Steve Morris, Facility Manager

Gas Turbine Research Centre (GTRC)

Heol Cefn Gwrgan Road

Margam

Port Talbot, UK

SA13 2EZ

Tel: ++ 44 (0) 1639 864751

e-mail:morrissm@cf.ac.uk

Web: www.cu-gtrc.co.uk

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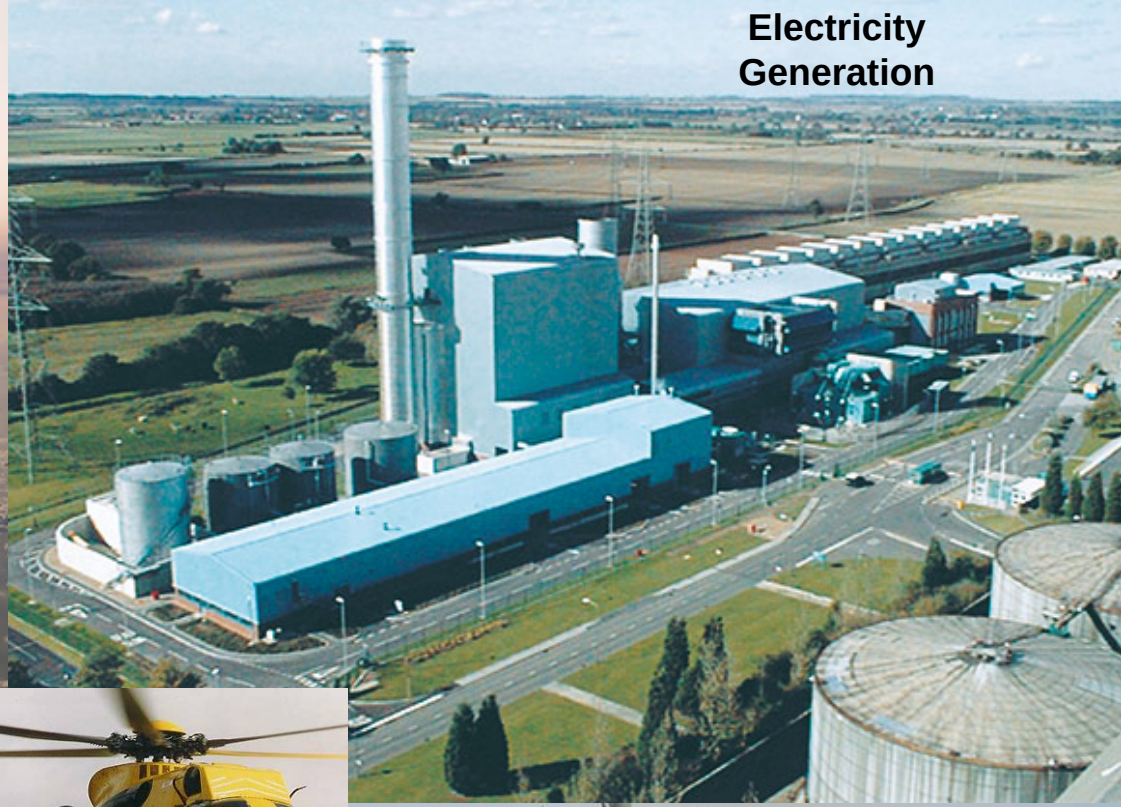
Oct 2007 GTRC opened by Wales' First Minister Rhodri Morgan

