U.S. Department
of Transportation
Federal Aviation
Administration

Evaluation of Amyris Direct Sugar to Hydrocarbon (DSHC) Fuel

Continuous Lower Energy, Emissions and Noise (CLEEN) Program

Submitted by Pratt & Whitney

DOT/FAA/AEE/2014-07

The Continuous Lower Energy, Emissions and Noise (CLEEN) Program is a Federal Aviation Administration NextGen effort to accelerate development of environmentally promising aircraft technologies and sustainable alternative fuels. The CLEEN Program is managed by the FAA's Office of Environment and Energy.

The report presented herein is a report deliverable submitted by Pratt & Whitney for a project conducted under the CLEEN Program to evaluate the feasibility of selected alternative fuels as viable drop-in replacements to petroleum jet fuel. This project was conducted under FAA other transaction agreement (OTA) DTFAWA-10-C-00041. This is report number DOT/FAA/AEE/2014-07 by the FAA's Office of Environment and Energy.

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In reply please refer to:
SSC:DTFAWA-10-C-00041/15

30 April 2014

FEDERAL AVIATION ADMINISTRATION
Jared Tritle, Contracting Officer
800 Independence Avenue, SW
Room 402
Washington, D.C. 20591

Subject: FINAL REPORT, PUBLIC RELEASE VERSION, **FR-27652-3a**

Reference: Contract No. DTFAWA-10-C-00041, Item No. 15

In accordance with the applicable requirements under the referenced contract, Pratt & Whitney herewith submits one (1) copy of the Public Release version of the Final Report for the subject contract.

Sincerely,

Sarah S. Christopher

Sarah Christopher
Program Data Manager

With enclosure:
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FR-27652-3 Rev 1
16 April 2014

CONTINUOUS LOWER ENERGY, EMISSIONS, AND NOISE (CLEEN) PROGRAM

P&WC ENGINE TEST AND COMBUSTOR RIG TEST PERFORMED ON 20 PERCENT AMYRIS FARNESANE/JET A BLEND

Prepared for
FAA Office of Environment and Energy

Prepared under
Contract No. DTFAWA-10-C-00041

In Response to
CDRL No. 15

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ACRONYMS

A

APA	Automatic Particle Analyzer
ASTM	ASTM International (Formally known as American Society for Testing and Materials)
ATP	Acceptance Test Procedure

C

CAAFI	Commercial Aviation Alternative Fuels Initiative
CH	Catalytic Hydrothermolysis
CLEEN	Continuous Lower Energy, Emissions, and Noise
CO	Carbon Monoxide
CO2	Carbon Dioxide

D

DoD	Department of Defense
dP	Pressure Differential
DSHC	Direct Sugar to Hydrocarbon

F

FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Control
FMU	Fuel Metering Unit
FN	Flow Number

G

GI	Ground Idle

I

ICAO	International Civil Aviation Organization
ITT	Inter-Turbine Temperature

L

LHV	Lower Heating Value
LII	Laser Induced Incandescence

N

N1	Low Rotor Speed
N2	High Rotor Speed
NRC	National Research Council
NOx	Oxides of Nitrogen

O

OEM	Original Equipment Manufacturers

P

P3	Combustor Inlet Pressure
PM	Particle Matter
P&W	Pratt & Whitney
P&WC	Pratt & Whitney Canada

S

SAE	Society of Automotive Engineers
SFC	Specific Fuel Consumption
SGS	SGS Canada Incorporated (Formally known as Société Général de Surveillance)

T

T3	Combustor Inlet Air Temperatures
TTI	Time to Idle
TTL	Time to Light

U

UHC	Unburned Hydrocarbon

COMPANIES AND ORGANIZATIONS

Amyris, Incorporated, CA, USA

ASTM International (Formally known as American Society for Testing and Materials), PA, USA

SGS Canada Incorporated (Formally known as Société Général de Surveillance) is part of SGS S.A., headquartered in Geneva, Switzerland

Total S.A., Paris, France

Université Laval, Quebec, Canada

Woodward Governor Company, CO, USA

1.0 Executive Summary

This report documents an engine test and a combustor test performed by Pratt & Whitney (P&W) in the evaluation of a branched C15 Farnesane paraffin for use as a jet fuel blending stock. The Farnesane was produced by Amyris, Incorporated (Amyris) and Total S.A. (Total) using a direct sugar to hydrocarbon (DSHC) process. The work was performed under the Continuous Lower Energy, Emission, and Noise (CLEEN) program, Contract DTFAWA-10-C-00041. P&W Canada (P&WC) performed a PW615F engine test on a baseline Jet A and a 20%/80% fuel blend of Amyris Farnesane/Jet A. The objective was to determine the impact of Amyris Farnesane on engine performance, operability and emissions. The PW615F is a 1,460 pound thrust, two-spool turbo fan with a reverse-flow combustor and dual-channel full authority digital engine control (FADEC). The engine tests were performed at the six performance points shown below. Specific Fuel Consumption (SFC), gaseous emissions: carbon monoxide (CO), unburned hydrocarbon (UHC), carbon dioxide (CO_2), oxides of nitrogen (NOx), smoke number, and particulate matter (PM), through laser induced incandescence (LII) were measured at these six points:

- Ground idle (GI)
- 30 percent power
- 50 percent power
- 85 percent power
- 93 percent power
- 100 percent takeoff power (1,460 lbf thrust).

No difference was observed in engine operability for the Amyris Farnesane fuel blend compared to that of the baseline Jet A-1 fuel. No negative impact was observed on SFC, gaseous emissions, smoke number, or PM. Inspection of fuel system components showed no adverse effects from operation on the Farnesane fuel blend.

Under the direction of P&WC, Université Laval performed tests on a single nozzle can combustor test section. Ground starts at 50, 0, -20, -30, and -40 °F and altitude relights at 15, 20, 25, 30, and 35 kft were performed. No starting differences or altitude relight lean boundary differences were observed. The rich limits were not achieved for the relights due to rig constraints.

2.0 Introduction

The objective of the Federal Aviation Administration (FAA) option to demonstrate alternate fuels is to demonstrate feasibility of selected alternative fuels as viable drop-in candidates to petroleum-derived fuels. Depending on the objective and scope of the specific task, alternative fuel feasibility, performance, and operability may be determined through engine, component, or laboratory testing. The alternative fuels being evaluated are selected based on fuel readiness level and FAA approval, with input from the engine and airplane original equipment manufacturers (OEMs), the U.S. Air Force, and the Commercial Aviation Alternative Fuels Initiative (CAAFI).

ASTM International (ASTM) and the Department of Defense (DoD) are currently evaluating a branched C15 Farnesane paraffin for use as a jet fuel blending stock. The Farnesane is produced by Amyris/Total using a direct sugar to hydrocarbon (DSHC) process. Farnesane is being evaluated for approval by industry and DoD according to ASTM D4054, *Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives*. Upon approval, it is expected that the Farnesane process will be included as an annex in ASTM D7566, *Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons*.

In November 2013, P&WC tested a PW615F engine at its Longueuil, Canada facility. The objective of this initiative was to determine the impact of the Farnesane blend on the performance properties, operability characteristics and emissions of a gas turbine engine. Additionally, in October 2013, Université Laval in Canada under the direction of P&WC, tested a generic can combustor to determine the impact of Farnesane on turbine engine combustor cold starting and altitude relight characteristics.

