Rolls-Royce CLEEN II Sustainable Aviation Fuels

Brad Belcher

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CLEEN II Consortium-Public Day, Virtual

Jurisdiction	Export Control Classification (Rating)	Date
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CLEEN Technologies

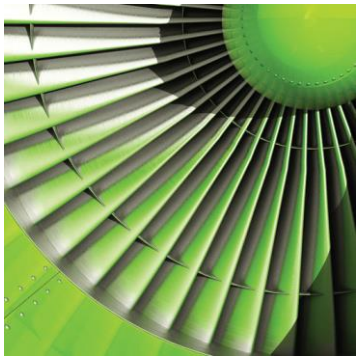
CLEEN Technology Name	Goal Impact	Benefits and Application
Alternative Jet Fuel Test and Evaluation (Area A)	Alternative Fuels	Promotes the development and introduction of viable, renewable alternative fuels to achieve the NextGen Air Transportation System goals. Data will be shared with the ASTM Aviation Fuel Community to support international approval of a fully synthetic jet fuel.

Rolls-Royce Sustainable Aviation Fuel Program

Elevator Speech

The Rolls-Royce Sustainable Aviation Fuel Program is promoting alternative jet fuel development, approval & deployment, which contributes to the attainment of FAA NextGen Air Transportation System goals. This robust evaluation program is characterizing a novel fully-synthetic fuel's performance under representative engine conditions. This goal is being accomplished through a series of "back-to-back" rig tests with conventional Jet A fuel to assess the fuel's impact on combustor performance and emissions. Elastomeric seal performance is also being assessed using the innovative Elastocon rig capability developed and demonstrated under CLEEN I. The data generated will be compared to prior work, assessed, and shared with the ASTM Aviation Fuel Community to support the International approval of a fully synthetic jet fuel.

Rolls-Royce Sustainable Aviation Fuel Program



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Program Scope

- Promotes the development and introduction of viable renewable alternative fuels to meet NextGen Air Transportation system goals
- A robust evaluation program that is characterizing a fully synthetic fuel's performance under representative engine conditions
- Accomplished through a series of "back-to-back" rig tests with conventional Jet A fuel
- Fuel chemistry/properties relationship upon fuel spray, combustor performance, operability, and emissions
- Elastomeric seal performance due to cyclic fuel switching under more realistic engine conditions
- Data generated can be shared with ASTM Aviation Fuel Community and aid in fuel certification process

Rolls-Royce Sustainable Aviation Fuel Program

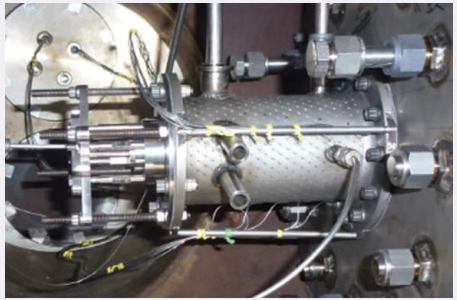
Benefits

- The data generated will support the international approval of a fully synthetic jet fuel
- Enhanced methods for predicting fuel performance on engine systems to support reduced cost and timescale of approvals
- Greater data and test capability to support environmental benefits (i.e., local air quality, increasing regulations)
- Renewable, synthetic alternative jet fuel for aerospace gas turbine engine applications should provide reduced aerospace environmental impact and increased energy security

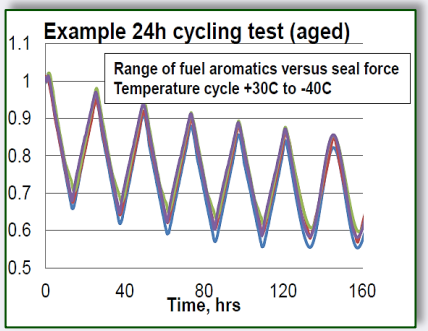
The purpose of the Test Program is to ensure the candidate fuel will have no negative impact on engine Safety, Durability, or Performance

Approach

- Proven sequential test program (“back-to-back” with Jet A)
  - Fuel requirements: 2200 gallons
  - Conduct laboratory and fit-for-purpose evaluation
  - Characterize fuel spray behavior
  - Utilize combustion rigs to assess fuel impact upon performance, operability, and emissions
  - Assess elastomeric seal performance using the innovative Elastocon rig
- Data generated will be compared to prior work, assessed and reported



Flame Tube



Seal Performance

Fuel Selected

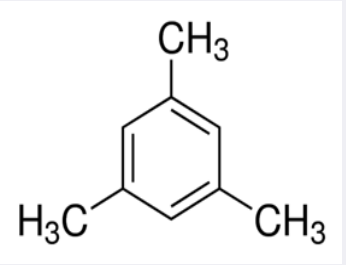
“LanzaTech Alcohol to Jet Synthetic Kerosene with Aromatics”

87%

Alcohol to Jet

+

13%



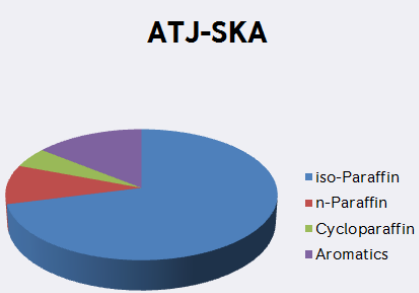
Mesitylene

- ✓ Fully synthetic kerosene fuel
- ✓ Allows for proper atomization and fuel system performance
- ✓ Acceptable combustion performance anticipated
- ✓ Acceptable elastomer seal performance

