



Alternate-Fueled Combustor-Sector Performance

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Prepared for the
14th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery
(ISROMAC-14)
sponsored by the Fluid Systems Technology (FST) of Technische Universitat Darmstadt
Honolulu, Hawaii, February 27–March 2, 2012

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Acknowledgments

The authors would like to thank the NASA GRC technical editing and publishing staff for their diligent efforts in completing our paper.

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This work was sponsored by the Fundamental Aeronautics Program at the NASA Glenn Research Center.

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Summary

In order to realize alternative fueling for military and commercial use, the industry has set forth guidelines that must be met by each fuel. These aviation fueling requirements are outlined in MIL-DTL-83133F(2008) or ASTM D 7566 Annex (2011) standards, and are classified as “drop-in” fuel replacements. This report provides combustor performance data for synthetic-paraffinic-kerosene- (SPK-) type (Fischer-Tropsch (FT)) fuel and blends with JP-8+100, relative to JP-8+100 as baseline fueling. Data were taken at various nominal inlet conditions: 75 psia (0.52 MPa) at 500 °F (533 K), 125 psia (0.86 MPa) at 625 °F (603 K), 175 psia (1.21 MPa) at 725 °F (658 K), and 225 psia (1.55 MPa) at 790 °F (694 K). Combustor performance analysis assessments were made for the change in flame temperatures, combustor efficiency, wall temperatures, and exhaust plane temperatures at 3, 4, and 5 percent combustor pressure drop (ΔP) for fuel:air ratios (F/A_s) ranging from 0.010 to 0.025. Significant general trends show lower liner temperatures and higher flame and combustor outlet temperatures with increases in FT fueling relative to JP-8+100 fueling. The latter affects both turbine efficiency and blade and vane lives.

Introduction

Finding an alternative fuel for aviation application requires a fuel feedstock with sustainable supply at a low cost with low or no negative environmental impact. The requirements for

these “drop-in” fuel replacements are outlined in the MIL-DTL-83133F(2008) or ASTM D 7566 Annex (2011), approved standards for military and civil use, respectively. Alternate jet fuels need to be compatible with current engines and aircraft fuel handling systems in order to reduce the need for new systems to accommodate new fuels that may perform differently than the currently used petroleum fuels.

Even proven alternate fuels face tough issues such as secure, sustainable productivity at competitive pricing. Recently, the Federal Aviation Administration (FAA) announced support of eight companies conducting research into commercial jet fuel alternatives that conform to ASTM D 7566 and are based on resources readily available in the United States (Ref. 1). One of the ideas being explored is to produce aviation fuels from carbon monoxide given off by industrial waste gases that would otherwise add to atmospheric pollution. Another idea is to explore the conversion from cellulosic and conventional plant sugars to fuels. Others involve the development of catalysts to convert different carbon sources into fuels in small-scale reactors to serve as distributed fuel production sources. Currently, the biofuels used by the U.S. Navy cost about \$26/gal (\$6.87/L) (Ref. 2). The money that the FAA is funneling into these projects could boost the production of cost-effective fuels from biomass and waste feedstocks to enable the affordability for commercial and military aviation fueling. Yet to date, the alternate fuels industry competitive costs and productivity have not responded to feedstock restraints, incentives, subsidies, or mandates, and compliance taxes are passed to consumers (Ref. 3).

Adopting alternate fuels and fuel blends requires the use of fuel-flexible systems (combustors and engines) without sacrificing performance requirements. For military aviation, an alternative for traditional fuel for gas turbine and diesel systems is required. However, in many proposed alternates, the lack of sufficient amounts of aromatics that swell some fuel system seals and sulfur, which provides fuel injection pump lubricity, have the potential to reduce design component useful life (Ref. 4). For these fuels, additives are needed to increase useful component life while maintaining the performance. It is thought that Fischer-Tropsch- (FT)-type fuels can support gas turbine engines at similar levels as well as have potential use for diesel systems.

This report provides preliminary combustor performance data for SPK-type FT fuel and blends relative to pure JP-8+100 (herein referred to as “JP-8”), the currently used aviation fuel. Data for “Combustor A,” a three-cup sector representative of current engine combustor technology (see computational fluid dynamics (CFD) images, Ref. 6, proprietary details withheld), were taken at 0, 50, and 100 percent FT fueling (denoted as JP-8, 50:50, and FT, respectively) with varied parameters of fuel:air ratio (F/A), percent combustor pressure drop ($\% \Delta P$), and absolute pressure. The data collected show that higher combustor operating temperatures have the potential to enhance system efficiency, but also take a toll on component life, as they have a greater impact on the oxidation and failure of the materials within the combustor and turbine. A small temperature difference of combustor gas entering the turbine can both be critical to turbine life and affect efficiency; there is a need for a good balance. “Bleed air,” used to cool the combustor, case, turbine blades, vanes, and nozzles, could be increased to compensate for the enhanced turbine inlet temperature; this parasitic air decreases the system efficiency but helps to maintain a reasonable turbine life.

Fuel specifications; the test facility conditions, operations, schematic, and fueling system; estimates of measurement errors; and combustor thermal data and postprocessing parameters of Combustor A are given in the Shouse et al. paper presented at ISROMAC 13 (Ref. 5). The CFD analysis and figures of combustor geometry and flow are in the Ryder et al. paper (Ref. 6), also presented there. Compositional examination of the synthetic-paraffinic kerosene with the compositional-explicit distillation curve method is discussed in the Bruno and Bailbourn article (Ref. 7), who makes a useful comparison for heats of combustion based on molecular weight, volume, and mass.

