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High-Octane and Mid-Octane Detonation Performance of Leaded and Unleaded Fuels in Naturally Aspirated, Piston, Spark Ignition Aircraft Engines

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16. Abstract

The full-scale engine detonation performance of mid- and high-octane leaded and unleaded fuels were compared at the onset of light detonation in a naturally aspirated Lycoming IO540-K and a naturally aspirated Lycoming IO320-B engine. The fuels were stressed by performing both mixture lean-outs and by increasing the manifold pressure. The high-octane fuels (100 motor octane number (MON) and above) were tested in the IO540-K engine, and the mid-octane (91 to 95 MON fuels) were tested in the IO320-B engine. For this testing, the MON was determined by ASTM International (ASTM) specification D 2700 and the supercharge rich rating was determined by ASTM D 909. A specially blended 100 low-lead (100 LL) aviation gasoline was tested. The 100 LL blend contained the maximum amount of allowable lead, while meeting the minimum MON of 100 and the minimum supercharge rich rating of 130 (described as 100/130 lead (L)), and met all current ASTM aviation gasoline specification D 910. The 100 LL blend performed significantly better than a 100 MON unleaded isooctane and a 100 MON and 161 supercharge rich rating unleaded amine-laden fuel in the IO540-K engine. The 100 LL did not perform as well as a 104 MON and 161 supercharge rich rating unleaded amine-laden fuel. The 100 LL fuel performed the same as a 100 MON and 100 supercharge rich rating leaded (100/100 L) fuel at the lower cruise power settings but performed much better at the higher power settings. This testing showed that the 100 LL significantly outperformed unleaded fuels of equivalent MON, even those with much higher supercharge rich ratings. The data also showed that the supercharge rich rating for leaded, hydrocarbon fuels is of greater significance at the higher power settings.

A 91 MON and 98 supercharge rich rating leaded fuel (91/98 L) significantly outperformed an unleaded 91 MON and 98 supercharge rich rating fuel (91/98 unleaded (UL)) in the IO320-B engine. The leaded 91/98 L fuel performed better than the 93 MON and 98 supercharge rich rating unleaded fuel (93/98 UL) and not as well as the 94 MON and 98 supercharge rich rating unleaded fuel (94/98 UL). For a mid-octane (~91 MON), straight hydrocarbon, unleaded and nonmetallic fuel to perform as well as a leaded fuel of equivalent motor octane and supercharge rich rating in a full-scale engine, the unleaded fuel would require 2 to 3 higher MON. The high-octane study was inconclusive in determining the equivalent unleaded MON detonation performance to the leaded MON.

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LIST OF ACRONYMS AND SYMBOLS

AFL	Air-to-fuel ratio for the left bank cylinder
AFR	Air-to-fuel ratio for the right bank cylinder
ASTM	ASTM International
BHP	Brake horsepower
BSFC	Brake-specific fuel consumption
BTDC	Before top dead center
CHT	Cylinder head temperature
EGT	Exhaust gas temperature
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FR	Full rich
hp	Horsepower
in. Hg	Inches of mercury
L	Leaded aviation gasoline
lb/bhp hr	Pounds per brake-horsepower hour
MAP	Manifold absolute pressure
MON	Motor octane number as determined by ASTM D 2700
NRP	Normal-rated power
PRF	Primary reference fuel
psi	Pounds per square inch
psig	Pounds per square inch gauge
rpm	Revolutions per minute
R&D	Research and development
TEL	Tetra-ethyl lead
TO	Takeoff
UL	Unleaded aviation gasoline
100 LL	Low-lead aviation gasoline
WOT	Wide-open throttle

EXECUTIVE SUMMARY

Researchers in the Federal Aviation Administration Propulsion and Fuel System Safety Branch at the FAA William J. Hughes Technical Center have been researching the detonation performance differences of leaded and unleaded fuels in spark ignition, piston aircraft engines.

A naturally aspirated Lycoming IO540-K engine and a naturally aspirated Lycoming IO320-B engine were detonation tested using high- and mid-octane leaded and unleaded fuels to determine and quantify the lead effects on full-scale engine detonation performance. Unleaded and leaded fuels of equivalent motor octane number (MON) and supercharge rich rating and of equivalent MON but different supercharge rich rating were compared. The detonation performance of leaded fuels were also compared to that of unleaded fuels of higher MON. The MON of the fuels was determined by ASTM International (ASTM) standard test method D 2700 and the supercharge rich rating was determined by ASTM D 909. Fuel mixture strength was adjusted to the point of moderate to severe detonation, and in a separate study, engine manifold pressure was adjusted to the point of moderate to severe detonation. The fuels were compared at the onset of light detonation. A specially blended 100 low-lead (100 LL) aviation gasoline, having the minimum allowable MON and supercharge rich rating, and meeting all ASTM D 910 aviation gasoline specification while containing the maximum amount of allowable lead was tested. In the IO540-K engine, the 100 LL significantly outperformed isooctane, an unleaded single boiling point fuel having a 100 MON and a 100 supercharge rich rating. The 100 LL (100/130 leaded (L)) also outperformed a leaded aviation gasoline with 100 MON and 100 supercharge rich rating (100/100 L) at the higher power settings but matched the performance at the lower cruise power settings. For leaded, hydrocarbon fuels, the supercharge rich rating had greater significance at higher power settings. The 100 LL outperformed an unleaded 100 MON and 161 supercharge rich rating amine fuel (100 amine) and did not perform as well as an unleaded 104 MON and 161 supercharge rich rating amine fuel (104 amine). The 100 LL significantly outperformed the unleaded fuels of equivalent MON, even those with significantly higher supercharge rich ratings.

In the Lycoming IO320-B engine, a 91 MON and 98 supercharge rich rating leaded fuel (91/98 L) was compared against an unleaded fuel of 91 MON and 98 supercharge rich rating (91/98 unleaded (UL)), against unleaded fuels having 93 and 94 MON with 98 supercharge rich rating (93/98 UL, and 94/98 UL), and against an unleaded 94 MON and 94 supercharge rich rating primary reference fuel (94 PRF). The 91/98 L leaded fuel significantly outperformed the 91/98 UL and the 94 PRF unleaded fuels. The 91/98 L fuel outperformed the 93/98 UL fuel and underperformed the 94/98 UL fuel. For mid-octane fuels, an unleaded, nonmetallic, full-boiling range hydrocarbon fuel will require 2 to 3 MON more than a leaded fuel of equivalent supercharge rich rating to provide the same full-scale engine detonation performance.

INTRODUCTION

PURPOSE.

This research evaluated the detonation performance of high- and mid-octane leaded and unleaded fuels of equivalent motor octane number (MON) and supercharge rich rating, between leaded fuels of equivalent MON with different supercharge rich ratings, and between leaded fuels and unleaded fuels of higher MON in full-scale piston, spark ignition, naturally aspirated aircraft engines.

BACKGROUND.

The Environmental Protection Agency (EPA) has exempted the general aviation community from complying with a 1990 Clean Air Act Amendment that banned the sale of fuels containing lead additives. The Airport and Aircraft Safety Research and Development (R&D) Division, Propulsion and Fuel Systems Branch located at the Federal Aviation Administration (FAA) William J. Hughes Technical Center has been researching unleaded aviation gasolines for many years to provide data toward the development of an unleaded aviation gasoline. It has long been suspected that lead additives provide an octane bonus in a full-sized engine above unleaded fuels of equivalent motor and supercharge rich ratings. This testing will explore the detonation performance difference, in both high- and mid-octane requirement engines, between leaded and unleaded fuels of equivalent octane, and will quantify that multicylinder engine detonation performance difference.

RELATED DOCUMENTS.

The following documents relate directly to the issues addressed herein:

- ASTM D 910, “Standard Specification for Aviation Gasolines.”
- ASTM D 2700, “Test Method for Detonation Characteristics of Motor and Aviation Fuels by the Motor Method.”
- ASTM D 909, “Test Method for Knock Characteristics of Aviation Gasolines by the Supercharge Method.”
- ASTM D 6424, “Practice for Octane Rating Naturally Aspirated Spark Ignition Aircraft Engines.”
- FAA Advisory Circular 33-47, “Detonation Testing in Reciprocating Aircraft Engines.”

TEST PROCEDURES

Two different aircraft engines were used for this study. One was a high-octane requirement Lycoming IO540-K engine and the other was a mid-octane requirement Lycoming IO320-B engine. Both engines were naturally aspirated.

Table 1 lists the specifications for the Lycoming IO540-K and IO320-B model engines. The IO in the engine model description refers to fuel injection and opposed cylinder, and the numerical value of the model description refers to the cubic inch cylinder displacement.

Table 1. Lycoming IO540-K and IO320-B Engine Model Specifications

Engine Make and Model	Compression Ratio	Normal-Rated Power (bhp)	Normal-Rated (rpm)	Ignition Timing (degrees before top dead center)	Cylinders	Bore (in.)	Stroke (in.)	ASTM D 910 Fuel
Lycoming IO540-K	8.7:1	300	2700	20	6	5.125	4.375	100 or 100 LL
Lycoming IO320-B	8.5:1	160	2700	25	4	5.125	3.875	91/96

bhp = break horsepower
rpm = revolutions per minute

They were both outfitted with individual cylinder pressure transducers as specified in the ASTM International (ASTM) Standard Practice D-6424 to monitor for detonation.

Both engines were installed in separate test stands and coupled to eddy-current dynamometers. Typical engine instrumentation is listed in table 2, and the engine parameter data were recorded at a rate of one scan of all channels every 1 second.

Sensors used to measure these parameters were installed at manufacturer recommended locations whenever possible and were calibrated prior to any engine testing. After the engine was installed and the instrumentation calibrated, a series of maintenance runs were performed to verify the engine systems integrity and instrumentation accuracy. Prior to any engine operation, the mixture cut-off and full-rich (FR) settings and the throttle stop and throw positions were checked.

Table 3 shows the octane values and lead content for the fuels used in the IO540-K engine. All hydrocarbon-based fuels listed throughout this report have the following format: MON/ supercharge rich rating followed by either an L or UL, depending on whether the fuel is leaded or unleaded. The unleaded 100 and 104 amine fuels contain an amine-based octane enhancer m-toluidine and are listed as either 100 amine or 104 amine. The MON is determined by the standardized ASTM D 2700 test, and the supercharge rich rating is determined by ASTM D 909. The 100 low-lead (100 LL) fuel was blended to meet all requirements of the current avgas

specification ASTM D 910, except the dye requirement, while having the minimum MON, the minimum supercharge rich rating, and containing the maximum amount of allowable lead.

Table 2. Typical Sensors and Installation Locations

Parameter	Sensor Type	Sensor Location
Cylinder head temperatures 1-6	Bayonnet, J-type thermocouple	Manufacturer's specified location
Exhaust gas temperatures 1-6	Band clamp, K-type thermocouple	Exhaust pipe within two inches of exhaust flange
Intake air temperature	T-type thermocouple	Intake duct just prior to throttle throat
Intake air pressure	Absolute pressure transducer	Intake duct just prior to throttle throat
Mass airflow rate	Kurz mass flow meter	Straight, smooth section of intake air duct. Six diameters downstream
Intake air humidity	Probe	Intake air duct
Manifold absolute pressure	Absolute pressure transducer	Intake manifold plenum after the fuel injection unit
Engine speed (rpm)	Magnetic pickup	Dynamometer shaft
Engine shaft torque	Load cell	Dynamometer
Fuel mass flow rate	Corliolis mass flow meter	After fuel control unit and prior to fuel manifold
Engine cowling air temperature	T-type thermocouple	Engine cowling plenum
Engine cowling air pressure	Gauge pressure transducer	Engine cowling plenum
Fuel temperature	Corliolis mass flow meter	After fuel control unit and prior to fuel manifold
Fuel mass density	Corliolis mass flow meter	After fuel control unit and prior to fuel manifold
Metered fuel pressure	Gauge pressure transducer	Output of fuel metering unit
Fuel pump pressure	Gauge pressure transducer	Output of engine driven pump
Oil temperature	J-type thermocouple	Return from oil cooler
Oil pressure	Gauge pressure transducer	Manufacturer's location in accessory case
Air-to-fuel ratio, left bank	Lambda exhaust gas sensor	Left bank of cylinders common exhaust pipe
Air-to-fuel ratio, right bank	Lambda exhaust gas sensor	Right bank of cylinders common exhaust pipe

Isooctane is an ASTM D 2700 primary reference fuel (PRF) which has, by definition 100 MON and 100 supercharge rating. For example, 100/100 L is a leaded fuel having approximately a 100 MON and a 100 supercharge rich rating. All fuels were blended using typical aviation gasoline components, with the exception of the amine additive, which is not currently used in aviation

gasoline. The fuel 94 PRF is a 94 MON ASTM D 910 reference fuel composed of 94% reference-grade isooctane and 6% reference-grade n-heptane.

Table 3. High-Octane Fuels Used in the IO540-K Engine

	Isooctane PRF	100/100 L	100 Amine	100 LL (100/130 L)	104 Amine
MON (ASTM D 2700)	100.0	100.0	100.0	100.3	104.0
Supercharge (ASTM D 909)	100	99	>161	132	>161
TEL gPb/l	0.000	0.501	0.000	0.568	0.000

The 100 and 104 amine fuels had supercharge performance that was better than the highest supercharge value, 161, listed in ASTM D 909. These fuels were listed as having >161 supercharge number.

The two leaded fuels listed in table 4 met all aviation gasoline specifications in ASTM D 910, except that no dye was added. All fuels in table 5, except for the 94 PRF, met the ASTM D 910 aviation gasoline specification with the following exceptions: no dye was added to the 91/98 leaded and unleaded blends, for the 93/98 UL and 94/98 UL unleaded blends, the vapor pressure was high by 1.1 and 1.7 kilo-Pascals, and the distillation loss was high by 0.7 and 1.0 and no dye was added.

Table 4. Mid-Octane Fuels Used in the IO320-B Engine

	91/98 UL	91/98 L	93/98 UL	94/98 UL	94 PRF
MON (ASTM D 2700)	91.9	91.8	93.2	94.1	94.0
Supercharge (ASTM D 909)	98	98	98	98	94
TEL gPb/l	0.000	0.502	0.000	0.000	0.000

MIXTURE LEAN-OUTS.

