DECARBONISATION OF GAS TURBINES WITH THE H2R® HYDROGEN RETROFIT BURNER

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1. OVERVIEW: H2R® DECARBONISATION OF GAS TURBINES

We have produced a Dry Very Low NOx Decarbonisation Conversion Kit for Gas Turbines

The H2R® operates with any proportion of Natural Gas & Hydrogen

- It is a Gas Turbine Life Extension Upgrade

- Converting existing GT assets reduces investment needs and further accelerates decarbonisation
- The only *truly Independent Provider* of Zero CO_2/Low NOx Combustion Systems for Gas Turbines
- Fuel flexibility: 100% H_2 to 100% Natural Gas in any proportion
- The H2R® may be customized for all gas turbine platforms and combustion systems

Eliminates CO_2 at the source

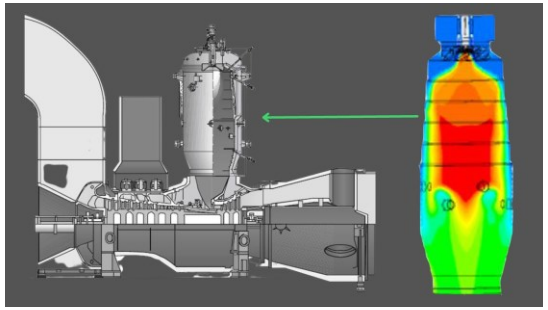
Fits to any gas turbines

Reduces Nitrous Oxides (NOx) emission

100% hydrogen energy

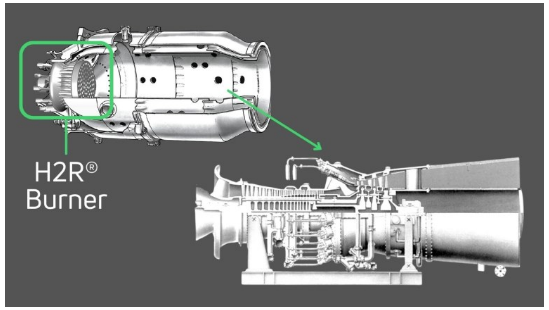
H2R® TEAM: GT EXPERIENCE, BADEN, SWITZERLAND

BBC



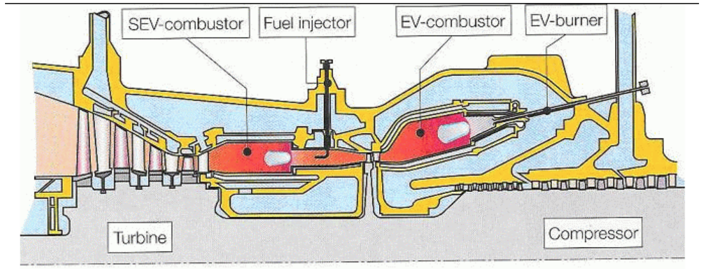
GT8/11/13

ABB



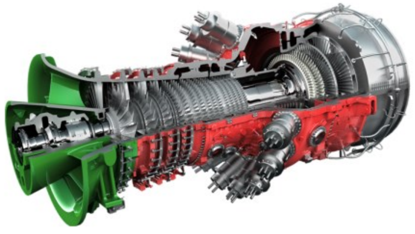
GT13E2, GT13E2MBTU (40 vol-% H2)
GT10B (SGT600), GTX100 (SGT800)

ABB/ALSTOM/GE



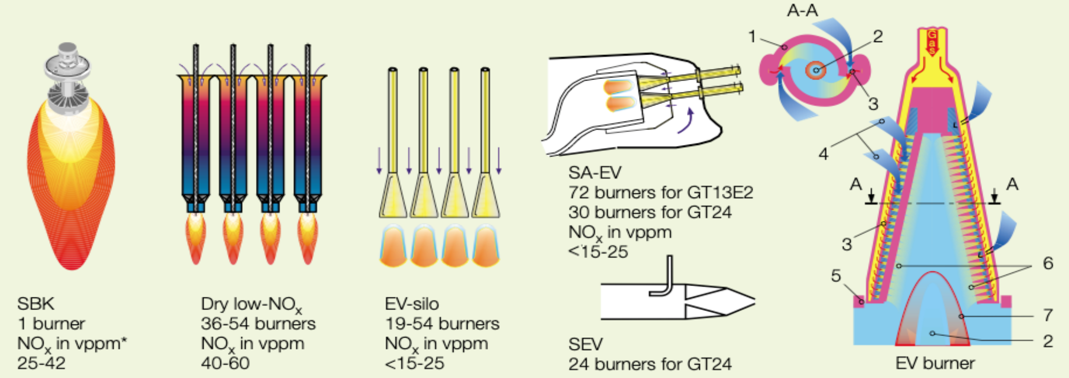
GT24 & GT26
Fr-5, Fr-6, Fr-7 & Fr-9

ALSTOM/GE/ANSALDO

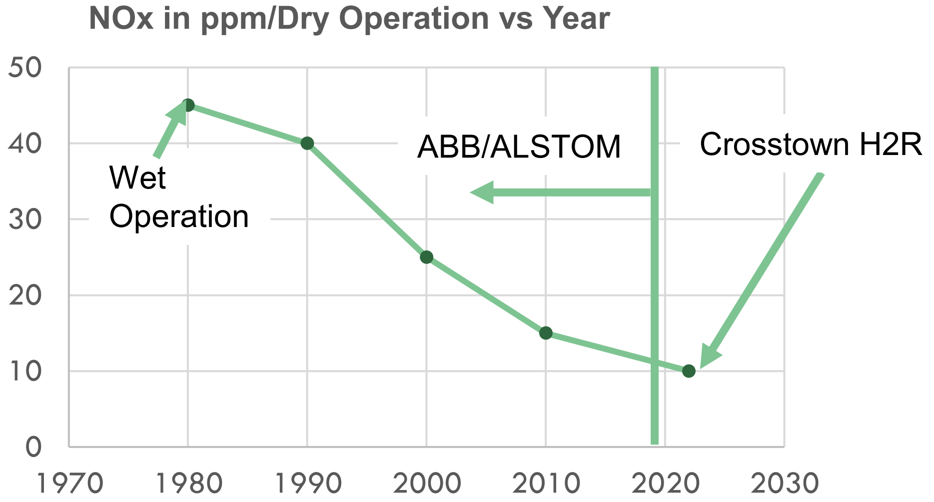


GT36
WI501F, SGT800, SGT4000F

1980's — 1990's — 2000's — 2015



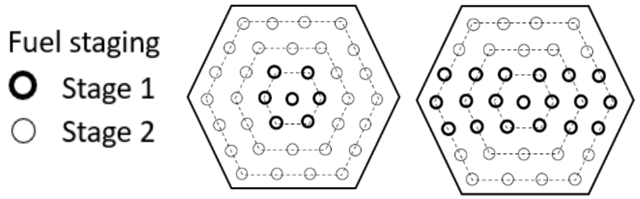
The H2R® team has over 120 patents on Dry Low NOx & Hydrogen Burner Systems, with over 35 years' experience

