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Hydrogen – Pressure Relief in Highly Dynamic Systems

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EUROPEAN CONFERENCE ON PLANT & PROCESS SAFETY 2022


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Introduction to REMBE®

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REMBE® - Your Specialist for

Explosion Safety Concepts

Pressure Relief Solutions

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Our Route to You!

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02 **REMBE**® Asia Pacific Pte. Ltd. | Singapore
03 **REMBE**® Bangkok Ltd. | Bangkok, Thailand
04 **REMBE**® China Ltd. | Shanghai, China
05 **REMBE**® GmbH Safety+Control | Brilon, Germany
06 **REMBE**® GmbH Safety+Control (DMCC Branch) | Dubai, United Arab Emirates
07 **REMBE**® Inc. | Fort Mill, SC, USA
08 **REMBE**® K.K. | Yokohama, Japan
09 **REMBE**® Oy | Helsinki, Finland
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REMBE® Alliance

REMBE® GmbH Safety+Control
REMBE® Kersting GmbH
REMBE® Fibre Force GmbH
REMBE® Research+Technology Center GmbH
REMBE® Advanced Services+Solutions GmbH

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Active participation on improving industrial safety standards.

Member of international standardisation boards and committees

VDMA | German Engineering Federation
CEN | Committee European for Norms
NFPA | National Fire Protection Association
IND EX® | International Association of Experts for Industrial Explosion Protection
CSE Institute | Center of Safety Excellence
VDI | Association of German Engineers
VDSI | Association for Safety, Health and Environmental Protection at Work
EHEDG | European Hygienic Engineering & Design Group
IFF | International Research Institute of Feed Technology
vfdb | German Fire Protection Association

MHEA | Materials Handling Engineers Association
FSA | Farm Service Agency of US Department of Agriculture
USDA | United States Department of Agriculture
DSIV | German Association of Bulk Industries
DIERS | Design Institute for Emergency Relief Systems
EIC | Energy Industries Council
VGB PowerTech | European technical association for power and heat generation
WJI | Wilhelm Jost Institute for physical and chemical engineering
ESMG | European Safety Management Group
DMRC | Direct Manufacturing Research Center

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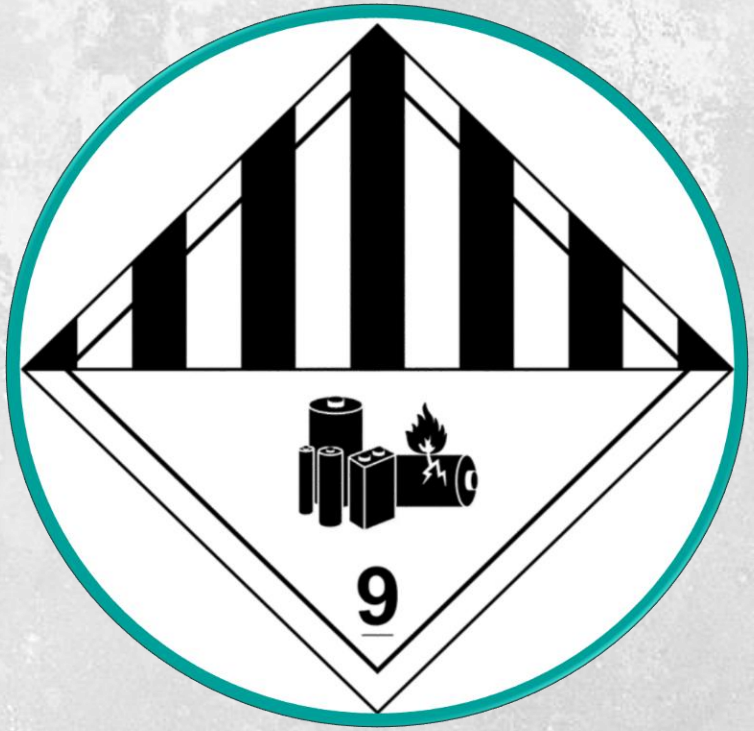
REMBE® and Renewables?