The fuels were tested at power settings ranging from takeoff (TO), 85%, 75%, and 65% power, as shown in table 5. TO is referred to as the condition of wide-open throttle (WOT), and maximum-rated revolutions per minute (rpm). The horsepower and rpm combinations were chosen from the engine manufacturer's specifications. The dynamometer operated in the speed mode, which resulted in varying the engine load to maintain the desired rpm. Typically, a fuel mixture richer than best power that was not detonating was set. The mixture was leaned steadily at a rate of change slower than 1 lb/hr/s of fuel mass flow, while the manifold pressure was held constant. The mixture was leaned until either moderate to heavy detonation or 25 degrees past peak exhaust gas temperature (EGT) was attained. TO power was attempted first, and the best power attained was used to calculate the 85%, 75% and 65% power settings.

All analyses and figures presented in this report rely on fuel mass flow rates and not volume flow rates, unless specified otherwise, as is customary in reporting engine data. The fuels were compared at light detonation onset.

Table 5. Power Settings for Mixture Lean-Outs

Power	MAP (in. Hg)	Engine Speed (rpm)
TO - NRP	WOT	2700
85% of TO	Adjusted to attain power	2600
75% of TO	Adjusted to attain power	2450
65% of TO	Adjusted to attain power	2350

NRP = Normal-rated power

VARIABLE MANIFOLD PRESSURE.

Engine speed and fuel mass flow combinations were investigated by starting from a nondetonating manifold pressure (MAP) and increasing the MAP, by slowly opening the throttle, in increments of 0.4 in-Hg, while holding the fuel mass flow rate steady, until moderate to heavy detonation occurred or WOT was reached. At each 0.4 in. Hg increment in MAP, the operator paused throttle adjustment for 3 seconds. The ignition timing, fuel mass flow, and rpm were constant during this process, which results in the horsepower output being directly proportional to the MAP. Fuel mixtures at best power, lean and rich of best power, and rpm settings from low cruise to TO were investigated. The fuels were compared at onset of light detonation.

The parameter settings listed in table 6 were maintained throughout both the mixture lean-outs and the variable MAP detonation tests.

Table 6. Parameter Settings for Detonation Tests

Parameter	Limit
Maximum cylinder head temperature	475° ±3°F (maximum as per engine manufacturer's detailed specifications)
All other cylinder head temperatures	Within 50°F of maximum cylinder head temperature
Induction air temperature	103° ±3°F
Induction air relative humidity	Less than 5%
Oil inlet temperature	245° –10°F (maximum as per engine manufacturer's detailed specifications)

RESULTS

MIXTURE LEAN-OUTS.

All mixture lean-outs were performed with constant MAP starting with a nondetonating mixture setting richer than best power. Power settings at four different rpm settings, ranging from cruise to TO, were tested. Testing on an eddy-current dynamometer in the speed mode means that changes to the mixture settings result in changes to the applied torque to maintain the constant rpm. Thus, for a constant rpm, the mean effective pressure and engine torque are directly proportional to the horsepower output. Therefore, all data was presented as detonation onset brake horsepower, corrected to standard day conditions, versus detonation onset fuel mass flow.

As a fuel is leaned from a mixture setting rich of best power, the propensity to detonate will increase as mixture leaning continues beyond best power until the power drop becomes significant.

When starting from a rich of best power, nondetonating mixture setting, the leaner the mixture achievable prior to the onset of detonation the better the detonation performance of the fuel. Therefore, for all corrected power versus fuel mass flow curves in this section, the farther to the left and the lower the fuel mass flow rates at detonation onset, the better the detonation performance of the fuel.

Figure 1 shows the points of light detonation onset for the tests using the Lycoming IO540-K engine. Four fuels of 100 MON were compared along with an amine-laden fuel of 104 MON. The 100 MON isooctane was outperformed by the 100 MON amine fuel, indicating that the full boiling range fuel with an amine component added detonation resistance in the full-scale engine that is not appreciated by the single-cylinder ASTM D 2700 MON test. The 100 MON leaded aviation gasoline (100 LL) significantly outperformed the 100 MON unleaded isooctane PRF and the unleaded 100 MON amine fuel. Thus, the 100 LL, 100/130 L, leaded fuel performed better than an unleaded fuel (100 amine) of equivalent MON with a much higher supercharge rich rating (>161). The 100 LL aviation gasoline performed equivalent to the 104 MON amine fuel, having a much higher supercharge rich rating (>161) at the cruise settings, but was outperformed at the high power settings. The 100/100 L fuel outperformed the isooctane at the cruise power settings and matched the performance at the higher power settings. The 100/130 L aviation gasoline performed equivalent to the leaded 100/100 L fuel at the lower cruise power settings but outperformed the 100/100 L fuel at the higher power settings. This shows that the lead improves the detonation performance of the fuel above what is suggested by the MON as determined by the single- cylinder test, and that the supercharge rich rating plays more of a role at the higher power settings than at the cruise power settings.

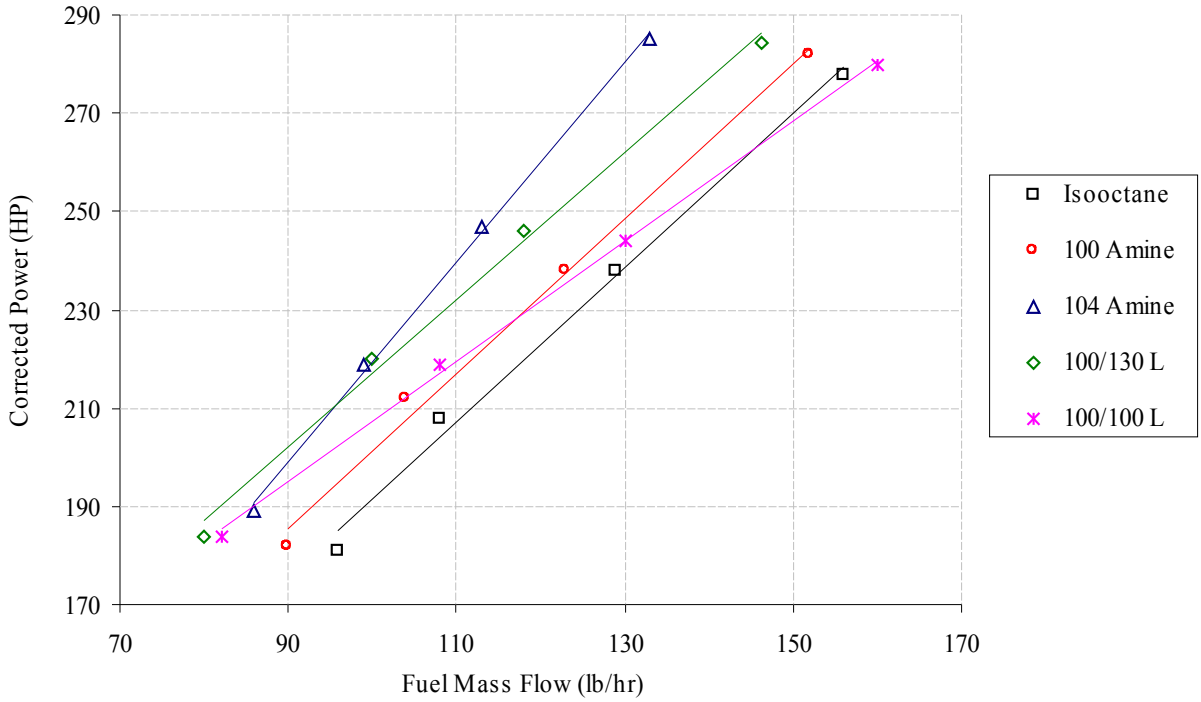

Figure 1. Lycoming IO540-K Engine Mixture Lean-Outs Detonation Onset for Leaded and Unleaded Fuels

Figure 2 shows points of light detonation onset for the Lycoming IO320-B engine mixture lean-out detonation tests. The 94 PRF fuel was tested twice, once at the beginning of the test and once at the end of the test, to show the repeatability of the testing. The data show the 94 PRF fuel gave the same result before and after the testing, indicating good test repeatability. These results also show that, for short-term operations on leaded fuels, there was little or no effect on detonation testing leaded and unleaded fuels in the same engine.

The 94/98 UL unleaded fuel provided detonation-free operation throughout the entire envelope of mixture adjustment. The leaded 91/98 L fuel outperformed the 93/98 UL unleaded fuel and underperformed the 94/98 UL fuel. The 91/98 L fuel significantly outperformed the 91/98 UL unleaded fuel, illustrating the detonation suppression effect that lead has in a full-scale engine. The 94 PRF single boiling point, single-cylinder reference fuel, with a 94 MON, was outperformed in the full-scale engine by the 91/98 UL full boiling range unleaded fuel of 91 MON. The 91/98 L leaded fuel with a 91 MON performed better than the 93 MON unleaded fuel of the same supercharge rating (93/98 UL) and not quite as well than the 94 MON unleaded fuel of the same supercharge rich rating (94/98 UL). Thus, in the full-scale engine, the leaded fuel exhibited detonation performance equivalent to that of an unleaded fuel of 2 to 3 MON higher.

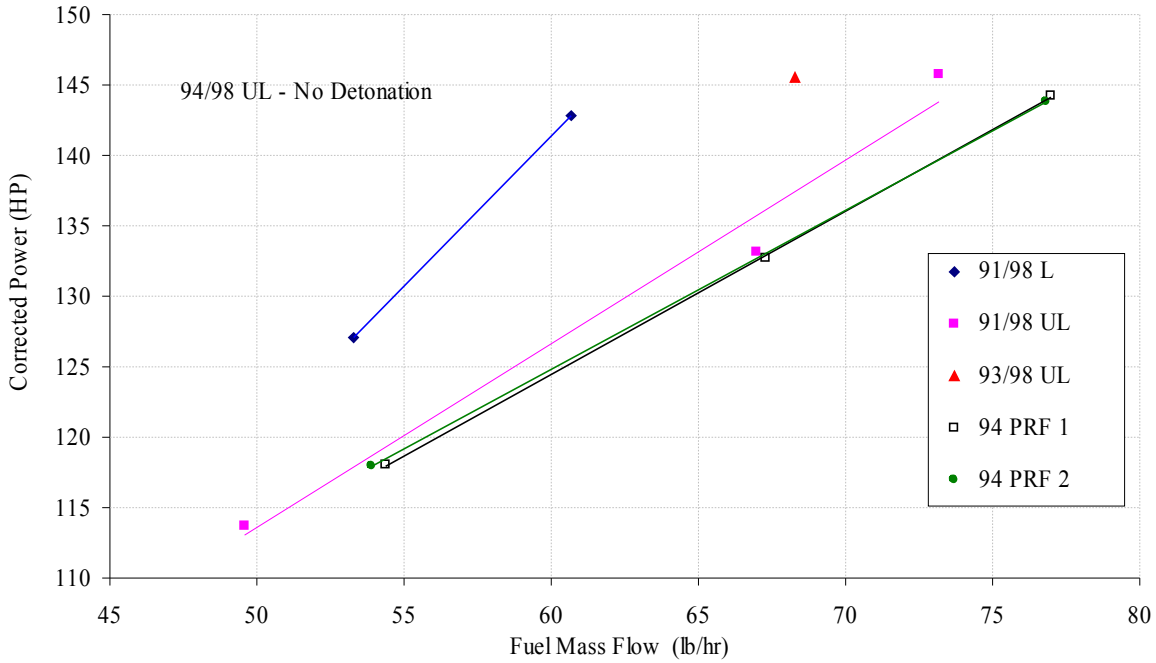

Figure 2. Lycoming IO320-B Engine Mixture Lean-Outs Detonation Onset for Leaded and Unleaded Fuels

VARIABLE MANIFOLD PRESSURE.

The fuel mass flow, ignition timing, and rpm were held steady while the MAP was increased in increments of 0.4 in. Hg until moderate to severe detonation was attained. The MAP was adjusted from a lower, nondetonating value by opening the throttle. Fuel mixture settings at best power and rich and lean of best power were investigated.

At every 0.4 in. Hg increment of manifold pressure, the operator paused throttle adjustment for 3 seconds to allow for at least 100 engine cycles of detonation data to be collected.

Both the Lycoming IO540-K and the IO320-B engines were operated by using a shaft dynamometer, which varied the shaft torque to maintain the rpm setting. Increases in the throttle directly increases the manifold pressure, engine torque, and hence engine brake horsepower. In this manner of testing, for a constant rpm, the mean effective pressure is directly proportional to the brake horsepower. The light detonation onset data in figures 3 through 7 were, therefore, presented as the brake horsepower (corrected for standard day conditions) at detonation onset versus the fuel mass flow at detonation onset. Figure 3 shows the IO540-K engine, and figures 4 through 7 show the IO320-B engine at the 2350, 2450, 2600, and 2700 rpm settings.