Airbus A380 largest passenger aircraft

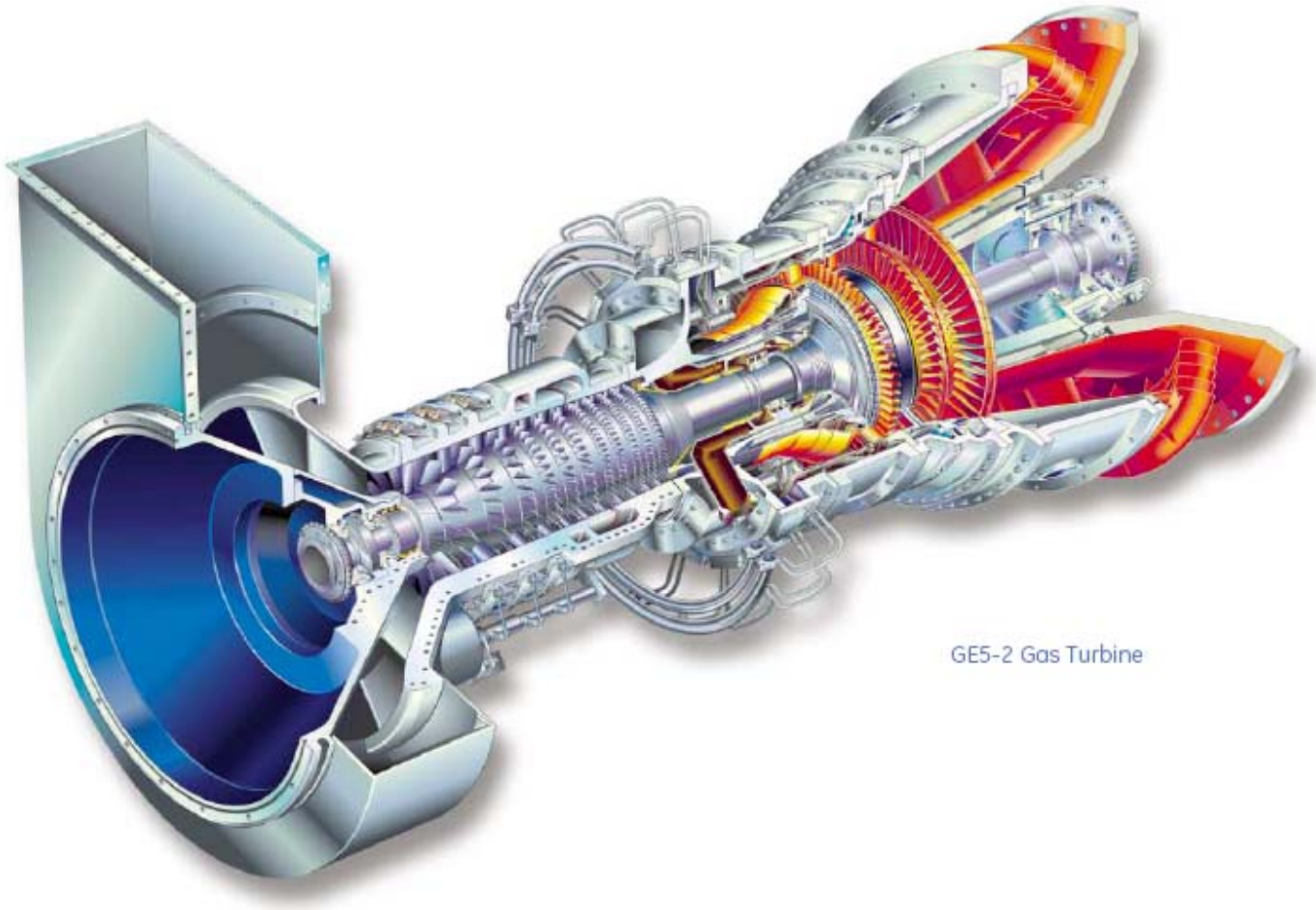
Electricity Generation



Concord fastest passenger aircraft Mach2+

Marine Power

Industrial Gas Turbine

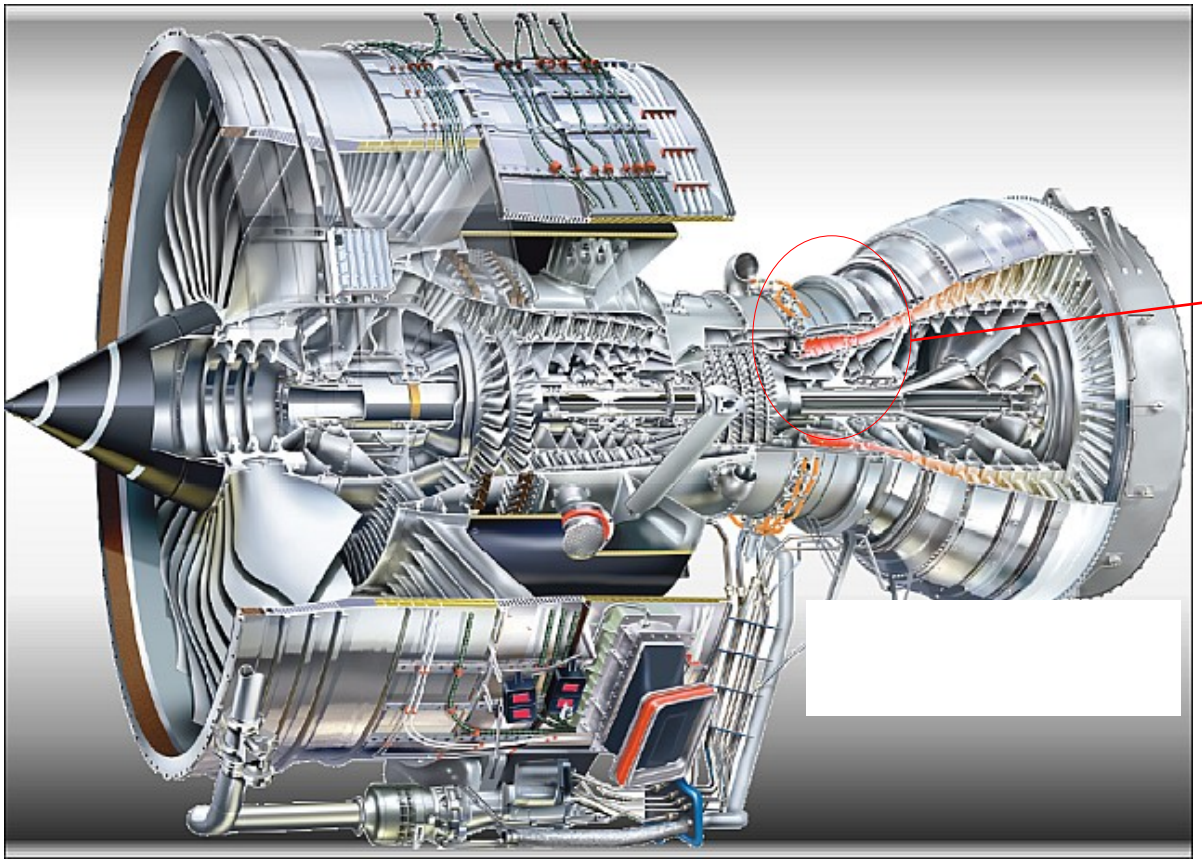


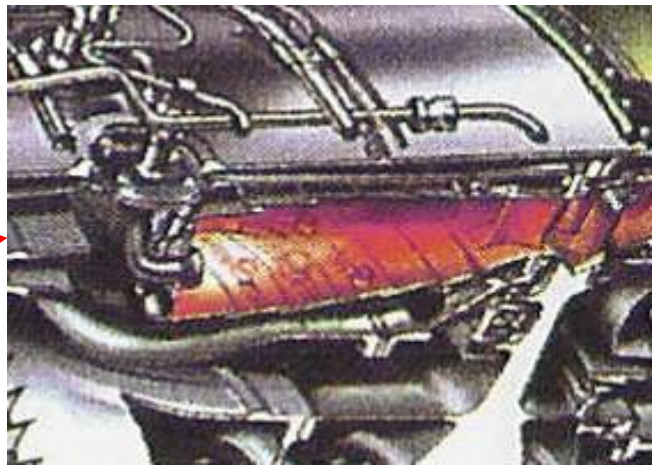
Driveshaft used to power a generator producing electricity

Fuels

- Diesel
- Natural Gas
- Biofuel
- Syngas
- Hydrogen

Aviation Gas Turbine – Combustor





Rolls Royce Trent-900 Used on Airbus A380

www.rolls-royce.com

Temperatures

- Inlet 900K
- Combustion 2000K
- Outlet 1400K

Research Drivers

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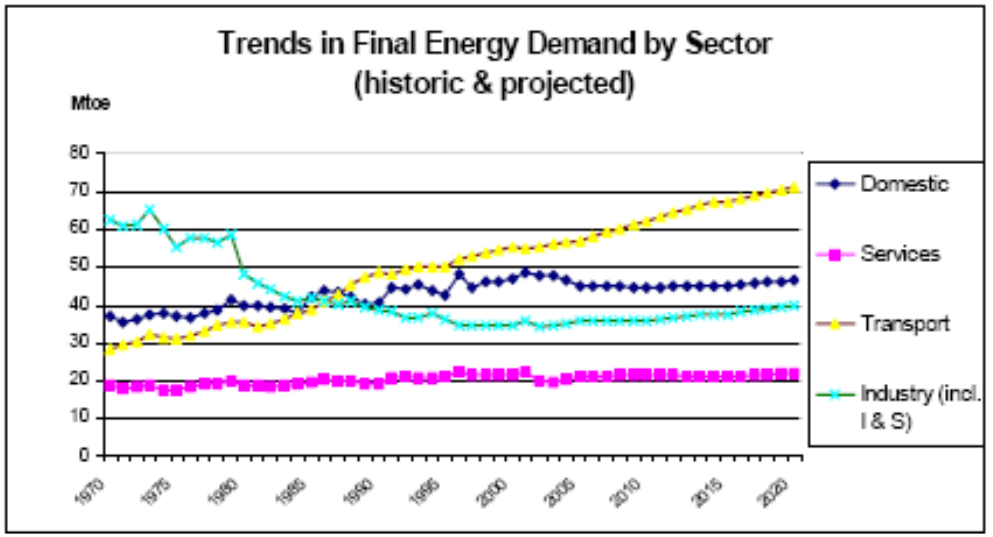
Kyoto Protocol – Domestic goal of reducing CO_2 emissions by 20% by 2010.

The Energy White Paper - Goals of setting the UK on a path to reduce CO_2 emissions by 60% by 2050**.**



Source - DTI Statistics 2006

ETN Conference October 2006
European Energy Policy. *Dr Derek M. Taylor*
Energy Advisor, European Commission

"Two sectors in which CO_2 emissions are expected to grow considerably. Transport and electricity production."