Quelle: www.dvgw-wasserstoff.de



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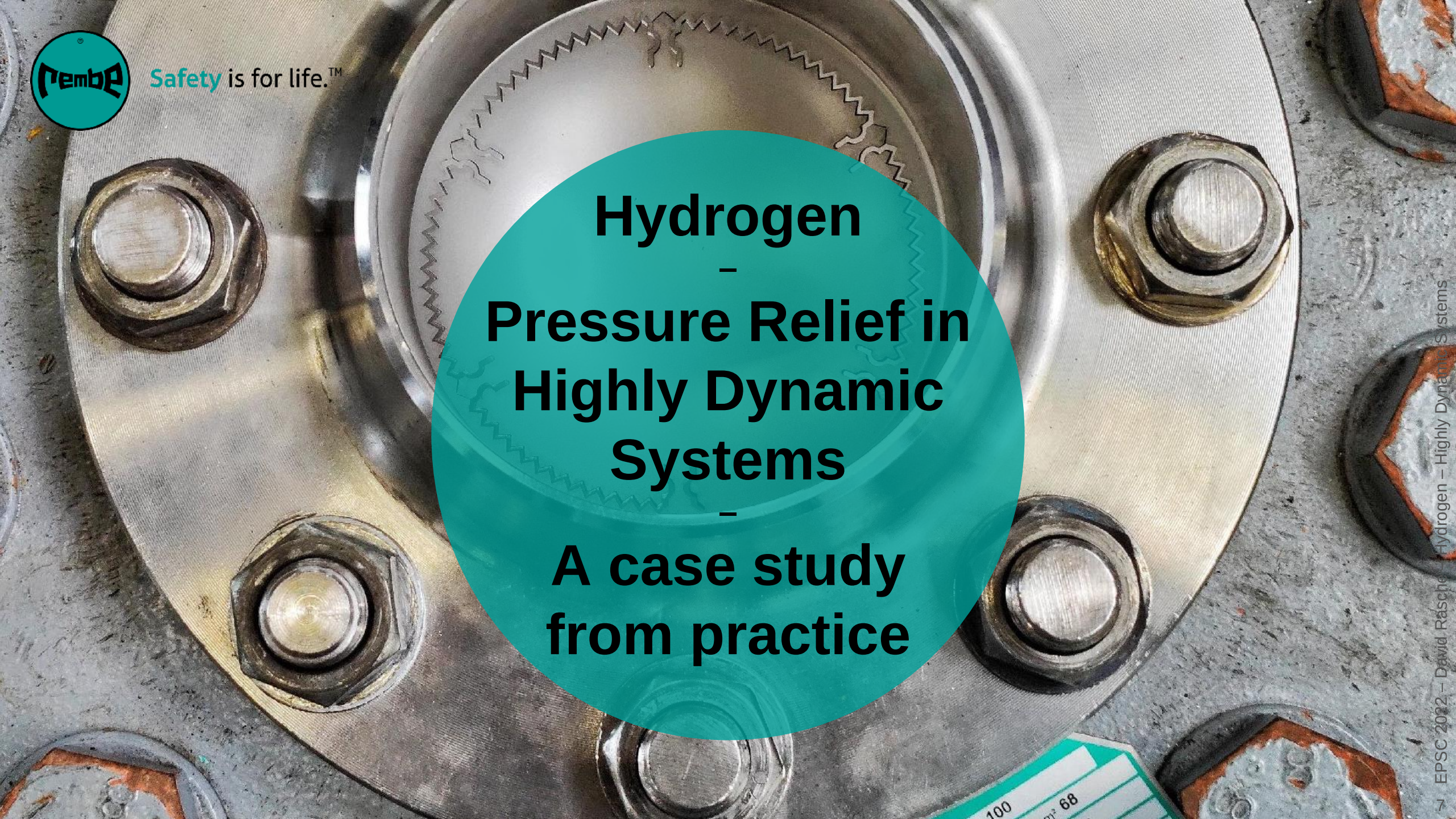
Hydrogen
–
Pressure Relief in Highly Dynamic Systems
–
A case study from practice