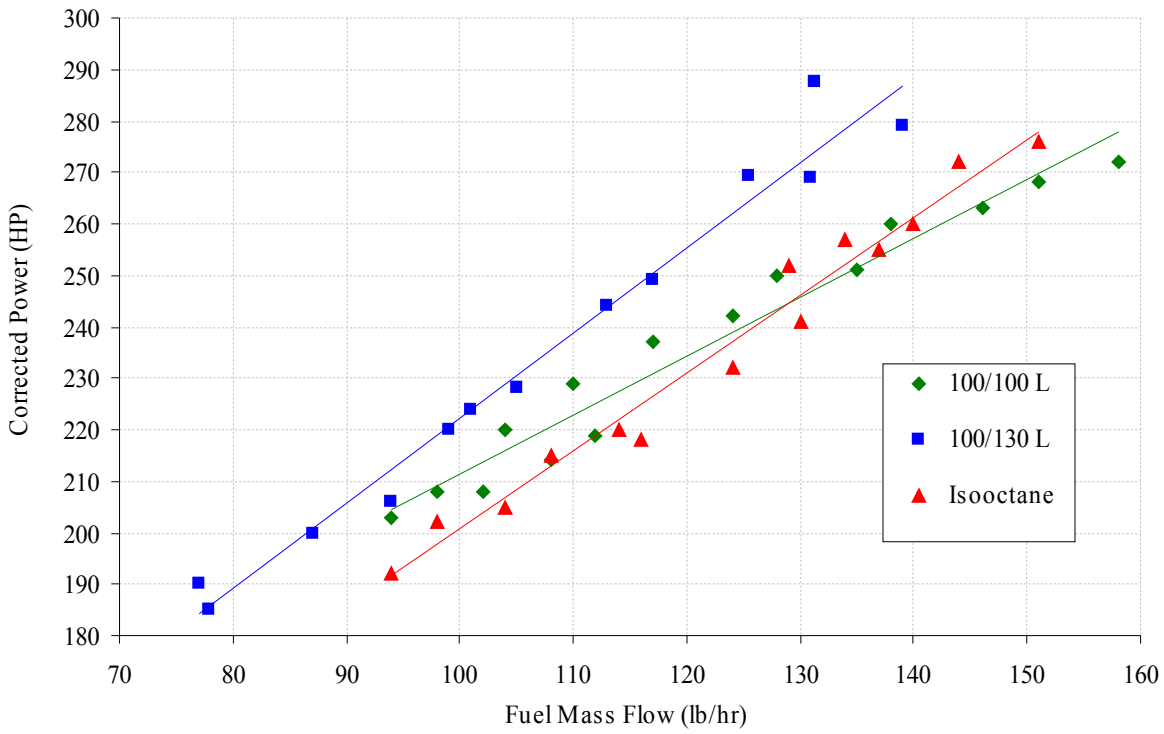

Figure 3. Lycoming IO540-K Engine Manifold Pressure Detonation Onset for Leaded and Unleaded Fuels With Equivalent MON but Different Supercharge Rich Ratings

Figure 3 shows that the 100/130 L leaded fuel significantly outperformed the 100 MON and 100 supercharge rich rating unleaded fuel, isooctane. At the lower power settings, the 100/100 L leaded fuel performed equivalent to the 100/130 L leaded fuel but was outperformed at the higher power settings. This shows that the supercharge rich rating for leaded fuels has more of an impact at the higher power settings. At the higher power setting, the 100/100 L leaded fuel performed the same as the isooctane.

Figures 4 through 7 show the same results as the variable mixture testing reported previously. The 91/98 L leaded fuel, with a 91 MON, performed significantly better than its unleaded counterpart of the same MON and supercharge rich rating, 91/98 UL. The 91 MON 91/98 L fuel performed better than the 93 MON 93/98 UL unleaded fuel and almost as well as the 94 MON 94/98 UL unleaded fuel. This indicates the same as the variable mixture testing because for a mid-octane unleaded hydrocarbon fuel of similar components to have the same detonation performance as the leaded fuel, the unleaded fuel would require 2 to 3 higher MON. The 94 PRF single boiling point reference fuel was outperformed by unleaded, hydrocarbon, full-range boiling fuels of lower MON in the full-scale engine.

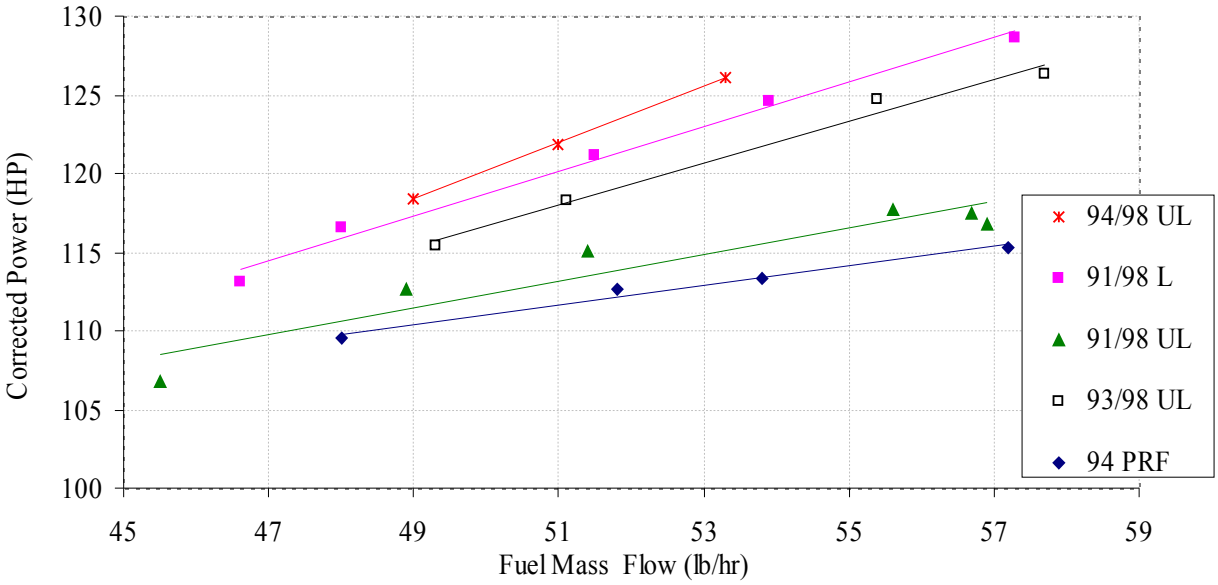

Figure 4. Lycoming IO320-B Engine Manifold Pressure Detonation Onset for Leaded and Unleaded Fuels at 2350 rpm

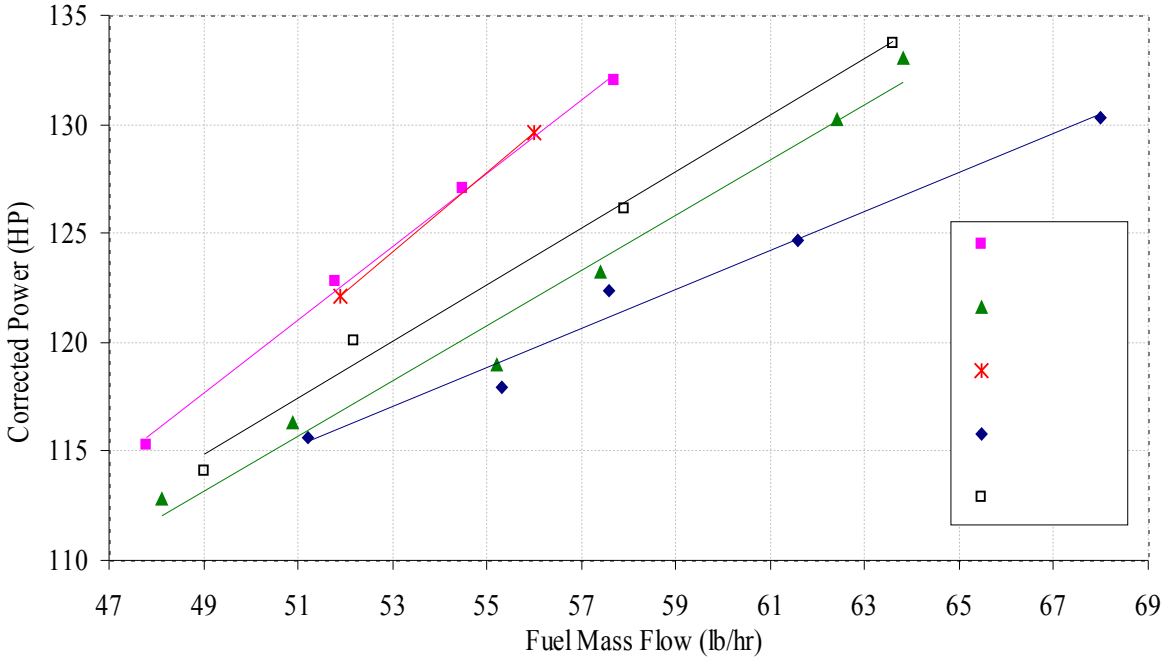

Figure 5. Lycoming IO320-B Engine Manifold Pressure Detonation Onset for Leaded and Unleaded Fuels at 2450 rpm

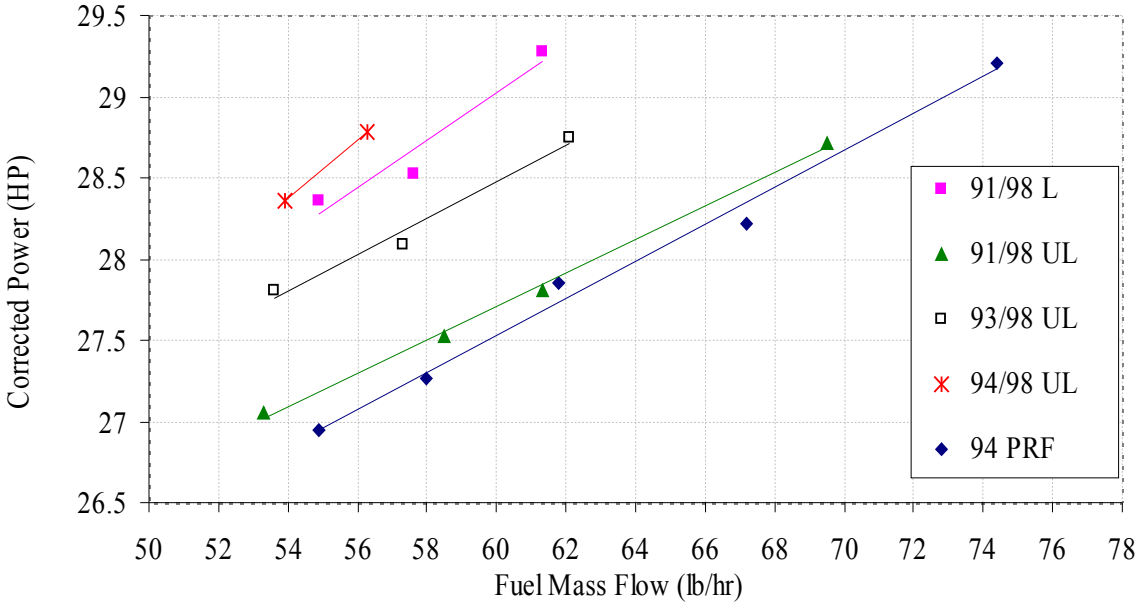

Figure 6. Lycoming IO320-B Engine Manifold Pressure Detonation Onset for Leaded and Unleaded Fuels at 2600 rpm

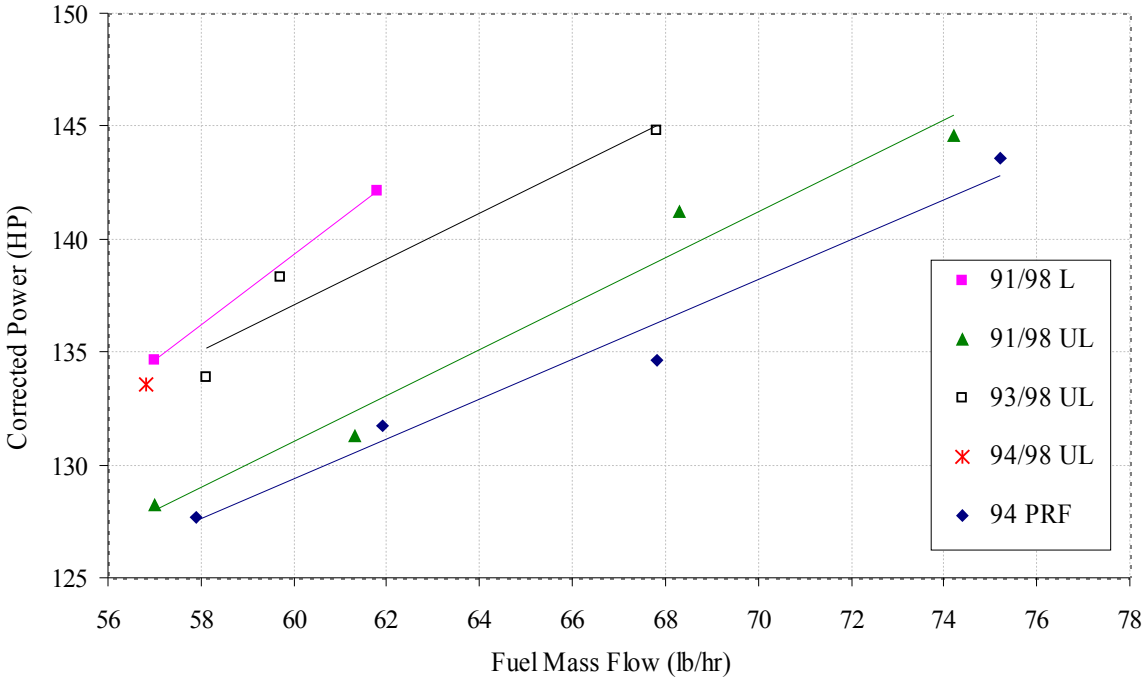

Figure 7. Lycoming IO320-B Engine Manifold Pressure Detonation Onset for Leaded and Unleaded Fuels at 2700 rpm

CONCLUSIONS

A naturally aspirated Lycoming IO540-K engine and a naturally aspirated Lycoming IO320-B engine were detonation-tested using high- and mid-octane leaded and unleaded fuels to determine and quantify the lead effects on full-scale engine detonation performance. Unleaded and leaded fuels of equivalent motor octane number (MON) and supercharge rich rating were compared. Fuel mixture strength was adjusted to the point of moderate to severe detonation, and in a separate test, the engine manifold pressure was adjusted to the point of moderate to severe detonation. The fuels' detonation performance was compared at onset of light detonation.

High-octane fuels (>100 MON) were investigated in the IO540-K engine, and mid-octane fuels (91 to 94 MON) were investigated in the IO320-B engine.

The 100 low-lead (LL), 100/130 leaded (L) aviation gasoline, which was blended to attain minimum allowable MON and supercharge rich rating while containing the maximum amount of lead, performed significantly better than the single boiling point, 100 MON isooctane primary reference fuel and the 100 MON, >161 supercharge rich rating 100 amine fuel. Full boiling range fuels offer better detonation performance in a full-scale engine than single boiling point reference fuels of similar MON.

The 100 LL, 100/130 L, leaded aviation gasoline performed the same as the 104 amine fuel, having a 104 MON and a supercharge rich rating of >161, at the lower power cruise settings, but not as well at the higher climb and takeoff power settings.

The 100 LL fuel performed the same as the 100/100 L fuel at the cruise power settings but performed significantly better at the higher power settings. For leaded hydrocarbon fuels, the supercharge rich rating has more significance at higher power settings.