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3.0 Approach

3.1 Test Facility

Engine testing was performed on a PW615F engine, Serial Number 6157 Build 12, at the P&WC engine test facility 1-18 in Longueuil, Canada. Engine installation is shown in ***Figure 1*** and ***Figure 2.***

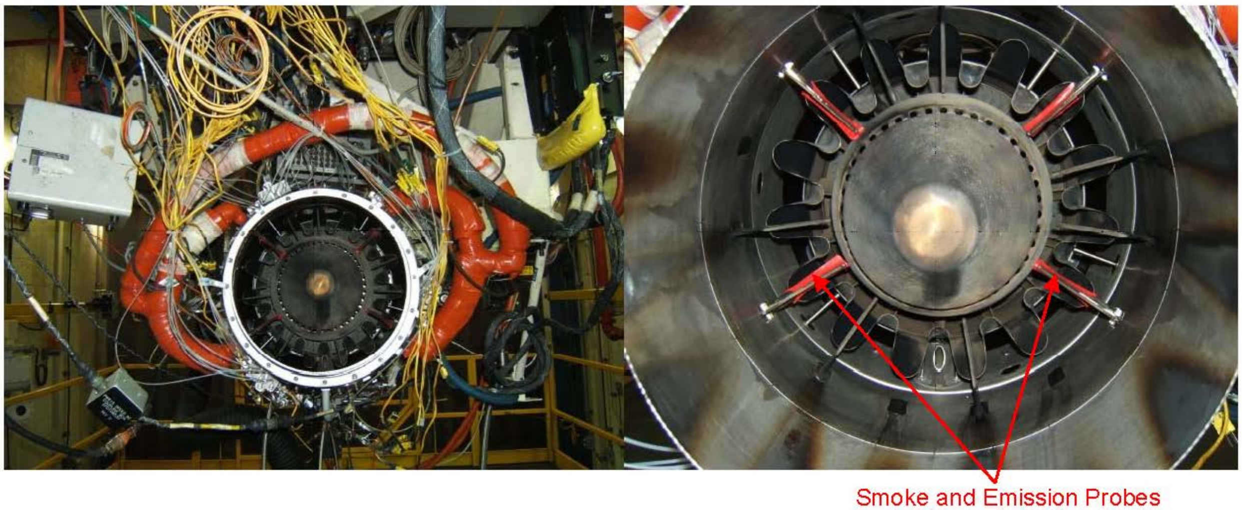

Figure 1. *Emissions Sampling System*

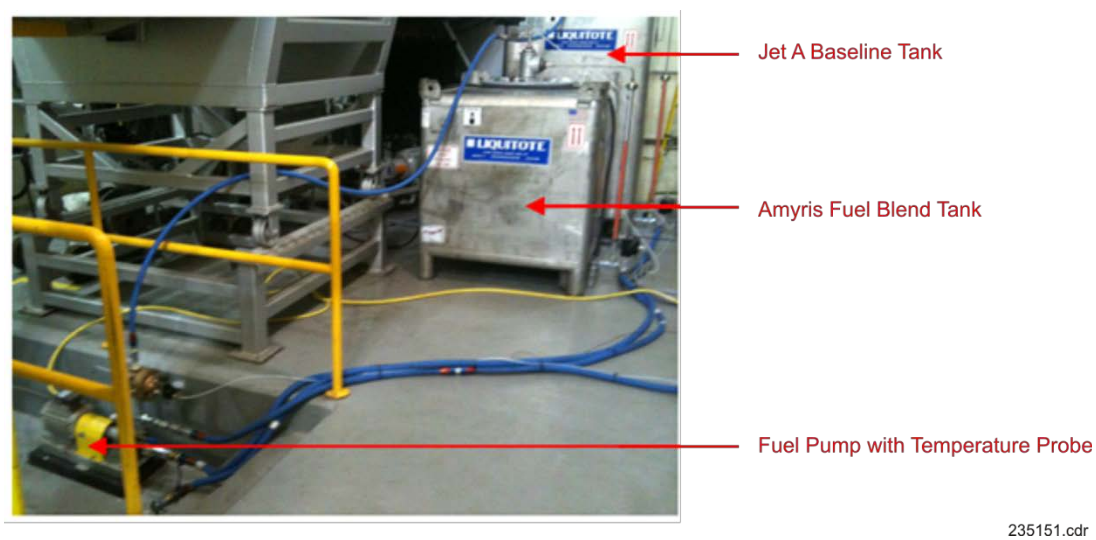

Figure 2. *Fuel Supply System*

3.2 Test Fuels

Test fuels included the following:

- Baseline Jet A-1
- Fuel blend containing 20 vol% Amyris Farnesane and 80 vol% Jet A-1.

Amyris supplied the test biofuel required for the engine and combustor tests. The same batch of Jet A-1 that was used in the baseline testing was also used to formulate the 20%/80% Amyris Farnesane/Jet A-1 blend. Preparation of the fuel blend was conducted at the National Research Council (NRC).

Each test fuel was analyzed to evaluate conformity against the ASTM D1655, *Standard Specification for Aviation Turbine Fuels*. The properties evaluation of each fuel sample was performed at S.G.S laboratory in Montreal, Canada, which is a P&WC approved laboratory. Results are presented in ***Section 4.1*** of this report.

The test sequence was as follows:

1. Baseline Jet A-1
2. 20%/80% Amyris Farnesane/Jet A-1
3. Baseline Jet A-1 repeated to document any deterioration in engine performance from the initial baseline.

In between each test, the engine fuel system and the facility fuel system was purged to remove any residual fuel prior to switching to the next test fuel. Two-hundred sixty-eight gallons of each fuel blend were supplied for the engine test. The test sequence was completed in 8.2 hours of engine operation.

3.3 Engine Tests

P&WC performed PW615F engine tests on the baseline Jet A-1 and 20%/80% fuel blend of Amyris Farnesane/Jet A-1 to determine the impact of Farnesane fuel on engine performance, operability and emissions. The PW615F is a 1,460 lb thrust, two-spool turbo fan with a reverse-flow combustor and dual-channel FADEC. A new engine fuel filter was installed prior to conducting each engine test. The fuel filters were inspected at the conclusion of each engine test for indication of contamination. A fuel sample was taken prior to each engine test. The fuel samples were analyzed to verify that the baseline fuel and the Farnesane fuel blend conformed to ASTM D1655. The engine tests were performed at the six performance points shown below. Specific fuel consumption (SFC), gaseous emissions (CO, UHC, CO_2, NOx), smoke number, and PM through laser induced incandescence (LII) were measured at all six points.

- GI
- 30 percent power
- 50 percent power
- 85 percent power
- 93 percent power
- 100 percent takeoff power (1,460 lbf thrust).

The basic criteria used to evaluate successful operation of the PW615F engine during smoke and emissions testing were as follows:

- No visible smoke and no substantial changes in emissions
- Repeatability of data measurements
- No hardware deterioration or carbon build up in between the runs as determined by borescope inspection.

Engine operability for the Farnesane fuel blend was compared to the baseline Jet A-1 fuel test results. Operability metrics included impact on engine start to GI, engine transient times from idle to takeoff power and from takeoff to idle power, flameout margin, forward and reverse engine bodies between idle and takeoff power.