Vision 2020 targets:

- Reduce fuel consumption and CO2 emissions by 50%
- Reduce perceived external noise by 50%
- Reduce NOx by 80%

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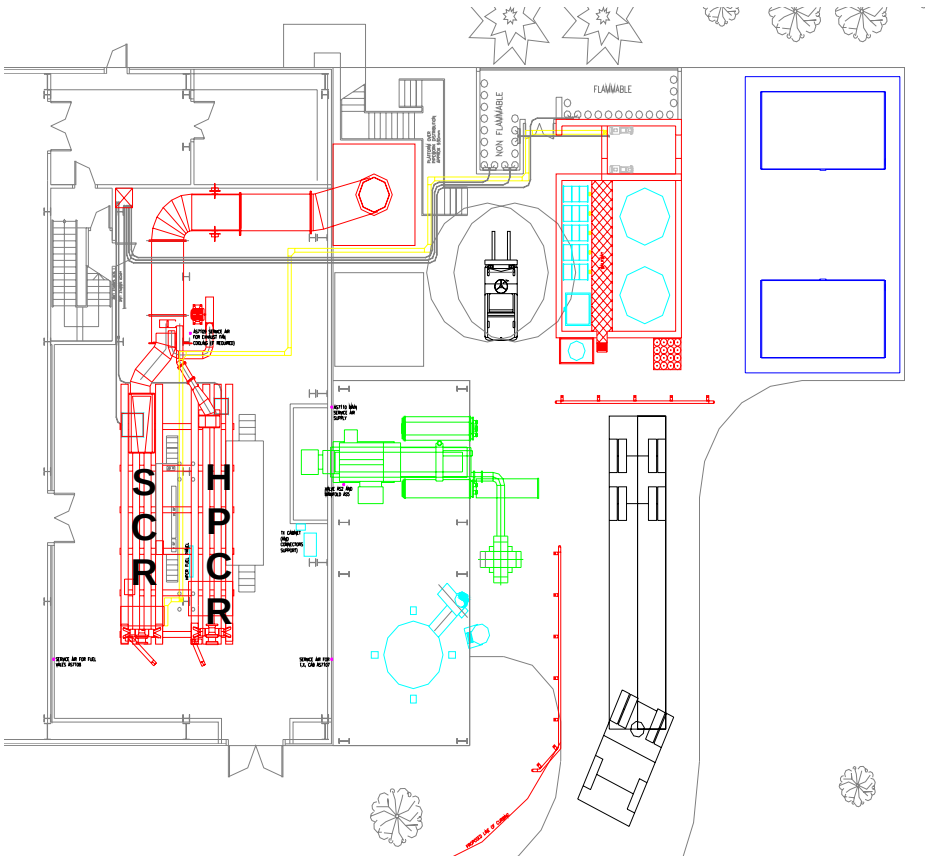
Plan View of GTRC



Two major combustion rigs with inlet air up to 16 bara, 900K and 5kg/s. Capable of running liquid and gaseous fuels.

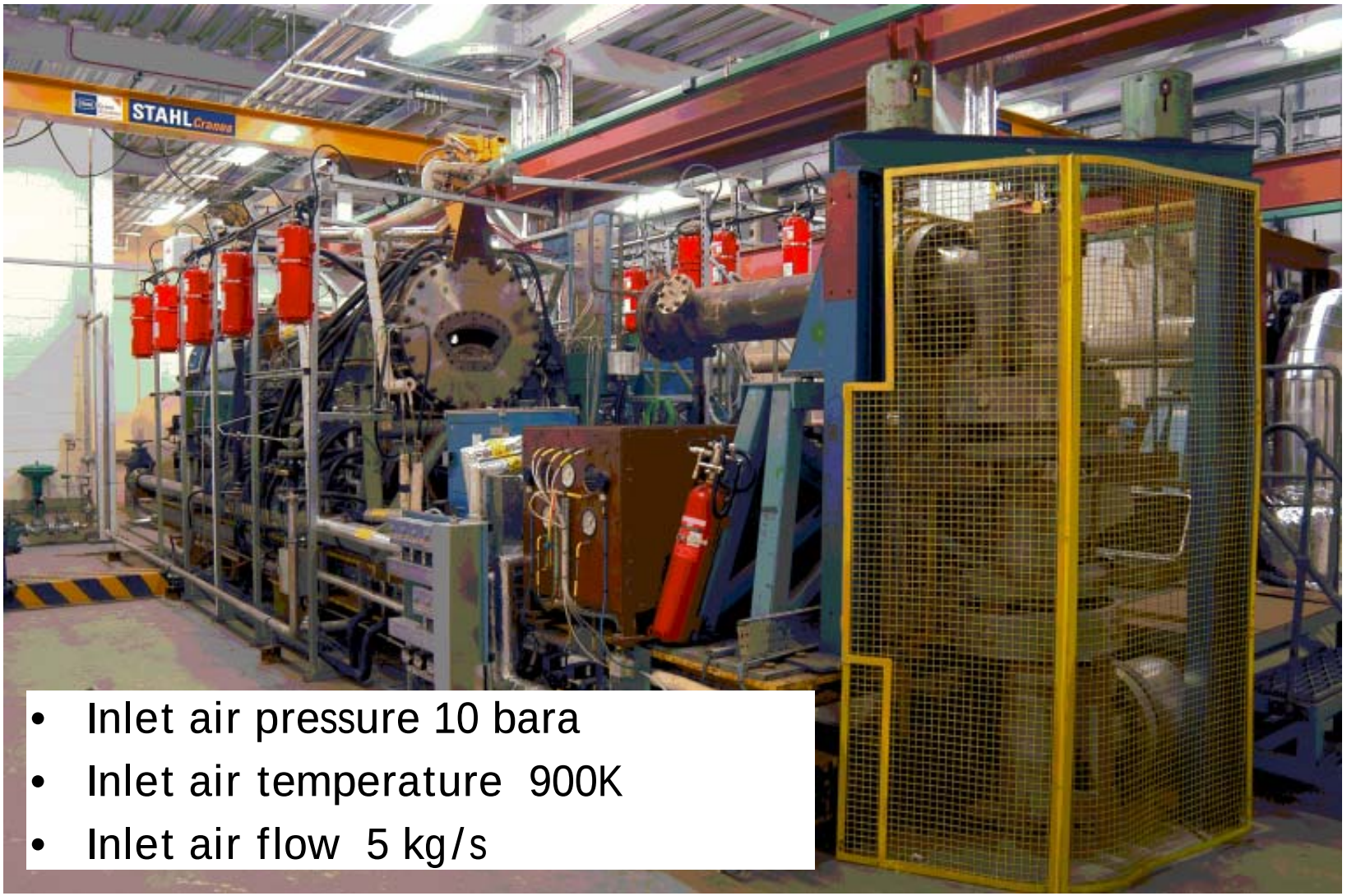
Supplied by a range of heavy-duty industrial equipment:

- 2.2 MW air compressor
- 6MW pre-heat

Sector Combustor Rig (SCR): Internal pollutant mapping of combustors

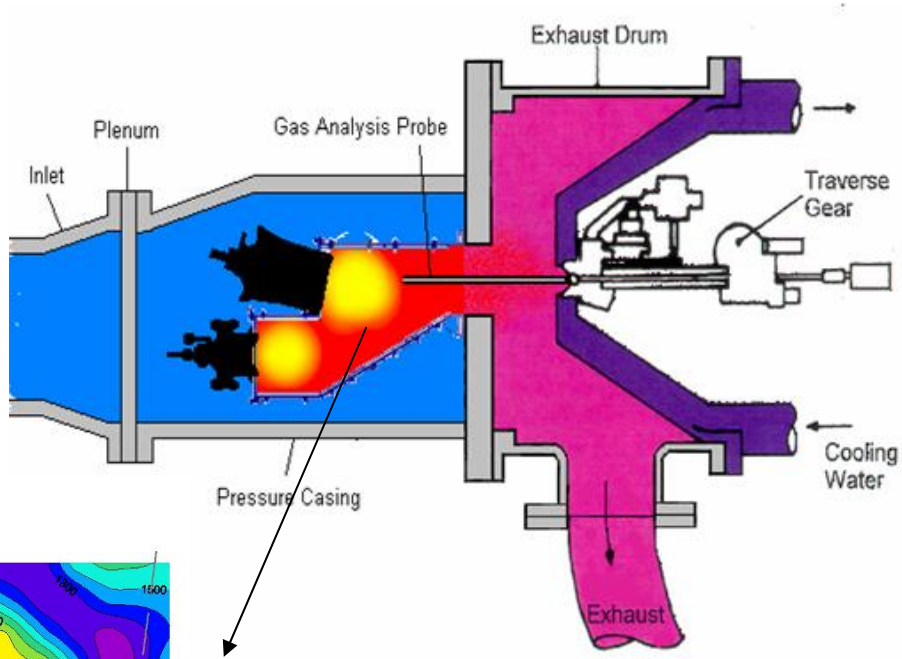
High Pressure Combustor Rig (HPCR): Fundamental combustion research such as burning velocity, auto-ignition delay time

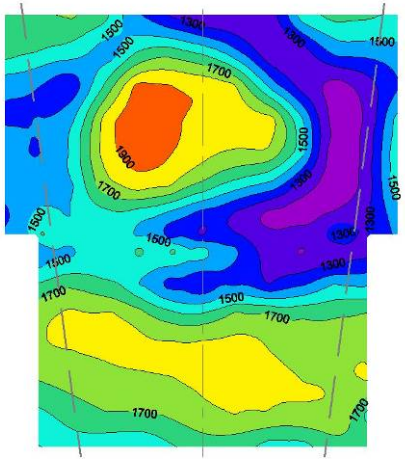
Sector Combustor Rig (SCR)



- Inlet air pressure 10 bara
- Inlet air temperature 900K
- Inlet air flow 5 kg/s

Sector Combustor Rig (SCR) Internal Traversing

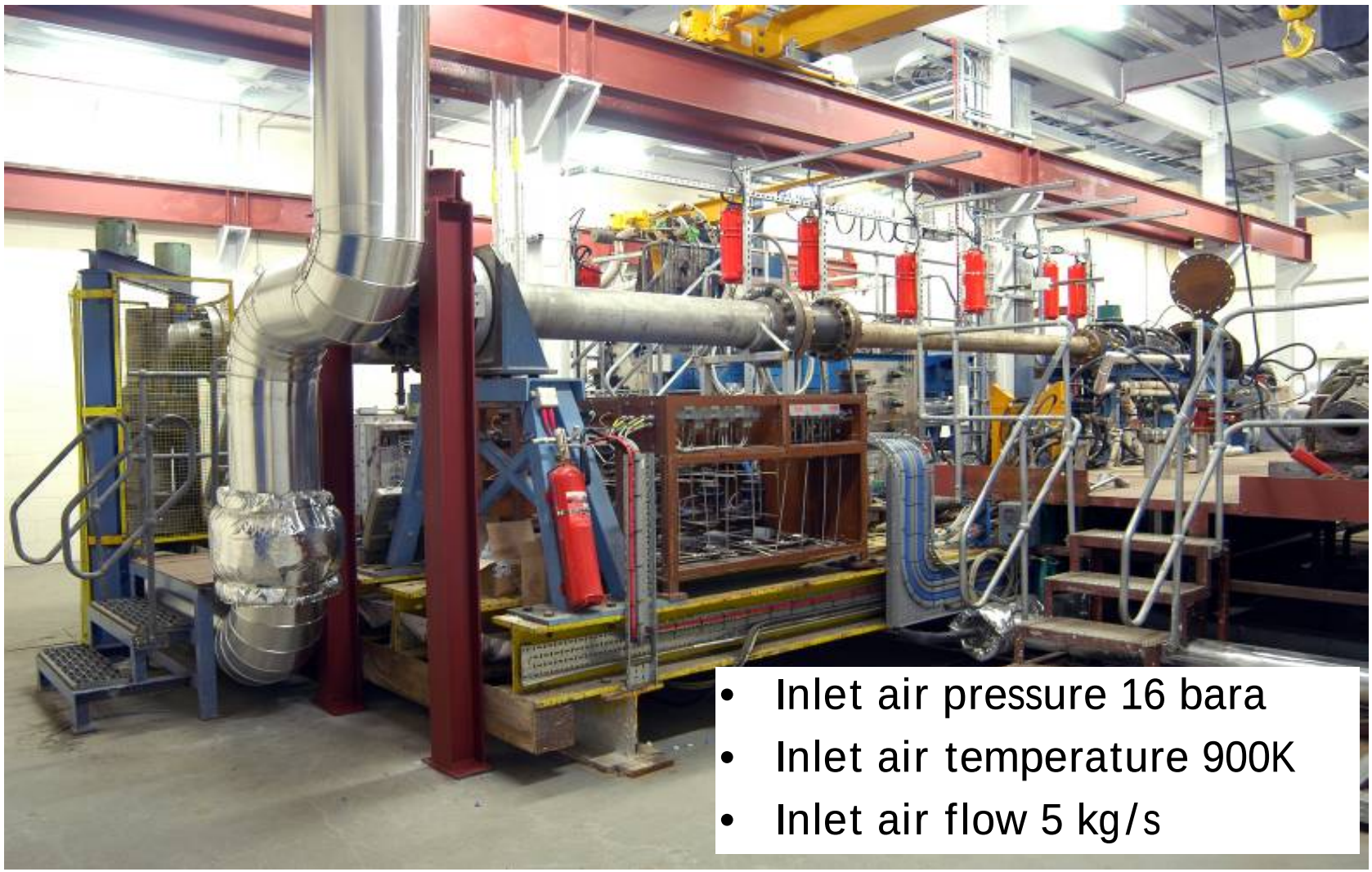




- Inlet air pressure 10 bara
- Inlet air temperature 900K
- Inlet air flow 5 kg/s

- On-line gas analysis traversing WITHIN combustors
- Online gas analysis: (NOx, CO, SOx, PM, etc..)
- Various fuels : Kerosene, diesel, NG, etc.