The 100 LL outperformed unleaded fuels of 100 MON even if they had a much higher supercharge rich rating.

The 91/98 L leaded aviation gasoline performed significantly better than the 91/98 unleaded (UL) fuel of the same MON and supercharge rich rating.

The 91/98 L leaded fuel performed better than the 93/98 UL unleaded fuel with similar supercharge rich rating and 93 MON.

The 91/98 L leaded fuel did not perform as well as the 94/98 UL unleaded fuel with similar supercharge rich rating and 94 MON.

For a mid-octane (~91 MON) unleaded, nonmetallic, hydrocarbon fuel-equivalent detonation performance in a full-scale engine requires 2 to 3 MON more than a leaded fuel of similar supercharge rich rating.

For the IO540-K engine, the unleaded fuel required 4 MON more than the 100 LL leaded fuel for equivalent detonation performance at the cruise rpm settings, despite the unleaded fuel having a

much higher supercharge rich rating. At higher (climb and TO) power settings, the data was inconclusive regarding the increase in unleaded MON needed for equivalent performance to leaded MON.

For short-term detonation testing with proper periods of interface time allowed, switching between leaded and unleaded fuels has minimal effect on the detonation performance of the unleaded fuels.

Supercharge rich ratings do not appear to have the same significance for unleaded fuels as they do for leaded, hydrocarbon fuels. This is an area that needs further investigation.

Appendix A contains the engine data at light detonation onset for the Lycoming IO540-K engine. Appendix B contains the engine data at light detonation onset for the Lycoming IO320-B engine.

APPENDIX A–LYCOMING IO540-K ENGINE LIGHT DETONATION ONSET PARAMETERS

Table A-1. Mixture Lean-Outs Using Isooctane

Test	T2-53	T2-53	T2-53	T2-53	T2-59	T2-59	T2-59
File	D	I	O	T	G	H	J
Fuel	Isooctane	Isooctane	Isooctane	Isooctane	Isooctane	Isooctane	Isooctane
MAP (in. Hg)	29.59	27.09	25.54	24.02	29.44	25.57	23.98
rpm	2701	2601	2451	2351	2701	2451	2351
Fuel Mass Flow (lb/hr)	156	129	108	96	158	104	93
Corrected Power (HP)	278	238	208	181	279	212	185
Torque (ft lb)	521	464	429	390	520	436	396
Brake Horsepower (BHP)	268	230	200	174	267	204	177
Temperature Corrected BHP	280	240	209	182	280	213	185
Brake Mean Effective Pressure (psi)	119.3	105.9	98	88.9	119.1	99.5	90.6
Fuel Volume Flow (gal / hr)	27.4	22.8	19.1	16.9	27.9	18.4	16.5
Brake Specific Fuel Consumption (lb / hp hr)	0.58	0.56	0.54	0.55	0.59	0.51	0.53
Temperature Corrected BSFC (lb / hp hr)	0.56	0.54	0.52	0.53	0.57	0.49	0.5
Corrected BSFC (lb / hp hr)	0.56	0.54	0.52	0.53	0.57	0.49	0.51
Inlet Air Temperature (°F)	106	104	104	104	105	106	105
Inlet Air Pressure (in. Hg)	30.09	30.1	30.1	30.09	29.98	29.98	29.97
Cowling Air Temperature (°F)	102	103	99	102	103	103	104
Cowling Air Pressure (in. H2O)	2.5	2.1	2.1	1.2	1.4	2.8	1.2
Fuel Inlet Temperature (°F)	89	92	93	94	90	94	95
Fuel Density (lb / gal)	5.68	5.67	5.67	5.67	5.67	5.66	5.66
Metered Fuel Pressure (psig)	8.9	5.9	4.2	3.3	9.8	4.8	3.9
Fuel Pump Outlet Pressure (psig)	19.5	19.4	19.2	19.1	24.2	23.8	23.9
CHT 1 (°F)	463	460	450	455	463	448	450
CHT 2 (°F)	434	442	439	447	435	437	440
CHT 3 (°F)	453	453	446	451	450	443	446
CHT 4 (°F)	433	434	432	440	429	429	432
CHT 5 (°F)	477	476	479	478	473	478	474
CHT 6 (°F)	456	456	456	462	454	452	456
EGT 1 (°F)	1376	1356	1352	1338	1376	1390	1388
EGT 2 (°F)	1353	1338	1346	1337	1357	1387	1385
EGT 3 (°F)	1381	1378	1370	1356	1390	1406	1405
EGT 4 (°F)	1359	1348	1351	1338	1365	1393	1391
EGT 5 (°F)	1393	1384	1372	1350	1398	1403	1401
EGT 6 (°F)	1375	1371	1377	1367	1386	1416	1409
Oil Inlet Temperature (°F)	237	239	238	237	235	236	235
Oil Pressure (psig)	66	64	62	62	66	62	61
Inlet Air Temperature - upstream (°F)	106	105	104	103	106	107	105
Humidity Ratio (gr / lb)	1	1	2	2	1	1	1
Mass Air Flow (lb / hr)	1758	1528	1342	1183	1663	1327	1191
Calculated Air-to-Fuel Ratio	11.3	11.9	12.4	12.3	10.5	12.7	12.7

Table A-2. Mixture Lean-Outs Using 100 Amine

Test	T2-53	T2-53	T2-53	T2-53	T2-59	T2-59
File	Z	AG	AN	AV	K	N
Fuel	100 Amine	100 Amine	100 Amine	100 Amine	100 Amine	100 Amine
MAP (in. Hg)	29.53	27.05	25.73	24.07	27.00	24.04
rpm	2701	2601	2451	2351	2601	2351
Fuel Mass Flow (lb / hr)	152	123	104	90	122	95
Corrected Power (HP)	282	238	212	182	240	185
Torque (ft lb)	528	464	437	393	466	396
Brake Horsepower (BHP)	271	230	204	176	231	177
Temperature Corrected BHP	284	240	213	183	241	185
Brake Mean Effective Pressure (psi)	120.6	106.1	99.8	89.9	106.2	90.7
Fuel Volume Flow (gal / hr)	26.1	21.2	18	15.5	20.9	16.4
Brake Specific Fuel Consumption (lb / hp hr)	0.56	0.54	0.52	0.51	0.53	0.54
Temperature Corrected BSFC (lb / hp hr)	0.54	0.51	0.49	0.49	0.51	0.52
Corrected BSFC (lb / hp hr)	0.54	0.52	0.49	0.5	0.51	0.52
Inlet Air Temperature (°F)	104	104	104	104	105	104
Inlet Air Pressure (in Hg)	30.08	30.07	30.05	30.06	29.98	29.98
Cowling Air Temperature (°F)	104	104	102	105	106	104
Cowling Air Pressure (in H2O)	3.5	4.8	2.8	2.8	4.2	1.7
Fuel Inlet Temperature (°F)	93	96	98	100	93	96
Fuel Density (lb / gal)	5.83	5.82	5.81	5.81	5.83	5.82
Metered Fuel Pressure (psig)	7.7	5.4	3.9	2.9	6.2	4.1
Fuel Pump Outlet Pressure (psig)	19.2	19.2	19.1	19.1	24.1	24
CHT 1 (°F)	461	455	449	456	458	449
CHT 2 (°F)	439	444	440	448	444	443
CHT 3 (°F)	453	450	444	454	454	447
CHT 4 (°F)	437	436	432	443	436	434
CHT 5 (°F)	476	475	472	479	478	476
CHT 6 (°F)	460	457	454	464	456	456
EGT 1 (°F)	1418	1410	1386	1412	1402	1369
EGT 2 (°F)	1397	1396	1380	1406	1386	1364
EGT 3 (°F)	1426	1428	1400	1425	1424	1384
EGT 4 (°F)	1403	1400	1384	1409	1392	1369
EGT 5 (°F)	1436	1436	1404	1424	1435	1382
EGT 6 (°F)	1422	1426	1406	1435	1418	1391
Oil Inlet Temperature (°F)	238	237	240	239	236	233
Oil Pressure (psig)	65	64	62	61	63	61
Inlet Air Temperature - upstream (°F)	104	104	103	104	106	105
Humidity Ratio (gr / lb)	1	1.8	2	1	1	1
Mass Air Flow (lb / hr)	1842	1539	1336	1201	1514	1204
Calculated Air-to-Fuel Ratio	12.1	12.6	12.8	13.3	12.4	12.6

Table A-3. Mixture Lean-Outs Using 104 Amine

Test	T2-54	T2-54	T2-54	T2-54	T2-59
File	F	Q	AA	AK	Q
Fuel	104 Amine	104 Amine	104 Amine	104 Amine	104 Amine
MAP (in. Hg)	29.61	27.53	26.21	24.46	29.45
rpm	2700	2601	2450	2351	2701
Fuel Mass Flow (lb / hr)	133	113	99	86	138
Corrected Power (HP)	285	247	219	189	285
Torque (ft lb)	533	483	453	407	531
Brake Horsepower (BHP)	274	239	211	182	273
Temperature Corrected BHP	287	249	221	190	286
Brake Mean Effective Pressure (psi)	121.8	110.2	103.1	92.9	121.8
Fuel Volume Flow (gal / hr)	22.2	18.8	16.5	14.5	23.1
Brake Specific Fuel Consumption (lb / hp hr)	0.48	0.47	0.47	0.48	0.51
Temperature Corrected BSFC (lb / hp hr)	0.46	0.45	0.45	0.46	0.48
Corrected BSFC (lb / hp hr)	0.47	0.46	0.45	0.46	0.49
Inlet Air Temperature (°F)	105	102	104	104	105
Inlet Air Pressure (in. Hg)	30.11	30.14	30.14	30.11	30.01
Cowling Air Temperature (°F)	104	106	102	102	105
Cowling Air Pressure (in. H2O)	4.1	2.6	2.1	2.4	4.9
Fuel Inlet Temperature (°F)	91	93	95	96	93
Fuel Density (lb / gal)	5.99	5.98	5.97	5.97	5.98
Metered Fuel Pressure (psig)	6.2	4.5	3.5	2.7	7.5
Fuel Pump Outlet Pressure (psig)	19.6	19.6	19.3	19.3	24.1
CHT 1 (°F)	458	448	446	452	457
CHT 2 (°F)	435	431	435	444	440
CHT 3 (°F)	451	442	444	450	450
CHT 4 (°F)	441	430	429	437	438
CHT 5 (°F)	476	473	474	479	480
CHT 6 (°F)	458	446	449	456	458
EGT 1 (°F)	1516	1495	1464	1461	1492
EGT 2 (°F)	1485	1479	1455	1459	1463
EGT 3 (°F)	1524	1513	1476	1476	1505
EGT 4 (°F)	1494	1480	1460	1463	1471
EGT 5 (°F)	1531	1528	1482	1476	1505
EGT 6 (°F)	1515	1506	1486	1489	1492
Oil Inlet Temperature (°F)	233	235	234	234	234
Oil Pressure (psig)	65	64	62	61	65
Inlet Air Temperature - upstream (°F)	104	102	103	102	107
Humidity Ratio (gr / lb)	13.3	1	1	1	0
Mass Air Flow (lb / hr)	1791	1583	1408	1228	1807
Calculated Air-to-Fuel Ratio	13.5	14.1	14.3	14.2	13.1

Table A-4. Mixture Lean-Outs Using 100 LL (100/130 L)

Test	T2-56	T2-56	T2-56	T2-59	T2-57	T2-59	T2-59
File	W	F	N	Y	H	Y	AC
Fuel	100/130 L	100/130 L	100/130 L	100/130 L	100/130 L	100/130 L	100/130 L
MAP (in. Hg)	26.35	29.75	27.54	26.37	23.93	26.37	29.44
rpm	2451	2701	2601	2451	2351	2451	2701
Fuel Mass Flow (lb / hr)	114	146	118	100	80	100	139
Corrected Power (HP)	216	284	246	220	184	220	286
Torque (ft lb)	448	535	479	454	396	454	535
Brake Horsepower (BHP)	209	275	237	212	177	212	275
Temperature Corrected BHP	218	287		221	185	221	287
Brake Mean Effective Pressure (psi)	102.6	122.3	109.6	104	90.7	104	122.3
Fuel Volume Flow (gal / hr)	21.1	24.7	20.1	17	13.8	17	23.7
Brake Specific Fuel Consumption (lb / hp hr)	0.55	0.53	0.5	0.47	0.46	0.47	0.51
Temperature Corrected BSFC (lb / hp hr)	0.52	0.51	0.48	0.45	0.43	0.45	0.49
Corrected BSFC (lb / hp hr)	0.53	0.51	0.48	0.45	0.43	0.45	0.49
Inlet Air Temperature (°F)	104	103	105	104	105	104	103
Inlet Air Pressure (in. Hg)	30.26	30.24	30.24	30	30.14	30	30
Cowling Air Temperature (°F)	102	102	105	104	102	104	103
Cowling Air Pressure (in. H2O)	3.3	3.3	2	3.1	2	3.1	4.6
Fuel Inlet Temperature (°F)	97	89	94	97	93	97	95
Fuel Density (lb / gal)	5.42	5.90	5.88	5.87	5.87	5.87	5.88
Metered Fuel Pressure (psig)	4.5	8.7	5.7	4.3	3.1	4.3	7.5
Fuel Pump Outlet Pressure (psig)	24.2	24.9	24.4	23.8	24.8	23.8	23.9
CHT 1 (°F)	442	455	454	452	444	452	458
CHT 2 (°F)	425	423	432	444	432	444	431
CHT 3 (°F)	447	450	449	447	442	447	449
CHT 4 (°F)	418	427	427	435	426	435	433
CHT 5 (°F)	478	476	473	477	477	477	477
CHT 6 (°F)	436	448	447	456	444	456	456
EGT 1 (°F)	1468	1425	1446	1458	1471	1458	1479
EGT 2 (°F)	1476	1407	1432	1447	1464	1447	1453
EGT 3 (°F)	1520	1440	1476	1477	1490	1477	1495
EGT 4 (°F)	1476	1411	1438	1458	1472	1458	1464
EGT 5 (°F)	1496	1447	1479	1479	1487	1479	1496
EGT 6 (°F)	1495	1428	1462	1480	1498	1480	1483
Oil Inlet Temperature (°F)	228	234	234	240	232	240	233
Oil Pressure (psig)	63	66	65	62	62	62	64
Inlet Air Temperature - upstream (°F)	105	103	105	104	105	104	104
Humidity Ratio (gr / lb)	1	1	1	1	1	1	1
Mass Air Flow (lb / hr)	1416	1786	1552	1385	1152	1385	1826
Calculated Air-to-Fuel Ratio	12.4	12.2	13.1	13.9	14.3	13.9	13.1