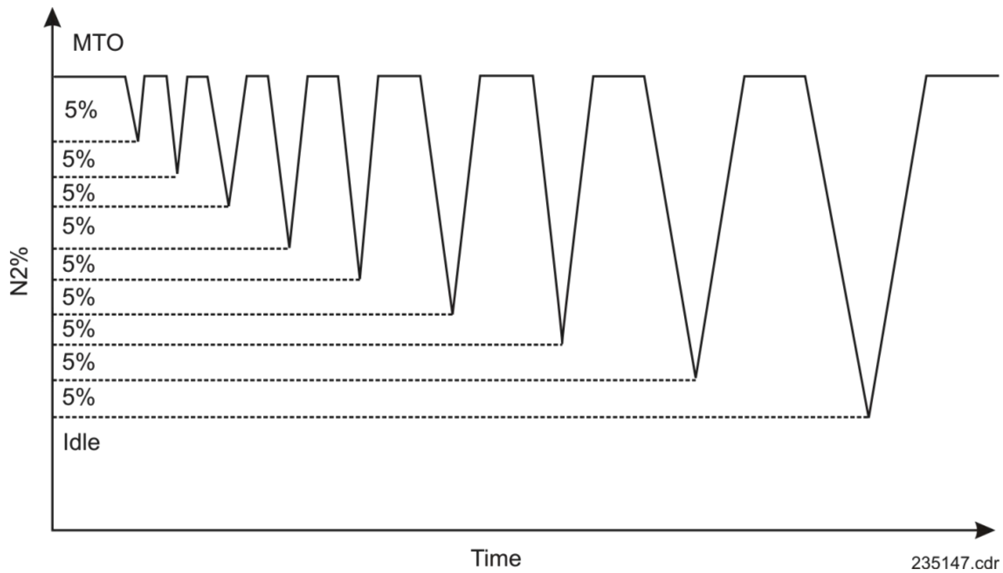

Figure 3. *Forward Bodies Manoeuvre*

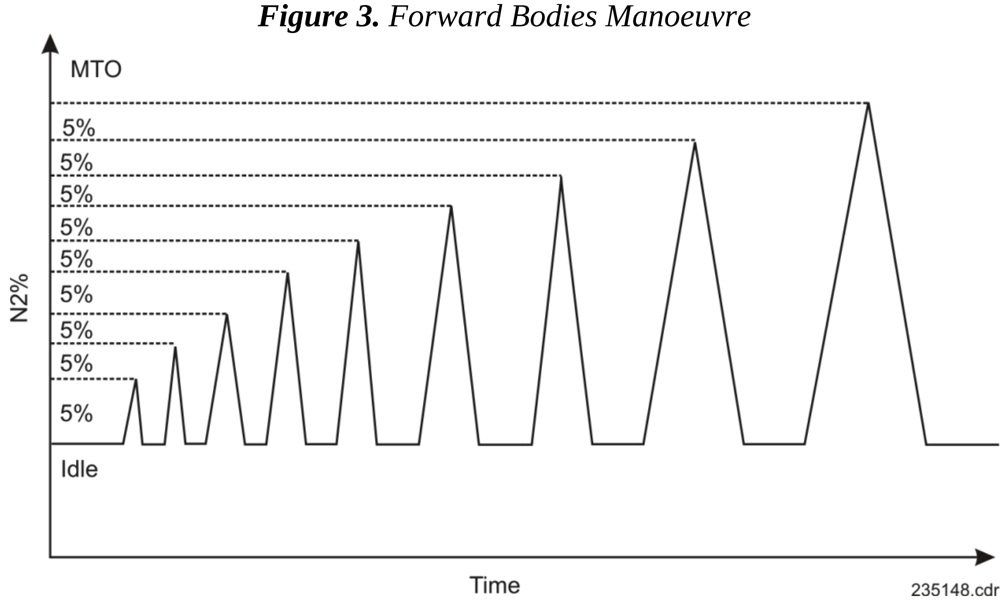

Figure 4. *Reverse Bodies Manoeuvre*

Before initiating the engine tests and after the completion of the test program, a visual inspection of the combustor fuel nozzles was carried out to determine if operation on the 20 percent Farnesane blend adversely affected these components. In addition, the fuel manifold assembly was flow checked and the 14 individual fuel nozzles tested for spray angle pattern and uniformity of coverage at the P&WC Mississauga facility. The fuel metering unit (FMU) was completely characterized using production acceptance test procedure (ATP-178) at the supplier facility Woodward Governor Company.

3.4 Single Nozzle Can Combustor Rig Tests

Under the direction of P&WC, Université Laval performed rig tests on a single fuel nozzle generic can combustor test section for each of the test fuels. The combustor operability tests included cold starts and altitude relights, as defined below.

Cold Starts: Cold start mapping was performed at sea level with a constant combustor inlet pressure (P3) for each test fuel. Cold start mapping was performed with a pressure differential (dP) across the combustor, ranging from 1 to 10 inches of water at five different combustor inlet air temperatures (T3) of 50, 0, -20, -30, and -40°F. The objective was to determine the minimum fuel flow rate at which cold start is successful at each of these conditions. With igniter turned on, a successful light-up was defined as lighting within 10 seconds of *fuel on* followed by 5 seconds of sustained flame. Three successful lights were required at the same fuel flow rate to define the cold start boundary at each T3 and dP condition.

Altitude Relights: Altitude relight tests were performed on each test fuel to determine maximum and minimum fuel-to-air ratio limits for which relight is successful. Mapping was initiated at 15,000 feet with a pressure differential (dP) across the combustor ranging from 1 to 3 percent dP/P3. Relights were performed at 15, 20, 25, 30, and 35 kft. At higher altitudes, the maximum combustor pressure drop achieved was lower. Rich limits were not determined due to rig constraints. With the igniter turned on, a successful light-up was defined as lighting within ten seconds of *fuel on* followed by five seconds of sustained flame. Three successful lights were required at the same fuel flow rate to define the altitude relight fuel flow rate at each T3 and dP condition.

4.0 Results and Discussion

4.1 Fuel Properties

A fuel sample was taken prior to each engine test. Each of the fuel samples was analyzed against ASTM D1655 requirements. Abbreviated fuel properties are presented in ***Table 1***. Results of the fuel sample analyses are shown in ***Appendix A***.

Table 1. *Test Fuel Properties*

Fuel Property	***Baseline Jet A-1***	***20% Amyris Farnesane/ 80% Jet A-1***
Hydrogen (% weight)	13.87	14.14
Hydrogen/Carbon	1.92	1.96
LHV (BTU/lb)	18,561	18,717

4.2 Fuel System Components

A new engine fuel filter was installed prior to conducting each engine test. The fuel filters were inspected at the conclusion of each engine test for indication of contamination. Each fuel filter patch was rinsed with acetone and the residue collected on a 0.45 µm Millipore filter patch. The residue was then evaluated by automatic particle analyzer (APA), followed by a visual examination of each patch. The evaluation did not reveal any indication of adverse effect from operation on the Farnesane fuel blend.

Before initiating the engine tests and after the completion of the test program, a visual inspection of the combustor and fuel nozzles was carried out. Inspection of combustor and fuel nozzle components showed no adverse effects from operation on the Farnesane fuel blend.

Before initiating the engine tests and after the completion of the test program, the fuel manifold assembly was flow checked and the 14 individual fuel nozzles tested for spray angle pattern and uniformity of coverage. The flow number (FN) is below the lower limit by 7 percent for nozzle position No. 3 for *Post-Amyris Farnesane* configuration as shown in ***Figure 5***. Due to a P&WC rig limitation, the flow check was conducted at 25 percent of the production acceptance test pressure normally performed at the fuel nozzle supplier. Further investigation of nozzles 2, 3, 5, and 12 was carried out. The rig set-up was modified to achieve higher pressures. The flow check was repeated at a higher pressure, 88 percent of production acceptance test pressure, and the nozzles passed.