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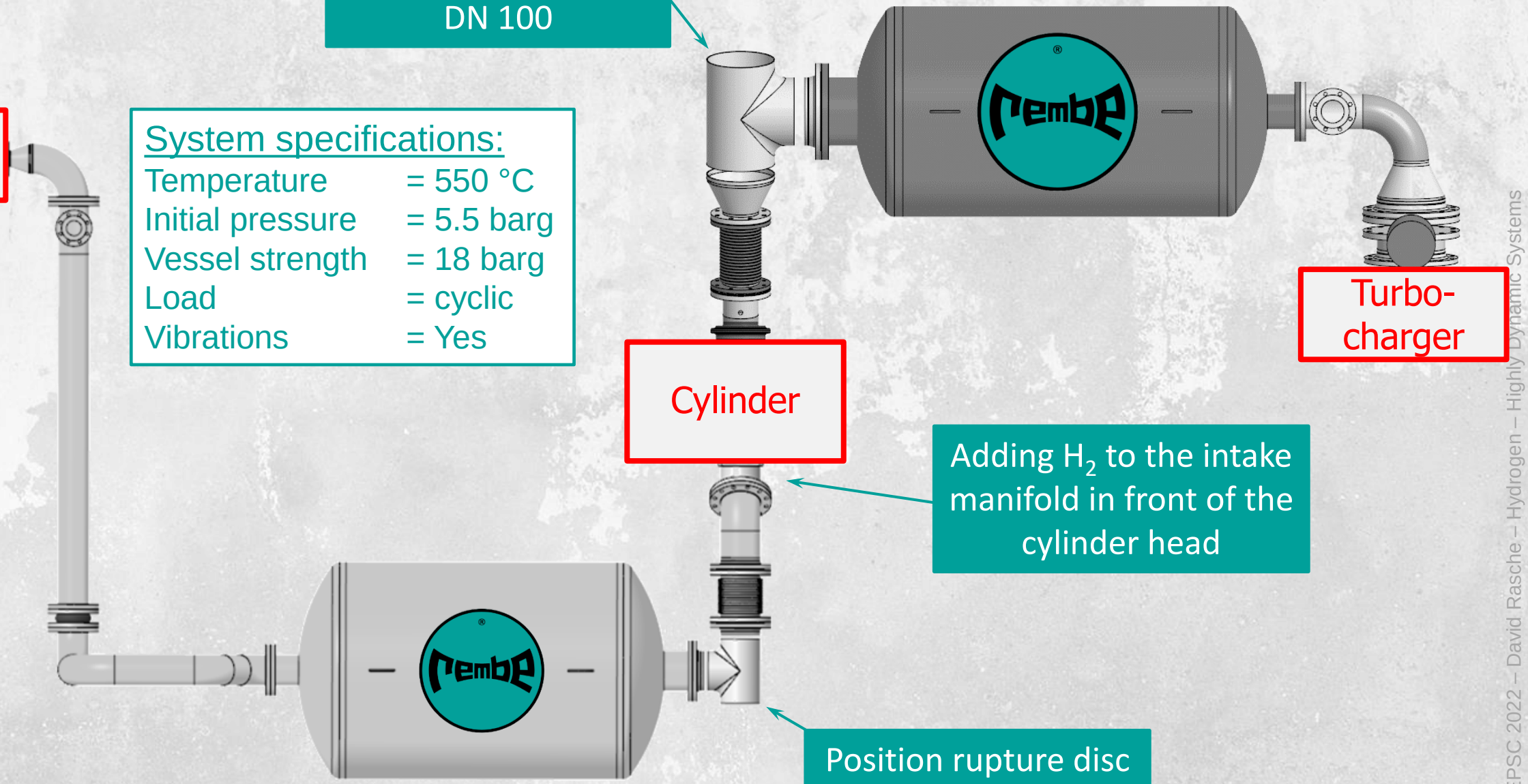
Process diagram

Position rupture disc
DN 100

Turbo-
charger



System specifications:

Temperature	= 550 °C
Initial pressure	= 5.5 barg
Vessel strength	= 18 barg
Load	= cyclic
Vibrations	= Yes

Turbo-
charger

Cylinder

Adding H_2 to the intake manifold in front of the cylinder head

Position rupture disc
DN 100

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Challenge

Changing over from methane to hydrogen operation

		Methane	Hydrogen
LEL	Vol-%	4.4	4.0
UEL	Vol-%	17.0	77.0
LOC	Vol-%	9.9	4.3
MIE	mJ	0.23	0.017
Calorific value	/ kWh/kg	13,9	33,3
Calorific value	/ kWh/m³	9,94	3,00
Stoichiometry	/ Vol %	9,46	29,55
Flame temperature	/ °C	1970	2130
K_G	/ bar m s^{-1}	68,4	>550
max. lam. flame speed	/ cm s^{-1}	43	346
max. expl. pressure	/ bar	8,2	8

- Mixture composition and precompression influence energy content significantly!
- Much faster pressure rise expected.
- Stronger tendency towards detonative transition
- **Explosion under pre-compression!**

~~DIN EN 14994 ?~~ ~~DIN EN ISO 4126 ??~~ ~~NFPA 68 ???~~

Finding: No secured design parameters!