Combustor Thermal Performance

The proprietary-geometry combustor, Combustor A, used for data collection represents a three-cup sector of a current engine combustor technology. Figure 1 shows a numerical model representation of Combustor A (Ref. 6). The Shouse et al. paper (Ref. 5) outlines the results given for the 225-psia

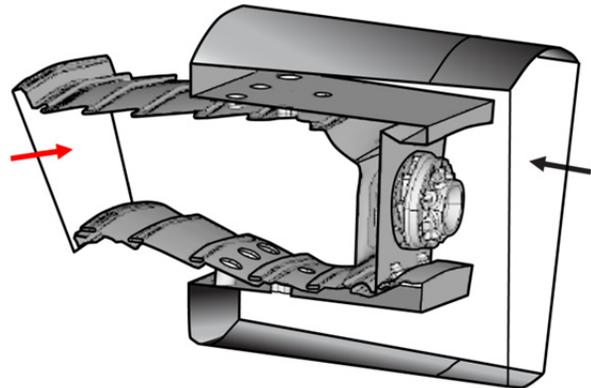


Figure 1.—Numerical model of Combustor A geometry: (1) total airflow into the sector (black arrow) and (2) exit pressure at the sector exit plane (red arrow).

(1.55-MPa) inlet condition, for three fueling compositions and three F/A values at 3 percent ΔP , and this report continues to analyze all four inlet combustor conditions at all three combustor ΔP values tested for the FT fuel blends of 0, 50, and 100 percent with JP-8 fueling. Data were taken at various nominal inlet conditions as follows:

- (1) FT fuel composition: 0, 50 (± 5 percent), and 100 percent
- (2) Pressure (P) and temperature (T):
 - 75 psia (0.52 MPa) and 500 °F (533 K)
 - 125 psia (0.86 MPa) and 625 °F (603 K)
 - 175 psia (1.21 MPa) and 725 °F (658 K)
 - 225 psia (1.55 MPa) and 790 °F (694 K)
- (3) Combustor pressure drop (ΔP): 3, 4, and 5 percent
- (4) F/A : 0.010, 0.015, 0.020, and 0.025

Combustor performance analysis assessments were made for the change in flame temperatures (T_{flame}), combustor efficiency, wall temperatures, and exhaust plane temperatures (T_{plane}).

The combustion efficiencies do not provide enough insight for determining significant combustor changes, yet they do show a trend to decrease with increased $\% \Delta P$; thus, other aforementioned (T_{flame} and T_{plane}) parameters will also be investigated. At 75 psia (0.52 MPa) the combustion efficiency of all fuel blends are outlined in Table I (Ref. 5).

Surface Thermal Measurements

Thermocouples and pressure taps were placed throughout the combustion chamber to record temperature and pressure. The details of pressure drop measurements will not be presented in this paper, but it should be noted that no inconsistent pressure measurements were found. The convection-cooled liner and wall surface temperature measurements are noted as either “sidewall” or “liner” (which has inside and outside faces).

TABLE I.—COMBUSTOR EFFICIENCY DATA SUMMARY

[(P, T)_{inlet} = (75 psia (0.52 MPa), 500 °F (533 K)).]

Fuel	%Δ <i>P</i>					
	3		4		5	
	<i>F/A</i>		<i>F/A</i>		<i>F/A</i>	
	0.010 to 0.020	0.025	0.010 to 0.020	0.025	0.010 to 0.020	0.025
	Efficiency, percent					
JP-8	99.61	99.32	99.56	99.10	99.46	99.20
50:50	99.65	99.24	99.56	99.09	99.46	98.90
FT	99.66	99.20	99.58	98.96	99.48	98.87
Average	99.64	99.25	99.56	99.05	99.47	98.99
Standard deviation	0.024	0.058	0.011	0.080	0.013	0.181

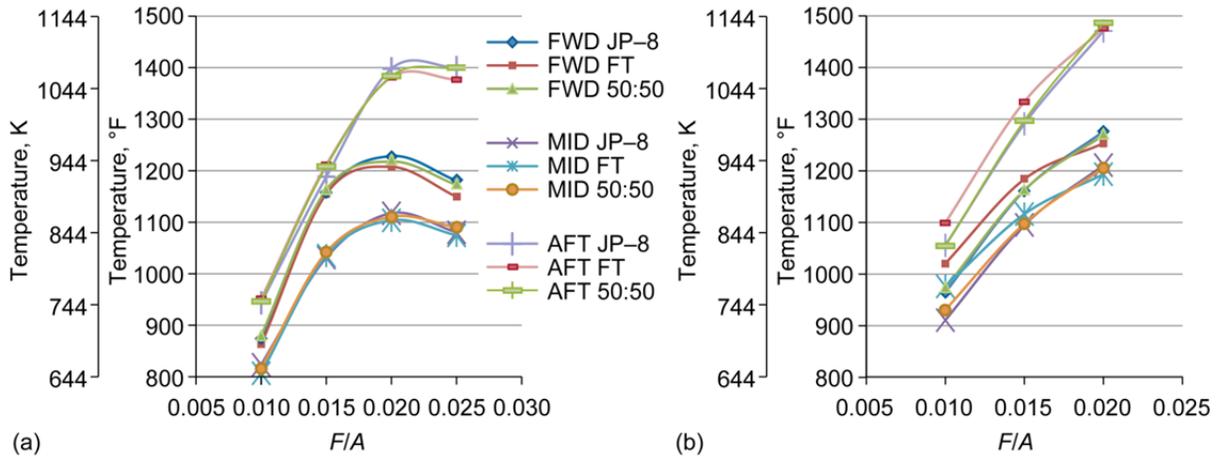


Figure 2.—Sidewall temperature variation along the combustor (from FWD to AFT) with fuel:air ratio *F/A* for Fischer-Tropsch (FT) and JP-8 fuels and a 50:50 blend at 4 percent pressure drop Δ*P*. (a) (P, T)_{inlet} = (75 psia (0.52 MPa), 500 °F (533 K)). (b) (P, T)_{inlet} = (125 psia (0.86 MPa), 625 °F (603 K)).