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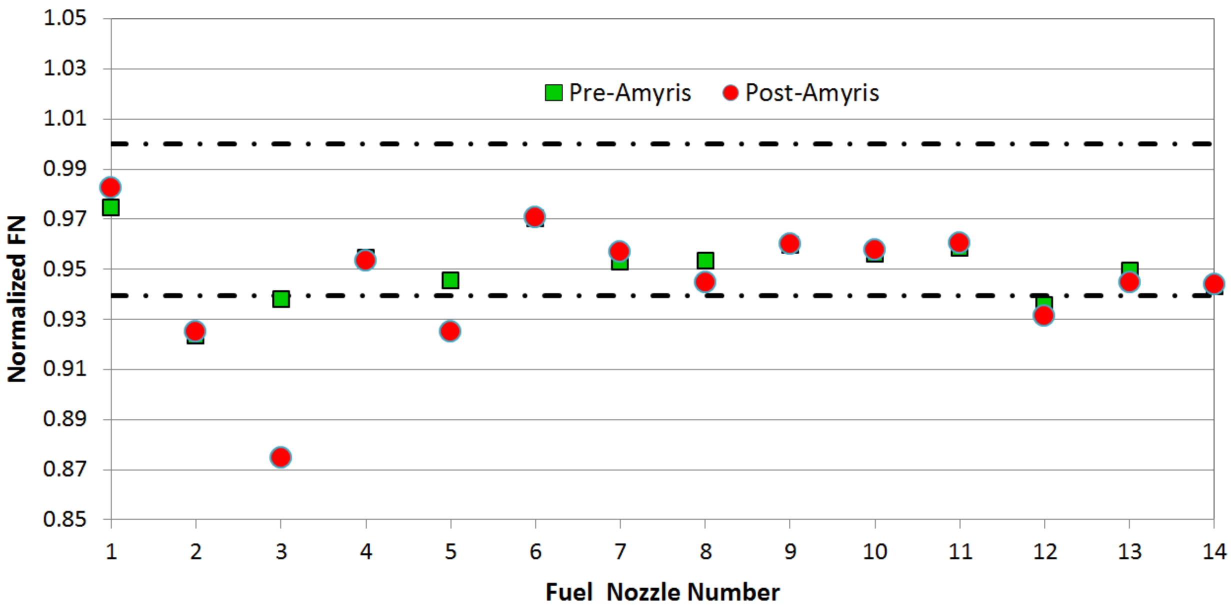

Figure 5. *Flow Number for Each Fuel Nozzle Before and After the Engine Tests*

The FMU was completely characterized using production Acceptance Test Procedure (ATP-178) at the supplier facility. The supplier is the Woodward Governor Company. The FMU S/N 14459839 was tested before and after the PW615F engine testing and found to meet all requirements of the ATP-178.

4.3 Engine Operability

Engine operability was evaluated during a series of manoeuvres performed with the test engine operating on the baseline Jet A-1. The manoeuvres were then repeated for the 20%/80% Amyris Farnesane/Jet A-1. The engine operability demonstrated while the engine was powered by the biofuel blend was then compared to that demonstrated with the baseline Jet A-1, to determine if any differences due to the change in fuel could be observed. No significant differences in engine operability were observed that could be attributed to the change in fuel.

When analyzing the engine starts performed with both the baseline Jet A-1 and Amyris Farnesane fuel blend, the parameters time to light (TTL) and time to idle (TTI), as well as the peak inter turbine temperature (ITT) can be used to evaluate the quality of the engine start. While differences within the measured values can be seen, previous testing has indicated that the delta observed between fuels is within the amount of scatter which can be expected for these types of measurements. This data was therefore taken to indicate that the fuels demonstrated approximately equivalent engine start characteristics.

Slam accelerations and decelerations between GI and takeoff power were also performed with both fuels under consideration. As defined by P&WC test procedures and control system requirements, representative acceleration and deceleration times were used in this comparison. The net differences in acceleration and deceleration times demonstrated by the biofuel blend, relative to the baseline Jet A-1, are not considered large enough to have a significant impact on the operability of the engine. The acceleration and deceleration capability demonstrated during the slam maneuvers performed are considered equivalent.

Negative fuel spiking tests were conducted to assess the flameout margin which exists within the test engine while operating with either of the fuels considered. For both fuels, a series of negative fuel spikes were repeated at least once until a flameout was observed, where the spike prior to flameout was identified as the limiting spike. These spikes were evaluated by comparing the ratio unit measured during the limiting spike, where the ratio unit is defined as the measured fuel flow normalized by the compressor exit pressure. While differences between the baseline Jet-A and the Farnesane blend can be seen, these differences are not large enough to indicate a significant shift in operability. Furthermore, the difference observed between the minimum values of the ratio unit spike between fuels is on the order of the scatter observed for this test, and the degree of scatter observed is consistent with previous tests. As well, the ratio unit profiles were almost identical for all limiting fuel spikes. The minute differences are not significant enough to demonstrate a discernable impact on engine operability between fuels.

Engine operability can be further quantified between fuels by observing if any differences are present when forward and reverse bodies are performed. Despite representing the most aggressive operability testing, none of the fuels produced an engine surge or flameout. Additionally, similar trends in the ITT and the ratio unit were observed. These results were taken to further indicate that the operability of the engine was maintained despite the change in fuel.

4.4 Engine Performance

Engine performance was evaluated by taking steady state measurements at six representative power settings: GI, 30 percent, 50 percent, 85 percent, 93 percent and 100 percent of rated takeoff thrust. A five minute stabilization time was used prior to taking any performance measurements. The results show that the biofuel blends had no significant impact on SFC, low rotor speed (N1) or high rotor speed (N2).

The pre to post-test comparison with the Jet A-1 baseline fuel revealed a small decrease in fuel consumption, but it was determined to be a result of a small error on fuel flow measurement. The biofuel results are compared with the repeat Jet A-1 fuel and presented in ***Table 2.***

Table 2. *Performance Test Main Parameters at a Takeoff Thrust of 1,460lbf*

Engine/Build		6157B12	6157B12	6157B12
Description		Baseline JET-A	Amyris Farnesane/ Jet-A (20/80%)	Repeat 100% JET-A
Test Date		11 May 2013	11 May 2013	11 June 2013
Parameters	***Units***			
SFC	-	1,000	1,002	1,002
WF	-	1,000	1,000	1,001
N1	-	1,000	1,000	0,999
N2	-	1,000	1,000	1,000

The performance parameters' deltas observed between the biofuel blend and the baseline tests were negligible. These deltas are well within typical scatter.

4.5 Smoke and Emissions

Engine exhaust emissions were measured and processed in accordance with International Civil Aviation Organization (ICAO) regulations [1]. The smoke analyzer and reflectometer were used in combination to calculate the smoke number at each condition point. An LII system was also used to measure the Particulate Matter (PM) mass and number count.

The fuel results show the naphthalene volume for 20%/80% Amyris Farnesane/Jet A-1 is 0.7 percent and for Jet A-1 is 0.9 percent. Smoke number did not change significantly between the various fuels, as expected due to their similar aromatic content. The smoke number values for the 20%/80% Amyris Farnesane/Jet A-1 biofuel blend are within the experimental scatter for Jet A-1. All other engine emissions for the baseline Jet A-1 and the 20%/80% Amyris Farnesane/Jet A-1 were within experimental scatter of those obtained with Jet A-1. Engine emission measurements for each fuel type are summarized in ***Figure 6***. Emission meter readings for each pollutant are plotted versus thrust. All results shown have been normalized.