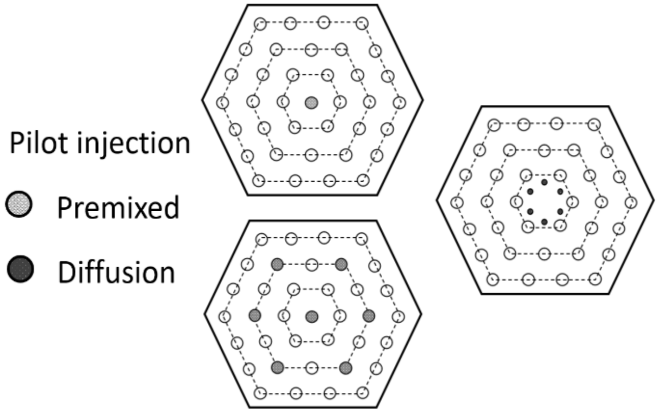


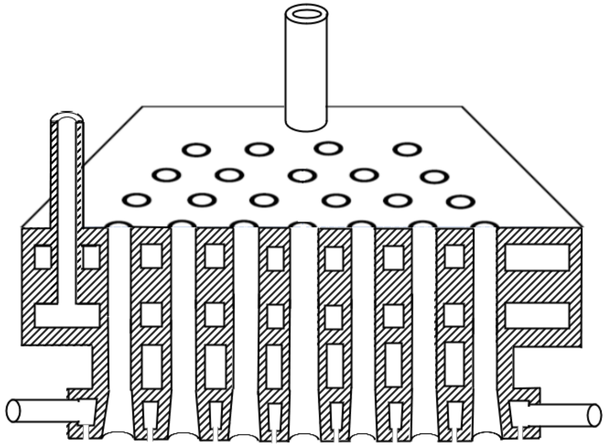
TECHNOLOGY PRINCIPLES

Integration of operational features for control and dynamics mitigation

- Variety of staging design potentials
- Piloting naturally integrated using premixed or diffusion layouts





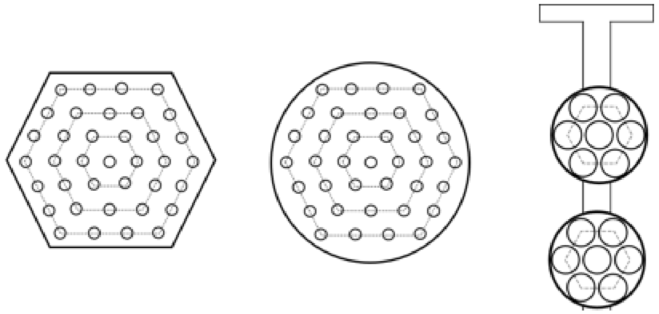


Cluster of tubular jet burners:
- Premixed jet flames
- Pipe flow, wide flashback margin
- Low-NOx with multitude of downsized jets

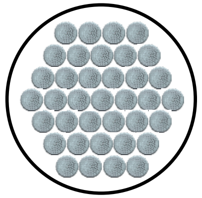
Modular concept:
- A cooling and dilution air module on the burner face, for cooling and flashback-barrier
- Combined or separate H_2/NG fuel injection
- Pilot fuel module
- Integration of central cartridges

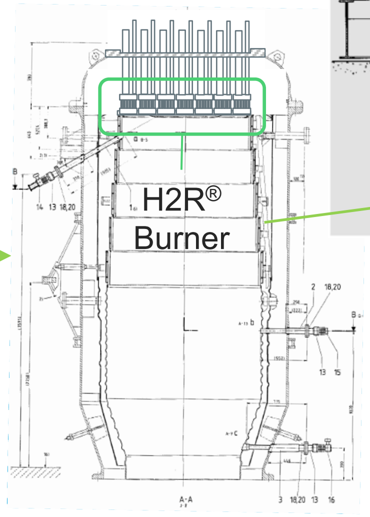
- Adaptability to specific combustor interfaces and integration requirements

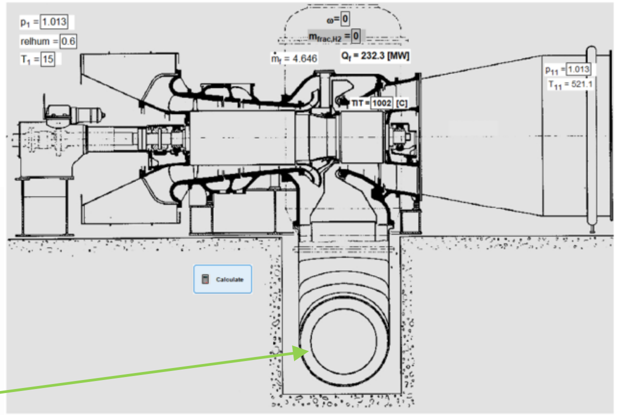
→ Limit modification to existing systems
→ Exploit available space
→ Optimize the area expansion for flame stabilization