Sidewalls

The forward, middle, and aft axial positions of the thermocouples along the sector combustor sidewalls are represented as “FWD,” “MID,” and “AFT.” Figure 2 represents the sidewall temperature data obtained from the (P, T)_{inlet} = [75 psia (0.52 MPa), 500 °F (533 K)] and the (P, T)_{inlet} = [125 psia (0.86 MPa), 625 °F (603 K)] runs at 4 percent Δ*P*. This figure adequately represents the sidewall temperature trends shown for all inlet pressures and %Δ*P*. Sidewall temperature profiles illustrate a decrease in temperature from the FWD to MID sections and an increase in temperatures from the MID to AFT along the combustor, where the temperatures are highest. The temperatures also increase as the *F/A* increases, the only exception being the *F/A* of 0.025 at 75 psia (0.52 MPa) inlet pressure, which slightly decreases in temperature relative to the *F/A* of 0.020. The 75 psia (0.52 MPa) data set is the only one that includes *F/A* of 0.025. Data for 75 psia (0.52 MPa) at 3, 4, and 5 percent Δ*P* at the *F/A* of 0.025 are consistent with this trend, with insufficient data to conclude whether this is a peak in combustor temperatures around *F/A* = 0.020. The sidewall

temperatures depend strongly on *F/A* and weakly on the fuel blend composition.

Unwrapped Combustor Liner

Figure 3 is a representative plot of the unwrapped liner surface temperatures for *F/A* of 0.010 at (P, T)_{inlet} = [75 psia (0.52 MPa), 500 °F (533 K)]. The term “unwrapped” refers to the normalized outside liner surface circumference (0 to 1) along with the normalized inner liner circumferential surface (1 to 2) as a continuous loop mapped onto a plane. Table II provides the combustor liner normalized circumferential Θ and axial *X* coordinates along with the thermal data. The unwrapped combustor liner temperature profile shows a peak temperature increase measured by the thermocouple as %Δ*P* increases as well as an increase with *F/A*.

The absolute inlet pressure and temperature of the system also shows an effect on the peak liner temperature (Fig. 3). Overall, the peaks in the temperature profile become more pronounced as *F/A* increases. They also become more pronounced as %Δ*P* increases, but *F/A* appears to have the greater effect.

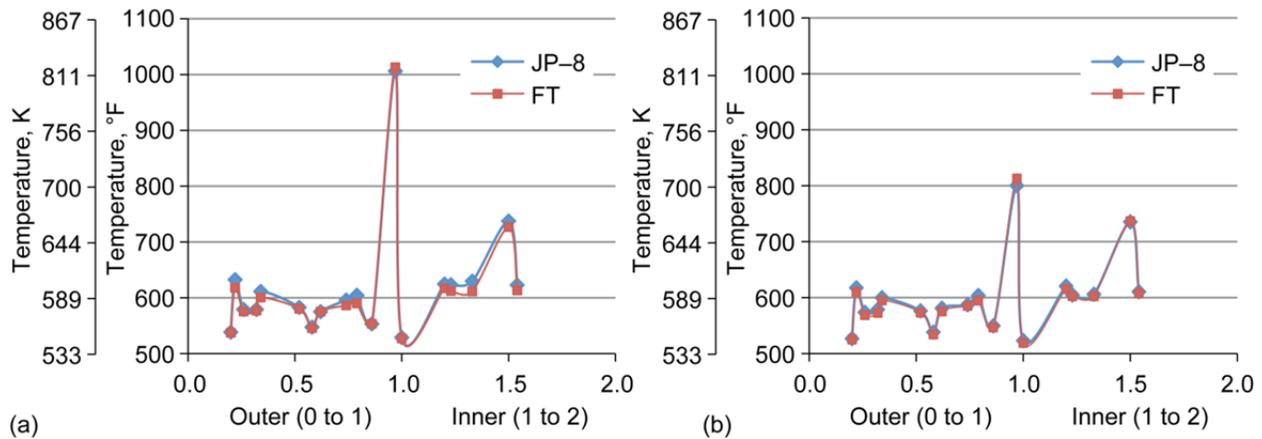


Figure 3.—Unwrapped combustor liner temperature profile with JP-8 and Fischer-Tropsch (FT) fuels for fuel:air ratio $F/A = 0.010$ and inlet pressure and temperature conditions $(P, T)_{inlet} = (75 \text{ psia } (0.52 \text{ MPa}), 500 \text{ °F } (533 \text{ K}))$ at different percent pressure drop $\% \Delta P$. (a) 3 percent. (b) 5 percent.

TABLE II.—COMBUSTOR OUTER AND INNER LINER TEMPERATURES, THERMAL DIFFERENCE DATA, AND NUMBER AND NAME OF THERMOCOUPLES (TCs) USED TO PLOT THERMAL PROFILES.^{a,b,c}
[From Ref. 5.]

TC	Unwrapped ^d			$F/A = 0.010$			$F/A = 0.015$			$F/A = 0.020$		
	TC no.	X	Θ	JP-8 Col C	FT Col G	50:50 Col F	JP-8 Col O	FT Col K	50:50 Col M	JP-8 Col Q	FT Col V	50:50 Col T
Outer liner												
			0.00									
TOTAL	22	0.94	0.20	817	825	825	852	850	846	882	873	881
TOLFL	20	0.00	0.22	900	904	907	968	935	946	1030	971	1002
TOLML	21	0.67	0.26	861	870	869	927	924	925	987	957	985
TOLMWA	24	0.19	0.32	870	875	878	962	917	944	1027	960	1002
TOLFM	27	0.00	0.34	899	902	908	983	944	956	1060	985	1024
TOLCA	25	1.00	0.52	862	872	872	920	910	912	986	952	974
TOLAM	28	0.94	0.58	814	825	825	852	851	850	888	874	886
TOLMR	36	0.67	0.62	873	887	884	953	918	941	1013	955	996
TOLFR	34	0.00	0.74	887	888	891	965	924	944	1016	956	1001
TOLMWI	23	0.33	0.79	879	879	884	933	905	914	992	937	969
TOLAR	37	0.84	0.86	831	843	843	877	872	874	917	906	922
TSWFD	41	0.22	0.97	1218	1288	1280	1438	1469	1444	1544	1565	1581
TSWFT	30	0.78	1.00	814	820	820	847	836	841	854	842	850
Inner liner												
TILMWI	38	0.50	1.20	897	908	906	994	969	976	1091	1023	1066
TILFR	35	0.00	1.23	890	917	919	995	959	967	1075	1006	1050
TILMWO	26	0.50	1.33	902	908	909	988	962	968	1096	1025	1071
TILCA	29	1.00	1.50	1056	1065	1058	1229	1217	1219	1411	1326	1348
TILFL	39	0.00	1.54	913	917	916	1002	970	981	1098	1030	1069
			2.00									