Table A-5. Mixture Lean-Outs Using 100/100 L

Test	T2-57	T2-57	T2-57	T2-59
File	O	W	AF	AF
Fuel	100/100 L	100/100 L	100/100 L	100/100 L
MAP (in. Hg)	27.51	26.35	23.93	29.4
rpm	2601	2451	2351	2701
Fuel Mass Flow (lb / hr)	130	108	82	160
Corrected Power (HP)	244	219	184	280
Torque (ft lb)	475	454	396	524
Brake Horsepower (BHP)	235	212	177	270
Temperature Corrected BHP	246	221	186	281
Brake Mean Effective Pressure (psi)	108.6	104	90.3	119.6
Fuel Volume Flow (gal / hr)	23.4	19.4	14.8	28.9
Brake Specific Fuel Consumption (lb / hp hr)	0.55	0.51	0.46	0.59
Temperature Corrected BSFC (lb / hp hr)	0.53	0.49	0.44	0.57
Corrected BSFC (lb / hp hr)	0.53	0.49	0.45	0.57
Inlet Air Temperature (°F)	105	104	106	103
Inlet Air Pressure (in. Hg)	30.15	30.15	30.15	29.97
Cowling Air Temperature (°F)	103	104	105	103
Cowling Air Pressure (in. H2O)	1.8	1.7	1.7	3.1
Fuel Inlet Temperature (°F)	92	94	96	92
Fuel Density (lb / gal)	5.56	5.56	5.55	5.55
Metered Fuel Pressure (psig)	7	5	3.2	10.1
Fuel Pump Outlet Pressure (psig)	24.4	24.2	24.1	23.6
CHT 1 (°F)	462	446	447	454
CHT 2 (°F)	440	432	435	440
CHT 3 (°F)	456	442	446	450
CHT 4 (°F)	434	426	429	434
CHT 5 (°F)	476	472	475	474
CHT 6 (°F)	457	447	446	456
EGT 1 (°F)	1373	1381	1451	1357
EGT 2 (°F)	1357	1372	1444	1340
EGT 3 (°F)	1396	1400	1468	1374
EGT 4 (°F)	1362	1380	1449	1350
EGT 5 (°F)	1406	1406	1463	1386
EGT 6 (°F)	1384	1400	1470	1363
Oil Inlet Temperature (°F)	235	232	233	234
Oil Pressure (psig)	64	62	61	64
Inlet Air Temperature - upstream (°F)	104	104	104	103
Humidity Ratio (gr / lb)	1	1	1	1.5
Mass Air Flow (lb / hr)	1530	1383	1179	1826
Calculated Air-to-Fuel Ratio	11.8	12.8	14.3	11.4

Table A-6. Variable Manifold Pressure Test Using 100/100 L

Test	T2-60	T2-60	T2-60	T2-60	T2-60	T2-60	T2-60
File	D	H	K	P	T	W	Y
Fuel	100/100 L	100/100 L	100/100 L	100/100 L	100/100 L	100/100 L	100/100 L
MAP (in. Hg)	29.23	28.81	28.41	28.02	28.06	27.91	27.2
rpm	2701	2701	2701	2701	2601	2601	2601
Torque (ft lb)	512	504	496	489	490	488	473
Brake Horsepower (BHP)	264	260	255	251	243	242	234
Temperature Corrected BHP	275	271	266	263	254	253	245
Corrected Power (HP)	272	268	263	260	251	250	242
Brake Mean Effective Pressure (psi)	117	115.4	113.1	111.8	111.8	111.8	107.7
Fuel Mass Flow (lb / hr)	158	151	146	138	135	128	124
Fuel Volume Flow (gal / hr)	28.2	27	26.2	24.7	24.2	23	22.4
Brake Specific Fuel Consumption (lb / hp hr)	0.6	0.58	0.57	0.55	0.56	0.53	0.53
Temperature Corrected BSFC (lb / hp hr)	0.57	0.56	0.55	0.52	0.53	0.51	0.51
Corrected BSFC (lb / hp hr)	0.58	0.56	0.56	0.53	0.54	0.52	0.52
Inlet Air Temperature (°F)	104	104	104	104	104	104	104
Inlet Air Pressure (in. Hg)	30.23	30.24	30.23	30.24	30.23	30.23	30.24
Cowling Air Temperature (°F)	102	103	105	100	106	106	106
Cowling Air Pressure (in. H2O)	1.1	3.3	2.9	1.3	3.9	2.2	4.2
Fuel Inlet Temperature (°F)	84	85	85	87	88	89	90
Fuel Density (lb / gal)	5.58	5.58	5.58	5.57	5.57	5.57	5.56
Metered Fuel Pressure (psig)	9.9	9.2	8.7	7.7	7.6	6.9	6.7
Fuel Pump Outlet Pressure (psig)	24.7	24.7	24.6	24.6	24.6	24.5	24.6
CHT 1 (°F)	468	463	464	457	457	454	460
CHT 2 (°F)	445	440	442	432	443	433	442
CHT 3 (°F)	458	454	455	445	452	444	450
CHT 4 (°F)	438	435	435	426	434	426	436
CHT 5 (°F)	476	476	477	471	477	471	480
CHT 6 (°F)	462	457	457	448	460	450	458
EGT 1 (°F)	1356	1368	1381	1406	1366	1388	1392
EGT 2 (°F)	1336	1347	1359	1381	1348	1366	1374
EGT 3 (°F)	1370	1384	1400	1422	1389	1408	1418
EGT 4 (°F)	1344	1350	1363	1384	1355	1378	1384
EGT 5 (°F)	1379	1394	1409	1427	1393	1411	1419
EGT 6 (°F)	1362	1372	1383	1407	1375	1392	1408
Oil Inlet Temperature (°F)	242	233	237	230	233	230	226
Oil Pressure (psig)	66	66	65	66	64	64	64
Inlet Air Temperature - upstream (°F)	105	105	105	105	105	104	104
Humidity Ratio (gr / lb)	0	0	0	0	0	0	0
Mass Air Flow (lb / hr)	1912	1954	1947	1944	1953	1956	1977
Calculated Air-to-Fuel Ratio	12.1	12.9	13.3	14.1	14.5	15.3	15.8

Table A-6. Variable Manifold Pressure Test Using 100/100 L (Continued)

Test	T2-60	T2-60	T2-60	T2-60	T2-60	T2-61	T2-61	T2-61
File	AF	AI	AN	AQ	AV	D	E	K
Fuel	100/100 L	100/100 L	100/100 L	100/100 L	100/100 L	100/100 L	100/100 L	100/100 L
MAP (in. Hg)	26.8	26.05	26.41	25.96	25.59	26.45	25.22	24.79
rpm	2601	2601	2451	2451	2452	2451	2451	2451
Torque (ft lb)	464	448	453	443	432	458	430	420
Brake Horsepower (BHP)	230	222	212	207	202	214	201	196
Temperature Corrected BHP	240	232	221	216	210	224	210	205
Corrected Power (HP)	237	229	219	214	208	220	208	203
Brake Mean Effective Pressure (psi)	106.2	102.3	103.6	101.2	98	104.3	98.1	95.6
Fuel Mass Flow (lb / hr)	117	110	112	108	102	104	98	94
Fuel Volume Flow (gal / hr)	21.1	19.7	20.1	19.6	18.5	18.5	17.4	16.8
Brake Specific Fuel Consumption (lb / hp hr)	0.51	0.49	0.53	0.53	0.51	0.48	0.49	0.48
Temperature Corrected BSFC (lb / hp hr)	0.49	0.47	0.51	0.5	0.48	0.46	0.47	0.46
Corrected BSFC (lb / hp hr)	0.49	0.48	0.51	0.51	0.49	0.47	0.47	0.46
Inlet Air Temperature (°F)	104	104	104	104	103	104	104	104
Inlet Air Pressure (in. Hg)	30.24	30.24	30.24	30.22	30.23	30.16	30.16	30.16
Cowling Air Temperature (°F)	106	102	102	106	102	101	104	98
Cowling Air Pressure (in. H2O)	3	3.2	2.5	3.3	2	2.5	4.5	1.5
Fuel Inlet Temperature (°F)	92	93	93	94	96	78	77	81
Fuel Density (lb / gal)	5.55	5.55	5.55	5.54	5.52	5.62	5.63	5.61
Metered Fuel Pressure (psig)	6	5.4	5.5	5.3	5.1	4.8	4.5	4.1
Fuel Pump Outlet Pressure (psig)	24.6	24.7	24.5	24.5	24.4	24.9	24.8	24.8
CHT 1 (°F)	453	456	452	452	451	454	452	449
CHT 2 (°F)	438	440	448	446	444	442	443	441
CHT 3 (°F)	446	446	449	449	447	446	446	443
CHT 4 (°F)	431	430	436	436	436	434	434	431
CHT 5 (°F)	474	474	476	477	475	474	477	475
CHT 6 (°F)	450	452	459	459	454	456	456	451
EGT 1 (°F)	1420	1432	1366	1372	1386	1412	1423	1439
EGT 2 (°F)	1400	1413	1359	1366	1381	1405	1414	1427
EGT 3 (°F)	1442	1458	1387	1393	1408	1434	1441	1456
EGT 4 (°F)	1408	1422	1367	1372	1383	1415	1419	1431
EGT 5 (°F)	1439	1454	1388	1392	1406	1440	1443	1457
EGT 6 (°F)	1433	1448	1390	1396	1410	1432	1442	1454
Oil Inlet Temperature (°F)	233	230	234	232	237	233	233	235
Oil Pressure (psig)	64	64	62	62	62	62	62	62
Inlet Air Temperature - upstream (°F)	105	105	104	104	104	105	105	105
Humidity Ratio (gr / lb)	0	0	0	0	0	0	0	0
Mass Air Flow (lb / hr)	1972	1768	1692	1758	1711	1672	1725	1748
Calculated Air-to-Fuel Ratio	16.9	16.1	15.1	16.2	16.8	16.1	17.6	18.5

Table A-7. Variable Manifold Pressure Test Using 100 LL (100/130 L)

Test	T2-61	T2-61	T2-62	T2-62	T2-62	T2-62
File	R	V	A	B	K	P
Fuel	100/130 L	100/130 L	100/130 L	100/130 L	100/130 L	100/130 L
MAP (in. Hg)	29.21	28.44	29.19	28.00	27.2	26.82
rpm	2701	2703	2701	2702	2601	2601
Torque (ft lb)	524	506	532	499	479	469
Brake Horsepower (BHP)	269	260	274	257	237	232
Temperature Corrected BHP	282	272	286	268	248	243
Corrected Power (HP)	279	269	288	270	249	244
Brake Mean Effective Pressure (psi)	120.3	115.4	122	114	109.5	107.2
Fuel Mass Flow (lb / hr)	139	131	131	126	117	113
Fuel Volume Flow (gal / hr)	23.5	22.1	22.1	21.2	19.6	19
Brake Specific Fuel Consumption (lb / hp hr)	0.52	0.5	0.48	0.49	0.49	0.49
Temperature Corrected BSFC (lb / hp hr)	0.49	0.48	0.46	0.47	0.47	0.47
Corrected BSFC (lb / hp hr)	0.5	0.49	0.46	0.47	0.47	0.46
Inlet Air Temperature (°F)	104	104	103	105	104	104
Inlet Air Pressure (in. Hg)	30.19	30.17	29.65	29.64	29.64	29.65
Cowling Air Temperature (°F)	100	102	105	109	103	100
Cowling Air Pressure (in. H2O)	4.5	4.6	4.1	4.6	3.6	4.5
Fuel Inlet Temperature (°F)	85	85	78	80	82	82
Fuel Density (lb / gal)	5.93	5.93	5.95	5.94	5.94	5.93
Metered Fuel Pressure (psig)	7.2	6.7	6.77	6.25	5.6	5.4
Fuel Pump Outlet Pressure (psig)	24.7	24.6	25.0	25.1	24.9	24.9
CHT 1 (°F)	464	463	460	458	458	462
CHT 2 (°F)	436	440	437	438	438	444
CHT 3 (°F)	452	452	449	450	448	452
CHT 4 (°F)	434	437	440	433	434	440
CHT 5 (°F)	479	479	477	475	476	477
CHT 6 (°F)	456	459	463	458	459	464
EGT 1 (°F)	1486	1489	1518	1507	1458	1471
EGT 2 (°F)	1460	1459	1488	1481	1436	1450
EGT 3 (°F)	1502	1504	1527	1524	1476	1491
EGT 4 (°F)	1468	1462	1498	1480	1439	1454
EGT 5 (°F)	1502	1514	1538	1537	1486	1496
EGT 6 (°F)	1486	1487	1516	1507	1465	1482
Oil Inlet Temperature (°F)	230	234	231	235	237	233
Oil Pressure (psig)	64	64	65	64	64	64
Inlet Air Temperature - upstream (°F)	106	105	106	107	106	106
Humidity Ratio (gr / lb)	0	1	0	0	0	0
Mass Air Flow (lb / hr)	1688	1924	700	550	430	413
Calculated Air-to-Fuel Ratio	12.1	14.7	22.4	18.4	15.4	15.3

Table A-7. Variable Manifold Pressure Test Using 100 LL (100/130 L) (Continued)