Test Results

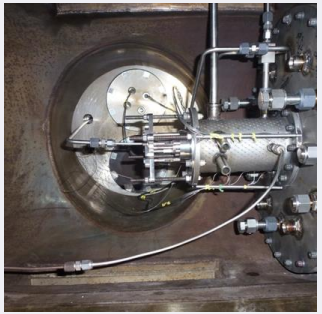
Summary of ATJ-SKA Back to Back Test Results

- Laboratory characterization:
  - Primarily iso-paraffinic composition
  - Acceptable volatility, fluidity, and thermal stability
- Overall spray performance similar to Jet A fuel, with only minor differences noted
- Combustion flame tube:
  - Lean stability deteriorated slightly
  - Emissions – NOx similar, but CO and UHC emissions are higher at certain conditions, leading to lower combustion efficiency
  - Combustion liner wall temperatures are similar



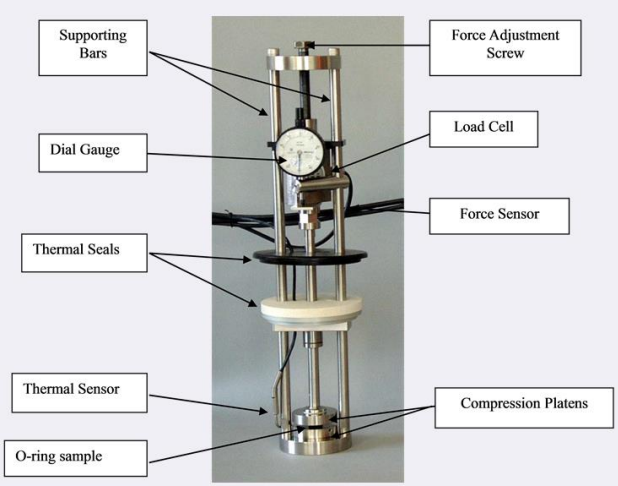
Chemistry

Fuel Spray



Combustion

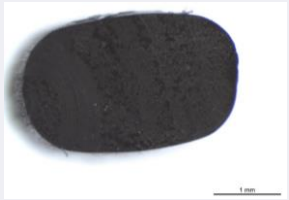
Test Results



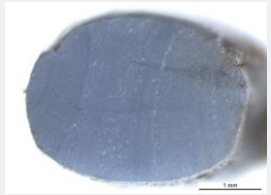
Summary of Elastomeric Seal Testing

- Novel test method showed differentiation in representatively aged seal performance for 5 elastomer materials and 3 aromatic levels
- 30°C Testing Results:
  - Suggest sealing force 4% Aromatic ATJ < 13% Aromatic ATJ < Jet A-1
  - Minimum retained sealing force of ~10% still considered functional
- -40°C Cyclic Testing Results:
  - Sealing force dependent on temperature, but retained sealing force never reached zero for worst case (fluorosilicone)
  - Performance of highly degraded seals at low temperature considered poor, as expected
- Post-test seal condition consistent with stress relaxation data

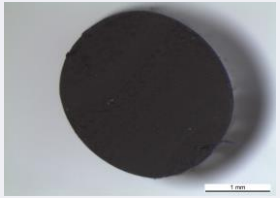
Nitrile



Fluorosilicone



Fluorocarbon



No Technical Data

Schedule

CLEEN II Sustainable Aviation Fuel Schedule

Rolls-Royce Sustainable Aviation Fuel Program	2016				2017				2018				2019				2020			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Fuel Selection & Delivery																				
Test Program																				
Draft Final Report																				

Program on track to finish Final Report 4Q 2020

Sustainable Aviation Fuel Program

Achievements

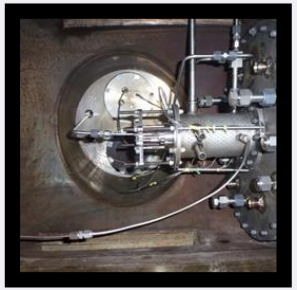
- **Completed Objectives**:
  - Laboratory and fit for purpose
  - Spray characterization
  - Elastocon compression stress relaxation data for five seal materials
  - Flame tube testing

- **Wrapping up:**
  - Deliver full draft technical report 4Q2020

Program on track to deliver objectives

Sustainable Aviation Fuel Test and Evaluation

Quad Chart



Benefits:

- The data generated will support the international approval of a fully-synthetic jet fuel
- Enhanced methods for predicting fuel performance on engine systems to support reduced cost and timescale of approvals
- Greater data and test capability to support environmental benefits (i.e., local air quality, increasing regulations)
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Objectives:

- Promote the development and introduction of viable renewable alternative fuels - NextGen Air Transportation systems goals
- Improved tools for predicting fuel performance and scientific understanding
- Data generated will aid in ASTM fuel certification process

Work Statement:

- Assess a fully synthetic jet fuel using low NOx combustion systems to determine fuel impact on performance, operability, and emissions
- Assess elastomeric seal performance using the innovative Elastocon rig

Accomplishments/Milestones:

- Objectives Completed: Laboratory, fit for purpose, spray characterization, Elastocon, and flame tube testing
- Wrapping up draft technical report

Schedule:

Rolls-Royce Sustainable Aviation Fuel Program	2016				2017				2018				2019				2020			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
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