^aGeometric position accuracy of thermocouple position coordinates is estimated at ± 1.5 percent.

^bFor nominal inlet pressure 225 psia (1.55 MPa), 800 °F (700 K), and 3 percent combustor pressure drop.

^cNote: TC no. and Col C, G, F, K, M, Q, V, and T are reference data set location parameters.

^d $X = x/L$ (which varies from 0 to 1), where x is the TC position measured from the liner inlet and L is the overall liner length.

$\Theta =$ circumferential TC position measured over the liner outside y/L_0 (0 to 1) and continuing back along the inside liner (1 to 2), where L_0 is half the unwrapped liner “width.” The normalized unwrapped coordinate (X, Θ) is the TC location (x, y) .

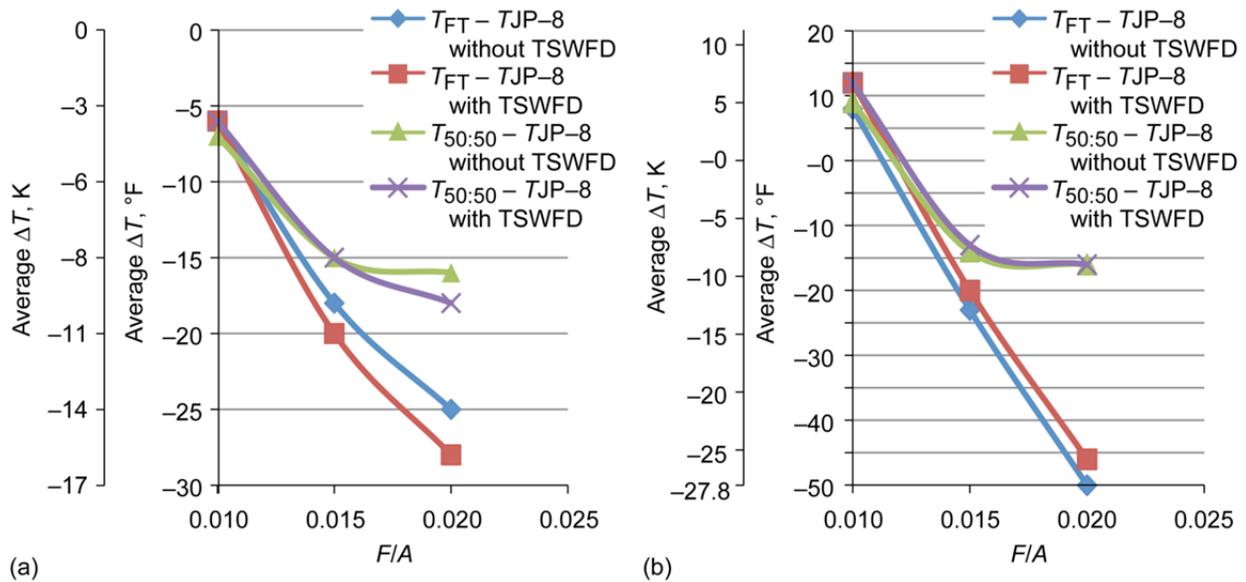


Figure 4.—Average combustor liner temperature differences for Fischer-Tropsch (FT) fuel and 50:50 blend with respect to JP-8 ($\Delta T = T_{\text{fuel blend}} - T_{\text{JP-8}}$) versus fuel:air ratio F/A for different inlet pressure and temperature conditions (P, T_{inlet}) at a pressure drop of 3 percent, with and without including sidewall temperature data from the FWD position (TSWFD). (a) ($P, T_{\text{inlet}} = (125 \text{ psia (0.86 MPa), 625 }^\circ\text{F (603 K))}$). (b) ($P, T_{\text{inlet}} = (225 \text{ psia (1.55 MPa), 790 }^\circ\text{F (694 K))}$).

TABLE III.—AVERAGE UNWRAPPED LINER TEMPERATURE DIFFERENCES ΔT :^a
FT FUEL AND 50:50 BLEND WITH RESPECT TO JP-8+100

Inlet pressure and temperature, (P, T_{inlet})	% ΔP , percent	$\Delta T = T_{\text{fuel blend}} - T_{\text{JP-8}}$, ^b °F											
		$F/A = 0.010$			$F/A = 0.015$			$F/A = 0.020$			$F/A = 0.025$		
		JP-8	FT	50:50	JP-8	FT	50:50	JP-8	FT	50:50	JP-8	FT	50:50
[75 psia (0.52 MPa), 500 °F (533 K)]	3	0	-4	-5	0	1	-6	0	-15	-11	0	-12	-16
	4	0	-2	0	0	-2	-2	0	-9	-7	0	-12	-8
	5	0	-3	-2	0	-1	-2	0	-2	-3	0	-3	1
[125 psia (0.86 MPa), 625 °F (603 K)]	3	0	-6	-6	0	-20	-15	0	-28	-18			
	4	0	1	-1	0	-6	-6	0	-29	-16			
	5	0	6	2	0	-10	-5	0	-23	-11			
[175 psia (1.21 MPa), 725 °F (658 K)]	3	0	7	2	0	-25	-6	0	-39	-18			
	4	0	1	0	0	-13	-10	0	-22	-14			
	5	0	2	1	0	-11	-7	0	-26	-17			
[225 psia (1.55 MPa), 790 °F (694 K)]	3	0	12	12	0	-20	-13	0	-46	-16			
	4	0	18	17	0	-9	-4	0	-31	-14			
	5	0	6	3	0	-9	1	0	-39	-14			

^a $\Delta T < 0$ implies cooler liner temperature.