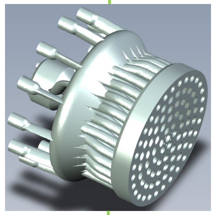
ZERO CARBON BURNER

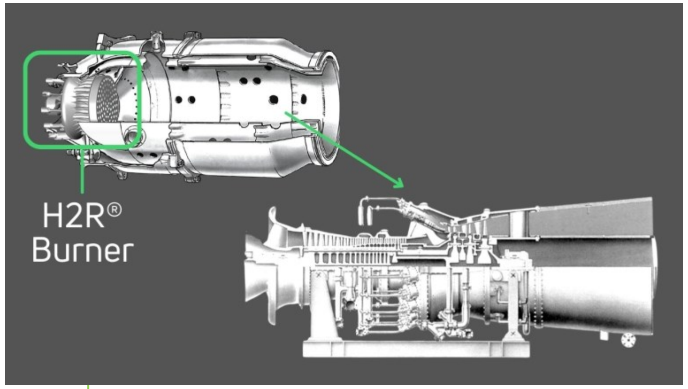






Gas turbines with Vertically mounted Combustor





Gas turbines with Axially mounted Combustor

Courtesy: Science Direct

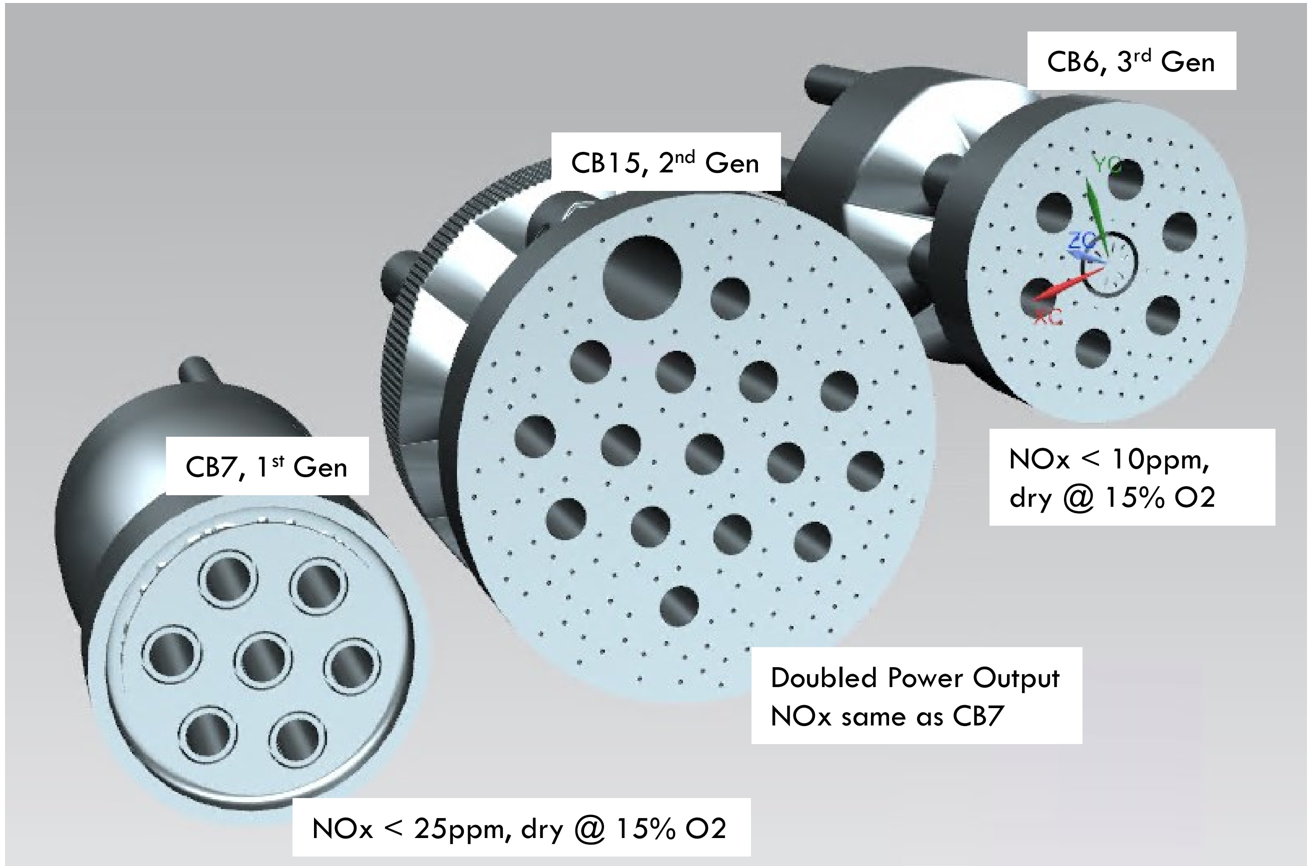
H2R® Dry Low NOx & Zero Carbon Replacement burner

Key Points:

- Recent tests (March 2021 - August 2022) have been successfully completed with 100% Hydrogen and no flashback
- Operability with 100% Natural Gas demonstrated, in order to transition from Gas to H2 as H2 becomes increasingly available.
- Dual-Fuel operation simultaneously with H2 & Natural Gas in any proportion

CP CROSSTOWN POWER

H2R® BURNER PROTOTYPES



Several variants of the burners have been developed and tested in the atmospheric test facility of FHNW:

A. 1st generation burner: CB7
   1 burner tested: ***proof of concept*** 100% H2 operation capability, low-NOx, effect of steam addition

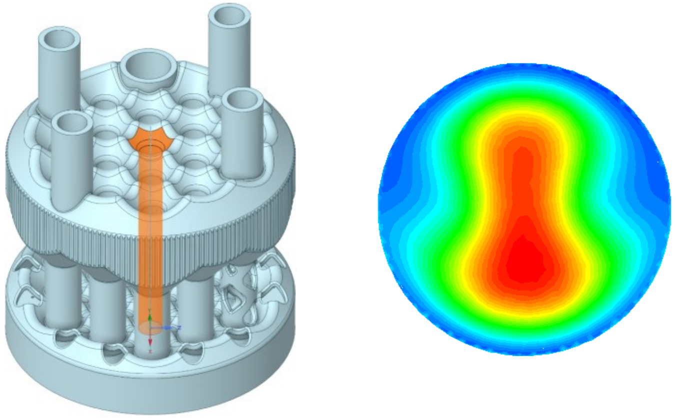
B. 2nd generation burners: CB15
   3 burners tested: verification of the burner ***modularity*** and ***scalability*** for power, mixing quality and ***durability*** assessments

C. 3rd generation burners: CB6
   4 burners tested: burner features for ***fuel flexibility***, integration of ***engine-ready features***

CROSSTOWN POWER

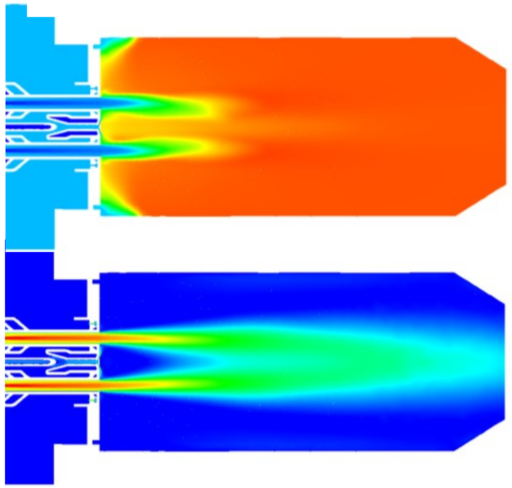
BURNER DEVELOPMENT – CFD AND DURABILITY ANALYSES

Optimisation of the mixing quality by CFD



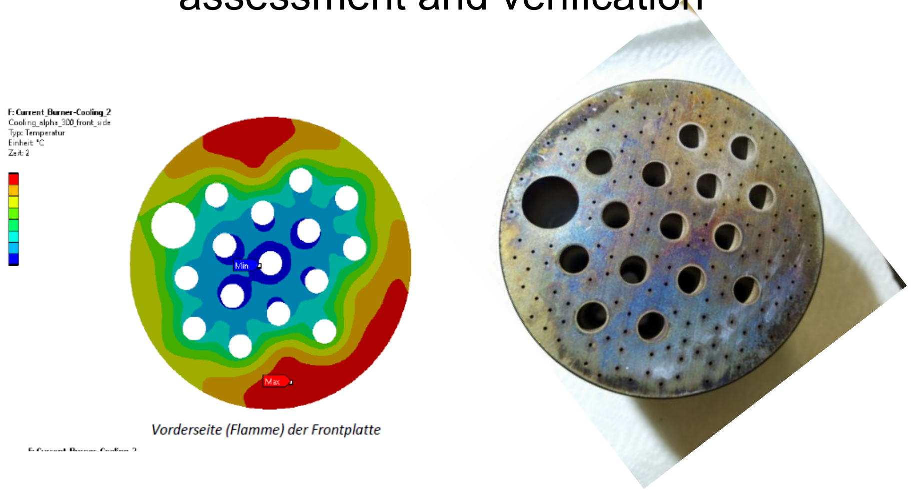
Injection layout to achieve fuel-air mixing quality and lean walls for flashback prevention

Support of integration with CFD



Capture of the burner internal characteristics and complex flow physics inside the combustor

Design of the burner cooling using FEA - assessment and verification



Accurate burner front face thermal state prediction, durability analysis and lifetime optimisation

