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LIGHTWEIGHT CFRP NITROGEN VESSELS ENABLING EFFICIENT HALON REPLACEMENT SOLUTIONS

THE TENTH TRIENNIAL INTERNATIONAL AIRCRAFT FIRE AND CABIN SAFETY RESEARCH CONFERENCE
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OVERVIEW

1 Lightweight Vessels as Enabler for Nitrogen Based Halon replacement - Motivation

2 Introduction to Lightweight Vessels

3 Novel Vessel & Valve Prototyping

4 Conclusions

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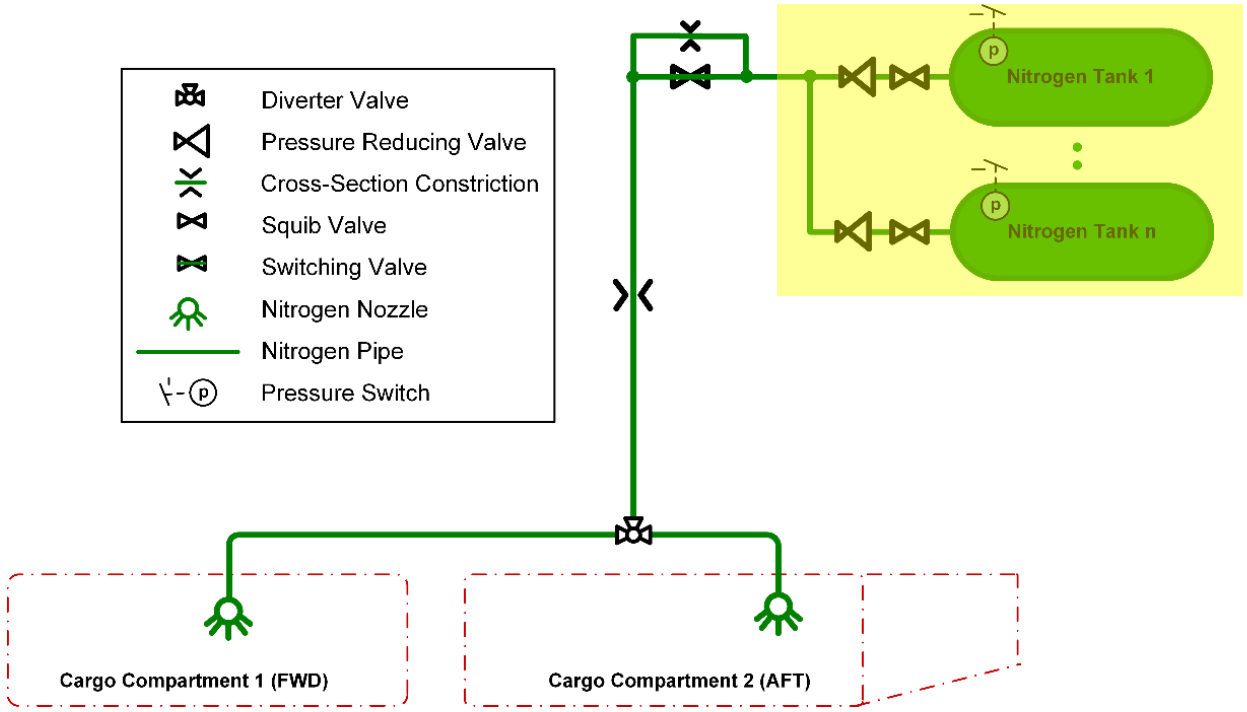
LIGHTWEIGHT VESSELS AS ENABLER FOR NITROGEN BASED HALON REPLACEMENT

BACKGROUND

Green Fire Suppression Halon Replacement based on Nitrogen



Principle of Fire Suppression:

Phase 1: "Knock-Down":

- Displacement of Oxygen by Nitrogen
- Cooling effect due to gas expansion

Phase 2: Long-term Suppression:

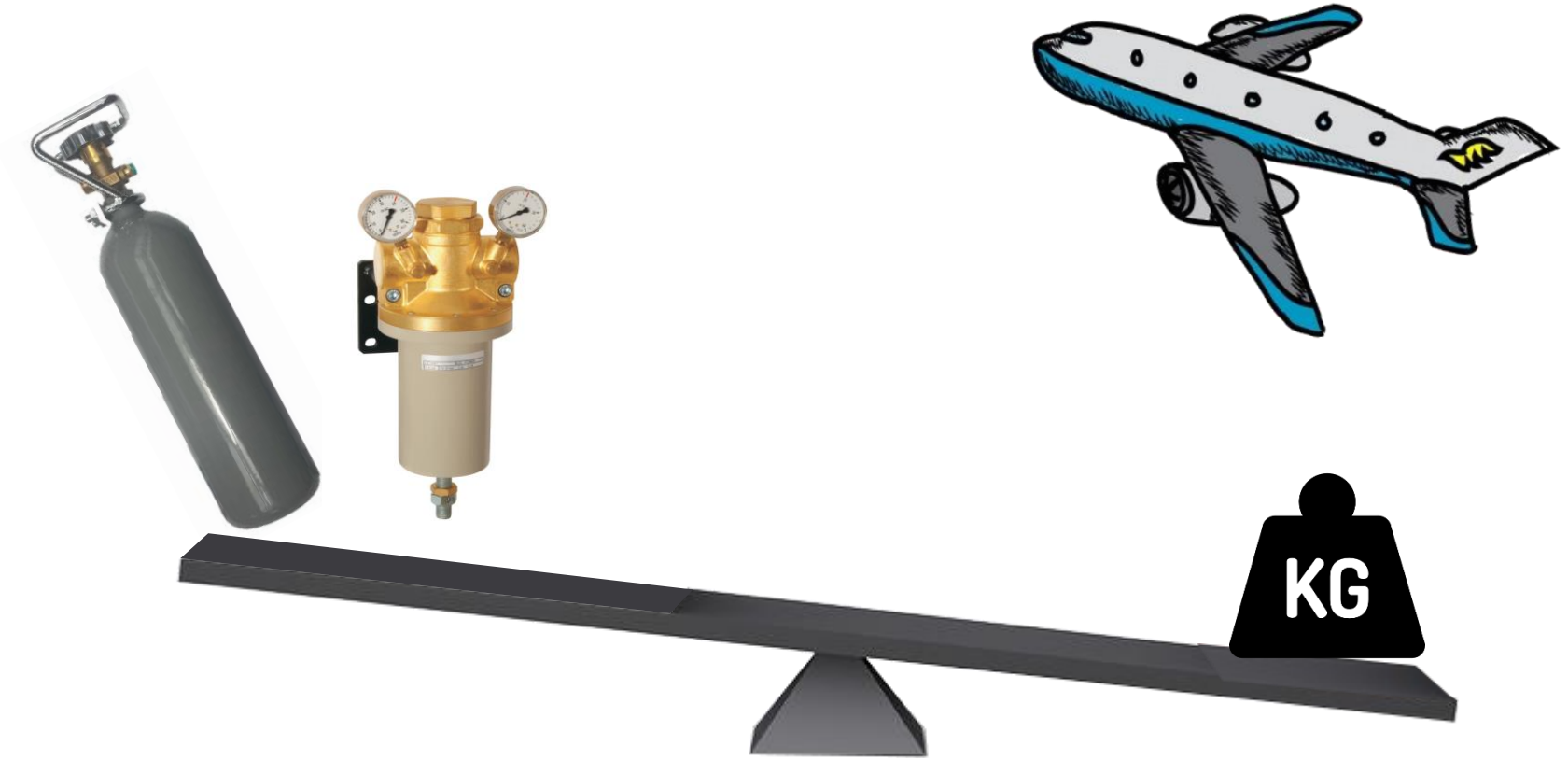
- Maintaining an Oxygen depleted atmosphere to prevent fire from flare up

Key System components:

- Nitrogen Distribution
  - Nozzles
  - Diverter und Squib Valves
  - Piping
- Nitrogen vessel
  - long term storage at > 344 bar
  - Constant pressure supply at high flow rates
  - Monitoring functions

MOTIVATION

Lightweight Storage is Key for Competitive System!