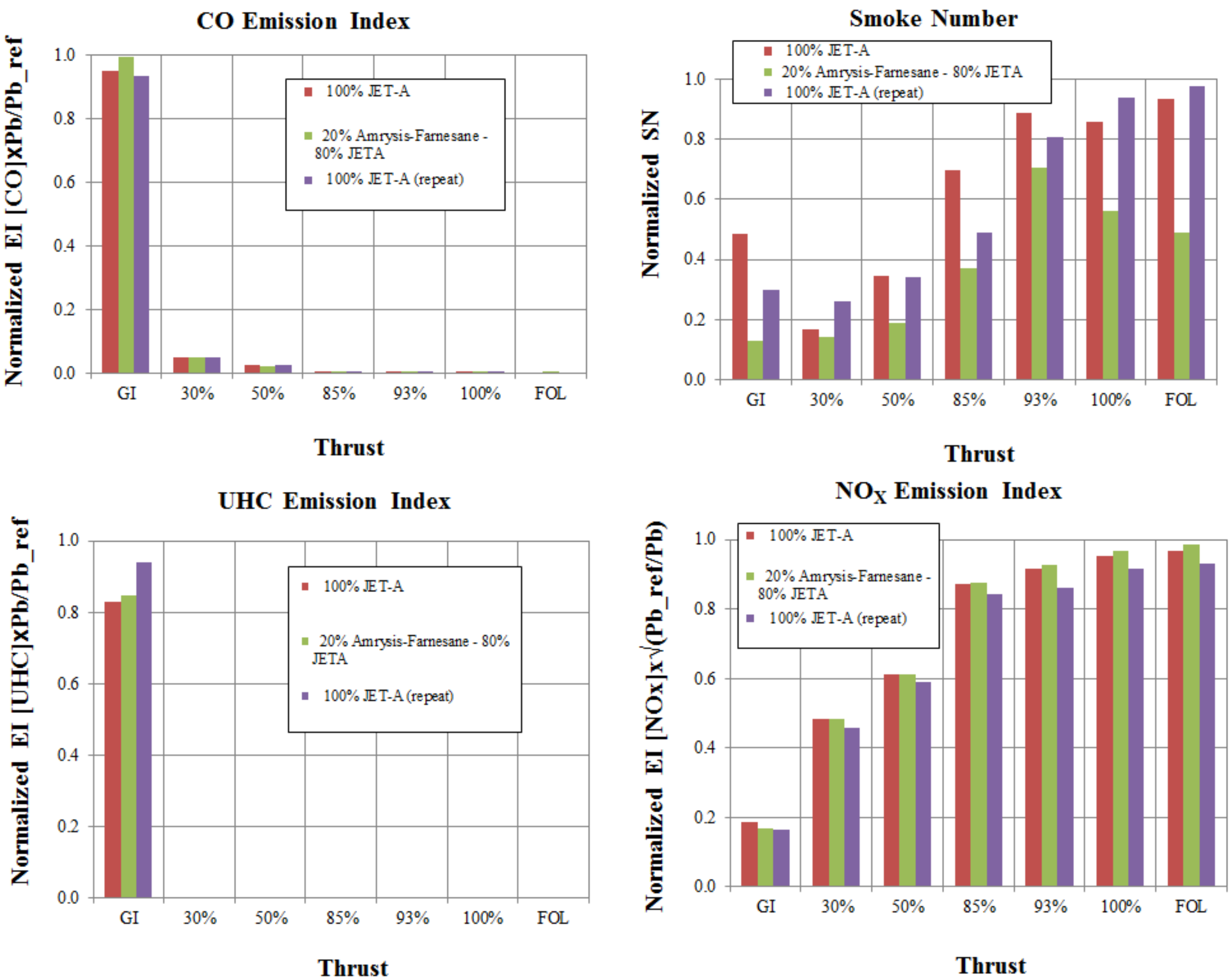

Figure 6. *Engine Emissions comparison of Jet A-1 and Amyris Farnesane Biofuel Blends*

As is evident in the plots, the Amyris Farnesane blend had no impact on UHC, CO, or NOx emissions. Any variation shown is within expected test scatter. Jet A-1 and 20%/80% Amyris Farnesane/Jet A-1 have similar aromatic content, so it is understandable that SAE Smoke Number are considered similar.

A LII 200 system was used as part of the test setup and measurement taken all each of the power settings. The purpose of the LII 200 measurements was to identify the soot mass concentration, and validate the correlation with smoke number.

The soot average mass concentrations and particle count number for 20%/80% Amyris Farnesane/Jet A-1 blend and baseline (JET-A) are presented in ***Table 3***. Smoke densities were calculated based on the smoke number collected from the smoke analyzer and reflectometer. Smoke densities were also measured as PM concentrations by an LII machine. Smoke density measured by the LII under-predicts the SAE smoke number at high power conditions, as calculated by the smoke analyzer and reflectometer by up to 49 percent. This amount of deviation is expected due to the use of very distinct sampling methods and analysis tools.

Table 3. *Summary of Mass Concentration and Particle Count Number by LII Equipment*

	100% JET-A		*Amyris Farnesane/Jet-A (20%/80%)*		*100% JET-A (Repeat)*	
Condition	***Mass Concentration (g/m3)***	***Count No.***	***Mass Concentration (g/m3)***	***Count No.***	***Mass Concentration (g/m3)***	***Count No.***
(GI)	0,091	0,898	0,053	0,803	0,085	0,983
438 lb	0,089	0,966	0,059	0,970	0,091	0,979
730 lb	0,158	0,996	0,139	0,996	0,169	0,992
1,241 lb	0,580	0,995	0,474	0,997	0,527	0,995
1,358 lb	0,703	0,996	0,561	0,995	0,872	0,996
1,460 lb	0,893	0,997	0,669	1,000	0,919	0,997
1,500 lb	1,000	0,996	0,728	0,994	0,960	0,996
GI	0,085	0,918	0,056	0,864	0,094	0,912
	AVG=	0,970	AVG=	0,952	AVG=	0,981
	STDev=	0,040	STDev=	0,076	STDev=	0,029