High Pressure Combustor Rig (HPCR)



- Inlet air pressure 16 bara
- Inlet air temperature 900K
- Inlet air flow 5 kg/s

HPCR Test Modules

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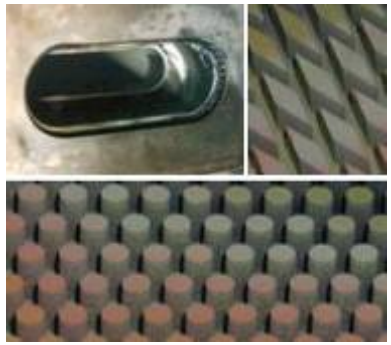
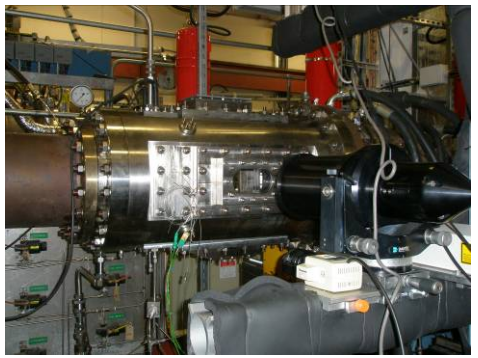
- Combustion Instability rig

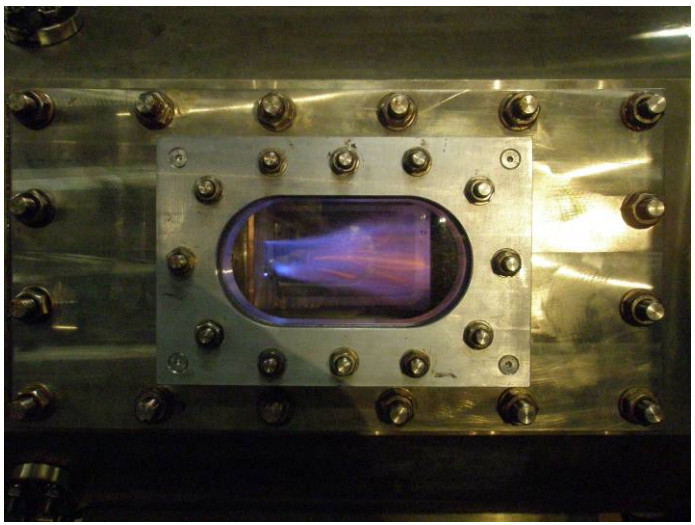
- Auto-ignition rig



- Wall cooling rig



- **UPGRADE: Optical Combustor**



- Inlet air pressure 16 bara
- Inlet air temperature 900K
- Inlet air flow 5 kg/s

HPCR Test Modules

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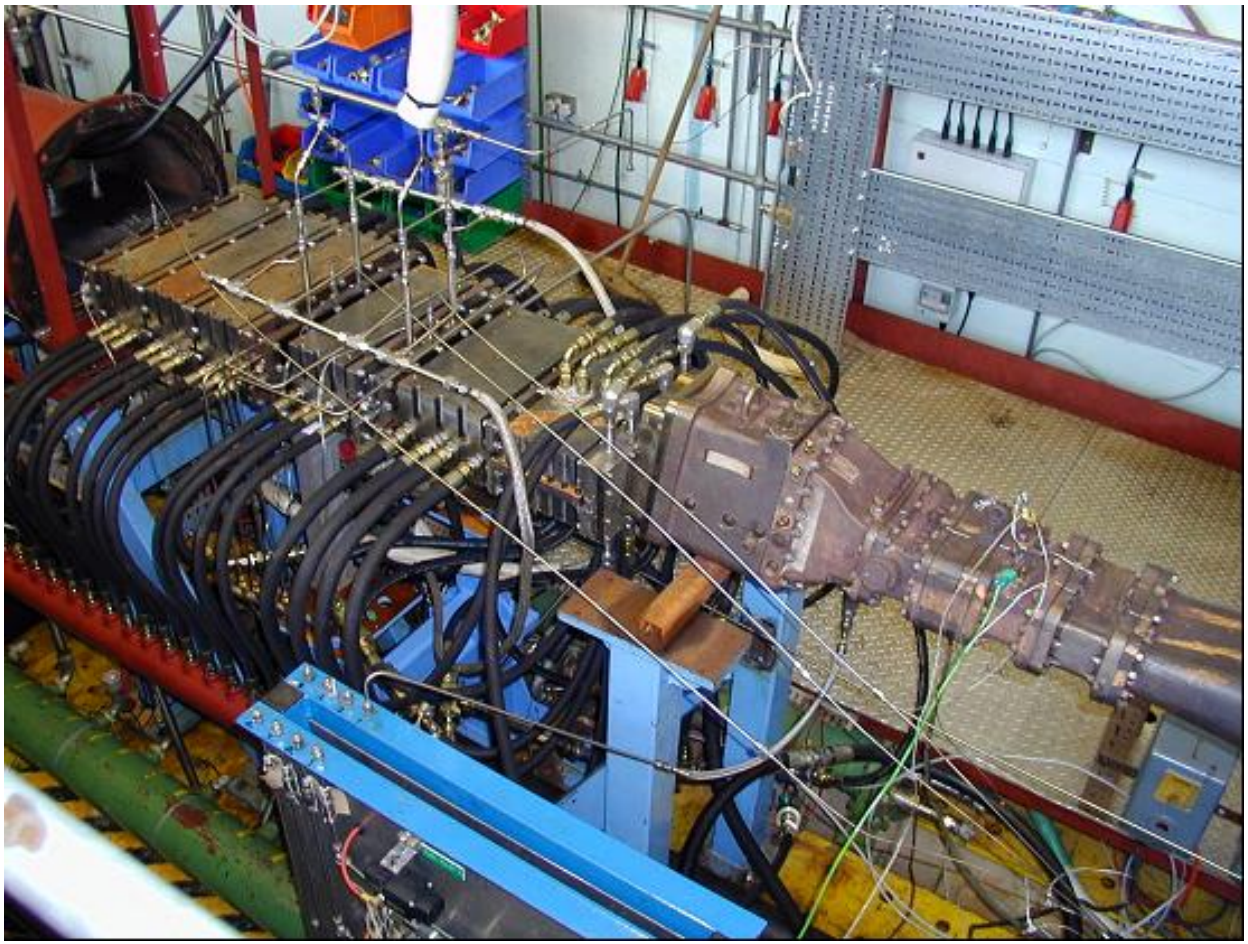
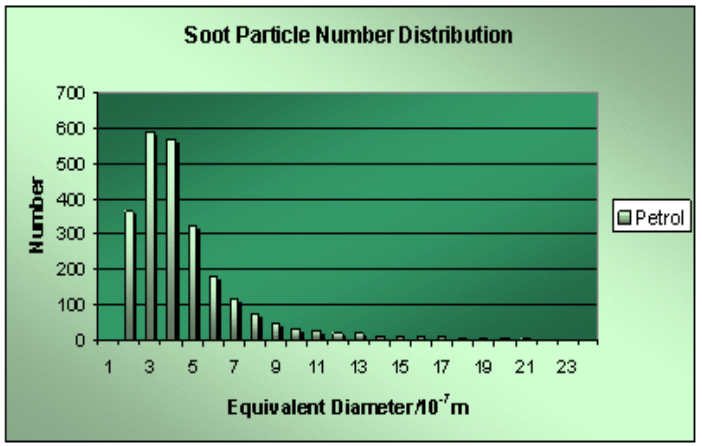
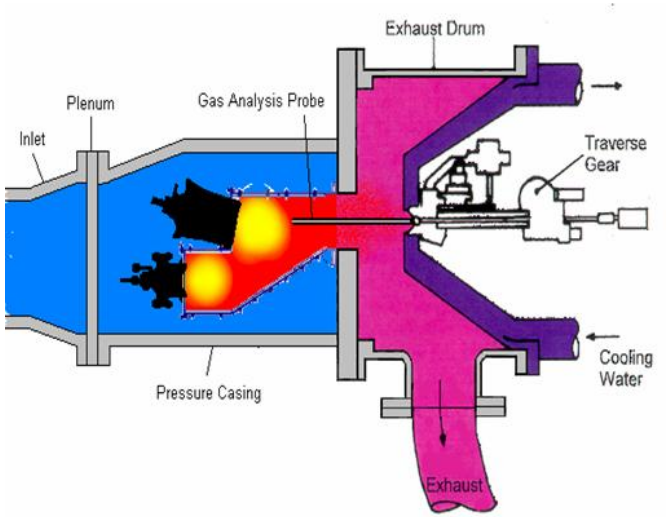
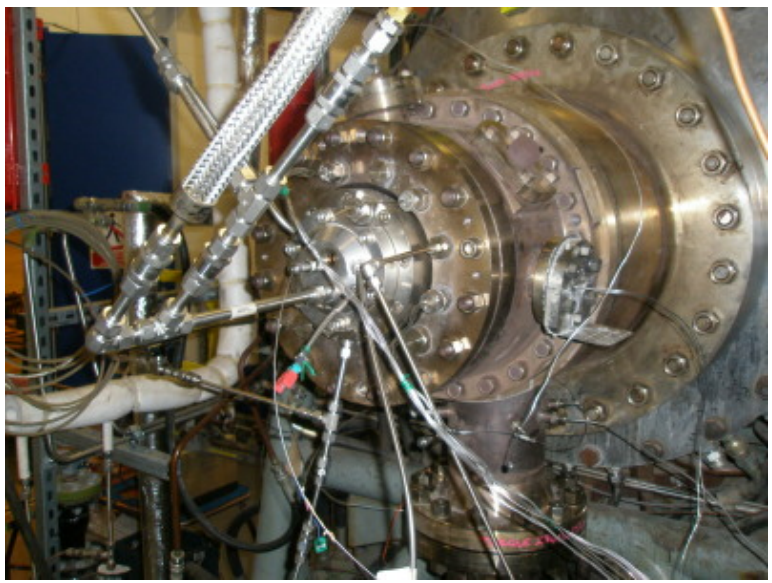
Hot End Simulator