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Challenge

Summery of identified issues

- How does the system react, including pressure relief devices?
- There is currently no "valid" normative basis for gas explosions under pre-compression.
- DIN EN 14994 so far only provides for atmospheric conditions. (The group is working on 3 different new models here.)
- How does the geometry affect the flame speed? →DDT

→ **Extremely dynamic system**

Question: Under what conditions can the system be operated with the existing safety concept?

Approach: Experimental validation of the protection concept!

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REMBE® RTC

Centre for explosion testing and battery safety
Accreditation in acc. with DIN EN ISO / IEC 17025:2018

RTC offers large scale:

- Explosion testing
- Fire tests
- Test on electrical (arc-) fault events
- Pressure testing
- Li-Ion testing
- Functional safety studies

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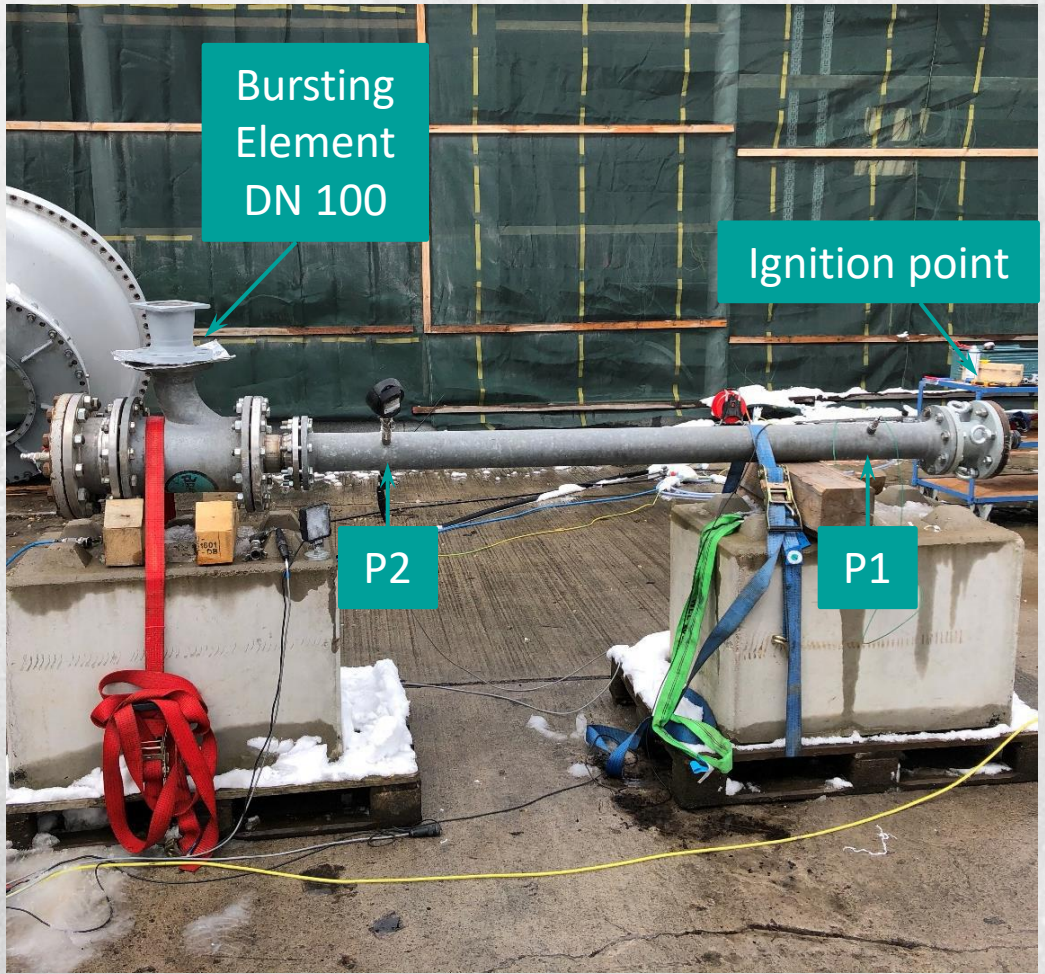
Approach

Experimental validation of the safety concept



Validation $p_{red} < p_{max}$

- Geometric reproduction of the exhaust section
- Volume, l/D and RD position close to reality
- Reference experiment CH_4
- Try different mixtures of H_2-Air to find safe working conditions
- Static ignition