^b ΔT (°F) = 1.8 ΔT (K).

Using Figure 3, it is difficult to differentiate between the temperature differences of the varied fuel blends. By calculating the difference in temperatures read by the thermocouples at each location on the combustor for the blend and the 100 percent FT fuel relative to those recorded for JP-8, $\Delta T = T_{\text{fuel blend}} - T_{\text{JP-8}}$ (where “fuel blend” refers to a 0 to 100 percent FT fuel blend with JP-8), a better sense for each fuel’s performance may be obtained. Figure 4 illustrates the trends seen for the average temperature differences in relation to F/A at ($P, T_{\text{inlet}} = [125 \text{ psia (0.86 MPa), 625 }^\circ\text{F (603 K)]}$ and

[225 psia (1.55 MPa) and 790 °F (694 K)] at 3 percent ΔP and gives a better picture for the heat performance of the fuels. Table III outlines all the average temperature differences (convective and radiation cooling) for all testing conditions.

The overall trend shows that at $F/A = 0.010$, both the blend and the FT fuel generally run at higher temperatures than JP-8 for all pressure values. As the F/A increases, the 50:50 blend and the FT fuel temperatures decrease, ending with cooler operating temperatures relative to JP-8 at the 0.020 ratio. With respect to the increasing F/A , there is a

larger deviation in the temperature performance of the FT and 50:50 fuels. At the higher F/A , the FT fuel runs at temperatures cooler than both the JP-8 and the blend, illustrating that at these higher F/A values, the impact of the FT performance within the blend decreases and JP-8 performance dominates. This would mean that at high F/A , the FT fuel would decrease liner temperatures relative to the JP-8 and the 50:50 blend and could increase component life within the combustor and yet not the turbine. Also, greater temperature differences are shown for higher inlet pressures and temperatures.

Combustion Exhaust Rake Temperature

The exhaust plane temperature trends are illustrated in Figure 5. These temperature profiles represent data-averaged temperature values collected through use of a temperature probe (rake) placed in the exhaust plane of the combustor. In these data, the signal from the top thermocouple was lost. For all data sets, there is a monotonic increase in the exhaust plane temperature as F/A is increased. The increase in $\% \Delta P$ also creates an increase in the temperature. At higher $\% \Delta P$ and F/A values, the FT fuel tends to run at higher exhaust temperatures compared to JP-8 and the blend, which also gives slightly higher temperatures. Upon further analysis, as F/A increases, the FT fuel at higher exhaust plane temperature generally has less effect on the performance of the blend compared to that of JP-8. There is not a large temperature difference between the fuels at the higher $\% \Delta P$ and F/A ($\Delta T = T_{\text{fuel blend}} - T_{\text{JP-8}} = \approx 20$ to 50 °F (11 to 27 °C)) where there are larger differences at higher inlet temperatures and pressures; however, a small change in temperature can have major impact on the turbine life and efficiency, so these effects must be taken into consideration when selecting an alternative turbine engine fuel.

Plotting the combustor exhaust rake temperature differences versus the inlet pressure and F/A (Fig. 6) displays a minimum, above which the variables have a positive effect on the combustor performance of alternate fuels over JP-8 fuels.

Performing the same analysis for all $\% \Delta P$ conditions for both the 100 percent and 50:50 FT fuel temperature difference data, it is clear that increasing the inlet pressure increases the temperature differences of the FT fuel compared to JP-8. There also appears to be a peak in performance around 3 to 4 percent ΔP for the alternate fuel in relation to the performance of JP-8 (illustrated in Fig. 7).

Calculated flame temperature data are outlined in Figure 8 for 225 psia (1.55 MPa) at 3 percent ΔP . As the inlet pressure and temperature is increased, there is a small increase in the flame temperature. The same trend is displayed with increasing $\% \Delta P$, although $\% \Delta P$ does not seem to affect the temperature differences between the fuels to a significant extent. The $\% \Delta P$ trend is more pronounced than that of the changing inlet pressure and temperature, especially when increasing F/A . At higher F/A , there is a greater difference in flame temperatures between the fuels. The FT generally had higher flame temperatures than the JP-8, and the 50:50 blend temperatures fell to temperatures between the FT and the JP-8 fuel. These trends are also displayed in Table IV, which contains the flame temperature differences between JP-8 and the FT fuels. No significant trend determining whether the FT or JP-8 performance had the dominant role in the flame temperature performance of the 50:50 blend was found.

Bester and Yates (Ref. 8) compared SPK to Jet-A1 fueling in an RR-Allison T63-A-700 Model 250-C18 B gas turbine engine and also cite approved FT-blended fuel use in civil aviation flying from South Africa based on UK Ministry of Defense DEFSTAN 91-91, Issue 3, 1999. It is gratifying to note that using a modified combustor engine system similar to that of Corporan et al. (Ref. 9), they found a 1.2-percent gain in turbine efficiency with SPK fueling over that of JetA-1 along with more favorable emissions. Although the present report provides a more comprehensive and complete comparisons of SPK to JetA-1 combustor performance for current commercial aircraft (Fig. 1), it lacks the turbine engine performance afforded by Bester and Yates including the cited increase in turbine efficiency.