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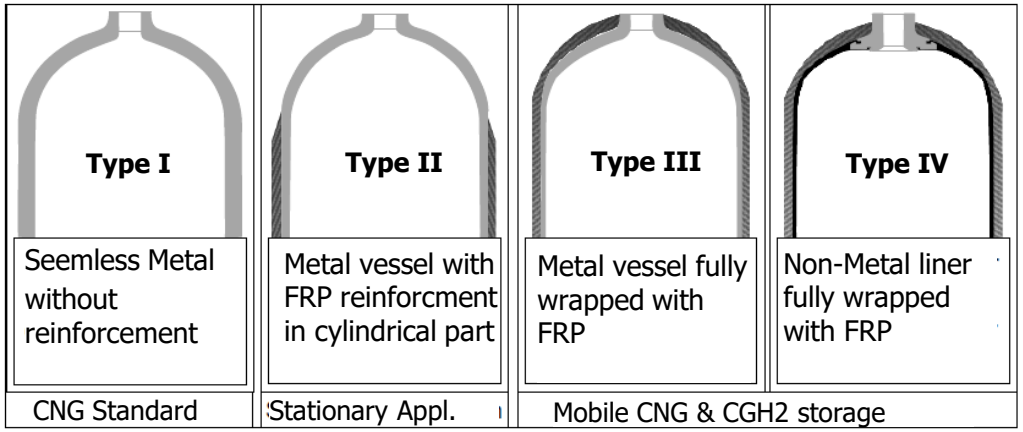
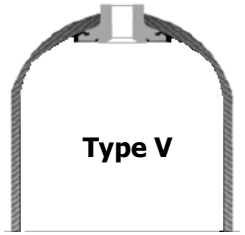
INTRODUCTION TO LIGHTWEIGHT VESSELS

FIBER REINFORCED PRESSURE VESSELS

Green Fire Suppression Halon Replacement based on Nitrogen



Pressure vessel types, based on: Rosen, P. A. : Beitrag zur Optimierung von Wasserstoffdruckbehältern; Dissertation; Springer 2018



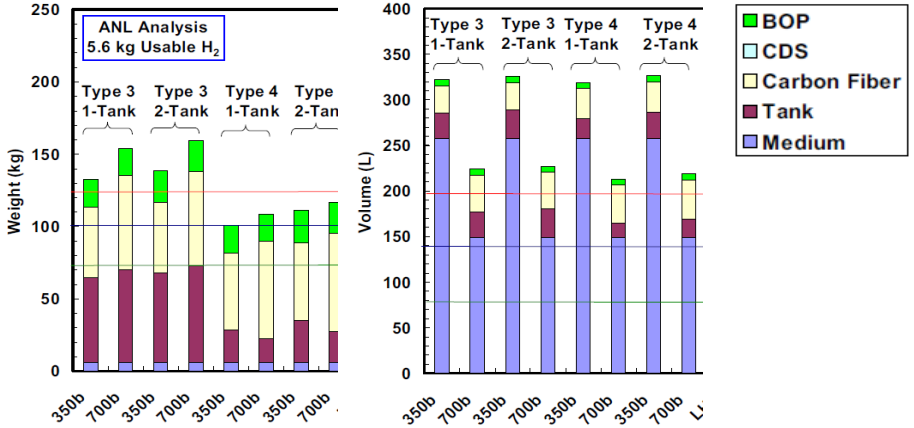
FRP vessel without dedicated liner

Still subject of current research projects

Vessel Type	Operation Pressure [bar]	Gravimetric density [weight %]
Type III	350	4.0...4.2
	700	3.5...3.6
Type IV	350	5.0...5.5
	700	4.8...5.2

Gravimetric Efficiency of Hydrogen Vessels

Rosen, P. A. : Beitrag zur Optimierung von Wasserstoffdruckbehältern; Dissertation; Springer 2018



Weight & Volume of Hydrogen Vessels: Ahluwalia, R.K. et al.:On-board and Off-board performance of hydrogen storage options for light-duty vehicles; international journal of hydrogen energy 37 (2012) p.2891-2910

Fazit:

- **Type IV vessels show an increased weight efficiency of ~ 25-30% compared to Type III**
- **Weight advantage is independent from selected operational pressure**
- **Polymer liner might be advantageous with respect to corrosion and fatigue behavior**

GLANCE AT REGULATORY ASPECTS

4.2. EASA policy

Based on the above considerations, EASA has determined that composite cylinders/receptacles qualified according to the following standards would be acceptable and considered suitable for the transportation of oxygen by aircraft, or for the installation of equipment containing oxygen on aircraft:

1. Any composite cylinder qualified according to ISO-11119-1 or -2 or -3 standards.
2. Any composite cylinder qualified according to any national or European norm, which mirrors or conforms to the international standards as in item 1 above[14].
3. Composite cylinders holding an approval under a DOT Special Permit, which includes clauses permitting their usage for oxygen on aircraft, are also acceptable[15].

Certification Memorandum: „Minimum qualification standards for oxygen cylinders used on board aircraft" CM-ECS-001 issue 1; 23rd May 2018

Conclusion:

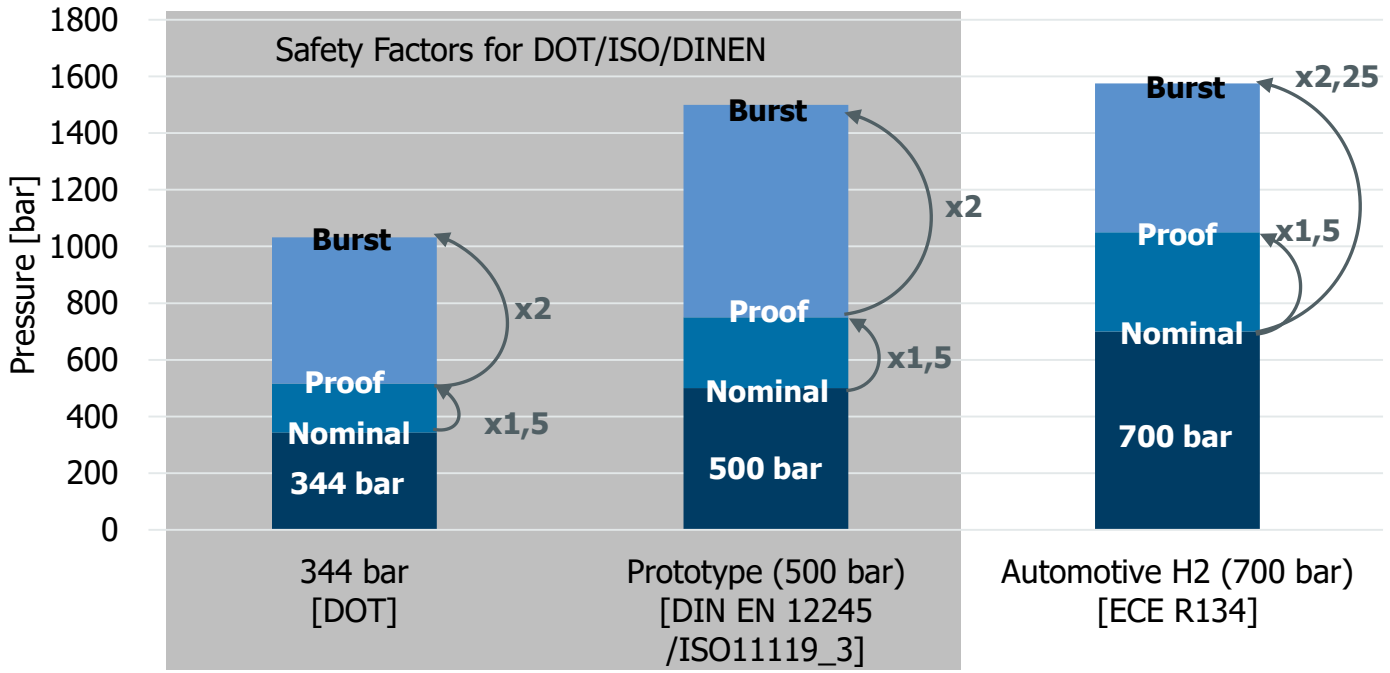
- **EASA accepts Composite (fiber reinforced) pressuraized vessels, which are certified according to ISO 11119-1;-2;-3; this included Type III & Type IV vessels**