Test	T2-62	T2-62	T2-62	T2-62	T2-62	T2-62	T2-62
File	W	AC	AH	AM	AO	AR	AT
Fuel	100/130 L	100/130 L	100/130 L	100/130 L	100/130 L	100/130 L	100/130 L
MAP (in. Hg)	25.59	25.19	26.00	24.80	24.37	23.57	23.23
rpm	2602	2602	2451	2451	2451	2451	2451
Torque (ft lb)	440	430	449	419	408	388	376
Brake Horsepower (BHP)	218	214	210	196	190	182	175
Temperature Corrected BHP	228	223	220	205	200	190	183
Corrected Power (HP)	228	224	220	206	200	190	185
Brake Mean Effective Pressure (psi)	100.4	98.3	102.5	95.7	93.5	88.8	86.2
Fuel Mass Flow (lb / hr)	105	101	99	94	87	77	78
Fuel Volume Flow (gal / hr)	17.7	17	16.7	15.8	14.7	13.1	13.1
Brake Specific Fuel Consumption (lb / hp hr)	0.48	0.47	0.47	0.48	0.46	0.43	0.44
Temperature Corrected BSFC (lb / hp hr)	0.46	0.45	0.45	0.46	0.43	0.41	0.42
Corrected BSFC (lb / hp hr)	0.46	0.45	0.45	0.46	0.43	0.4	0.42
Inlet Air Temperature (°F)	104	104	104	105	105	105	104
Inlet Air Pressure (in. Hg)	29.65	29.64	29.64	29.65	29.65	29.63	29.64
Cowling Air Temperature (°F)	99	98	104	107	103	102	107
Cowling Air Pressure (in. H2O)	1.3	2.8	2.6	3.7	4.1	1.9	1.6
Fuel Inlet Temperature (°F)	82	84	85	86	86	86	85
Fuel Density (lb / gal)	5.94	5.93	5.92	5.92	5.92	5.91	5.92
Metered Fuel Pressure (psig)	4.7	4.5	4.3	4.0	3.8	3.3	3.0
Fuel Pump Outlet Pressure (psig)	25.0	25.0	24.8	24.6	24.8	24.8	24.9
CHT 1 (°F)	456	449	452	452	449	450	447
CHT 2 (°F)	442	434	444	445	440	441	438
CHT 3 (°F)	448	442	446	449	447	447	445
CHT 4 (°F)	433	428	438	438	435	432	430
CHT 5 (°F)	474	472	476	477	475	475	472
CHT 6 (°F)	458	452	464	464	460	460	459
EGT 1 (°F)	1471	1484	1463	1463	1478	1512	1525
EGT 2 (°F)	1452	1466	1442	1449	1466	1501	1511
EGT 3 (°F)	1496	1511	1478	1478	1494	1533	1545
EGT 4 (°F)	1458	1476	1456	1457	1474	1508	1520
EGT 5 (°F)	1494	1510	1483	1484	1492	1526	1540
EGT 6 (°F)	1488	1502	1484	1489	1500	1540	1547
Oil Inlet Temperature (°F)	233	230	233	234	236	235	234
Oil Pressure (psig)	64	64	62	62	62	62	62
Inlet Air Temperature - upstream (°F)	106	106	105	105	105	105	105
Humidity Ratio (gr / lb)	0	0	0	0	0	0	0
Mass Air Flow (lb / hr)	390	360	360	330	330	330	305
Calculated Air-to-Fuel Ratio	15.6	15.0	15.3	14.7	15.9	18.0	16.4

Table A-8. Variable Manifold Test Using Isooctane

Test	T2-63	T2-63	T2-63	T2-63	T2-63	T2-63	T2-63
File	D	L	Q	S	Y	AC	AK
Fuel	Isooctane	Isooctane	Isooctane	Isooctane	Isooctane	Isooctane	Isooctane
MAP (in. Hg)	28.79	28.41	27.2	26.81	27.99	28.41	25.98
rpm	2701	2703	2703	2703	2603	2603	2604
Torque (ft lb)	510	504	471	465	493	500	446
Brake Horsepower (BHP)	262	260	242	239	244	248	221
Temperature Corrected BHP	274	271	253	250	256	259	231
Corrected Power (HP)	276	272	255	252	257	260	232
Brake Mean Effective Pressure (psi)	116.7	115.4	107.6	106.3	112.2	114.2	101.8
Fuel Mass Flow (lb / hr)	151	144	137	129	134	140	124
Fuel Volume Flow (gal / hr)	26.5	25.2	24.1	22.6	23.6	24.5	21.7
Brake Specific Fuel Consumption (lb / hp hr)	0.57	0.56	0.57	0.54	0.55	0.56	0.56
Temperature Corrected BSFC (lb / hp hr)	0.55	0.53	0.54	0.52	0.53	0.54	0.54
Corrected BSFC (lb / hp hr)	0.55	0.53	0.54	0.51	0.53	0.54	0.54
Inlet Air Temperature (°F)	104	105	105	105	104	103	104
Inlet Air Pressure (in. Hg)	29.65	29.63	29.65	29.65	29.65	29.66	29.64
Cowling Air Temperature (°F)	104	100	106	100	97	107	96
Cowling Air Pressure (in. H2O)	1.8	3.5	1.3	1.8	2.8	4.1	1.7
Fuel Inlet Temperature (°F)	82	80	81	81	82	82	80
Fuel Density (lb / gal)	5.71	5.72	5.71	5.71	5.71	5.71	5.72
Metered Fuel Pressure (psig)	9.1	8.3	7.6	7.0	7.5	8.1	6.3
Fuel Pump Outlet Pressure (psig)	24.7	24.9	24.9	24.9	24.9	24.8	24.6
CHT 1 (°F)	460	456	456	455	451	454	456
CHT 2 (°F)	435	436	439	436	434	440	438
CHT 3 (°F)	451	452	453	449	450	452	448
CHT 4 (°F)	432	432	434	429	430	436	434
CHT 5 (°F)	473	474	476	474	476	478	474
CHT 6 (°F)	461	458	457	454	457	459	454
EGT 1 (°F)	1390	1404	1392	1421	1374	1364	1366
EGT 2 (°F)	1364	1384	1367	1394	1354	1346	1351
EGT 3 (°F)	1397	1416	1407	1436	1388	1378	1390
EGT 4 (°F)	1372	1386	1372	1396	1362	1352	1356
EGT 5 (°F)	1408	1432	1421	1442	1394	1386	1394
EGT 6 (°F)	1390	1410	1396	1422	1386	1380	1382
Oil Inlet Temperature (°F)	239	206	206	206	206	236	235
Oil Pressure (psig)	64	69	69	69	68	64	64
Inlet Air Temperature - upstream (°F)	107	106	106	106	106	104	106
Humidity Ratio (gr / lb)	0	0	0	0	0	0	0
Mass Air Flow (lb / hr)	650	615	520	500	440	470	400
Calculated Air-to-Fuel Ratio	18.1	17.9	15.9	16.3	13.8	14.1	13.5

Table A-8. Variable Manifold Test Using Isooctane (Continued)

Test	T2-63	T2-63	T2-63	T2-63	T2-63	T2-63	T2-63
File	AO	AU	AV	AZ	BD	BJ	BO
Fuel	Isooctane	Isooctane	Isooctane	Isooctane	Isooctane	Isooctane	Isooctane
MAP (in. Hg)	26.8	24.77	26.02	25.60	24.79	24.43	23.62
rpm	2604	2604	2454	2454	2454	2454	2454
Torque (ft lb)	462	418	448	438	416	412	390
Brake Horsepower (BHP)	229	208	209	205	195	192	182
Temperature Corrected BHP	239	216	219	214	203	201	191
Corrected Power (HP)	241	218	220	215	205	202	192
Brake Mean Effective Pressure (psi)	105.6	95.2	102.1	99.8	95.2	94.1	88.9
Fuel Mass Flow (lb / hr)	130	116	114	108	104	98	94
Fuel Volume Flow (gal / hr)	22.7	20.2	19.8	18.8	18.1	17.1	16.6
Brake Specific Fuel Consumption (lb / hp hr)	0.57	0.56	0.54	0.53	0.53	0.51	0.52
Temperature Corrected BSFC (lb / hp hr)	0.54	0.53	0.52	0.50	0.51	0.48	0.49
Corrected BSFC (lb / hp hr)	0.54	0.53	0.52	0.50	0.51	0.48	0.49
Inlet Air Temperature (°F)	104	104	104	104	104	104	104
Inlet Air Pressure (in. Hg)	29.63	29.64	29.65	29.65	29.63	29.63	29.63
Cowling Air Temperature (°F)	97	94	74	80	94	95	84
Cowling Air Pressure (in. H2O)	2.9	3.6	0.9	3.7	1.1	0.8	3.6
Fuel Inlet Temperature (°F)	78	80	78	80	83	81	83
Fuel Density (lb / gal)	5.73	5.71	5.72	5.72	5.71	5.71	5.71
Metered Fuel Pressure (psig)	7.0	5.7	5.5	5.2	4.7	4.2	4.1
Fuel Pump Outlet Pressure (psig)	24.8	24.9	24.6	24.8	24.8	24.8	24.8
CHT 1 (°F)	460	448	448	456	454	450	450
CHT 2 (°F)	440	434	440	448	436	443	440
CHT 3 (°F)	450	444	444	450	445	448	449
CHT 4 (°F)	433	428	430	440	428	435	433
CHT 5 (°F)	476	471	470	478	473	475	477
CHT 6 (°F)	457	448	452	460	455	458	458
EGT 1 (°F)	1361	1356	1344	1366	1367	1401	1405
EGT 2 (°F)	1350	1348	1331	1360	1359	1387	1397
EGT 3 (°F)	1380	1384	1358	1386	1385	1412	1420
EGT 4 (°F)	1351	1354	1338	1368	1364	1394	1400
EGT 5 (°F)	1388	1384	1374	1396	1388	1416	1422
EGT 6 (°F)	1377	1377	1374	1402	1400	1429	1440
Oil Inlet Temperature (°F)	236	234	232	239	233	238	235
Oil Pressure (psig)	63	64	62	62	62	62	62
Inlet Air Temperature - upstream (°F)	106	106	105	105	105	105	105
Humidity Ratio (gr / lb)	0	0	0	0	0	0	0
Mass Air Flow (lb / hr)	430	380	380	360	365	340	340
Calculated Air-to-Fuel Ratio	13.9	13.7	14.0	14.0	14.7	14.6	15.2

APPENDIX B–LYCOMING IO320-B ENGINE LIGHT DETONATION ONSET PARAMETERS

Table B-1. Mixture Lean-Outs Using 91/98 L, 91/98 UL, and 93/98 UL

Test	t2_9_AK	t2_9_AJ	t2_8_C	t2_8_B	t2_8_A	t2_8_R
Fuel	91/98 L	91/98 L	91/98 UL	91/98 UL	91/98 UL	93/98 UL
MAP (in. Hg)	28.15	29.24	27.30	28.23	29.24	29.23
rpm	2600	2699	2449	2600	2701	2700
Fuel Mass Flow (lb / hr)	53.3	60.7	49.6	67	73.2	68.3
Corrected Power (HP)	127.1	142.8	113.7	133.1	145.8	145.5
Torque (ft lb)	248	268	235	259	273	273
Brake Horsepower (BHP)	122.6	137.5	109.7	128.2	140.4	140.2
Temperature Corrected BHP	127.9	143.5	114.4	133.8	146.4	146.3
Brake Mean Effective Pressure (psi)	103.4	111.8	98.2	108.2	114	113.9
Fuel Volume Flow (gal / hr)	9.1	10.4	8.3	11.3	12.3	11.7
Brake Specific Fuel Consumption (lb / hp hr)	0.435	0.441	0.453	0.522	0.522	0.487
Temperature Corrected BSFC (lb / hp hr)	0.416	0.423	0.434	0.5	0.5	0.467
Corrected BSFC (lb / hp hr)	0.419	0.425	0.437	0.503	0.503	0.469
Inlet Air Temperature (°F)	103	103	102	102	102	103
Inlet Air Pressure (in. Hg)	30.03	30.01	30.04	30.01	29.99	30.01
Cowling Air Temperature (°F)	104	103	103	103	103	103
Cowling Air Pressure (in. H2O)	8.8	2.3	4.4	6.6	8.6	5.4
Fuel Inlet Temperature (°F)	89	89	81	80	79	83
Fuel Density (lb / gal)	5.83	5.82	5.95	5.95	5.95	5.85
Metered Fuel Pressure (psig)	2.7	3.0	2.0	3.8	4.6	4.1
Fuel Pump Outlet Pressure (psig)	25.7	25.3	26	25.3	24.8	25.3
CHT 1 (°F)	456	451	453	453	451	452
CHT 2 (°F)	480	471	478	474	472	473
CHT 3 (°F)	479	478	476	480	481	479
CHT 4 (°F)	474	470	472	473	473	472
EGT 1 (°F)	1425	1394	1381	1328	1341	1381
EGT 2 (°F)	1385	1352	1350	1279	1299	1336
EGT 3 (°F)	1396	1372	1359	1307	1323	1365
EGT 4 (°F)	1434	1400	1393	1324	1345	1388
Air-to-Fuel Ratio Right	15.68	15.15	15.34	13.87	13.96	14.17
Air-to-Fuel Ratio Left	15.86	15.40	15.65	14.27	14.34	14.39
Oil Inlet Temperature (°F)	233	239	236	238	237	233
Oil Pressure (psig)	59	59	58	59	60	60
Inlet Air Temperature - upstream (°F)	104	104	104	104	104	104
Humidity Ratio (gr / lb)	1.4	1.6	1.6	1.4	1.5	1.7
Relative Humidity (%)	1.5	1.7	1.8	1.5	1.6	1.8
Mass Air Flow (lb / hr)	1056	1206	905	1065	1209	1209
Calculated Air-to-Fuel Ratio	19.83	19.88	18.23	15.90	16.50	17.70