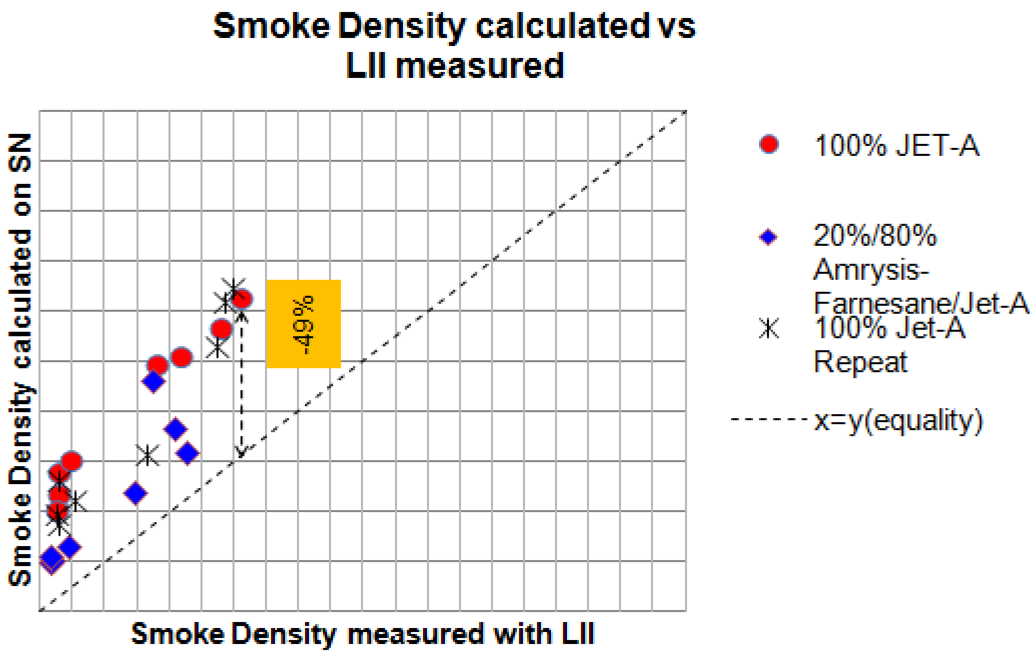

Figure 7. *Smoke Density Comparison Between Smoke Analyzer and LII Equipment*

4.6 Can Combustor Cold Start

The lean ignition boundary, at 0 and -40°F for a combustor pressure differential ranging from 1 to 10 in. H_2O, is shown in ***Figure 8*** and ***Figure 9***. The start characteristics at the two temperatures for 20%/80% Amyris Farnesane/Jet A-1 behave similarly to the baseline Jet A-1 fuel. Cold start mapping was also performed at combustor inlet temperatures of 50, -20, and -30°F. Results of these tests show a similar result.

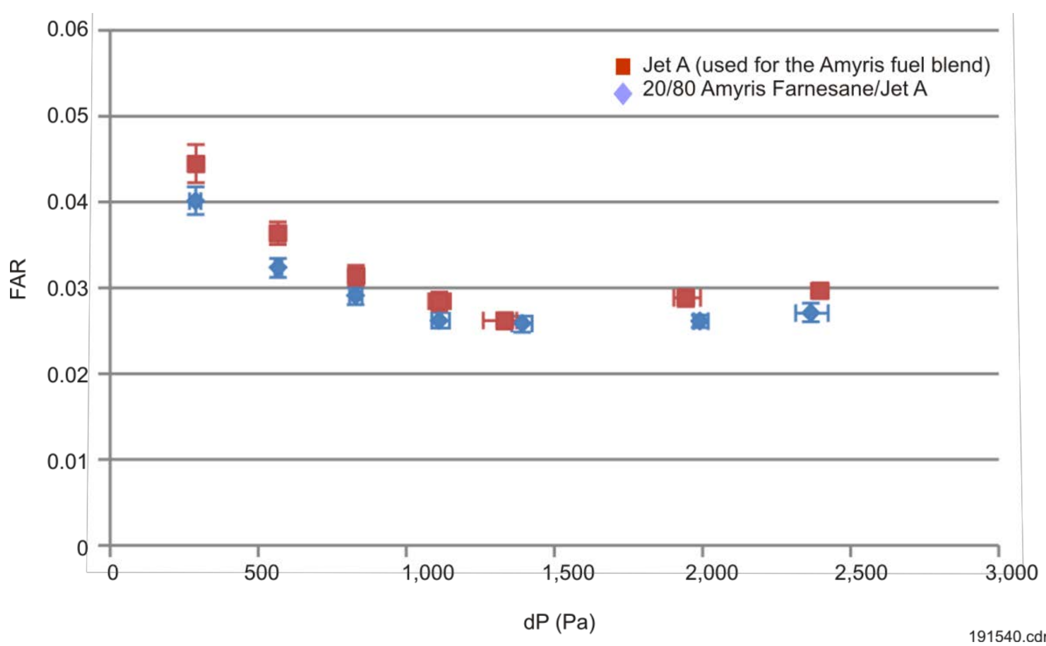

Figure 8. *Amyris Farnesane Cold Start at 0°F*

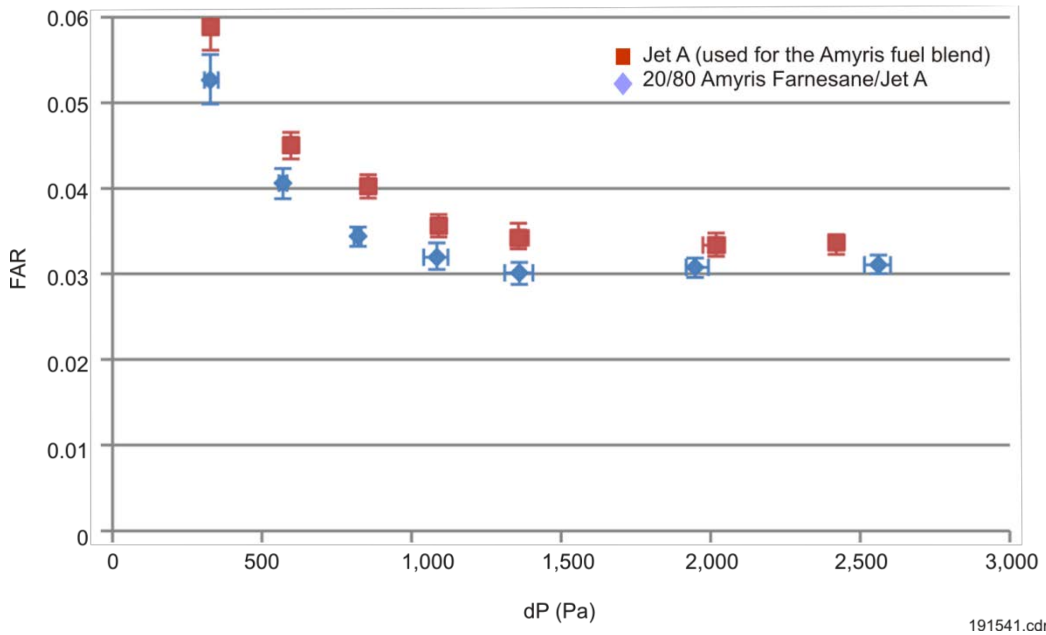

Figure 9. *Amyris Farnesane Cold Start at -40°F*

4.7 Can Combustor Altitude Relights

Altitude relights were performed at the following conditions; 15, 20, 25, 30, and 35 kft. The lean ignition boundary was determined. The rich ignition boundary was not determined due to rig limitations. The lean ignition boundary for successful starts at 15 kft and 25 kft is shown in ***Figure 10*** and ***Figure 11***. The relight response at the tested altitudes is similar for the 20%/80% Amyris Farnesane biofuel blend compared to the Jet A-1 baseline.