Experiment 1 & 2.
Siemens Traversing & TST





Siemens Internal Traversing:

- Siemens combustor for industrial gas turbine running diesel with a natural gas pilot
- 200 sample points within the combustor
- Logging NO, NO2, O2, CO2, THC
- ASME Turbo Expo 2008 conference paper “Detailed Internal Measurements of a Siemens Combustor Operating at Gas Turbine Relevant Conditions”
- PhD Student Yura Sevcenco has been assisting and will be continuing work in this area

True Surface Temperature:

- True surface temperature measurements of the Siemens combustor on the HPCR
- High speed data logging
- Inlet conditions 850k, 14bara
- Diesel main with natural gas pilot

Experiment 3.
Liquid Autoignition

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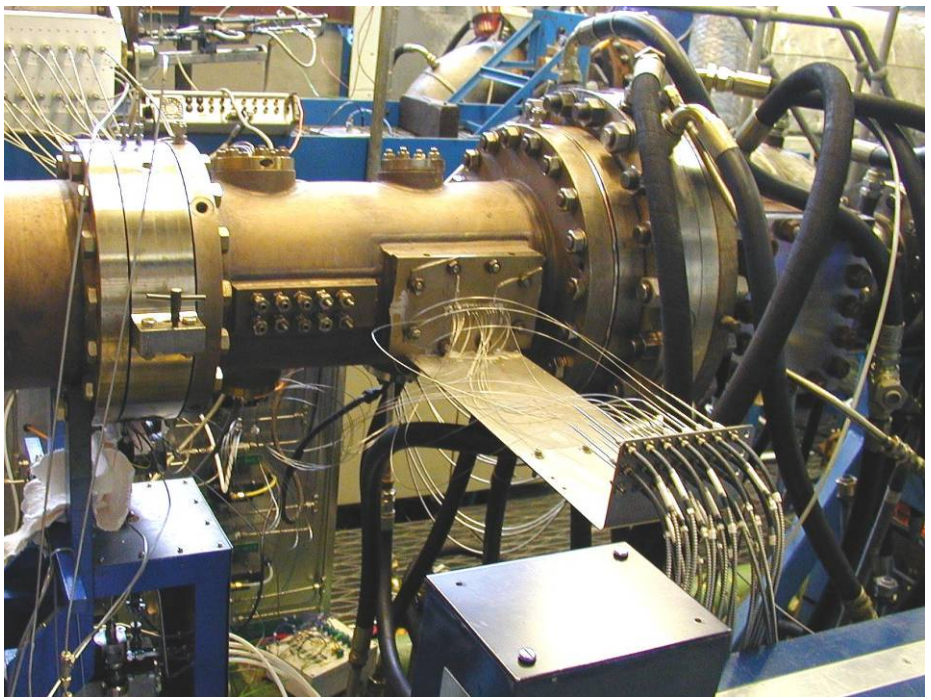
Liquid Autoignition Delay Time (ADT)

- Provided test facilities to QinetiQ
- Part of the AFTUR contract with QinetiQ
- Delivered on the HPCR rig at the GTRC
- Inlet conditions 850K, 14bara
- Diesel and biodiesel



Experiment 4 & 5.
High Pressure Gaseous and Liquid Burning Velocity

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Gaseous Burning Velocity (BV)

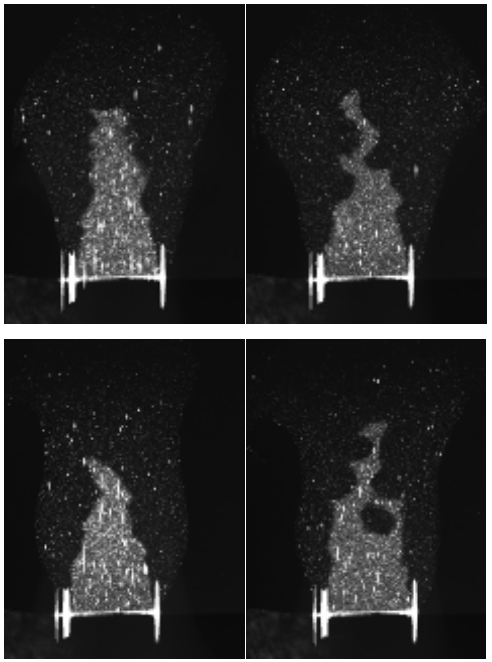
- Part of the AFTUR FP5 project contract with QinetiQ
- Delivered on the HPCR
- Inlet conditions up to 673K, 10bara
- Methane
- Methane CO2 mixtures
- Methane H2 mixtures

Liquid Burning Velocity (BV)

- Delivered on the HPCR
- Inlet conditions up to 673K, 10bara
- Diesel and biodiesel

Experiment 4 & 5. High Pressure Gaseous and Liquid Burning Velocity

- Part of FP5 project AFTUR to develop optical techniques for use in high pressure burner.
- LDA to determine turbulence intensity.
- Using a laser sheet and high speed camera the density of the seed can be used to determine the flame front.
- High seed-density areas indicates the reactant zone and the low seed-density indicates product zone.
- Flame front is clearly identified.
- Image processing allows the average cone to be defined. 800 images used.