NORMATIVE DESIGN PHILOSOPHIES AND IMPACT ON WEIGHT

Transport vessels

- Required Safety factors are usually independant from working pressure level
- ISO11119_3 does not explicitly state a working pressure limit
- Absolute safety (=material) reserve and component weight increase with working pressure

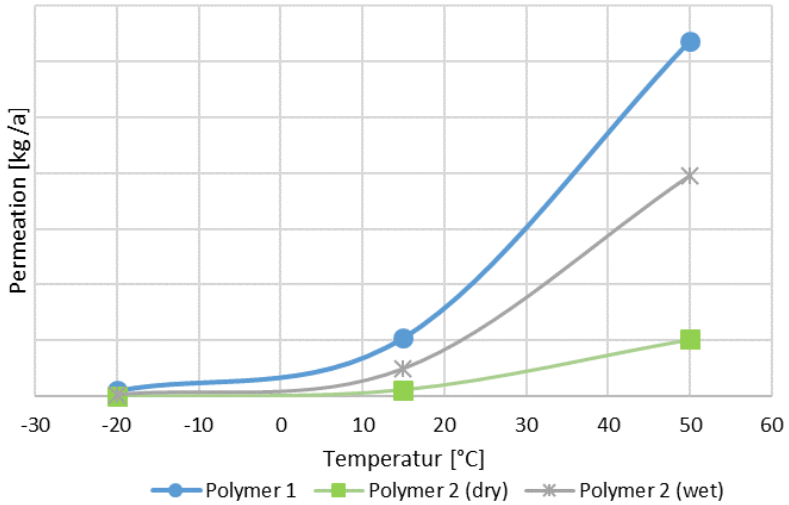
- **But:** For permanently installed vessels (e.g. Automotive) a different philosophy for safety factors is used → **Potential for significant weight reduction**



FIBER REINFORCED PRESSURE VESSELS

Selection of Liner Materials

- Permeation describes the penetration of a liquid or gas into a solid. It can be used to quantify loss of Nitrogen during service life.
- Permeation is strongly temperature dependant
- The shown examples result in a theoretical pressure loss of 5.5% over 5 years



- Design Variables to decrease permeation losses are:
  - Liner Material (Polymer)
  - Liner wall thickness
  - Additional Permeation barriers