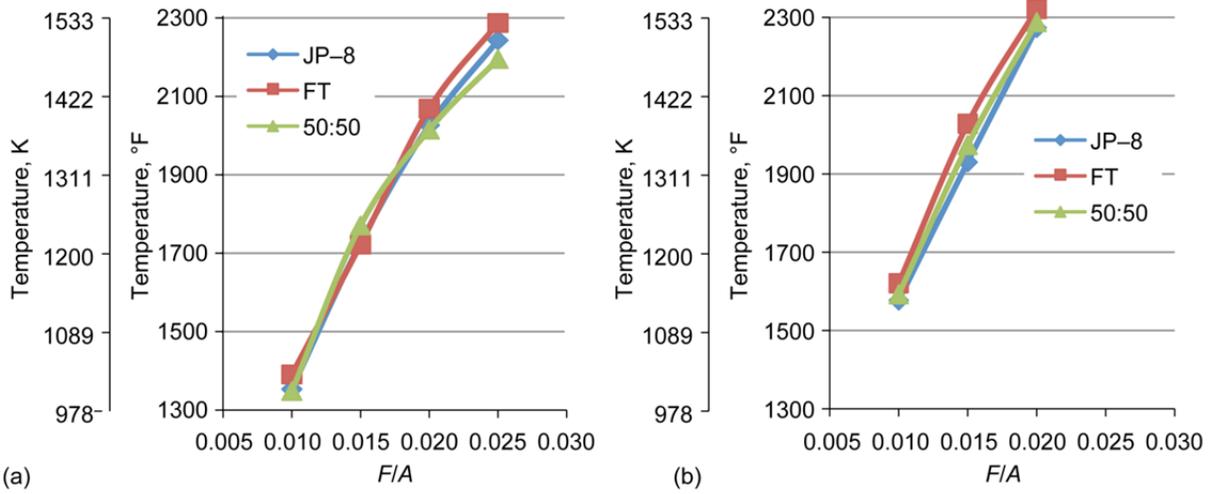


Figure 5.—Exhaust plume temperatures as a function of JP-8 and Fischer-Tropsch (FT) fuels and a 50:50 blend as a function of fuel:air ratio F/A for two combustor inlet pressure and temperature conditions $(P, T)_{inlet}$ at a pressure drop of 3 percent. (a) $(P, T)_{inlet} = (75 \text{ psia (0.52 MPa)}, 500^\circ \text{ F (533 K)})$. (b) $(P, T)_{inlet} = (225 \text{ psia (1.55 MPa)}, 790^\circ \text{ F (694 K)})$.