Methane Flame Raw Images

Average

Experiment 6
Particulate Sampling

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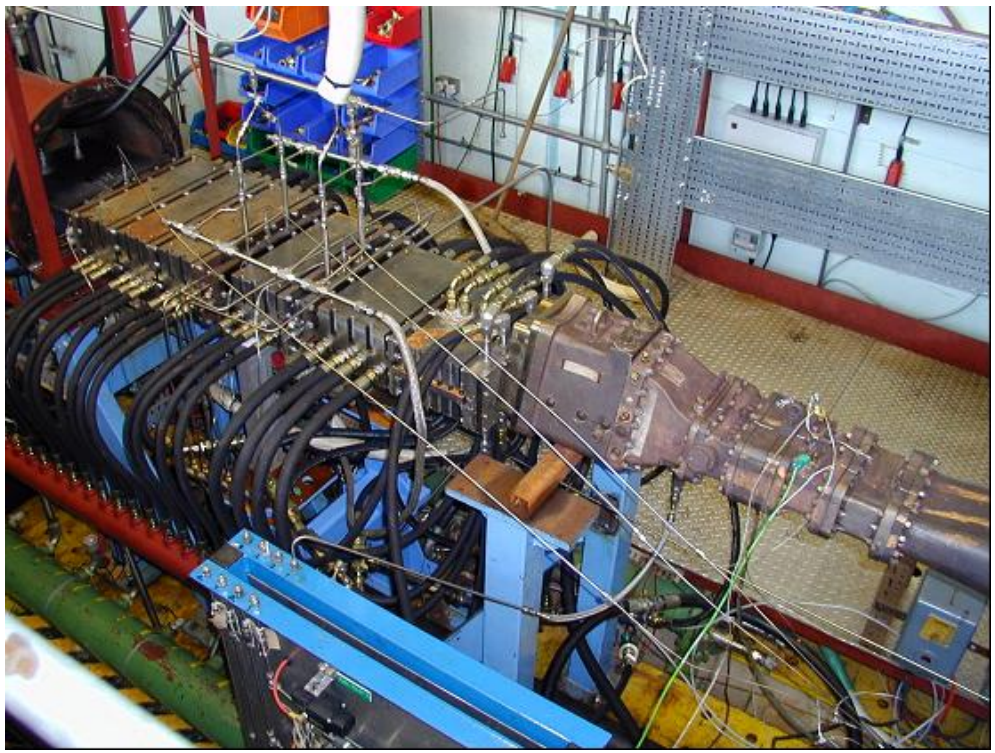
Project partners included DLR, QinetiQ, Rolls-Royce, University of Manchester, Manchester Metropolitan University, Onera and Vienna University of Technology.

The key purpose of this study was to test and evaluate techniques and methods for particulate matter measurement in the exhaust of aircraft engines at engine exit operational/flight conditions.

This study aimed to provide the atmospheric science community with necessary information on instrument applicability and method characteristics under real-world conditions corresponding to engine certification measurements.

This study involved services requested by the European Aviation Safety Agency (EASA) with current research work going on in the framework of the European Network of Excellence ECATS (Environmentally Compatible Air Transport System) and within the UK OMEGA project in order to promote European research in this area.



Hot End
Simulator

Future Gas Turbine Combustor Improvements

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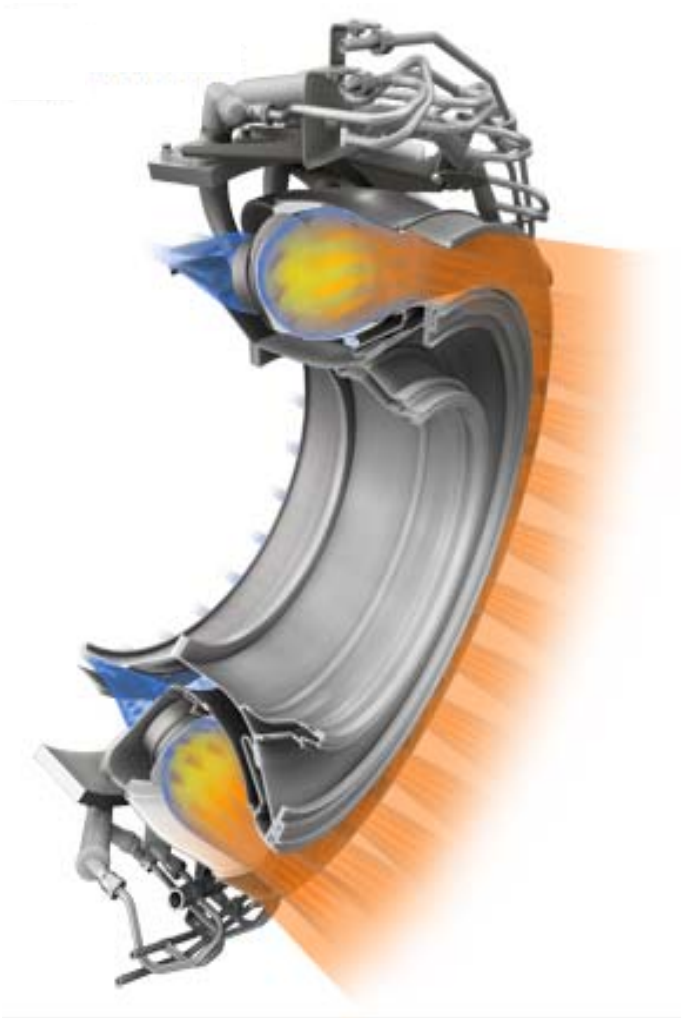
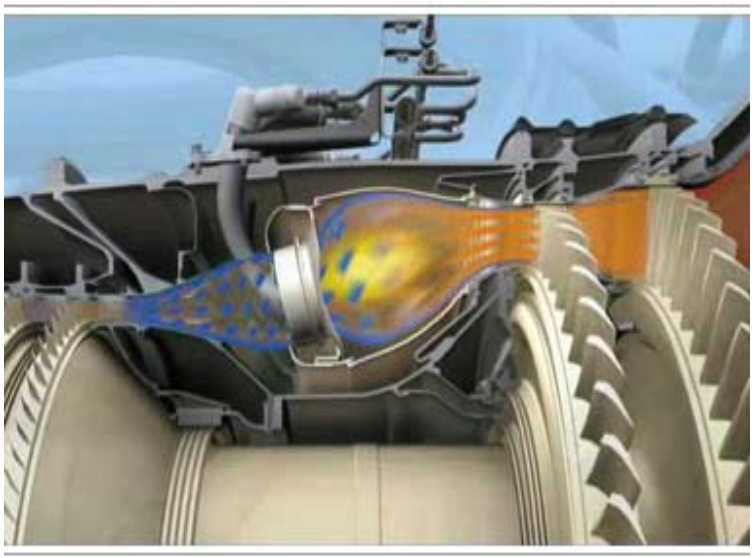
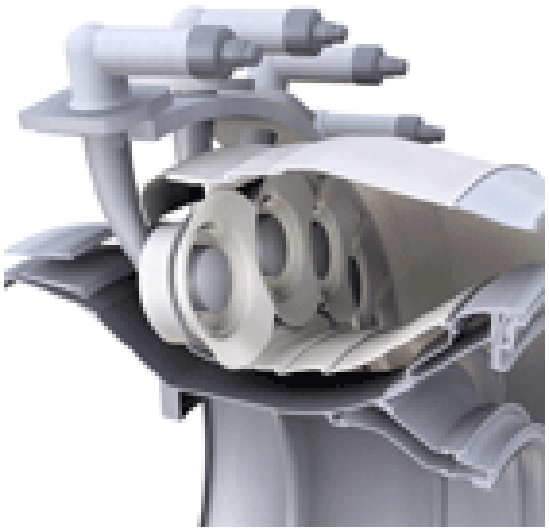
Next Generation Combustor GE-nx