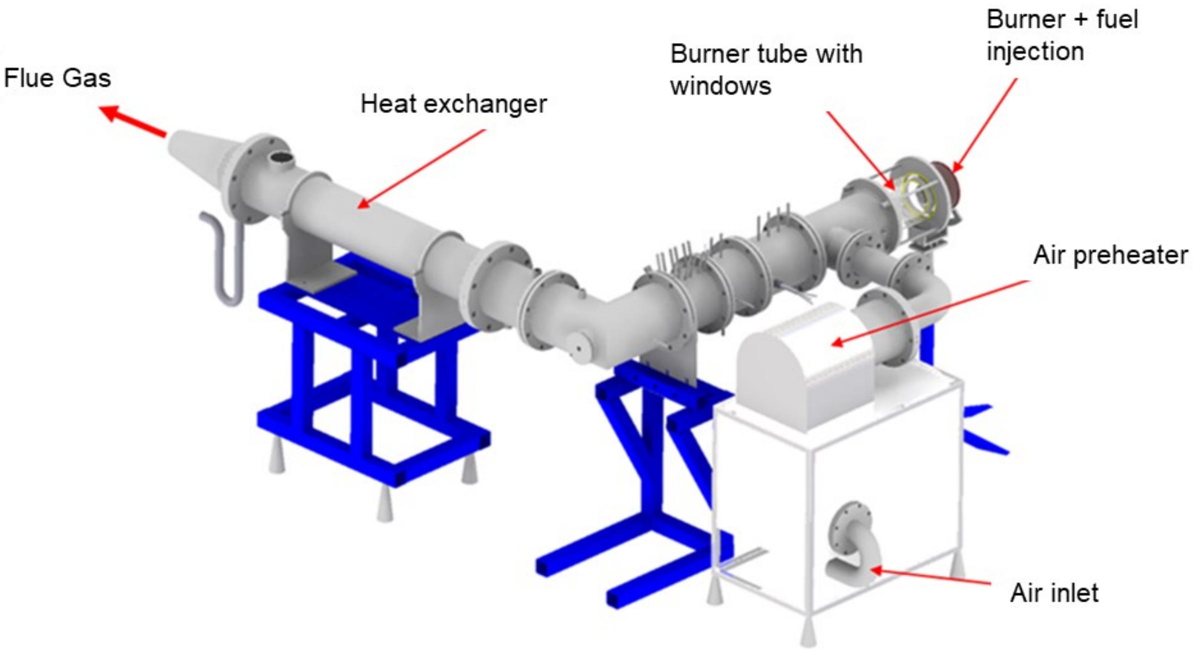
- Development using high-fidelity simulation methods
- Advanced dual system cooling of Front Panel
- Experimental verification of the design intent – indication of sufficient part lifetime
- Pressure drop tailored to application

TEST RIG FOR DEVELOPMENT AND VALIDATION

1st Gen
2020

2nd Gen
2021

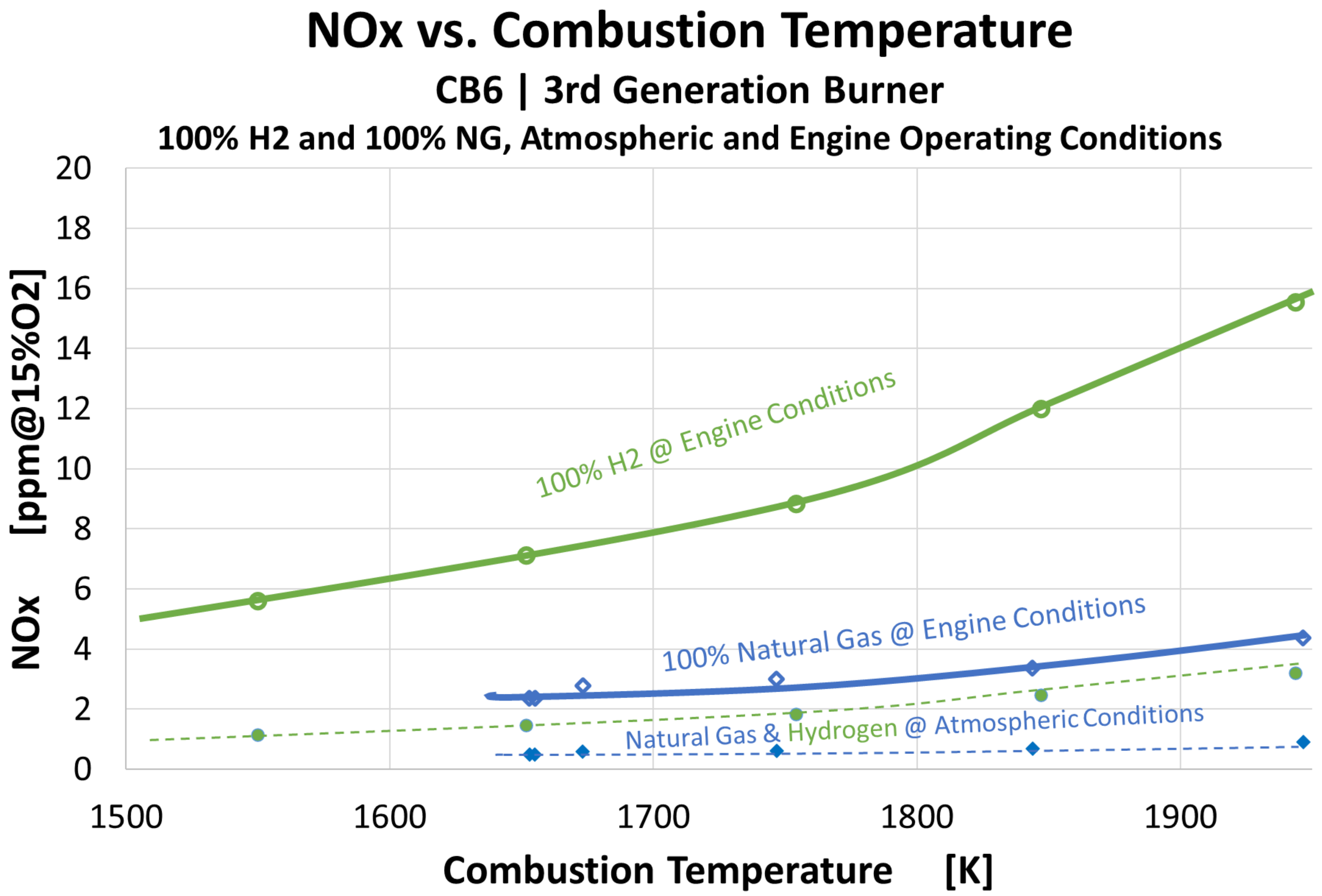
3rd Gen
2022



Test Facility Operational capability:

- Air mass flow rate: max. 80 g/s
- Thermal power: max. 100 kW
- Air preheat temperature: max. 550 ^{O}C
- Burner tube diameter: 130 mm
- Hot gas temperature: up to 2000 K (max)

