ENABLE·H2

Fuel tank sizing methodology for cryogenic hydrogen fuelled air transport

D. Nalianda

Lecturer in Gas Turbine Engineering & Technology

WP1 Lead (Tech Evaluation) - ENABLEH2

P. Rompokos, A. Rolt, V. Sethi and X. Sun

Propulsion Engineering Centre, SATM Cranfield University

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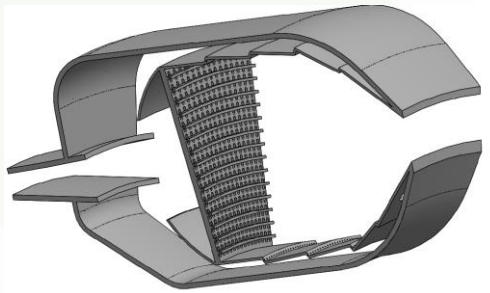
SESSION VII Cryogenic fuels/electrofuels

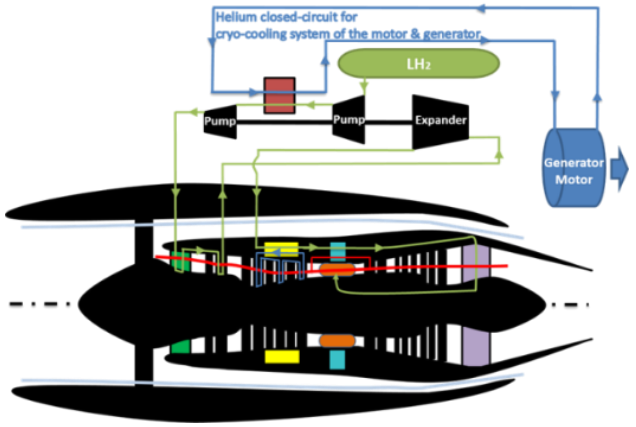
Context

ENABLEH2- Enabling Cryogenic Hydrogen-Based CO2-free Air Transport

- Liquid hydrogen (LH_2) is an alternative to hydrocarbon fuel sources that could lead to a zero carbon industry.
- Maturing key enabling technologies for LH_2 which will contribute to decarbonising civil aviation (TRL 2 – TRL4):
  1. Hydrogen micromix combustion – ultra low NO_x
  2. Fuel system heat management – exploiting LH_2's formidable heat sink potential
- Technology evaluation – Techno-economic Environmental Risk Assessment (TERA)
- Addressing key challenges/scepticism – economic viability and safety
- Establishing roadmaps for the introduction of LH_2
- EU H2020 Project ~4M€, collaborate with 20+ Key Civil Aviation Stakeholders (partners + industry advisory board members)