- CFD modelled
- Annular combustors
- Improved mixing, pre-mixing
- Improved cooling, materials and coatings
- Lean combustion
- Low NOx
- Alternative and Renewable Fuels

Future Gas Turbine Alternative and Renewable Fuels

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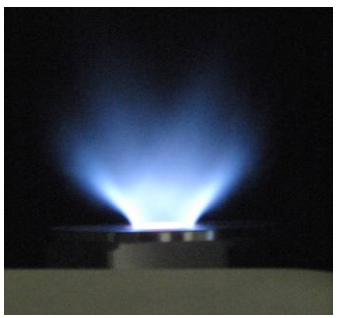
At the moment some 20% of the world's (50% in Wales) total electricity supply is derived from GT based systems primarily fired on natural gas. As the price and demand for natural gas increases, the use of alternative and renewable fuels will become increasingly important for power generators and large scale process industries

Renewable fuels include those derived via the gasification and pyrolysis of biomass, biologically derived products from Anaerobic Digestion (AD) and renewable hydrogen. Alternative fuels include syngases produced from the gasification of coal and the waste gases from steel making and refinery plants such as Corus at Port Talbot.

Numerous problems arise, such as substantially variable heating values, improper location of the flame front, overheating of components, mal temperature and velocity distributions, increased emissions of NOx, CO and hydrocarbons and dangerous vibration levels engendered by the coupling of the combustion process with naturally occurring acoustic and other modes of oscillation in the system

Methane



Propane

BOS 60%CO, 1%H2

COG 65%H2, 25%CH4, 6%CO

100% Hydrogen

Future Gas Turbine Flash Back

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Many of these alternative fuels will be rich in Hydrogen and as such will have significantly faster burning rates and shorter ignition delay times.

Instability is a problem for the new generation of gas turbines running lean pre-mixed combustion and variable CV fuels. Instability brings operation issues as well as combustion problems such as flash back and blow off.

Blow Off

Flash Back

Damage Caused by Flash Back

Complimentary Activities

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Atmospheric Furnace

- 2MWth
- Furnace Temperatures > 1500C.
- Currently using domestic heating oil, but could run biodiesel and with slight modification natural gas.

Approximate dimensions:

Diameter = 1.3m
Length = 4m
4 Probe insertion points run along the length at 1.2m, 1.8m, 2.4m and 3.0m from burner face.

- Optical Access
- Exhaust sampling

Complimentary Activities

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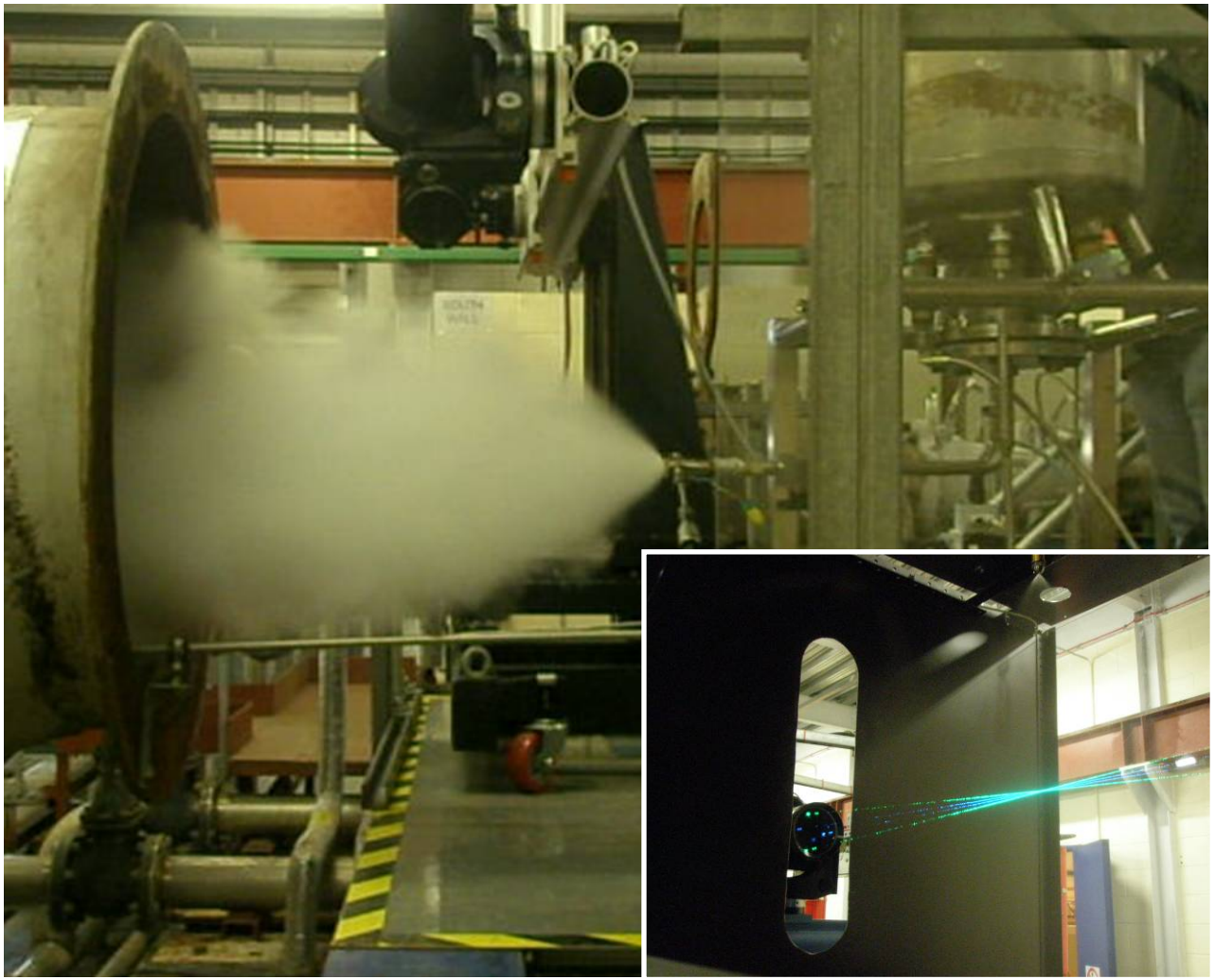
Large Scale Sprays



Rig Capabilities:

- Up to 100g/s
- Water, Gasoline, Diesel
- Air Assist
- Steam Assist
- Fuel Pre-Heat

Measurements:

- Laser sheet imaging
- Shadowography
- Phase Doppler Anemometry (PDA)

Complimentary Activities

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Combustion Training

1. Introduction to basic combustion principles
2. Examples of combustion applications
3. Flammability & Explosive Limits of Typical Fuels
4. Inherent Risk & Hazard of Combustion
5. The prevention of explosions
6. Brief overview of relevant regulations