Table B-2. Mixture Lean-Outs Using 94 PRF

Test	t2_8_AR	t2_8_AQ	t2_8_AP	t2_9_BM	t2_9_BO
Fuel	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF
MAP (in. Hg)	27.36	28.17	29.23	27.36	29.24
rpm	2450	2601	2700	2450	2701
Fuel Mass Flow (lb / hr)	54.4	67.3	77	53.9	76.8
Corrected Power (HP)	118	132.7	144.2	117.9	143.8
Torque (ft lb)	244	258	270	244	269
Brake Horsepower (BHP)	113.9	127.9	138.9	113.8	138.4
Temperature Corrected BHP	118.9	133.6	145.1	118.7	144.5
Brake Mean Effective Pressure (psi)	102	107.9	112.9	101.9	112.5
Fuel Volume Flow (gal / hr)	9.6	11.8	13.5	9.5	13.5
Brake Specific Fuel Consumption (lb / hp hr)	0.478	0.526	0.554	0.474	0.554
Temperature Corrected BSFC (lb / hp hr)	0.458	0.504	0.53	0.454	0.531
Corrected BSFC (lb / hp hr)	0.461	0.507	0.534	0.457	0.534
Inlet Air Temperature (°F)	103	103	103	103	103
Inlet Air Pressure (in. Hg)	30.06	30.04	30.02	30.06	30.01
Cowling Air Temperature (°F)	104	103	104	104	103
Cowling Air Pressure (in. H2O)	2.1	2.3	3	2.1	5.3
Fuel Inlet Temperature (°F)	85	85	84	85	89
Fuel Density (lb / gal)	5.68	5.69	5.69	5.68	5.67
Metered Fuel Pressure (psig)	2.7	3.8	5.1	2.6	5.1
Fuel Pump Outlet Pressure (psig)	25.1	24.9	24.4	25.4	24.8
CHT 1 (°F)	443	445	447	443	454
CHT 2 (°F)	465	469	472	465	476
CHT 3 (°F)	471	475	479	471	479
CHT 4 (°F)	466	469	470	467	474
EGT 1 (°F)	1319	1303	1299	1323	1293
EGT 2 (°F)	1283	1257	1259	1288	1257
EGT 3 (°F)	1295	1282	1280	1300	1280
EGT 4 (°F)	1325	1300	1299	1330	1295
Air-to-Fuel Ratio Right	14.36	13.71	13.24	14.53	13.43
Air-to-Fuel Ratio Left	14.62	14.16	13.60	14.56	14.03
Oil Inlet Temperature (°F)	243	245	230	242	237
Oil Pressure (psig)	57	58	60	57	60
Inlet Air Temperature - upstream (°F)	103	104	104	103	104
Humidity Ratio (gr / lb)	1.6	1.5	1.5	1.7	1.4
Relative Humidity (%)	1.8	1.7	1.6	1.8	1.5
Mass Air Flow (lb / hr)	914	1062	1211	914	1210
Calculated Air-to-Fuel Ratio	16.81	15.79	15.74	16.97	15.77

Table B-3. Variable Manifold Pressure Test Using 91/98 L

Test	T2_9_BH	T2_9_BG	T2_9_BF	T2_9_BE	T2_9_BD	T2_9_BC
Fuel	91/98 L	91/98 L	91/98 L	91/98 L	91/98 L	91/98 L
MAP (in. Hg)	27.93	28.38	28.55	29.02	29.45	27.73
rpm	2350	2350	2350	2350	2350	2451
Fuel Mass Flow (lb / hr)	46.6	48	51.5	53.9	57.3	47.8
Corrected Power (HP)	113.1	116.5	121.1	124.6	128.6	115.3
Torque (ft lb)	244	251	261	269	277	238
Brake Horsepower (BHP)	109	112.3	116.8	120.2	123.9	111.1
Temperature Corrected BHP	113.8	117.2	121.9	125.4	129.3	116
Brake Mean Effective Pressure (psi)	101.7	104.9	109.0	112.2	115.7	99.5
Fuel Volume Flow (gal / hr)	8.0	8.2	8.8	9.2	9.8	8.2
Brake Specific Fuel Consumption (lb / hp hr)	0.427	0.427	0.441	0.448	0.462	0.43
Temperature Corrected BSFC (lb / hp hr)	0.409	0.409	0.423	0.429	0.443	0.412
Corrected BSFC (lb / hp hr)	0.412	0.412	0.425	0.432	0.445	0.414
Inlet Air Temperature (°F)	103	103	103	103	103	103
Inlet Air Pressure (in. Hg)	30.04	30.03	30.05	30.04	30.03	30.03
Cowling Air Temperature (°F)	104	104	103	103	103	104
Cowling Air Pressure (in. H2O)	2.7	2.5	2.5	6.4	4.6	2.2
Fuel Inlet Temperature (°F)	90	90	90	91	91	90
Fuel Density (lb / gal)	5.83	5.83	5.83	5.82	5.83	5.83
Metered Fuel Pressure (psig)	2.2	2.2	2.5	2.8	3	2.2
Fuel Pump Outlet Pressure (psig)	25.3	25.5	25.5	25	25.2	25.7
CHT 1 (°F)	450	455	449	459	454	448
CHT 2 (°F)	475	477	473	481	477	473
CHT 3 (°F)	470	474	469	483	477	464
CHT 4 (°F)	468	473	468	484	478	463
EGT 1 (°F)	1456	1440	1403	1382	1354	1456
EGT 2 (°F)	1433	1416	1382	1363	1333	1425
EGT 3 (°F)	1416	1406	1382	1367	1340	1420
EGT 4 (°F)	1456	1441	1416	1406	1375	1458
Air-to-Fuel Ratio Right	15.23	15.24	14.86	14.97	14.45	15.55
Air-to-Fuel Ratio Left	15.64	15.43	15.08	15.3	14.64	15.71
Oil Inlet Temperature (°F)	236	232	227	244	243	231
Oil Pressure (psig)	56	57	57	56	56	58
Inlet Air Temperature - upstream (°F)	104	104	104	104	104	103
Humidity Ratio (gr / lb)	1.4	1.5	1.5	1.4	1.4	1.6
Relative Humidity (%)	1.5	1.7	1.6	1.5	1.6	1.7
Mass Air Flow (lb / hr)	889	916	932	956	985	908
Calculated Air-to-Fuel Ratio	19.10	19.09	18.11	17.75	17.20	19.00

Table B-3. Variable Manifold Pressure Test Using 91/98 L (Continued)

Test	T2_9_BB	T2_9_BA	T2_9_AZ	T2_9_AX	T2_9_AW
Fuel	91/98 L	91/98 L	91/98 L	91/98 L	91/98 L
MAP (in. Hg)	28.35	28.79	29.23	28.36	28.52
rpm	2450	2451	2451	2600	2601
Fuel Mass Flow (lb / hr)	51.8	54.5	57.7	54.9	57.6
Corrected Power (HP)	122.8	127.1	132	129.3	133.4
Torque (ft lb)	254	262	272	252	260
Brake Horsepower (BHP)	118.4	122.4	127.1	124.6	128.6
Temperature Corrected BHP	123.6	127.8	132.7	130.1	134.2
Brake Mean Effective Pressure (psi)	106.0	109.6	113.8	105.1	108.5
Fuel Volume Flow (gal / hr)	8.9	9.3	9.9	9.4	9.9
Brake Specific Fuel Consumption (lb / hp hr)	0.438	0.445	0.454	0.441	0.448
Temperature Corrected BSFC (lb / hp hr)	0.419	0.426	0.435	0.422	0.429
Corrected BSFC (lb / hp hr)	0.422	0.429	0.437	0.425	0.431
Inlet Air Temperature (°F)	103	103	103	103	103
Inlet Air Pressure (in. Hg)	30.03	30.03	30.01	30.03	30.03
Cowling Air Temperature (°F)	103	104	103	104	103
Cowling Air Pressure (in. H2O)	8.9	5.4	3.8	7.8	4.4
Fuel Inlet Temperature (°F)	90	90	90	89	90
Fuel Density (lb / gal)	5.83	5.83	5.83	5.83	5.83
Metered Fuel Pressure (psig)	2.8	3	3.2	2.9	3.1
Fuel Pump Outlet Pressure (psig)	25.4	25.1	24.9	25.6	25.1
CHT 1 (°F)	454	457	455	459	455
CHT 2 (°F)	479	477	473	483	475
CHT 3 (°F)	472	477	475	477	475
CHT 4 (°F)	473	479	478	478	475
EGT 1 (°F)	1435	1422	1391	1469	1458
EGT 2 (°F)	1409	1393	1368	1428	1420
EGT 3 (°F)	1413	1404	1375	1445	1427
EGT 4 (°F)	1457	1449	1420	1488	1475
Air-to-Fuel Ratio Right	15.32	14.82	14.65	15.37	14.85
Air-to-Fuel Ratio Left	15.68	15.13	14.8	15.83	15.13
Oil Inlet Temperature (°F)	228	240	228	232	232
Oil Pressure (psig)	58	57	58	60	59
Inlet Air Temperature - upstream (°F)	104	104	104	104	104
Humidity Ratio (gr / lb)	1.4	1.5	1.6	1.4	1.4
Relative Humidity (%)	1.5	1.6	1.8	1.5	1.5
Mass Air Flow (lb / hr)	945	967	994	1033	1064
Calculated Air-to-Fuel Ratio	18.25	17.75	17.24	18.82	18.48

Table B-3. Variable Manifold Pressure Test Using 91/98 L (Continued)

Test	T2_9_AV	T2_9_AK	T2_9_AS	T2_9_AQ	T2_9_AJ
Fuel	91/98 L	91/98 L	91/98 L	91/98 L	91/98 L
MAP (in. Hg)	29.28	28.15	28.7	29.11	29.24
rpm	2600	2600	2700	2700	2699
Fuel Mass Flow (lb / hr)	61.3	53.3	57	61.8	60.7
Corrected Power (HP)	140.8	127.1	134.6	142.1	142.8
Torque (ft lb)	274	248	252	266	268
Brake Horsepower (BHP)	135.6	122.6	129.8	136.9	137.5
Temperature Corrected BHP	141.6	127.9	135.4	142.9	143.5
Brake Mean Effective Pressure (psi)	114.4	103.4	105.4	111.2	111.8
Fuel Volume Flow (gal / hr)	10.5	9.1	9.8	10.6	10.4
Brake Specific Fuel Consumption (lb / hp hr)	0.452	0.435	0.439	0.452	0.441
Temperature Corrected BSFC (lb / hp hr)	0.433	0.416	0.421	0.433	0.423
Corrected BSFC (lb / hp hr)	0.435	0.419	0.423	0.435	0.425
Inlet Air Temperature (°F)	103	103	103	103	103
Inlet Air Pressure (in. Hg)	30.01	30.03	30.03	30.02	30.01
Cowling Air Temperature (°F)	103	104	104	103	103
Cowling Air Pressure (in. H2O)	8.8	8.8	2.6	2.3	2.3
Fuel Inlet Temperature (°F)	90	89	90	89	89
Fuel Density (lb / gal)	5.83	5.83	5.83	5.83	5.82
Metered Fuel Pressure (psig)	3.4	2.7	2.9	3.2	3
Fuel Pump Outlet Pressure (psig)	25.6	25.7	25.3	25.4	25.3
CHT 1 (°F)	460	456	457	455	451
CHT 2 (°F)	483	480	479	475	471
CHT 3 (°F)	481	479	471	476	478
CHT 4 (°F)	485	474	471	470	470
EGT 1 (°F)	1431	1425	1500	1456	1394
EGT 2 (°F)	1393	1385	1464	1416	1352
EGT 3 (°F)	1405	1396	1461	1429	1372
EGT 4 (°F)	1451	1434	1511	1475	1400
Air-to-Fuel Ratio Right	15.11	15.68	15.25	14.86	15.15
Air-to-Fuel Ratio Left	15.11	15.86	15.39	15.11	15.4
Oil Inlet Temperature (°F)	244	233	244	228	239
Oil Pressure (psig)	58	59	58	60	59
Inlet Air Temperature - upstream (°F)	104	104	104	104	104
Humidity Ratio (gr / lb)	1.5	1.4	1.3	1.4	1.6
Relative Humidity (%)	1.7	1.5	1.5	1.5	1.7
Mass Air Flow (lb / hr)	1131	1056	1142	1167	1206
Calculated Air-to-Fuel Ratio	18.45	19.83	20.05	18.88	19.88

Table B-4. Variable Manifold Pressure Test Using 91/98 UL

Test	T2_9_AI	T2_8_Q	T2_8_P	T2_9_AH	T2_8_O	T2_9_AG	T2_9_AE
Fuel	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL
MAP (in. Hg)	27.39	27.11	27.71	28.12	27.99	27.86	27.01
rpm	2350	2350	2350	2351	2350	2350	2450
Fuel Mass Flow (lb / hr)	48.9	45.5	51.4	55.6	56.7	56.9	48.1
Corrected Power (HP)	112.6	106.8	115.1	117.7	117.5	116.8	112.8
Torque (ft lb)	242	230	248	254	253	252	233
Brake Horsepower (BHP)	108.5	103	111	113.5	113.3	112.6	108.7
Temperature Corrected BHP	113.2	107.5	115.8	118.5	118.2	117.5	113.5
Brake Mean Effective Pressure (psi)	101.3	96.1	103.6	105.9	105.8	105.1	97.4
Fuel Volume Flow (gal / hr)	8.3	7.7	8.7	9.4	9.6	9.7	8.2
Brake Specific Fuel Consumption (lb / hp hr)	0.451	0.442	0.463	0.49	0.5	0.5	0.442
Temperature Corrected BSFC (lb / hp hr)	0.432	0.424	0.444	0.47	0.48	0.48	0.424
Corrected BSFC (lb / hp hr)	0.435	0.426	0.447	0.472	0.48	0.49	0.426
Inlet Air Temperature (°F)	103	103	102	103	102	103	103
Inlet Air Pressure (in. Hg)	30.03	30.04	30.04	30.04	30.04	30.04	30.03
Cowling Air Temperature (°F)	103	103	103	104	103	104	104
Cowling Air Pressure (in. H2O)	4.3	2.1	1.8	2.5	4.2	2	4.5
Fuel Inlet Temperature (°F)	92	84	84	92	84	92	92
Fuel Density (lb / gal)	5.89	5.93	5.93	5.89	5.93	5.89	5.89
Metered Fuel Pressure (psig)	2.4	1.9	2.3	2.9	2.8	3	2.5
Fuel Pump Outlet Pressure (psig)	25.7	25.6	25.6	25.5	25.5	25.1	25.5
CHT 1 (°F)	455	455	452	452	452	452	454
CHT 2 (°F)	478	474	472	476	477	473	479
CHT 3 (°F)	476	473	472	475	474	477	472
CHT 4 (°F)	472	470	471	472	474	473	472
EGT 1 (°F)	1430	1460	1394	1367	1351	1342	1467
EGT 2 (°F)	1403	1438	1377	1349	1331	1322	1428
EGT 3 (°F)	1390	1427	1373	1348	1334	1329	1423
EGT 4 (°F)	1426	1469	1410	1378	1366	1355	1464
Air-to-Fuel Ratio Right	15.04	15.1	14.71	14.21	14.03	14.03	15.01
Air-to-Fuel Ratio Left	15.06	15.38	14.82	14.51	14.44	14.38	15.5
Oil Inlet Temperature (°F)	230	236	230	238	228	228	237
Oil Pressure (psig)	57	57	58	56	58	58	57
Inlet Air Temperature - upstream (°F)	104	104	104	104	104	103	104
Humidity Ratio (gr / lb)	1.6	1.4	1.6	1.5	1.3	1.4	1.6
Relative Humidity (%)	1.7	1.6	1.8	1.7	1.6	1.5	1.8
Mass Air Flow (lb / hr)	875	854	885	895	899	897	877
Calculated Air-to-Fuel Ratio	17.88	18.77	17.23	16.08	15.87	15.78	18.24

