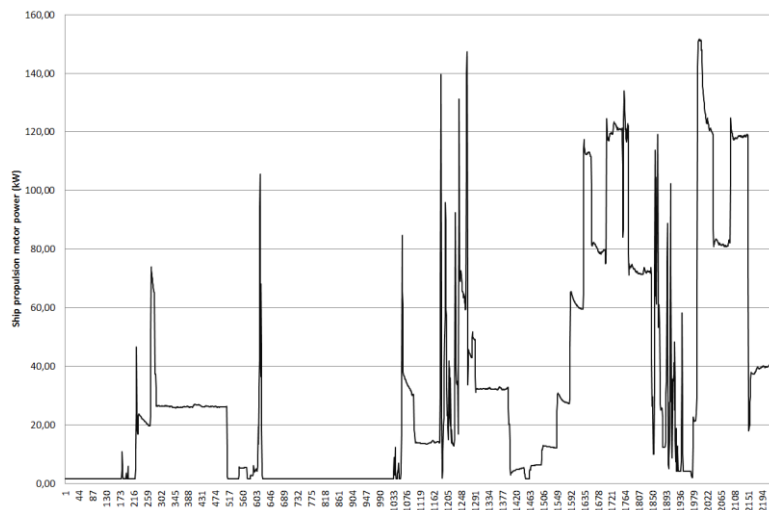
# Ship Layout



Source: Linde Group

# Hybrid Setup & Power Management

- Determine the real power demands as the basis for the hybridisation concept



Area of Operation	1 <sup>st</sup> Fuel Cell System	2 <sup>nd</sup> Fuel Cell System	Battery
Alster	Base load (20 - 25 kW)	Turned off Backup for first FC system	Provides peak load, serves as buffer; backup for safe return in case of failure of both FC systems
Alster-Canals	Base load (10 - 20 kW)	Turned off Backup for first FC system	Provides peak load, serves as buffer; backup for safe return in case of failure of both FC systems
Fleete	Main load (10 - 40 kW)	Provides additional power (if required)	Provides peak load, serves as buffer; backup for safe return in case of failure of both FC systems
Elb	Main load (25 - 40 kW)	Provides additional power (if required)	Provides peak load, serves as buffer; backup for safe return in case of failure of both FC systems



# Assemblies FC System

## H<sub>2</sub> Refill System

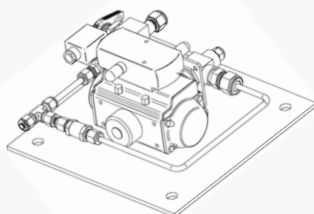
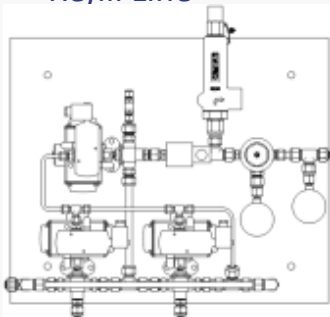


## H<sub>2</sub> Storage / N<sub>2</sub> Storage



## Double Block and Bleed H<sub>2</sub>

### Refill Line



### Midpressure Line

## FC Power Pack



# Components Electric Power System

## Man-Machine-Interface



- System information for captain
- Emergency button
- Battery information (SOC, voltage, temperature)
- Gas storage information (gas contained in tank)
- FC information (FC power, failure notice, system status)



## Traction / Buffer Battery



- Closed gel battery (Lead Acid)
- 7 Battery blocks (40 cells)
- Total of 280 cells
- Voltage DC link:  
 $7 \times 80 \text{ VDC} = 560 \text{ VDC}$

## DC/DC Converter



- Input voltage range:  
10 - 730 V
- Max. input current: 350 A
- Voltage DC link:  
up to 750 VDC
- Cooling: liquid cooled

# Safety Concept – Theroretical Basis

## PACKAGING AND SYSTEM LAYOUT

### Avoiding H<sub>2</sub> Leakage

- Welding instead of screwing
- Depressurizing high and mid pressure pipes if not in use
- Inerting mid and low pressure pipes if not in use
- Double-walled pipes

### Ex-Zone Concept

- Sectional classification in ship
- Forced air ventilation of areas with possibility of H<sub>2</sub> leakage
- Monitoring gas concentration

### CONTROL

#### Micro Controller and CVMU's

- Keep system in normal parameters
- Normal shut-down if first level switching points are reached
- Prevent system from getting damaged
- Prevent hydrogen from leaving the system

### SAFETY CIRCUIT

#### Hard Wired Safety Circuit

- Switches for temperature, pressure and flow
- Emergency shut-down if switching points are reached
- Preventing system from getting damaged
- Preventing hydrogen from leaving the system