Hydrogen Micromix combustor



Fuel system heat management concept

Project Partners

Industrial Advisory Board

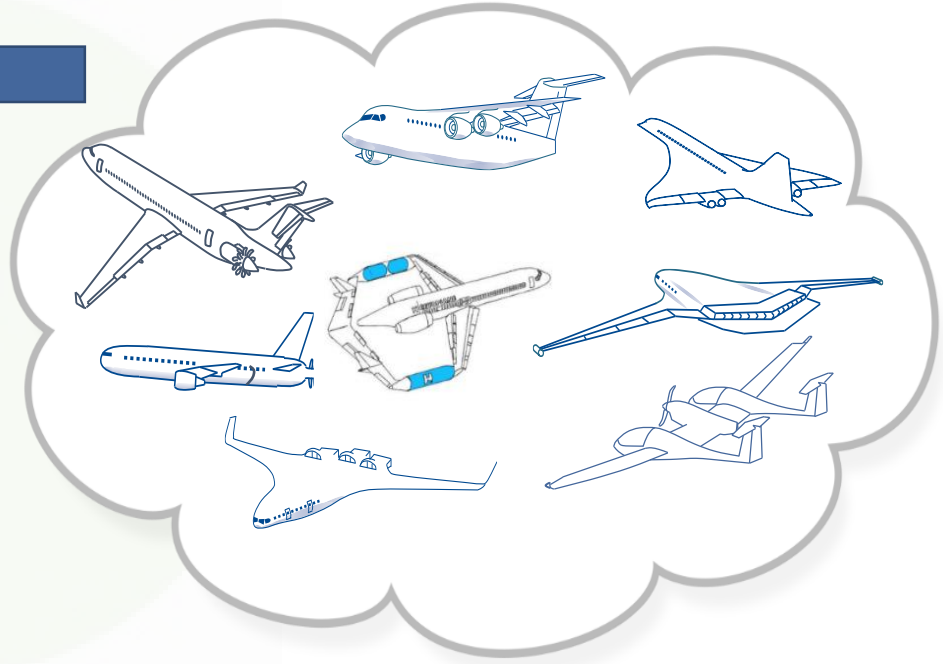
Technology Evaluation

1. Qualitative technology down-selection

2. Best case scenarios for Jet A-1, LNG and biofuels

3. LH2 T&W and BWB aircraft system modelling

4. Technology and scenario evaluation



Long Range concepts

Short- medium Range concepts

SAFRAN Group, Isikveren and Turnbull

GA no. 769241

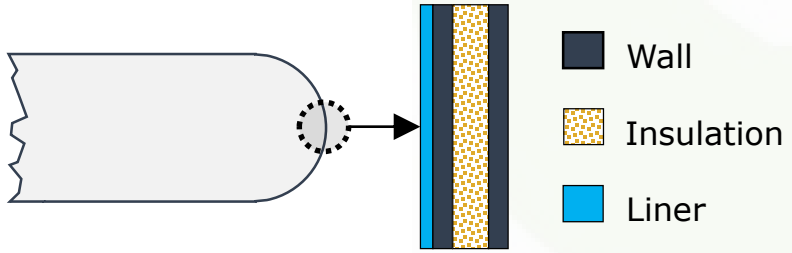
Technology Evaluation

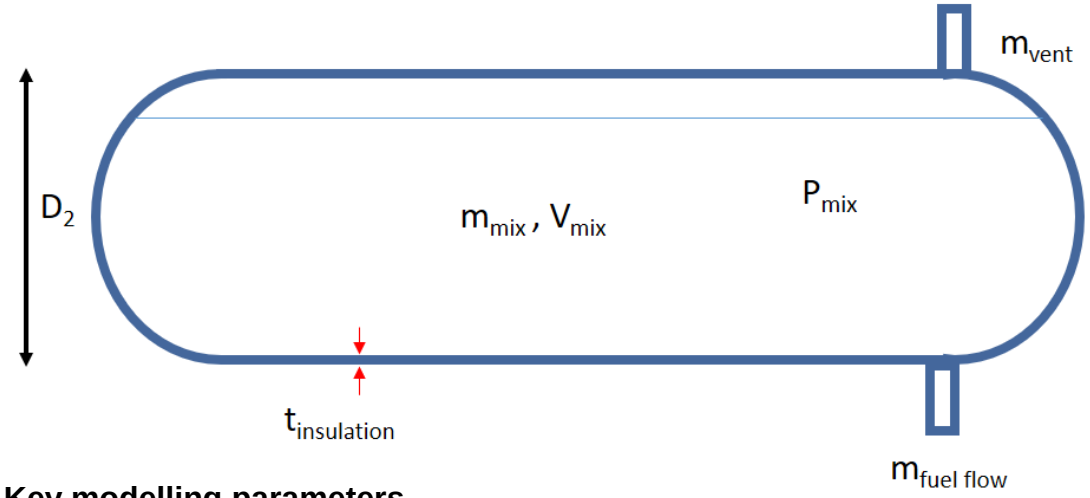
LH_2

- Hydrogen liquefies at 20.3 K (−252.9°C) – storage vessels require cryogenic systems and sophisticated insulation techniques

Tank structure

- Cylindrical tanks with hemispherical cap ends
- Dimensions, material and fuel storage properties





Key modelling parameters

m_{mix}	Mass of mixture	P_{mix}	Pressure of mixture
V_{mix}	Volume available	$m_{fuel\ flow}$	Mass of LH_2 extracted
D_2	External diameter	m_{vent}	Mass of fuel vented (at time step)
$t_{insulation}$	Thickness of insulation		