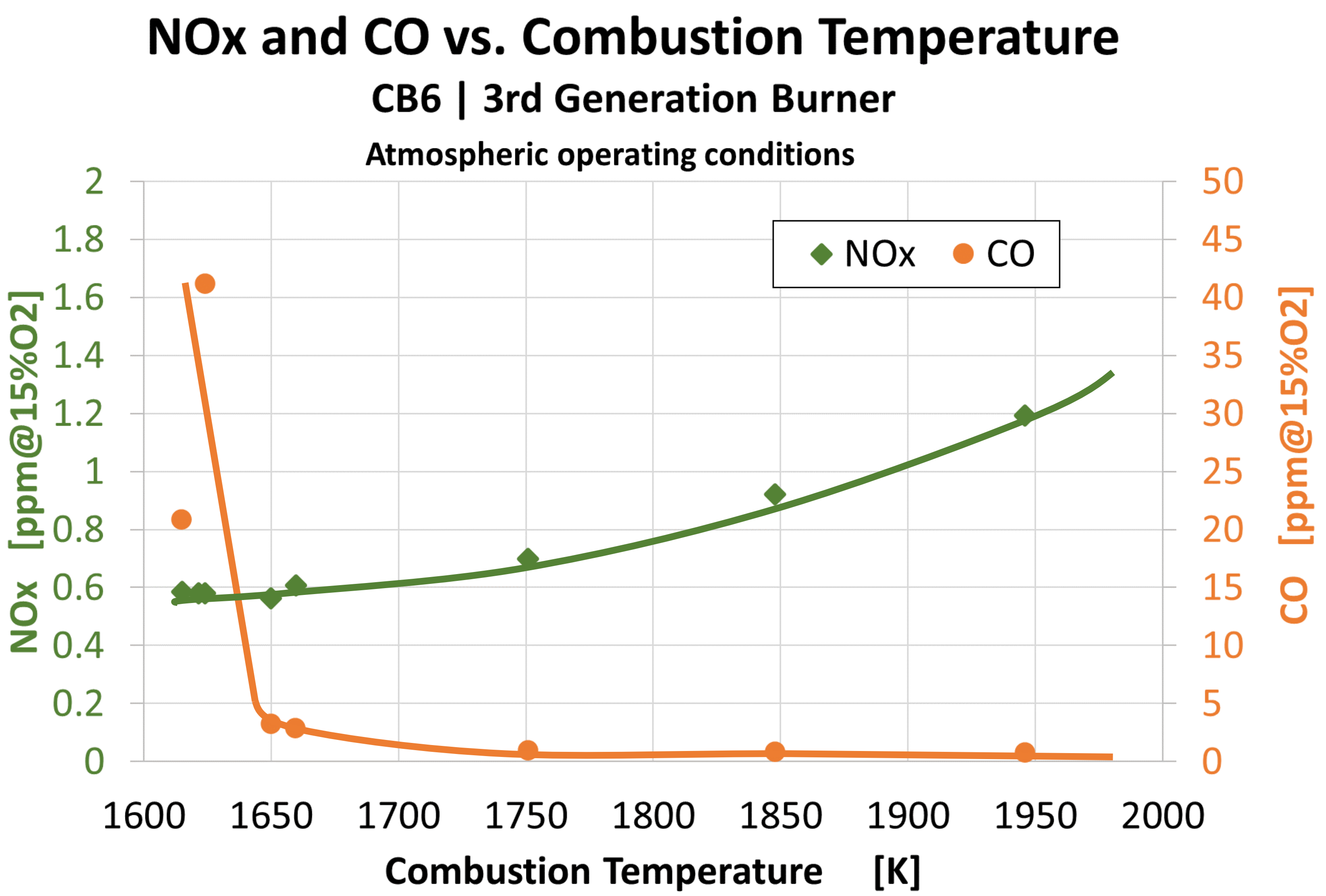
NOX EMISSIONS FOR 100% NG & H2 OPERATION



Data taken at atmospheric pressure and extrapolated to typical engine conditions based on industry standard correlations

Extrapolations aligned with past team's experience for Natural Gas. Same correlations used for Hydrogen

OPERATIONAL WINDOW - NG OPERATION

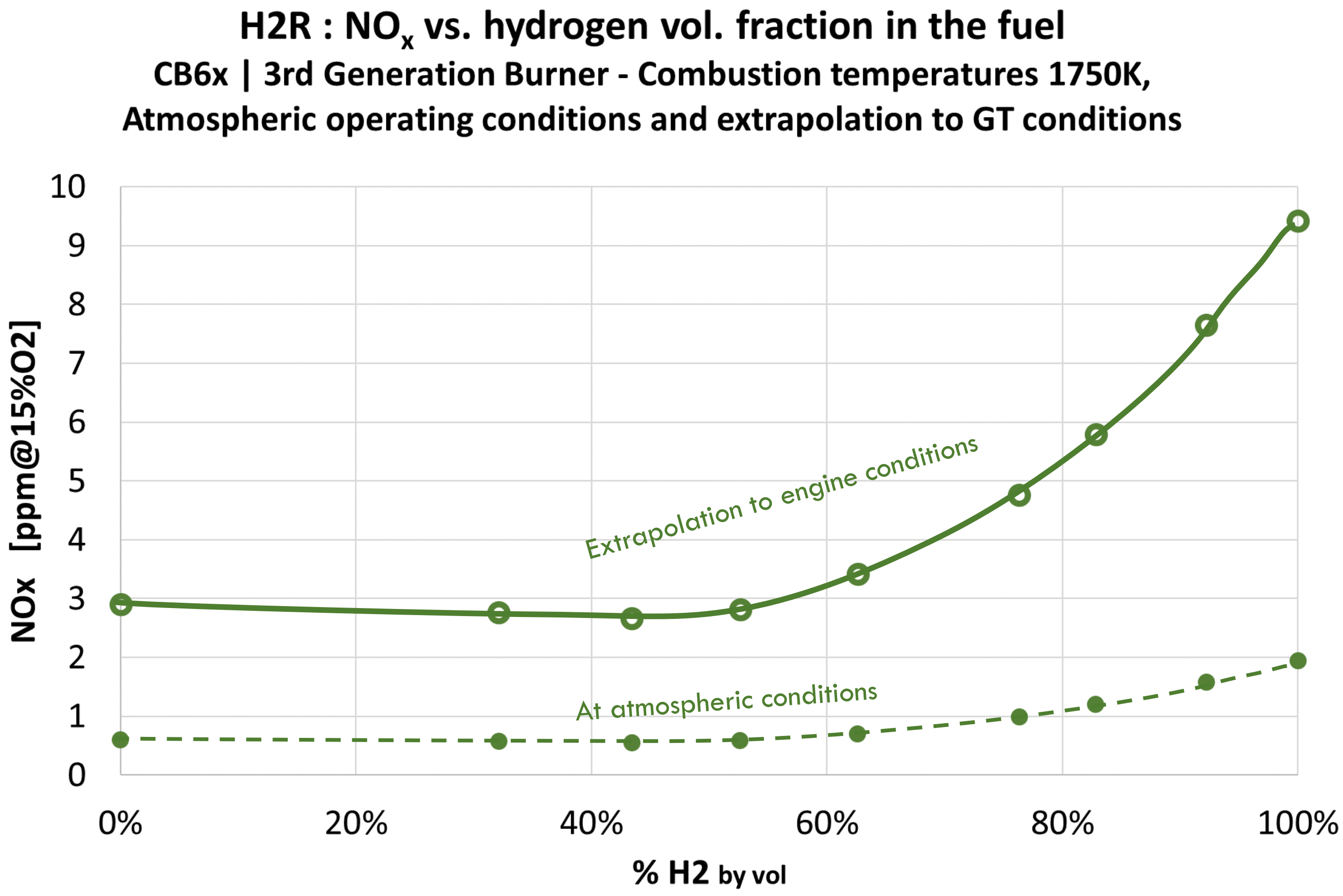


Pure Natural Gas operation at atmospheric conditions

Very low NOx achieved up to high combustion temperatures

Low CO emissions *above* 1650K for unpiloted operation, providing a wide window of emission compliant operation