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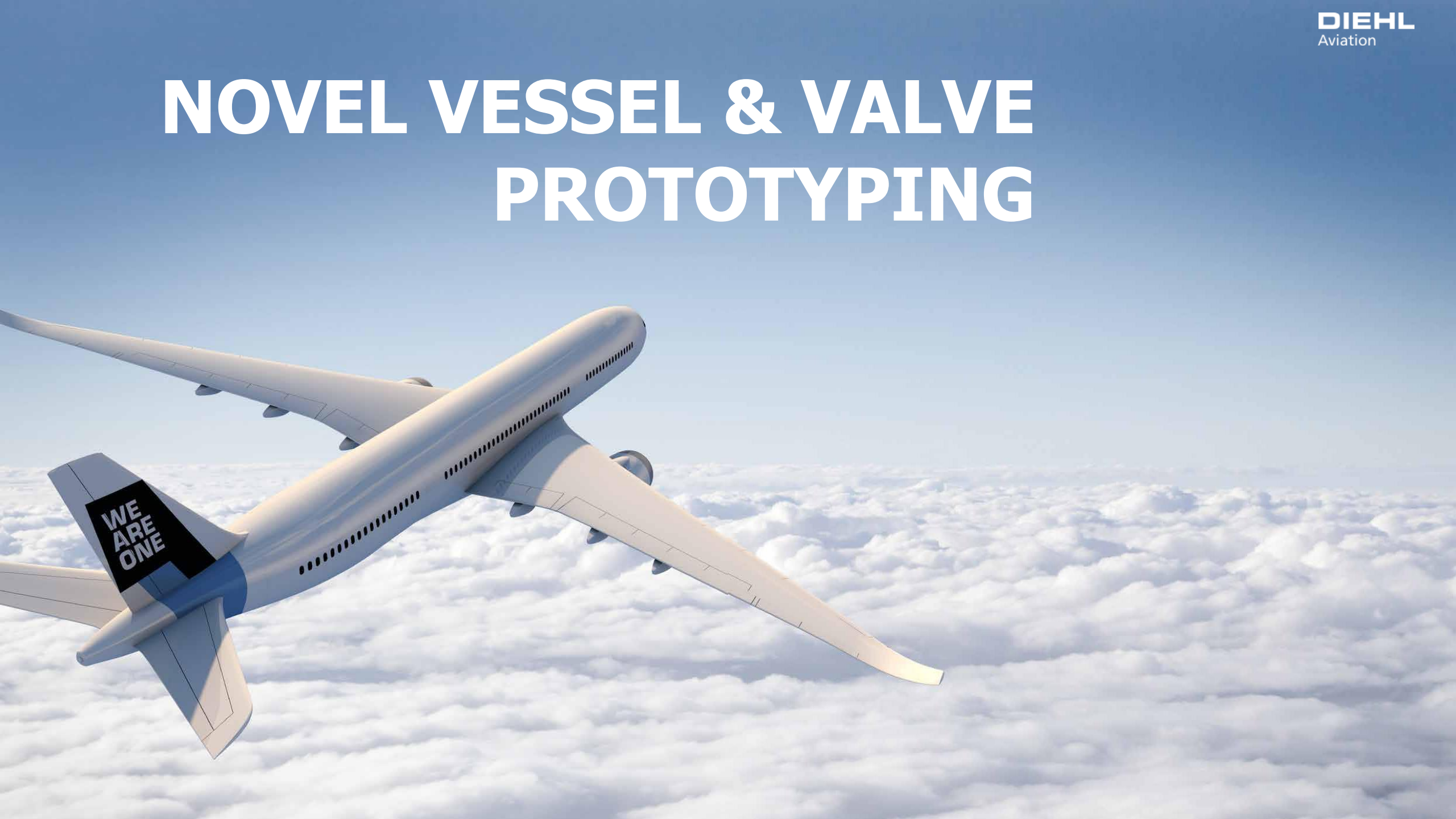
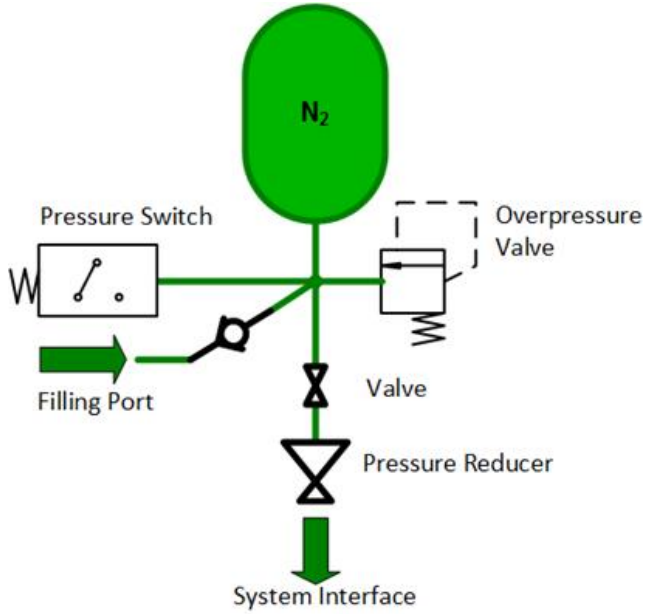
NOVEL VESSEL & VALVE PROTOTYPING