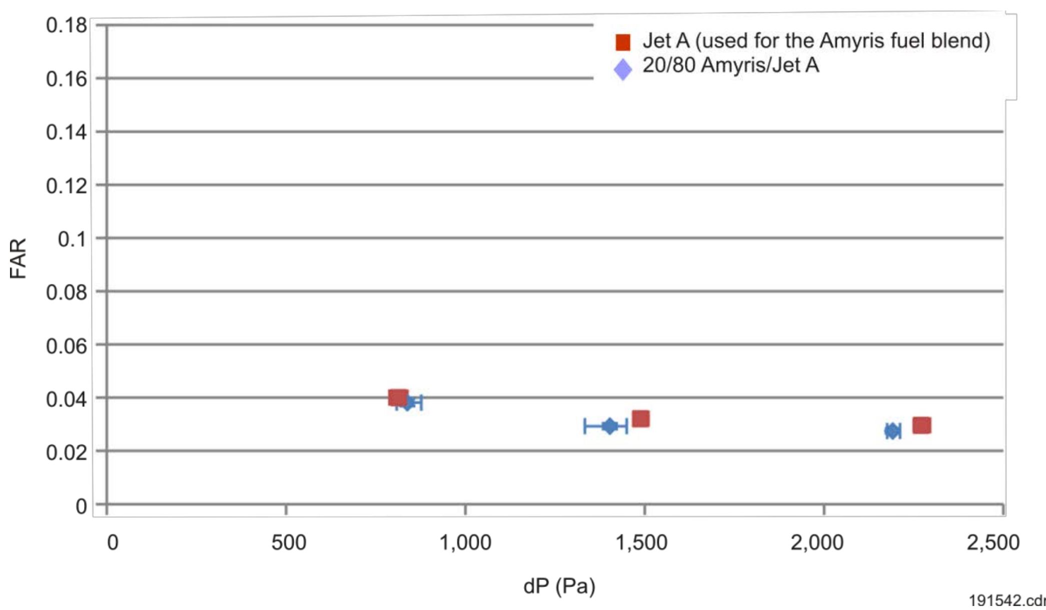

Figure 10. *Amyris Altitude Relight at 15kft*

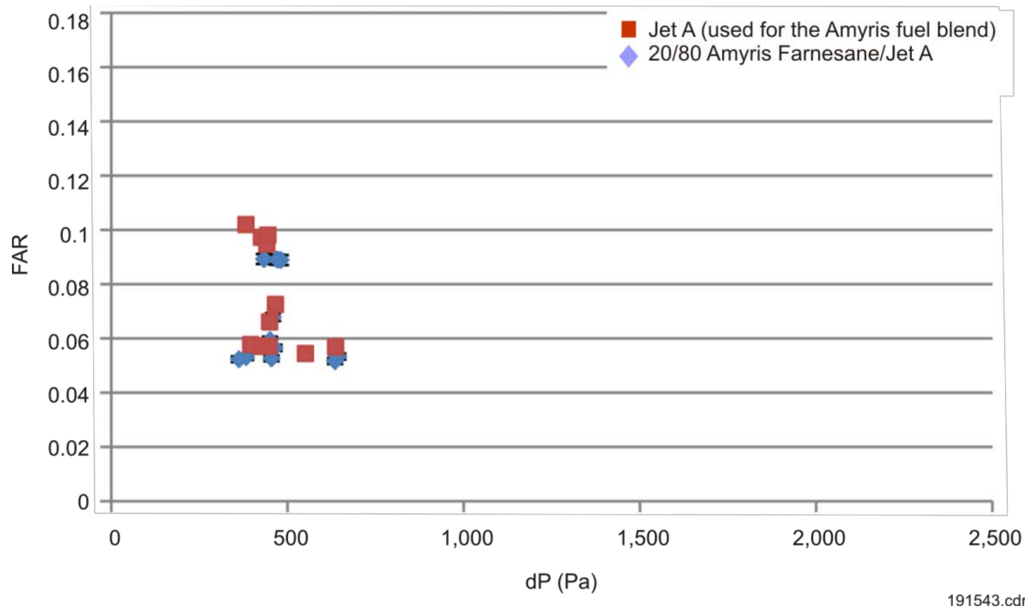

Figure 11. *Amyris Altitude Relight at 30kft*

5.0 Conclusions

No difference was observed in PW615F engine operability for the 20%/80% Amyris Farnesane/Jet A-1 biofuel blend compared to that of the baseline Jet A-1 fuel. No negative impact was observed on SFC, gaseous emissions, smoke number, or PM. Inspection of fuel system components showed no adverse effects from operation on the Farnesane fuel blend.

Single nozzle can combustor tests were conducted at Université Laval under the direction of P&WC. Ground starts at 50, 0, -20, -30, and -40 °F and altitude relights at 15, 20, 25, 30, and 35 kft were performed. No starting differences or altitude relight lean boundary differences were observed. The rich limits were not achieved for the relights due to rig constraints.

The successful completion of the PW615F engine test performed on a Farnesane fuel is a significant milestone in the approval process defined by ASTM D4054, *Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives*. The results of this engine test will be included in an ASTM research report along with results from specification tests, fit-for-purpose tests, component tests, and a possible engine endurance test. The ASTM research report will be used by the engine and airplane manufacturers, DoD, FAA, and ASTM to approve Farnesane blends for use in military and commercial aircraft.

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6.0 References

[1] International Civil Aviation Organization Environmental Protection Annex 16, Volume II Aircraft Engine Emissions, Second Edition – 1993.

Appendix A– Fuel Properties Analysis

DATE: 21-Nov-2013

SGS Oil, Gas and Chemicals SGS Canada Inc. 11000A Sherbrooke Street East, Unit 33, Montreal-East, Qc, Canada, H1B 5W1 Tel: +1-514-645-8754	PRATT & WHITNEY CANADA INC 1000 MARIE-VICTORIN UNITE 01AI3 LONGUEUIL CANADA J4G 1A1

Certificate of Analysis: MT13-00382.001

WARNING: The sample(s) to which the findings recorded herein (the "Findings") relate was(were) drawn and / or provided by the Client or by a third party acting at the Client's direction. The Findings constitute no warranty of the sample's representativeness of any goods and strictly relate to the sample(s). The Company accepts no liability with regard to the origin or source from which the sample(s) is/are said to be extracted.

802-0757

CLIENT ORDER NUMBER :	PO # 4501873251	SGS ORDER NO.:	612342
CLIENT ID :	C13112316	PRODUCT DESCRIPTION :	Jet A1 - 100%
LOCATION :	na		
SAMPLE SOURCE :	Supplied by Client	SOURCE ID :	Engine 6157B12
SAMPLE TYPE :	As submitted	SAMPLED BY :	Client
SAMPLED :	--	RECEIVED :	14-Nov-2013
ANALYSED :	19-Nov-2013 - 21-Nov-2013	COMPLETED :	21-Nov-2013

PROPERTY	METHOD	RESULTS	UNITS
Density at 15°C	ASTM D4052	801.0	kg/m³
Distillation of Petroleum Products at Atmospheric Pressure	ASTM D86		
Initial boiling point (IBP)		152.6	°C
10% Recovered at		170.4	°C
20% Recovered at		179.0	°C
50% Recovered at		201.7	°C
90% Recovered at		244.4	°C
Final boiling point (FBP)		266.5	°C
% Residue		1.3	% (v/v)
% Loss		0.7	% (v/v)
Net Heat of Combustion - Corrected for Sulfur	ASTM D3338	43.292	MJ/kg
Aromatics content	ASTM D1319	16.4	% (v/v)
Naphthalene Content (Procedure A)	ASTM D1840	0.90	% (v/v)
Smoke Point - Manual Apparatus	ASTM D1322	23.0	mm
Hydrogen Content	ASTM D3343	13.87	% (m/m)
Mercaptan Sulphur	ASTM D3227	0.0005	% (m/m)
Kinematic Viscosity at -20°C	ASTM D445	4.189	mm²/s
Acid Number	ASTM D3242	0.006	mg KOH/g
Total Sulfur Content	ASTM D4294	0.0225	% (m/m)
Freezing Point	ASTM D5972	-48.6	°C
TAG Flash Point (Closed cup)	ASTM D56	42.0	°C
Copper Strip corrosion (2h / 100°C)	ASTM D130	1a	Rating