NOX EMISSIONS FOR FUEL BLENDS

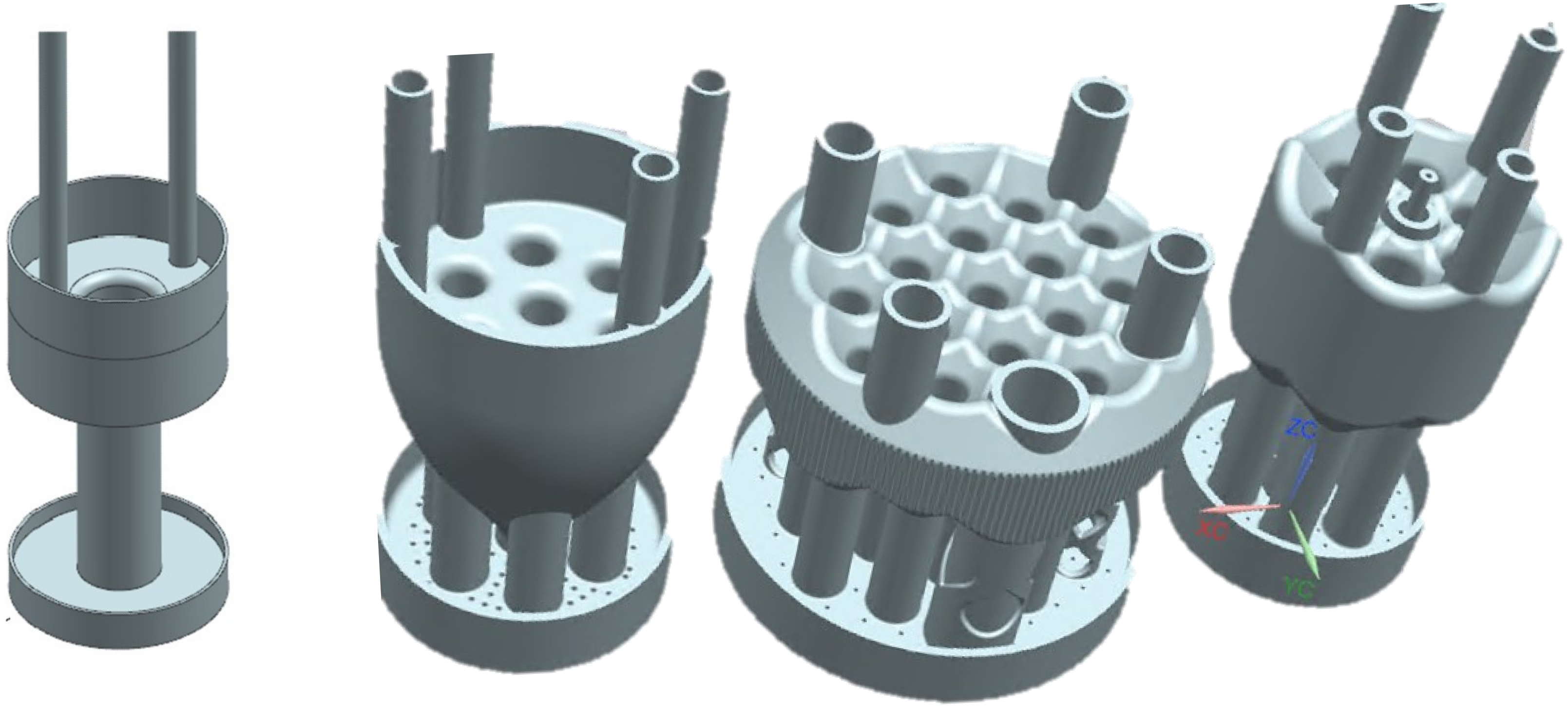


- 3rd generation burner: 4 burners tested for various fuel blends of natural gas / hydrogen
- NOx increase is observed during atmospheric tests to start at >50% H2 share by volume in the fuel composition