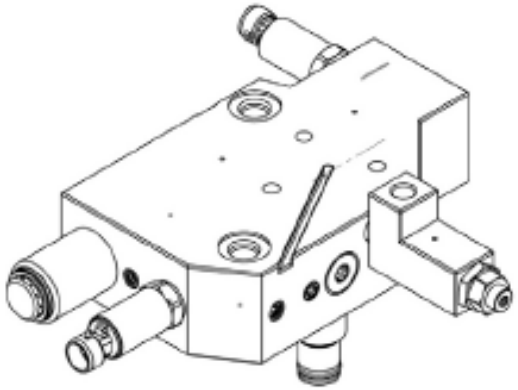


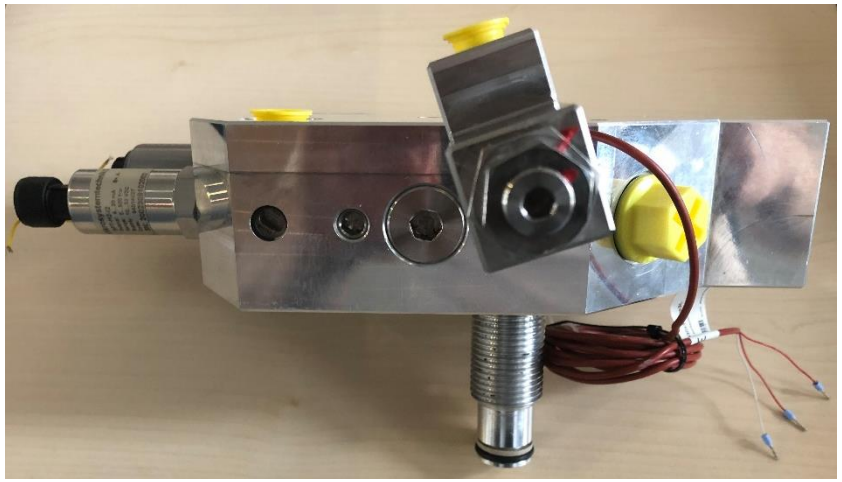
VALVE

Key Characteristics

- On Tank Valve (OTV) which is mounted on Composite Vessel
- Main Function: Providing constant Nitrogen mass flow with a defined outlet pressure range during discharge of the vessel
- Temperature & pressure monitoring of valve
- High reliability for opening of the vent due to mechanical design
- Ensuring that valve remains open after activation
- Lightweight design







COMPOSITE VESSEL

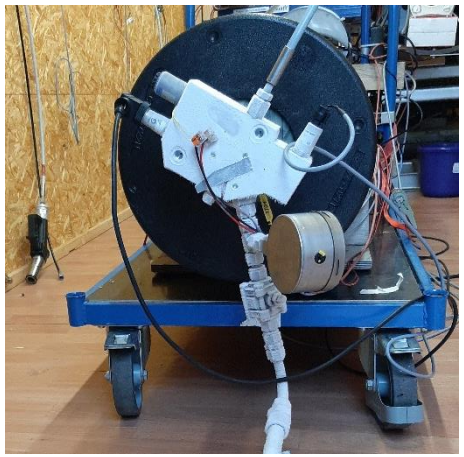
- Type IV CFRP Lightweight vessel
- Volume approx. 90 litres
- Working pressure 500 bar
- Qualified according to DIN EN 12445 (similar to ISO 11119)
  - Norm for transport vessels for non oxidative gases
  - Load cycles >12.000
  - Temperatures >70°C und Temperature variation -40°C to +60°C
  - Drop from heights
  - Saltwater resistance

TESTING AND VALIDATION

- Proof and Burst Pressure tests (burst >1500 bar) ✓
- Functional testing Filling & Discharge
  - Fast discharge without ice formation ✓
  - Specified flow rate during discharge period ✓
  - Specified outlet pressure window ✓
  - Leakage test after cycling ✓







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CONCLUSIONS

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- First aerospace relevant prototype hardware for fire suppression systems using Nitrogen was designed, built and tested!
- Normative regulations do allow use of lightweight CFRP vessels…
- …, but review/ adjustment of regulations could help to reduce weight significantly while maintaining same level of safety.
- Lightweight vessels and valves are key enablers for halon replacement solutions based on nitrogen and might help reduce possible weight penalties of other agents, as well!

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This project has received funding from the Clean Sky 2 Joint Undertaking (JU) under grant agreement No 945535. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Clean Sky 2 JU members other than the Union.

Clean Sky 2
JOINT UNDERTAKING

Parts of the reults origin from the project BILBO, which was co-funded by the German Federal Minsitry For Digital and Transport

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