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AUTHORISED SIGNATORY

Souhila Ouelhadj
Laboratory Supervisor - Chemist

THIS DOCUMENT CONTAINS NO TECHNICAL DATA SUBJECT TO THE EAR OR ITAR

DATE: 21-Nov-2013

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802-0757

CLIENT ORDER NUMBER :	PO # 4501873251	SGS ORDER NO.:	612342
CLIENT ID :	C13112316	PRODUCT DESCRIPTION :	Jet A1 - 100%
LOCATION :	na		
SAMPLE SOURCE :	Supplied by Client	SOURCE ID :	Engine 6157B12
SAMPLE TYPE :	As submitted	SAMPLED BY :	Client
SAMPLED :	--	RECEIVED :	14-Nov-2013
ANALYSED :	19-Nov-2013 - 21-Nov-2013	COMPLETED :	21-Nov-2013

PROPERTY	METHOD	RESULTS	UNITS
Existent Gum	IP 540	<1	mg/100mL
Volume of Sample Filtered	ASTM D5452	4.0	L
Particulate Contamination	ASTM D5452	0.25	mg/L
Color Rating - Dry Membrane	ASTM D5452 - X1	B1	Rating
MSEP-A (with SDA)	ASTM D3948	80	Rating
Conductivity	ASTM D2624	300	pS/m
Observed Temperature	ASTM D2624	24.2	°C

**** End of Analytical Results ****

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DATE: 16-Dec-2013

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Certificate of Analysis: MT13-00476.001

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802-0840

CLIENT ORDER NUMBER :	PO # 4501873251	SGS ORDER NO.:	620547
CLIENT ID :	C13112316	PRODUCT DESCRIPTION :	Jet A1 - 100%
LOCATION :	na		
SAMPLE SOURCE :	Supplied by Client	SOURCE ID :	Engine 6157B12
SAMPLE TYPE :	As submitted	SAMPLED BY :	Client
SAMPLED :	--	RECEIVED :	14-Nov-2013
ANALYSED :	16-Dec-2013	COMPLETED :	16-Dec-2013

REPORT COMMENT : *** 8 bottles of 1 L received. Analysis were performed on a composite of 7 bottles. 1 bottle failed appearance and was not include on the composite.**
***This document is related to SGS CoA MT13-00382.001 Reissue 1 dated Nov.21.2013**

PROPERTY	METHOD	RESULTS	UNITS
Thermal Oxidation Stability of Aviation Turbine Fuel (JFTOT Procedure)	ASTM D3241		
Heater Tube Control Temperature		260	°C
Heater Tube Deposit Rating		<1	---
Maximum Pressure Drop		1	mm Hg
Spent Fuel at End of Test		450	ml

**** End of Analytical Results ****

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Souhila Ouelhadj
2004-059
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Annie Coté
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Certificate of Analysis: MT13-00393.001

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802-0757

CLIENT ORDER NUMBER :	PO # 4501873251	SGS ORDER NO.:	612342
CLIENT ID :	C13112316	PRODUCT DESCRIPTION :	Jet A1 - Biofuel blend (80% Jet-A1+20% Amyris)
LOCATION :	na		
SAMPLE SOURCE :	Supplied by Client	SOURCE ID :	Engine 6157B12
SAMPLE TYPE :	As submitted	SAMPLED BY :	Client
SAMPLED :	--	RECEIVED :	14-Nov-2013
ANALYSED :	19-Nov-2013 - 21-Nov-2013	COMPLETED :	21-Nov-2013

PROPERTY	METHOD	RESULTS	UNITS
Density at 15°C	ASTM D4052	795.4	kg/m³
Distillation of Petroleum Products at Atmospheric Pressure	ASTM D86		
Initial boiling point (IBP)		154.8	°C
10% Recovered at		177.0	°C
20% Recovered at		186.3	°C
50% Recovered at		215.1	°C
90% Recovered at		246.9	°C
Final boiling point (FBP)		263.8	°C
% Residue		1.3	% (v/v)
% Loss		0.9	% (v/v)
Net Heat of Combustion - Corrected for Sulfur	ASTM D3338	43.445	MJ/kg
Aromatics content	ASTM D1319	13.0	% (v/v)
Naphthalene Content (Procedure A)	ASTM D1840	0.70	% (v/v)
Smoke Point - Manual Apparatus	ASTM D1322	25.5	mm
Hydrogen Content	ASTM D3343	14.14	% (m/m)
Mercaptan Sulphur	ASTM D3227	0.0004	% (m/m)
Kinematic Viscosity at -20°C	ASTM D445	5.096	mm²/s
Acid Number	ASTM D3242	0.005	mg KOH/g
Total Sulfur Content	ASTM D4294	0.0206	% (m/m)
Freezing Point	ASTM D5972	-51.1	°C
TAG Flash Point (Closed cup)	ASTM D56	44.5	°C

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Laboratory Supervisor - Chemist

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DATE: 21-Nov-2013

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802-0757

CLIENT ORDER NUMBER :	PO # 4501873251	SGS ORDER NO.:	612342
CLIENT ID :	C13112316	PRODUCT DESCRIPTION :	Jet A1 - Biofuel blend (80% Jet-A1+20% Amyris)
LOCATION :	na		
SAMPLE SOURCE :	Supplied by Client	SOURCE ID :	Engine 6157B12
SAMPLE TYPE :	As submitted	SAMPLED BY :	Client
SAMPLED :	--	RECEIVED :	14-Nov-2013
ANALYSED :	19-Nov-2013 - 21-Nov-2013	COMPLETED :	21-Nov-2013

PROPERTY	METHOD	RESULTS	UNITS
Copper Strip corrosion (2h / 100°C)	ASTM D130	1a	Rating
Existent Gum	IP 540	2	mg/100mL
Volume of Sample Filtered	ASTM D5452	4.0	L
Particulate Contamination	ASTM D5452	1.38	mg/L
Color Rating - Dry Membrane	ASTM D5452 - X1	G2	Rating
MSEP-A (with SDA)	ASTM D3948	77	Rating
Conductivity	ASTM D2624	405	pS/m
Observed Temperature	ASTM D2624	23.7	°C

**** End of Analytical Results ****

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DATE: 16-Dec-2013

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802-0840

CLIENT ORDER NUMBER :	PO # 4501873251	SGS ORDER NO.:	620547
CLIENT ID :	C13112316	PRODUCT DESCRIPTION :	Jet A1 - Biofuel blend (80% Jet-A1 + 20% Amyris)
LOCATION :	na		
SAMPLE SOURCE :	Supplied by Client	SOURCE ID :	Engine 6157B12
SAMPLE TYPE :	As submitted	SAMPLED BY :	Client
SAMPLED :	--	RECEIVED :	14-Nov-2013
ANALYSED :	16-Dec-2013	COMPLETED :	16-Dec-2013

REPORT COMMENT : ***Analysis were performed on the composite of the eight bottles received for this sample.**
***This document is related to SGS CoA MT13-00393.001 Reissue 1 dated Nov.21.2013**

PROPERTY	METHOD	RESULTS	UNITS
Thermal Oxidation Stability of Aviation Turbine Fuel (JFTOT Procedure)	ASTM D3241		
Heater Tube Control Temperature		260	°C
Heater Tube Deposit Rating		<1	---
Maximum Pressure Drop		1	mm Hg
Spent Fuel at End of Test		450	ml

**** End of Analytical Results ****

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