→ Goal: Determination p_{red}

Video of the Experiment

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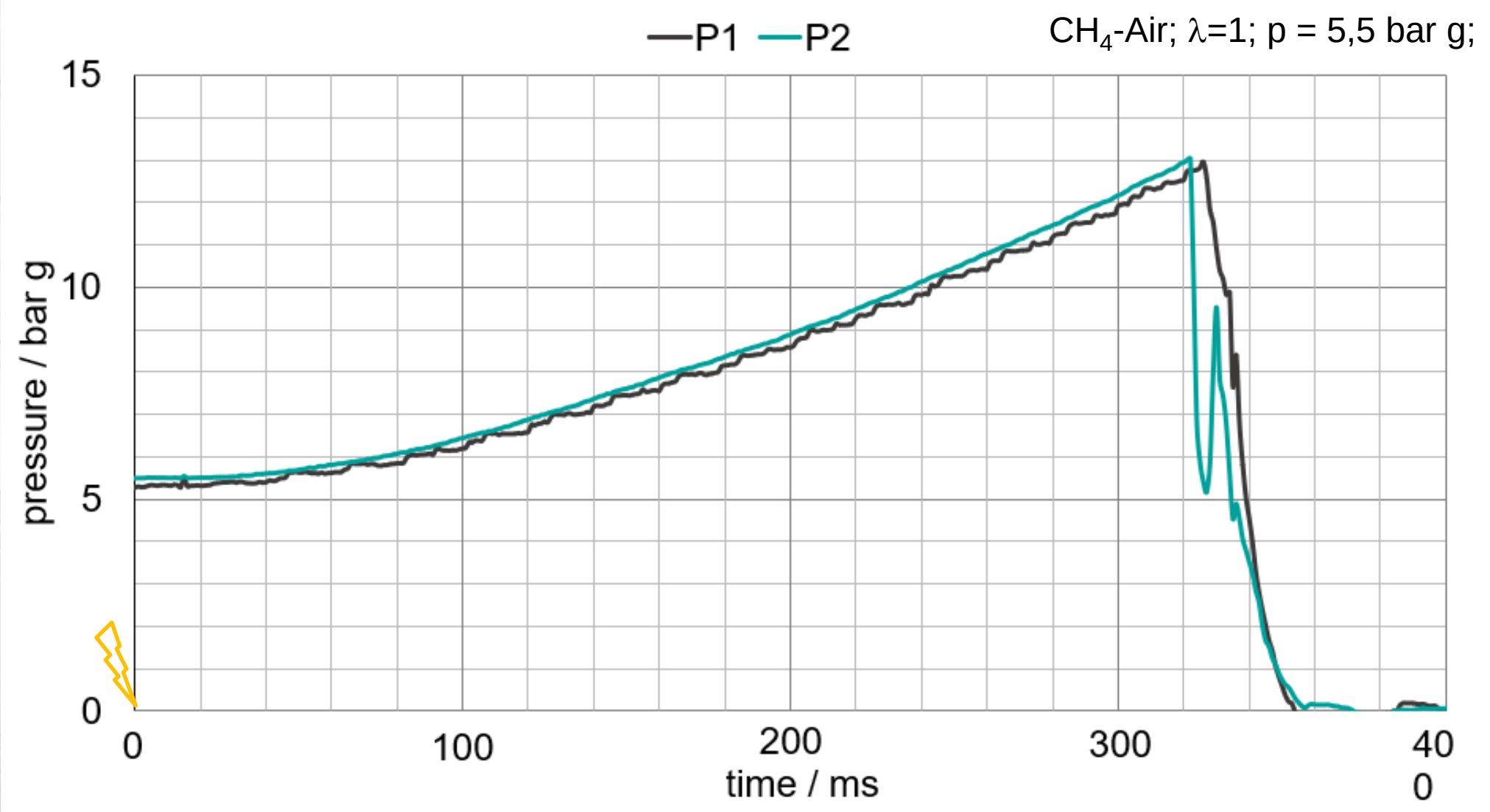