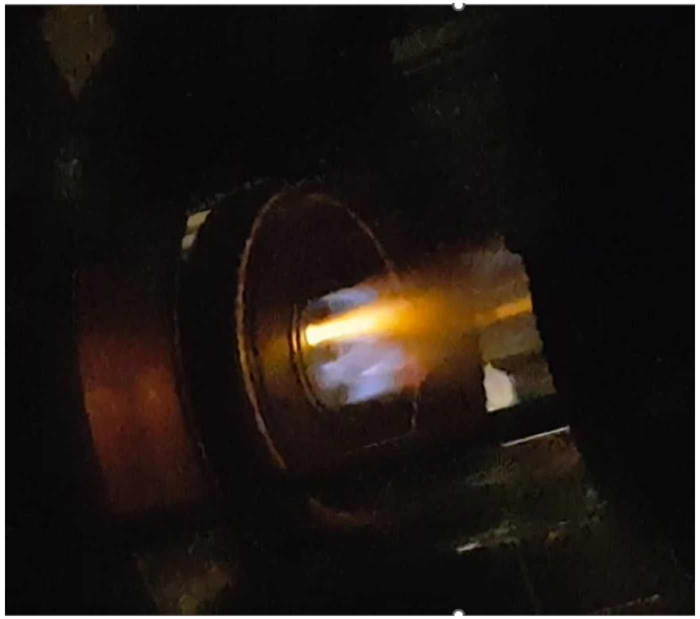
FLASHBACK MARGIN

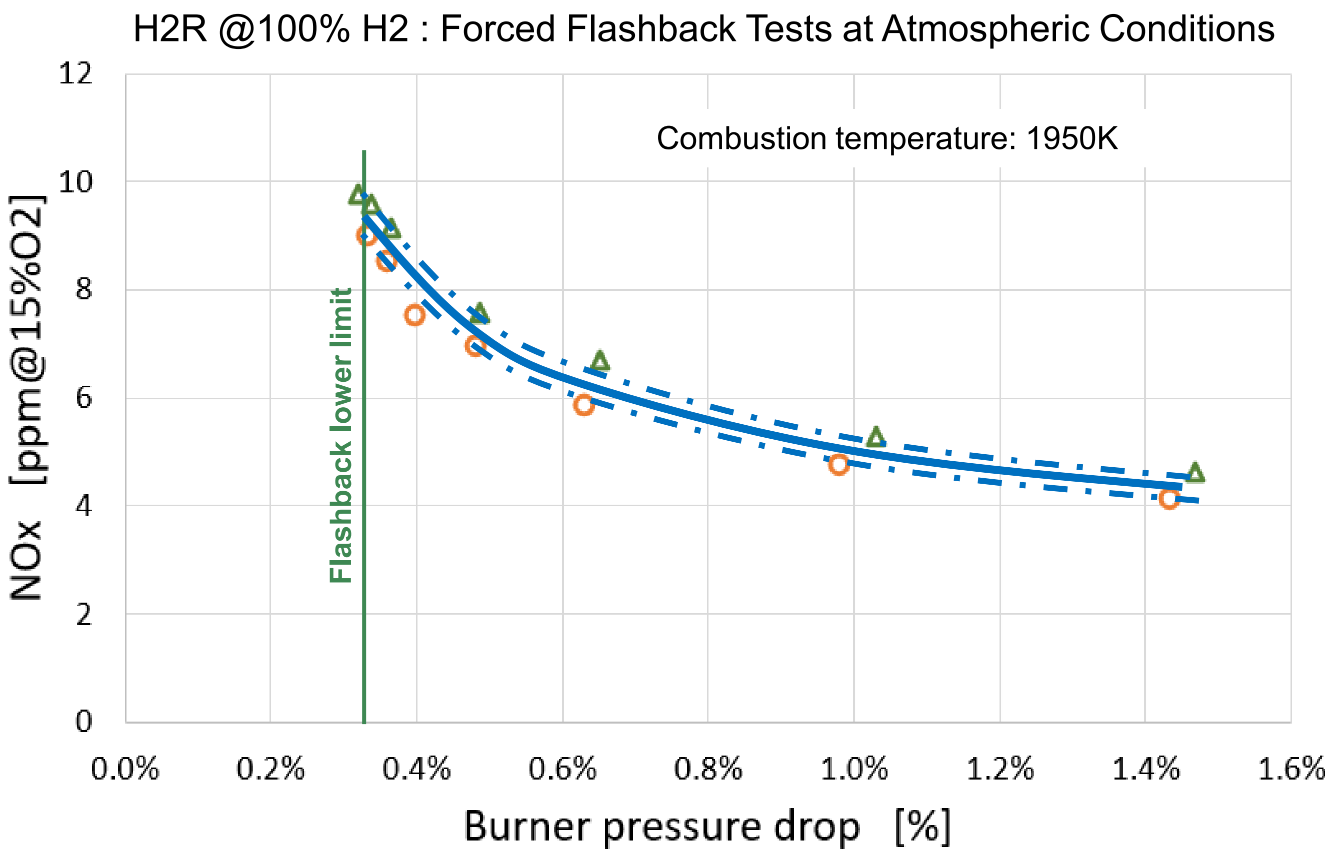
Flashback limits and mitigations have been extensively studied

Results from single tube experiment and more complex and industrial solutions have supported the design of specific burner features



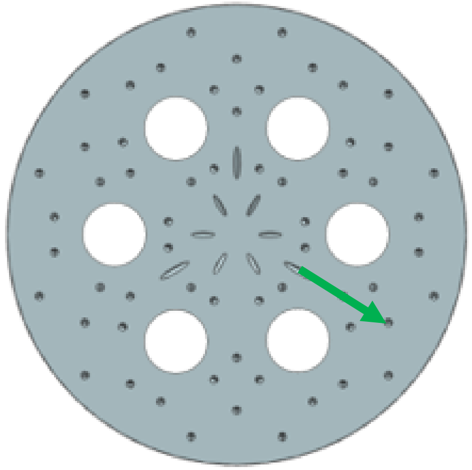
ATMOSPHERIC FLASHBACK TESTS

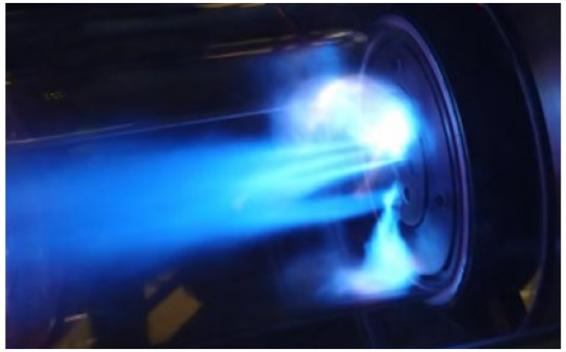


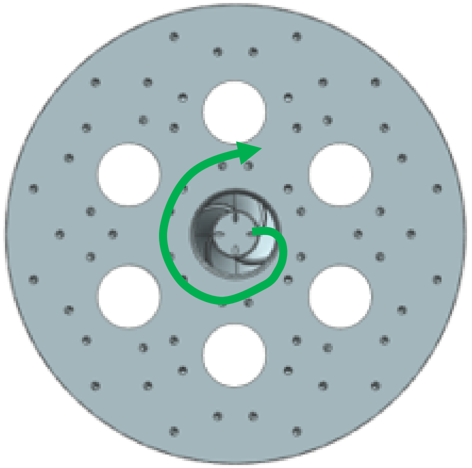


- Tests carried at 400°C preheat temperature and ~1950K firing temperature
- Repeated tests show consistent flashback boundaries at ΔP /P ~ 0.3%
- Whilst most GTs operate with a ΔP/P > 2.5%

PILOT DESIGNS FOR THE 3RD GENERATION BURNERS







→ diffusion pilot and outer stabilization: the diffusion-type pilot creates a small reaction zone and mixes with the main flow at low pilot flow, and burns in the outer zone at high flows

→ partially premix pilot and inner stabilization: burns in the central region and sustains the flame along the inner recirculation

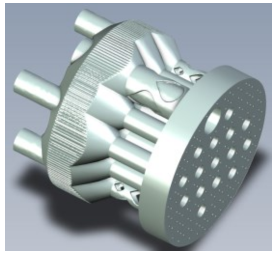
H2R® ADAPTION TO A 15MW AERODERIVATIVE GAS TURBINE

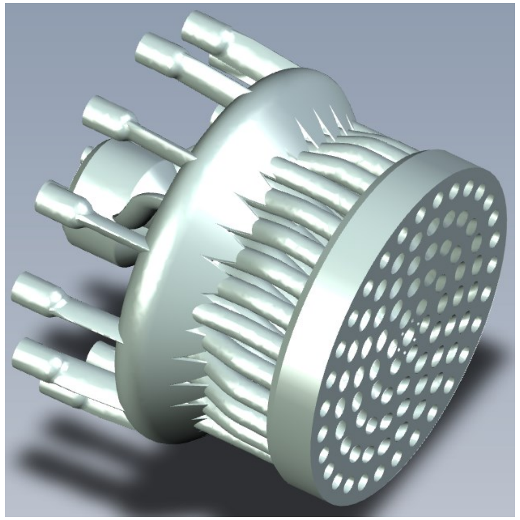
Upscale of the validated technology to the required throughput capacity

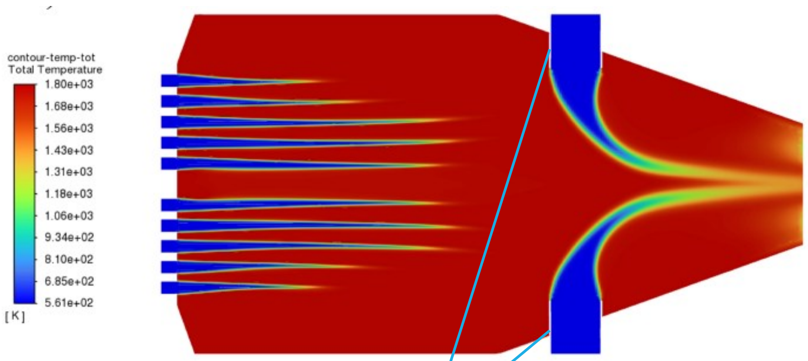
→ 2nd generation burner specific power of ~0.1MW_{th}/bar