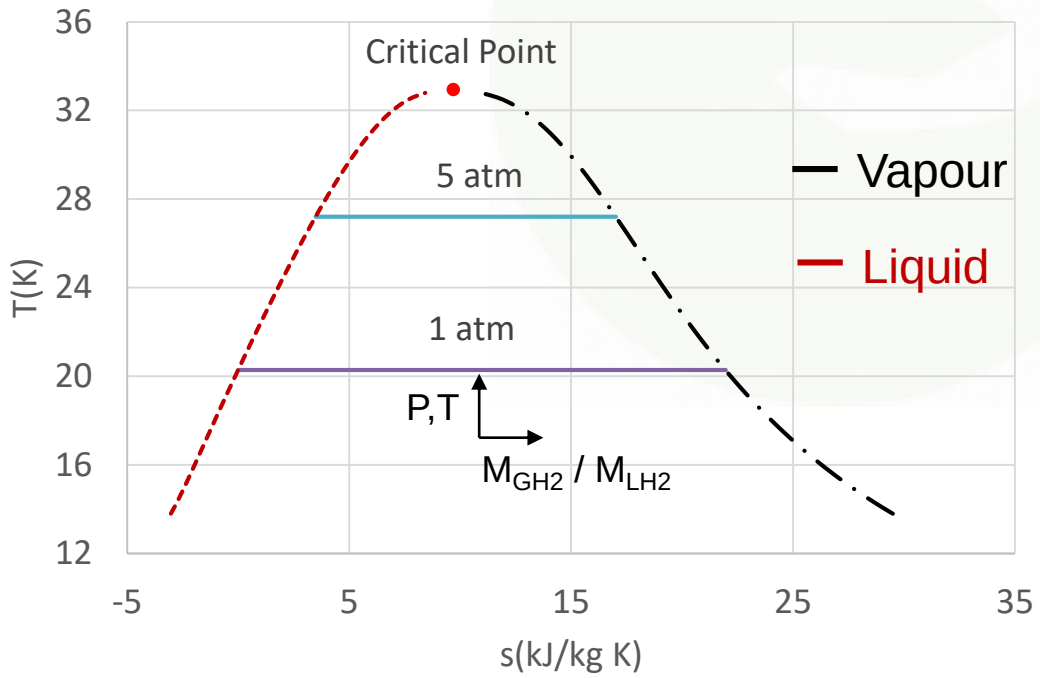
Long Range concepts

Short- medium Range concepts

Modelling approach

Hydrogen mixture properties

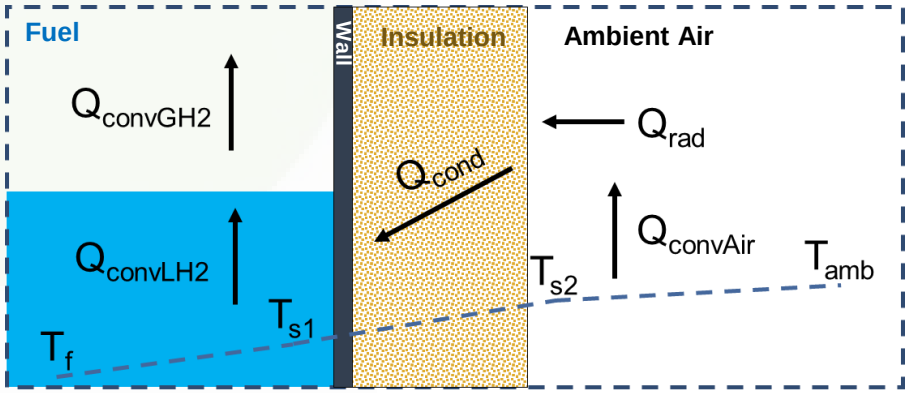
- Inside the tank there is a mixture of liquid and gaseous hydrogen at all times
- The mixture is at saturated conditions and considered homogenous



Heat transfer is based on:

- Tank dimensions
- Insulation material
- Fuel and ambient temperature

$$Q_{convfuel} = Q_{cond} = Q_{convAir} + Q_{rad}$$



Rate of pressure change

$$\frac{dp}{dt} = \frac{\phi}{V}\left[Q - \dot{m}_{out} \cdot h_{lg} \cdot \left(x + \frac{\rho_g}{\rho_l - \rho_g}\right)\right]$$