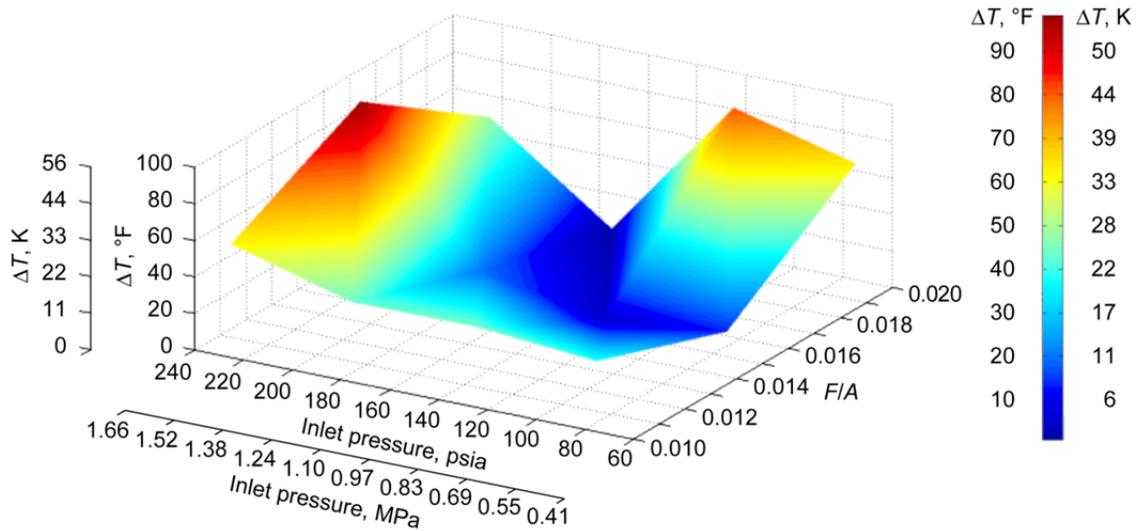
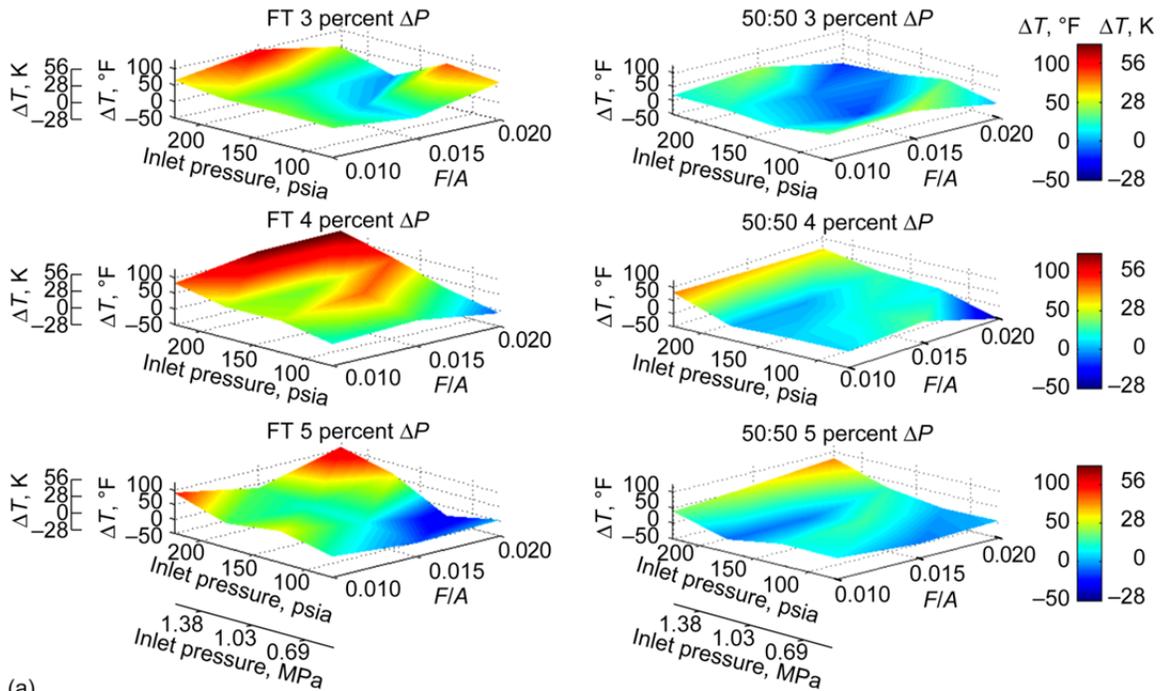
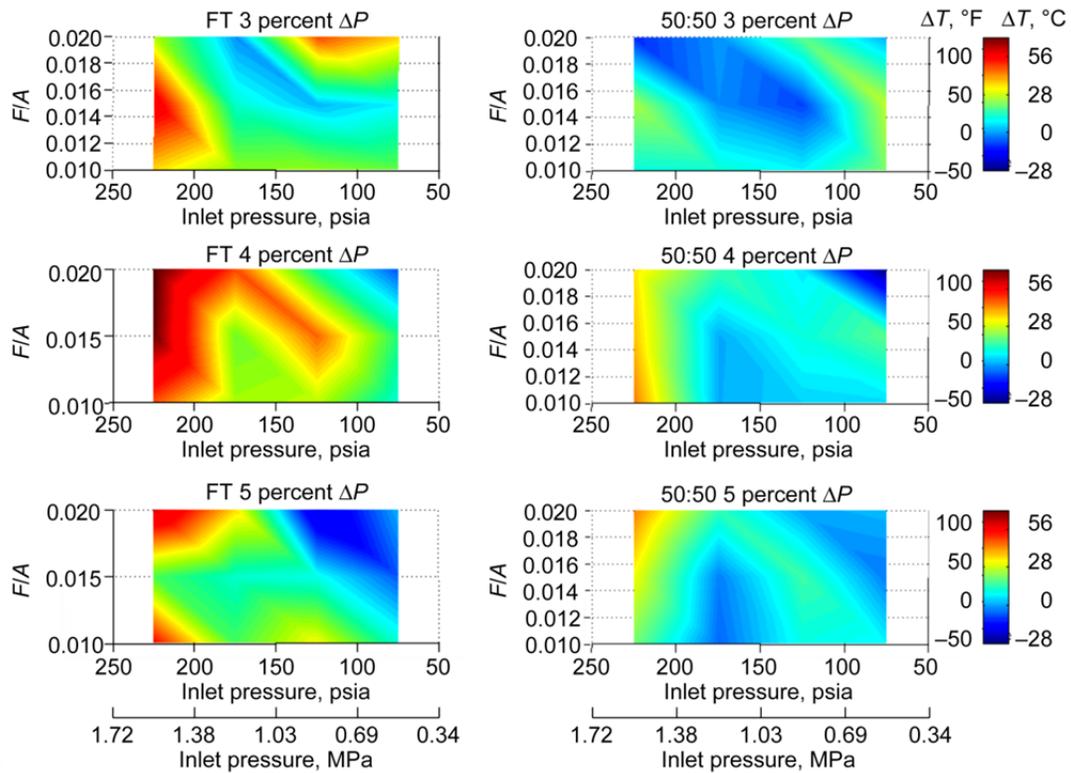


Figure 6.—Combustor exhaust rake temperature differences ($\Delta T = T_{\text{fuel blend}} - T_{\text{JP-8}}$, °F) versus inlet pressure and fuel:air ratio F/A at 3 percent combustor pressure drop ΔP for Fischer-Tropsch (FT) fuel compared with JP-8 fuel, showing pressure and F/A combinations that improve performance (warmer colors) (1 MPa = 145 psia).



(a)



(b)

Figure 7.—Combustor rake temperature differences ($\Delta T = T_{\text{fuel blend}} - T_{\text{JP-8}}$, °F) versus inlet pressure and fuel:air ratio F/A for 3, 4, and 5 percent pressure drop ΔP for Fischer-Tropsch (FT) fuel and 50:50 blend with JP-8 with respect to JP-8 fuel, showing pressure and F/A combinations that improve performance (warmer colors). (ΔT , °F = 1.8 ΔT (K) and 1 MPa = 145 psia.) (a) Isometric view. (b) Projected view.

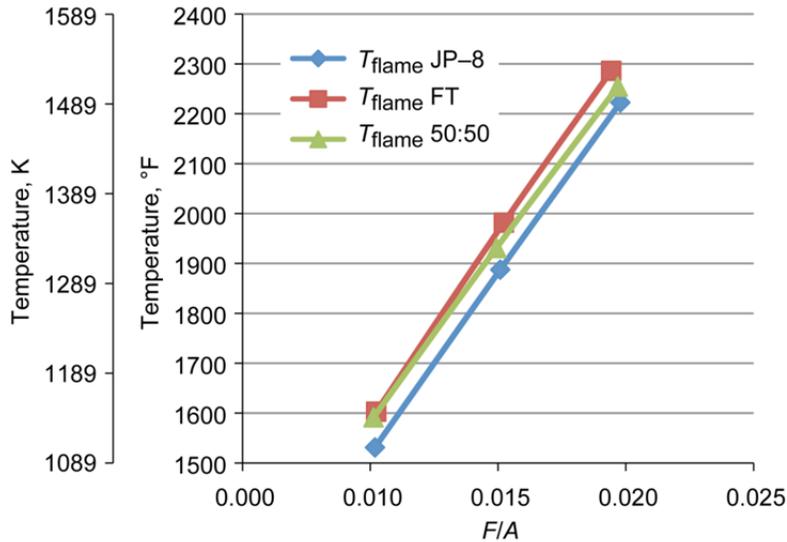


Figure 8.—Calculated flame temperature (T_{flame}) variation with fuel:air ratio F/A and fuel composition for combustor inlet pressure and temperature ($P, T_{\text{inlet}} = (225 \text{ psia (1.55 MPa), 790 }^\circ\text{F (694 K))}$) at 3 percent combustor pressure drop ΔP .