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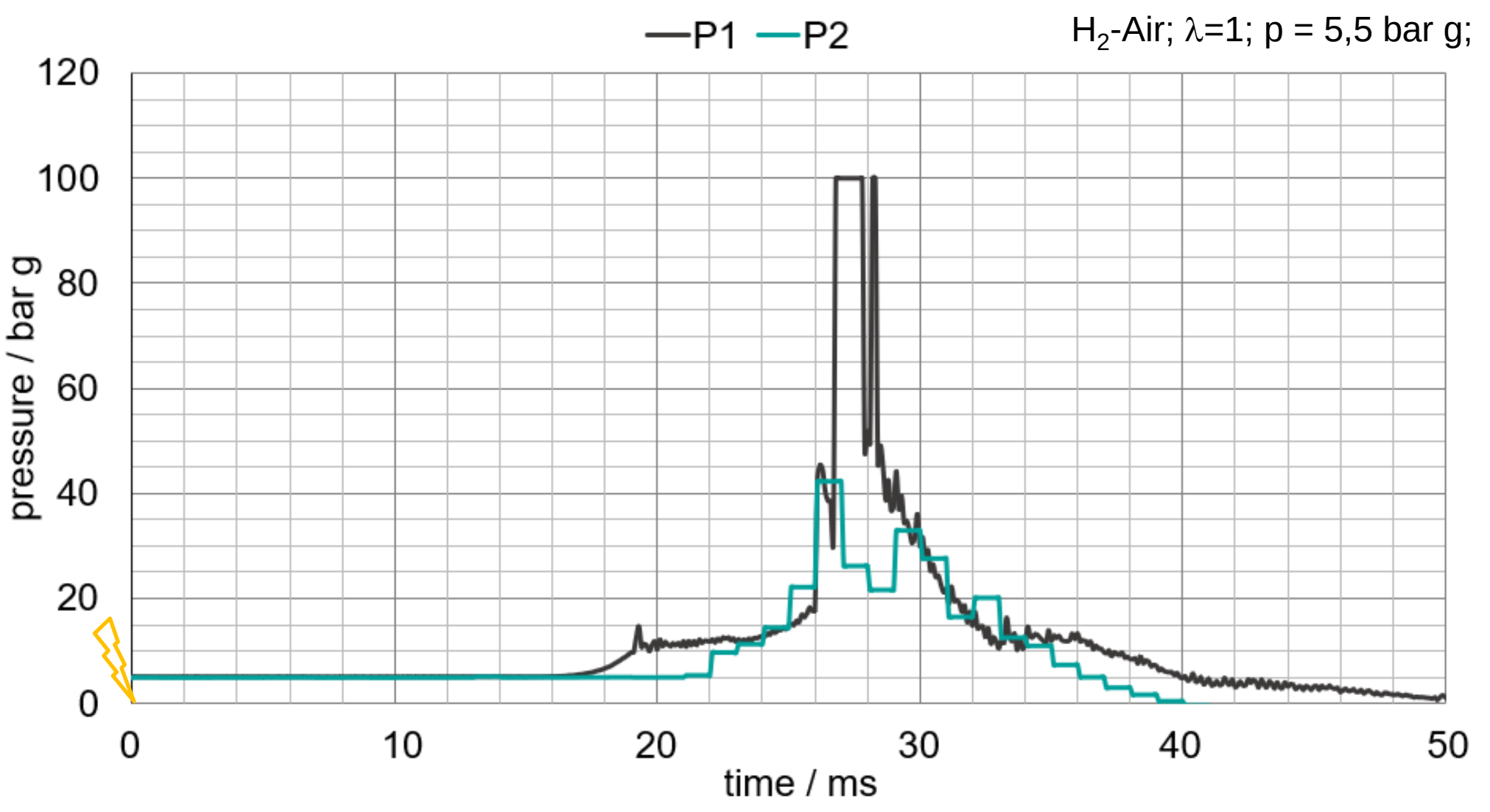