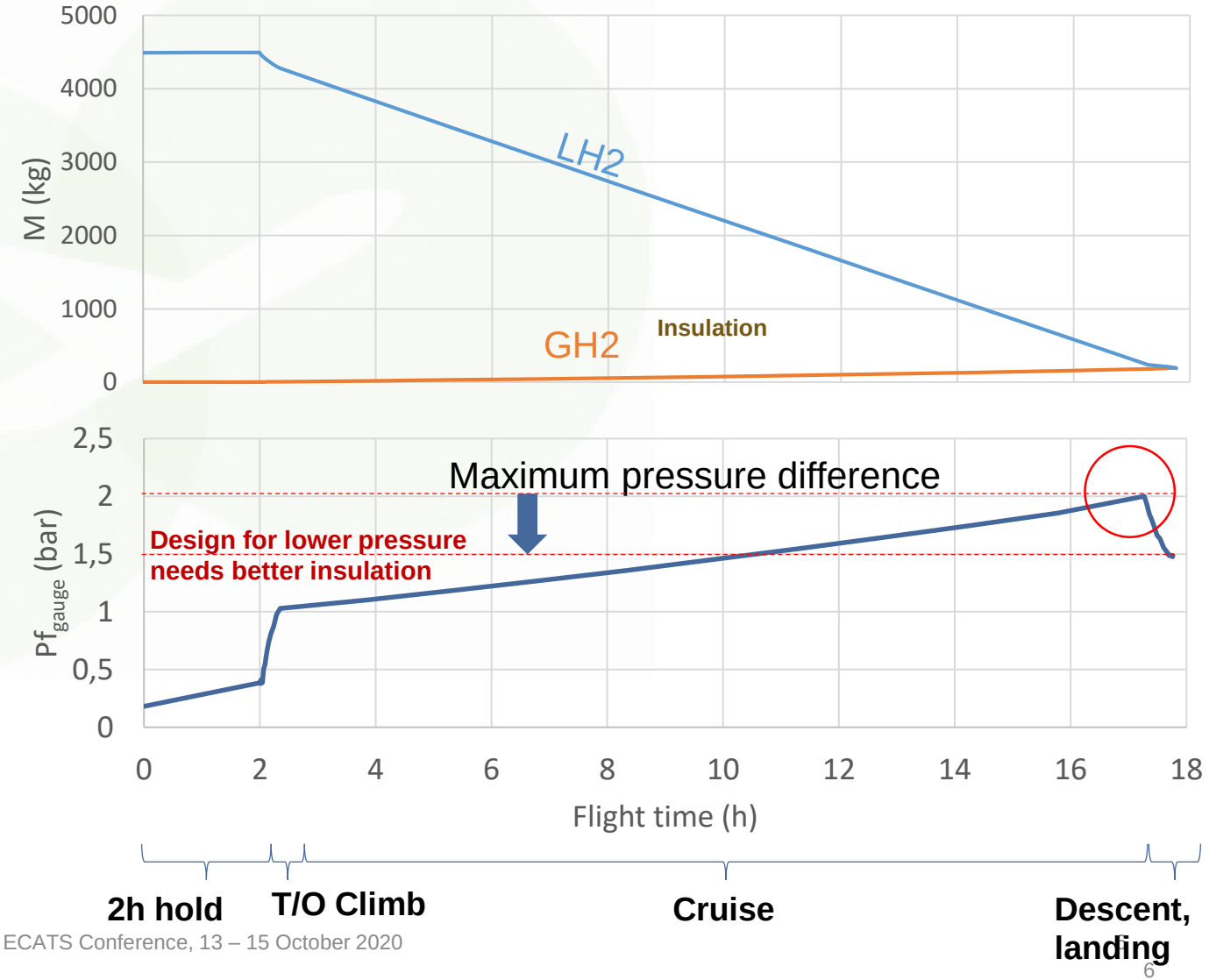
$$\phi = \frac{1}{\rho \cdot \left(\frac{\partial u}{\partial p}\right)_\rho}$$

A factor is applied to account for temperature stratification

Q : Heat Transfer
h_{lg} : Latent heat of Vaporisation
M : Mass
ρ : density
φ : Energy derivative
x : Mixture quality

Mission level assessment

- Long range mission
- 2 hours ground hold before take-off
- Assumes no GH_2 is vented for pressure relief
- Tank wall sized to withstand maximum pressure difference
- Tank is oversized to compensate for the evaporated (unusable) LH_2



Conclusions

- Methodology to design and size cryogenic fuel tanks
- Consideration of pressure changes within the tank is critical to design
- Design must withstand maximum pressure difference cycles
- Tank oversized to compensate for evaporated LH_2 – implications of considering boil-off

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Thank you !

WP1 Lead
Devaiah Nalianda, CU
Devaiah.Nalianda@cranfield.ac.uk

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