TABLE IV.—FLAME TEMPERATURE DIFFERENCES ΔT FOR FT FUEL AND 50:50 BLEND WITH RESPECT TO JP-8+100
[Combustion at ($P, T_{\text{inlet}} = [225 \text{ psia (1.55 MPa), 790 }^\circ\text{F (694 K)]$.)]

% ΔP , percent	$\Delta T = T_{\text{fuel blend}} - T_{\text{JP-8}}$, °F (K)					
	$F/A = 0.010$		$F/A = 0.010$		$F/A = 0.010$	
	Fuel blend		Fuel blend		Fuel blend	
	FT	50:50	FT	50:50	FT	50:50
3	73 (41)	55 (31)	94 (52)	43 (24)	34 (19)	-3 (-2)
4	107 (59)	90 (50)	84 (47)	41 (23)	105 (58)	42 (23)
5	71 (39)	33 (18)	63 (35)	52 (29)	90 (50)	70 (39)

Conclusions

The data and analysis of combustor sector alternate fuel performance of Combustor A show lower average liner temperatures and higher flame and average combustor outlet temperatures with increasing Fischer-Tropsch (FT) relative to JP-8+100 fueling. The combustor outlet temperature affects turbine efficiency and blade and vane lives and may be due to the higher heat of combustion of the FT fuel per unit mass. Thus, the engine would not be running at higher fuel:air ratio (F/A). A more accurate way to assess how these outlet temperatures will affect the turbine life would be to look at the pattern factor of the exhaust temperatures.

Sidewall temperatures depend mainly on F/A for performance decreasing in temperature from the FWD to MID and increasing in temperature from the MID to AFT. The unwrapped liner temperature data show that the blend and the FT fuel run hotter than JP-8 at lower F/A , but cooler at F/A

above ~ 0.015 . At the higher F/A values the FT fuel temperature differs more so from the JP-8 than the blend. Peak liner temperatures also increase with increasing F/A and $\% \Delta P$ but seem unaffected by the type of fuel blend to a significant extent. Lower liner temperatures result from decreased radiative heat transfer from reduced aromatic content.

The 100 percent FT fuel tends to run at higher exhaust temperatures compared to the JP-8 and 50:50 blend fuels, with a similar trend for flame temperature. Overall, increasing F/A and $\% \Delta P$ increases the thermal performance of the combustor, which will almost always occur unless there is a decrease in the efficiency of combustion.

Glenn Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, September 10, 2013.

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1. REPORT DATE (DD-MM-YYYY) 01-09-2013		2. REPORT TYPE Technical Paper		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Alternate-Fueled Combustor-Sector Performance			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Thomas, Anna, E.; Saxena, Nikita, T.; Shouse, Dale, T.; Neuroth, Craig; Hendricks, Robert, C.; Lynch, Amy; Frayne, Charles, W.; Stutrud, Jeffrey, S.; Corporan, Edwin; Hankins, Terry			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER WBS 561581.02.08.03.16.03		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration John H. Glenn Research Center at Lewis Field Cleveland, Ohio 44135-3191			8. PERFORMING ORGANIZATION REPORT NUMBER E-17902-1		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001			10. SPONSORING/MONITOR'S ACRONYM(S) NASA		
			11. SPONSORING/MONITORING REPORT NUMBER NASA/TP-2013-217735		
12. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified-Unlimited Subject Categories: 07, 44, 45, and 05 Available electronically at http://www.sti.nasa.gov This publication is available from the NASA Center for AeroSpace Information, 443-757-5802					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT In order to realize alternative fueling for military and commercial use, the industry has set forth guidelines that must be met by each fuel. These aviation fueling requirements are outlined in MIL-DTL-83133F(2008) or ASTM D 7566 Annex (2011) standards, and are classified as "drop-in" fuel replacements. This report provides combustor performance data for synthetic-paraffinic-kerosene- (SPK-) type (Fischer-Tropsch (FT)) fuel and blends with JP-8+100, relative to JP-8+100 as baseline fueling. Data were taken at various nominal inlet conditions: 75 psia (0.52 MPa) at 500 °F (533 K), 125 psia (0.86 MPa) at 625 °F (603 K), 175 psia (1.21 MPa) at 725 °F (658 K), and 225 psia (1.55 MPa) at 790 °F (694 K). Combustor performance analysis assessments were made for the change in flame temperatures, combustor efficiency, wall temperatures, and exhaust plane temperatures at 3, 4, and 5 percent combustor pressure drop (DP) for fuel:air ratios (F/A) ranging from 0.010 to 0.025. Significant general trends show lower liner temperatures and higher flame and combustor outlet temperatures with increases in FT fueling relative to JP-8+100 fueling. The latter affects both turbine efficiency and blade and vane lives.					
15. SUBJECT TERMS Green aviation; Fueling; Energy; Particulates; Pollution control; Air pollution; Combustion product; Combustor design					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 18	19a. NAME OF RESPONSIBLE PERSON STI Help Desk (email:help@sti.nasa.gov)
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (include area code) 443-757-5802