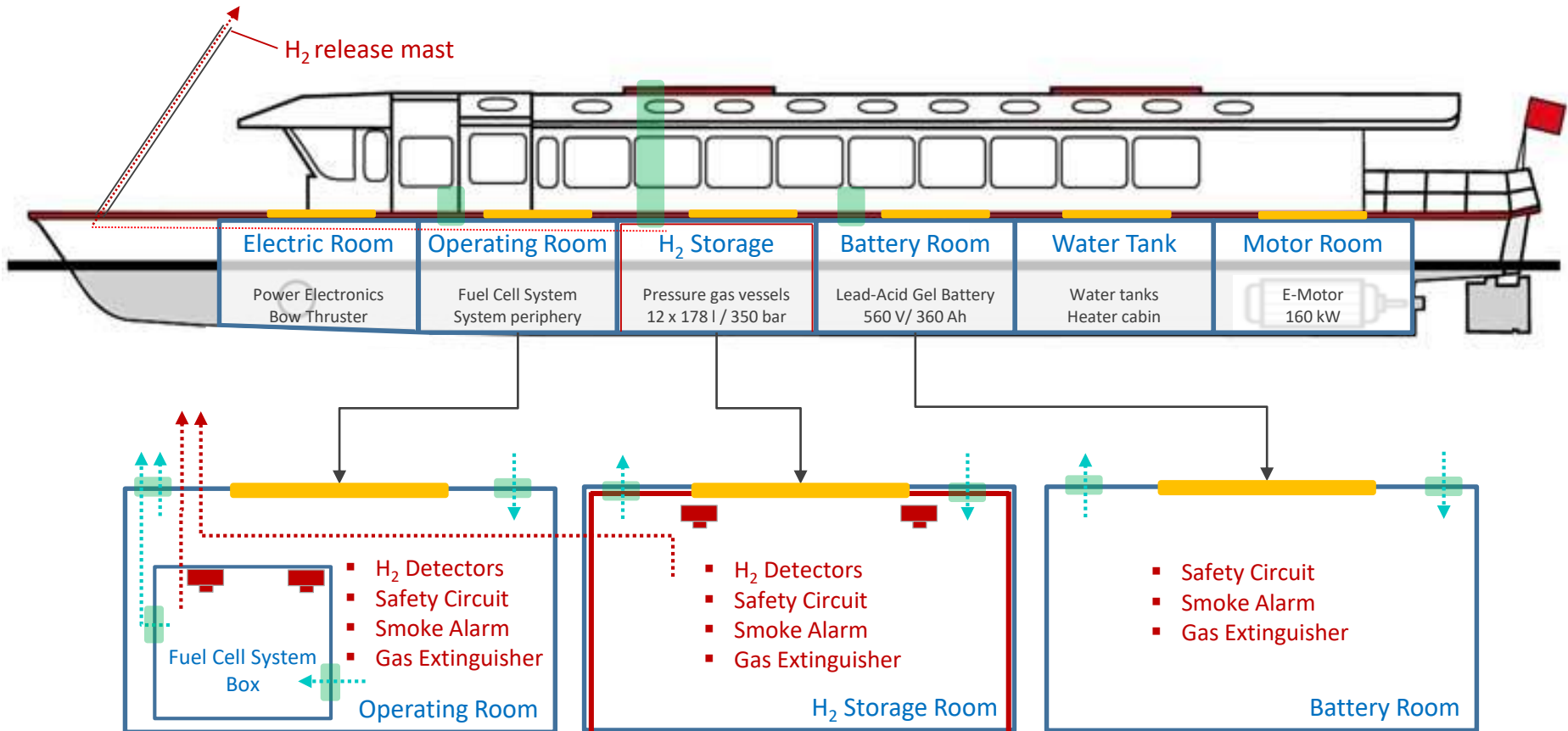
### PRD's

#### Pressure Relief Devices

- Safety valves
- Melting fuses
- Preventing the system from getting damaged
- Releasing hydrogen to environment if set pressure points or temperatures of melting fuse are reached



# Safety Concept – Realization in the Ship



# The 'Alterwasser-Incident'

## Fire on board of FCS ALSTERWASSER

- No injured or dead people!
- The safety concept was working properly without any limitation
- Neither fuel cell system nor H<sub>2</sub> were responsible for the fire
- Cause was a wrong battery installation by an external battery company
- The Fuel Cell System was brought in a safe state by the safety system as soon as the fire spread rapidly
- Despite the massive damage by the fire, there was no damage to the fuel cell system and the hydrogen storage!



No damage to or from the fuel cell or the hydrogen storage!



Source: F. Vogler,  
GL - Germanischer Lloyd  
4<sup>th</sup> ICHS Conference, 2011

- R & D in the field of fuel cell technology and energy solutions
- Consulting, market and feasibility studies
- As a partner in national and European (funding) projects
- Simulation, design and hybridization strategies for drive trains and energy supply
- Design and engineering and of complete fuel cell-based energy solutions
- Test and validation of system components
- Prototyping and serial production of Fuel Cell Systems
- Project management for energy solutions
- Training for customers and users, 24/7 service



Thank you for your attention!



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