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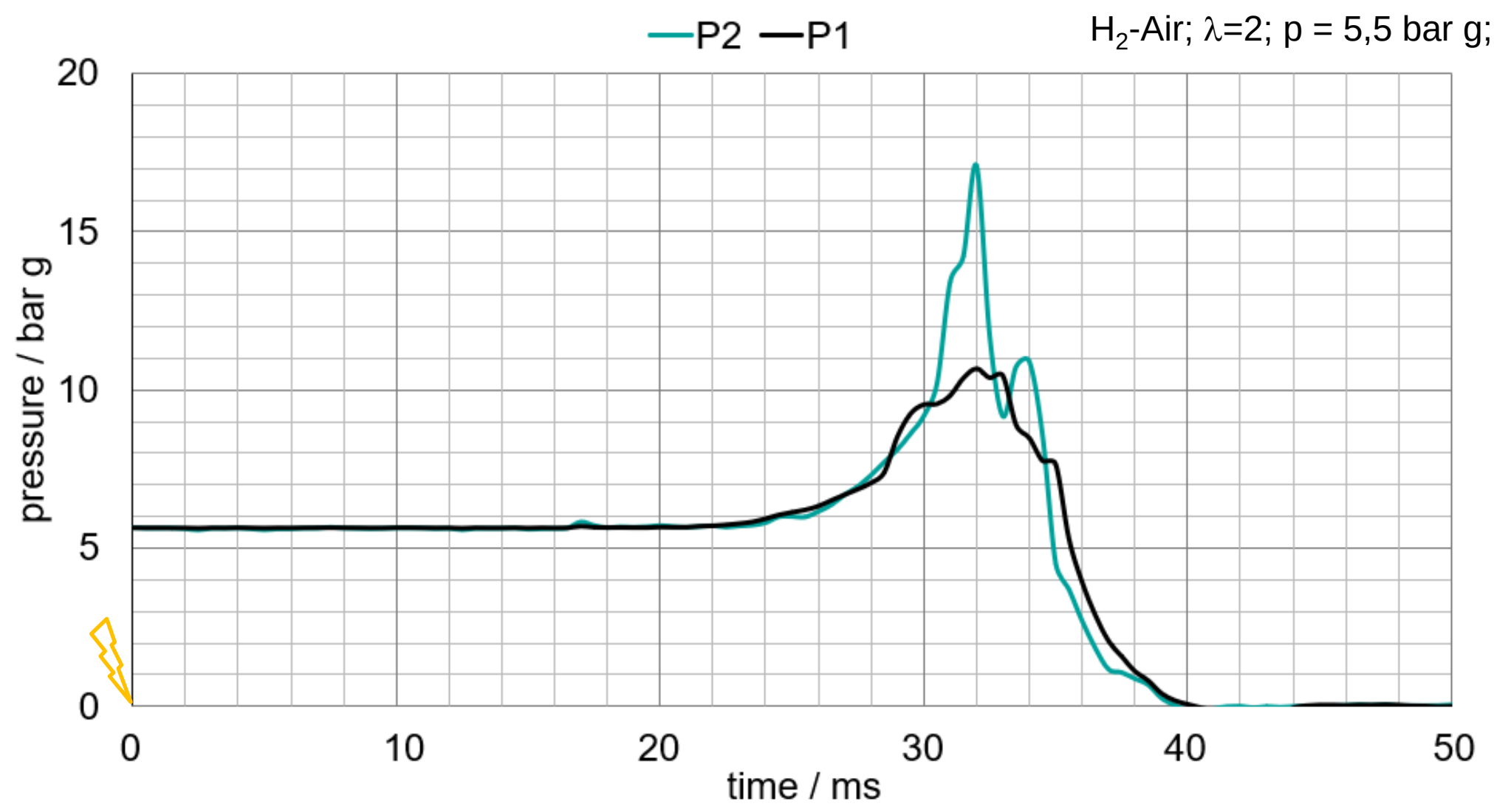

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Validation Results

Expected finding:

Do not carelessly substitute / blend CH_4 with H_2!

- $\lambda = 1$ cannot be realised with the present relief concept.
- Maximum pressure clearly exceeded, indications of starting or ongoing detonation
- For $\lambda > 2$, p_{max} is acceptable; Recommendation: Operation at $\lambda = 3$
- **Rupture discs suitable for relieving H_2 gas explosions.**

Side-Topic: Is Flameless Venting possible for H_2-Air explosions?

→ The experiment proves that it is possible under certain boundary conditions. Especially valuable in the maritime sector.

Video of the Experiment

Video of the Experiment

No flames. No thermal damage to the indicators.

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Summary & Conclusion

- "New" energy systems also bring "new" challenges in pressure relief.
- The dynamics of hydrogen explosions (especially under pre-pressure) are difficult to predict, even with experimental validation.
- Pressure relief via rupture discs works, even flameless.
- A wider awareness of the safety risks of these "new" technologies must be created.
- **The normative bases / codes & standards must be improved, and more complex models must be set up.**
- **Safety aspects limit the application of hydrogen in the context of the energy transition.**

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Thank you for your Attention

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