→ Full size design for engine burner with a specific power of up to 1.0 MW_{th}/bar

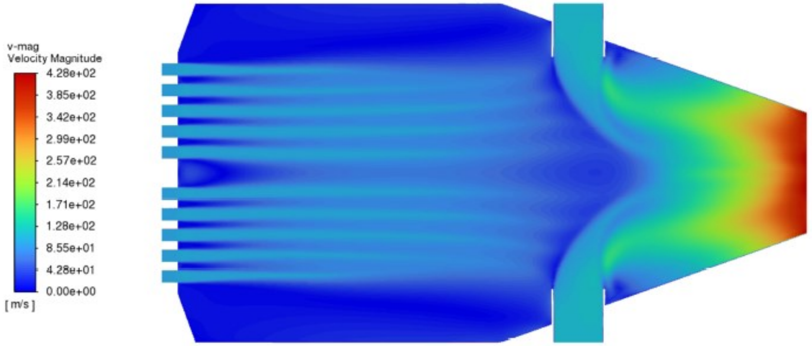
Additive manufacture of burner, mounting system & dual fuel inlet system



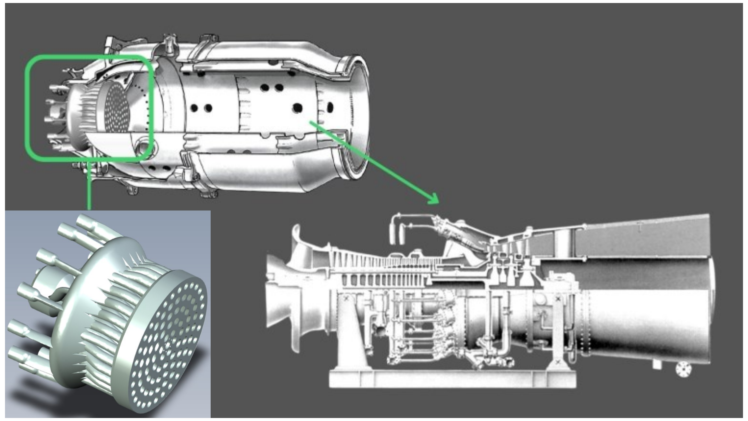




Dilution air injection optimization for turbine traverse control



H2R® ADAPTION TO A 15MW AERODERIVATIVE ENGINE



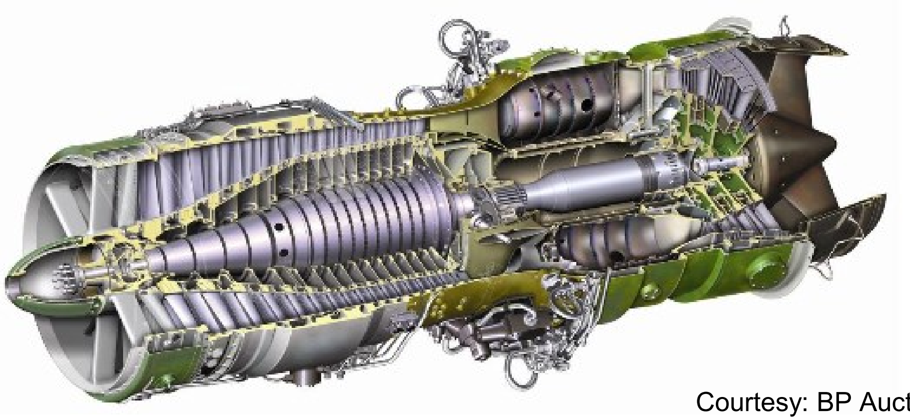
Courtesy: Science Direct

H2R® Customisation completed.

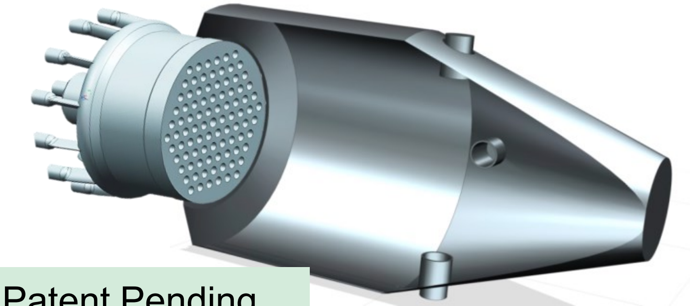
Unpiloted operation:

- NOx reduction from 45ppm down to 5ppm Natural Gas
- With Hydrogen NOx down to 9ppm

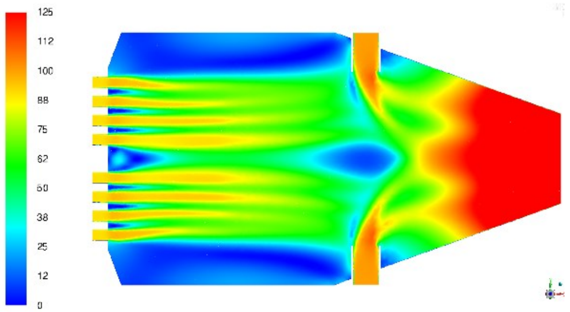
Expected first engine operation in H2/2024



Courtesy: BP Auction



Patent Pending On H2R® Burner



Computational simulation of Burner & Combustor

➔ Expected operation confirmed by simulations & tests

		CH4		CH4/H2 50:50 by mass	H2 100%
		Current burner	H2R converted		
Power	[MW]	15.2	15.2	15.60	15.64
Efficiency	[%]	29.2	29.2	29.7	30.1
Fuel Consumption	[kg/s]	1.04	1.04	0.61	0.44
NOx Emissions	[$ppm_{dry,\ 15\%}$]	> 45	15	20	25
CO2 Reduction	[tons/hr]	0	0	3.7	8.9

H2R® as a transitional technology and hydrogen-ready: emission reduction, increase in power and efficiency

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H2R®: SUMMARY & NEXT STEPS

The H2R® burner has been developed as a retrofit solution to permit gas turbine operation on Natural Gas, Hydrogen and any mixture thereof, using the same hardware

- Technology proven: Proof-of-Concept demonstrated | Stable Operation, no flashback with 100% Hydrogen
- Tests conducted with Eight different burner variants show consistently very low NOx
- Empirical & CFD Extrapolation to GT conditions:
  - NOx < 5ppm for Natural Gas & NOx < 10ppm for Hydrogen for unpiloted conditions
- Scalability & durability of the burner concept confirmed
- All burners capable of blended operation from 100% Natural Gas to 100% Hydrogen in any proportion

Next Steps:

- Demonstration at Gas Turbine pressures & temperatures
- Testing of the full can configuration with the final adaption of the burner
- Full Engine trials planned in H2/2024
- Adaptions of the H2R® technology to other gas turbines currently underway

THANK YOU FOR YOUR ATTENTION

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Discussion