Table B-4. Variable Manifold Pressure Test Using 91/98 UL (Continued)

Test	T2_8_N	T2_9_AD	T2_8_M	T2_9_AF	T2_8_I	T2_8_C	T2_9_AC	T2_9_AB
Fuel	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL
MAP (in. Hg)	27.49	27.62	28.15	29.02	29.37	27.3	27.05	27.52
rpm	2450	2450	2450	2450	2450	2449	2600	2600
Fuel Mass Flow (lb / hr)	50.9	55.2	57.4	62.4	63.8	49.6	53.3	58.5
Corrected Power (HP)	116.3	119	123.2	130.2	133	113.7	121.1	126.6
Torque (ft lb)	240	246	255	269	275	235	236	247
Brake Horsepower (BHP)	112.1	114.7	118.8	125.3	128.1	109.7	116.8	122.1
Temperature Corrected BHP	117	119.7	124	130.9	133.7	114.4	121.9	127.4
Brake Mean Effective Pressure (psi)	100.4	102.7	106.4	112.2	114.7	98.2	98.6	103.0
Fuel Volume Flow (gal / hr)	8.6	9.4	9.7	10.6	10.8	8.3	9.0	9.9
Brake Specific Fuel Consumption (lb / hp hr)	0.454	0.481	0.483	0.498	0.498	0.453	0.456	0.479
Temperature Corrected BSFC (lb / hp hr)	0.435	0.461	0.463	0.477	0.477	0.434	0.437	0.459
Corrected BSFC (lb / hp hr)	0.438	0.464	0.466	0.479	0.48	0.437	0.44	0.462
Inlet Air Temperature (°F)	103	103	102	103	102	102	103	103
Inlet Air Pressure (in. Hg)	30.04	30.04	30.04	30	30.01	30.04	30.05	30.04
Cowling Air Temperature (°F)	103	103	103	104	103	103	104	104
Cowling Air Pressure (in. H2O)	8.8	4.7	3.4	2	8.7	4.4	3.1	3.2
Fuel Inlet Temperature (°F)	83	91	83	92	84	81	91	90
Fuel Density (lb / gal)	5.93	5.89	5.93	5.89	5.93	5.95	5.9	5.9
Metered Fuel Pressure (psig)	2.5	2.9	2.9	3.5	3.6	2	2.8	3.1
Fuel Pump Outlet Pressure (psig)	25.8	25.1	25.5	25.3	25.2	26	25.2	25.5
CHT 1 (°F)	458	456	454	452	455	453	451	456
CHT 2 (°F)	481	477	479	475	477	478	477	480
CHT 3 (°F)	478	477	477	474	479	476	470	475
CHT 4 (°F)	477	473	475	475	478	472	469	475
EGT 1 (°F)	1431	1400	1383	1357	1364	1381	1457	1435
EGT 2 (°F)	1402	1375	1352	1338	1332	1350	1417	1398
EGT 3 (°F)	1410	1379	1363	1337	1347	1359	1429	1414
EGT 4 (°F)	1449	1411	1396	1376	1383	1393	1474	1457
Air-to-Fuel Ratio Right	15.05	14.47	14.23	13.97	14.26	15.34	15.01	14.46
Air-to-Fuel Ratio Left	15.5	14.71	14.62	14.39	14.68	15.65	14.94	14.65
Oil Inlet Temperature (°F)	240	236	231	232	243	236	243	236
Oil Pressure (psig)	57	57	58	58	57	58	58	59
Inlet Air Temperature - upstream (°F)	104	103	104	104	104	104	104	103
Humidity Ratio (gr / lb)	1.5	1.4	1.6	1.5	1.4	1.6	1.5	1.6
Relative Humidity (%)	1.6	1.6	1.8	1.6	1.6	1.8	1.6	1.8
Mass Air Flow (lb / hr)	894	903	934	988	1020	905	959	986
Calculated Air-to-Fuel Ratio	17.58	16.36	16.29	15.83	15.99	18.23	18.02	16.86

Table B-4. Variable Manifold Pressure Test Using 91/98 UL (Continued)

Test	T2_8_K	T2_8_J	T2_8_B	T2_9_AA	T2_8_H	T2_8_G	T2_8_F	T2_8_A
Fuel	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL	91/98 UL
MAP (in. Hg)	27.81	28.71	28.23	27.21	27.25	28.62	29.23	29.24
rpm	2600	2601	2600	2699	2700	2700	2700	2701
Fuel Mass Flow (lb / hr)	61.3	69.5	67	57	61.3	68.3	74.2	73.2
Corrected Power (HP)	130	136.4	133.1	128.2	131.3	141.2	144.6	145.8
Torque (ft lb)	253	265	259	240	246	265	271	273
Brake Horsepower (BHP)	125.3	131.3	128.2	123.5	126.6	136.1	139.2	140.4
Temperature Corrected BHP	130.8	137.1	133.8	129	132	142	145.3	146.4
Brake Mean Effective Pressure (psi)	105.7	110.8	108.2	100.4	102.8	110.6	113.1	114.0
Fuel Volume Flow (gal / hr)	10.3	11.7	11.3	9.7	10.3	11.5	12.5	12.3
Brake Specific Fuel Consumption (lb / hp hr)	0.489	0.529	0.522	0.461	0.484	0.502	0.533	0.522
Temperature Corrected BSFC (lb / hp hr)	0.469	0.507	0.5	0.442	0.464	0.481	0.511	0.5
Corrected BSFC (lb / hp hr)	0.471	0.51	0.503	0.444	0.467	0.484	0.513	0.503
Inlet Air Temperature (°F)	103	103	102	103	102	102	102	102
Inlet Air Pressure (in. Hg)	30.04	30.01	30.01	30.04	30.03	30.02	29.99	29.99
Cowling Air Temperature (°F)	103	103	103	103	103	103	103	103
Cowling Air Pressure (in. H2O)	3.9	3.6	6.6	6.7	2.3	2.7	8.7	8.6
Fuel Inlet Temperature (°F)	84	83	80	90	82	82	82	79
Fuel Density (lb / gal)	5.93	5.93	5.95	5.9	5.93	5.94	5.94	5.95
Metered Fuel Pressure (psig)	3.2	4.1	3.8	3.2	3.1	3.8	4.9	4.6
Fuel Pump Outlet Pressure (psig)	25.6	25.1	25.3	25.2	25.4	25.1	25.2	24.8
CHT 1 (°F)	451	452	453	455	451	453	456	451
CHT 2 (°F)	477	476	474	476	474	475	475	472
CHT 3 (°F)	472	476	480	478	472	476	481	481
CHT 4 (°F)	468	471	473	474	467	469	477	473
EGT 1 (°F)	1409	1369	1328	1458	1434	1400	1361	1341
EGT 2 (°F)	1365	1324	1279	1422	1388	1356	1319	1299
EGT 3 (°F)	1383	1344	1307	1435	1401	1373	1342	1323
EGT 4 (°F)	1417	1374	1324	1483	1442	1407	1368	1345
Air-to-Fuel Ratio Right	14.36	13.83	13.87	15.11	14.39	14.03	13.75	13.96
Air-to-Fuel Ratio Left	14.45	14	14.27	15.23	14.6	14.37	13.92	14.34
Oil Inlet Temperature (°F)	246	238	238	234	233	248	238	237
Oil Pressure (psig)	58	59	59	60	61	58	60	60
Inlet Air Temperature - upstream (°F)	104	104	104	104	104	104	103	104
Humidity Ratio (gr / lb)	1.5	1.6	1.4	1.4	1.4	1.5	1.6	1.5
Relative Humidity (%)	1.6	1.7	1.5	1.6	1.5	1.6	1.8	1.6
Mass Air Flow (lb / hr)	1017	1081	1065	1031	1055	1144	1199	1209
Calculated Air-to-Fuel Ratio	16.59	15.54	15.90	18.11	17.21	16.75	16.17	16.50

Table B-5. Variable Manifold Pressure Test Using 93/98 UL

Test	T2_8_AN	T2_8_Al	T2_8_AK	T2_9_Z	T2_6_P	T2_6_Q	T2_6_R	T2_6_S
Fuel	93/98 UL	93/98 UL	93/98 UL	93/98 UL	93/98 UL	93/98 UL	93/98 UL	93/98 UL
MAP (in. Hg)	28.22	28.22	29.01	29.22	27.26	28.05	28.54	29.46
rpm	2349	2349	2350	2350	2450	2449	2450	2449
Fuel Mass Flow (lb / hr)	49.3	51.1	55.4	57.7	49	52.2	57.9	63.6
Corrected Power (HP)	115.4	118.3	124.7	126.3	114.1	120.1	126.1	133.7
Torque (ft lb)	249	255	269	272	236	249	261	277
Brake Horsepower (BHP)	111.3	114.1	120.2	121.6	110.3	116	121.8	129
Temperature Corrected BHP	116.2	119.1	125.5	126.9	115.2	121.1	127.2	134.8
Brake Mean Effective Pressure (psi)	103.9	106.5	112.2	113.6	98.7	103.9	109.0	115.6
Fuel Volume Flow (gal / hr)	8.5	8.8	9.5	9.9	8.4	9.0	9.9	10.9
Brake Specific Fuel Consumption (lb / hp hr)	0.443	0.448	0.461	0.474	0.445	0.45	0.475	0.493
Temperature Corrected BSFC (lb / hp hr)	0.425	0.429	0.441	0.454	0.426	0.431	0.455	0.472
Corrected BSFC (lb / hp hr)	0.428	0.432	0.444	0.457	0.429	0.435	0.459	0.475
Inlet Air Temperature (°F)	103	103	103	103	104	103	104	104
Inlet Air Pressure (in. Hg)	30.06	30.06	30.05	30.01	30.13	30.13	30.12	30.1
Cowling Air Temperature (°F)	104	104	104	103	107	108	108	108
Cowling Air Pressure (in. H2O)	4	2.5	3.1	2	2.8	8.3	3.3	4.3
Fuel Inlet Temperature (°F)	86	86	86	89	93	93	92	90
Fuel Density (lb / gal)	5.84	5.84	5.84	5.82	5.83	5.83	5.83	5.83
Metered Fuel Pressure (psig)	2.5	2.6	2.8	3.2	2.4	2.7	3.1	3.5
Fuel Pump Outlet Pressure (psig)	25.6	25.3	25.4	25.2	25.6	25.6	25.6	25.5
CHT 1 (°F)	454	451	454	449	461	458	454	450
CHT 2 (°F)	476	472	476	470	478	480	476	471
CHT 3 (°F)	477	473	476	476	472	476	475	475
CHT 4 (°F)	477	471	476	475	470	473	472	475
EGT 1 (°F)	1463	1402	1388	1361	1470	1451	1390	1356
EGT 2 (°F)	1431	1379	1368	1340	1432	1425	1368	1327
EGT 3 (°F)	1419	1381	1373	1351	1437	1428	1384	1341
EGT 4 (°F)	1455	1414	1406	1379	1471	1466	1420	1380
Air-to-Fuel Ratio Right	15.11	14.47	14.56	14.17	15.02	15.19	14.15	14.12
Air-to-Fuel Ratio Left	15.27	14.86	14.95	14.64	15.26	15.38	14.39	14.24
Oil Inlet Temperature (°F)	242	244	229	232	232	230	227	245
Oil Pressure (psig)	56	56	58	57	59	59	59	57
Inlet Air Temperature - upstream (°F)	104	103	104	104	103	103	103	103
Humidity Ratio (gr / lb)	1.7	1.5	1.5	1.6	1.1	1	1	1
Relative Humidity (%)	1.9	1.7	1.6	1.8	1.2	1.2	1.1	1.1
Mass Air Flow (lb / hr)	916	910	952	969	888	922	956	1030
Calculated Air-to-Fuel Ratio	18.56	17.81	17.18	16.80	18.11	17.65	16.51	16.20

Table B-5. Variable Manifold Pressure Test Using 93/98 UL (Continued)

Test	T2_8_Z	T2_8_AB	T2_8_AA	T2_8_AC	T2_8_X	T2_8_W	T2_8_R
Fuel	93/98 UL	93/98 UL	93/98 UL	93/98 UL	93/98 UL	93/98 UL	93/98 UL
MAP (in. Hg)	28.75	27.81	28.09	28.2	28.61	29.24	29.23
rpm	2600	2600	2601	2700	2700	2700	2700
Fuel Mass Flow (lb / hr)	62.1	53.6	57.3	58.1	59.7	67.8	68.3
Corrected Power (HP)	136.2	124.4	131.1	133.9	138.3	144.8	145.5
Torque (ft lb)	265	242	255	251	259	271	273
Brake Horsepower (BHP)	131.3	120	126.4	129.1	133.2	139.5	140.2
Temperature Corrected BHP	137	125.2	131.8	134.7	139	145.6	146.3
Brake Mean Effective Pressure (psi)	110.8	101.3	106.6	104.9	108.3	113.3	113.9
Fuel Volume Flow (gal / hr)	10.6	9.2	9.8	9.9	10.2	11.6	11.7
Brake Specific Fuel Consumption (lb / hp hr)	0.473	0.446	0.453	0.45	0.448	0.486	0.487
Temperature Corrected BSFC (lb / hp hr)	0.453	0.428	0.434	0.431	0.43	0.466	0.467
Corrected BSFC (lb / hp hr)	0.456	0.43	0.437	0.434	0.432	0.468	0.469
Inlet Air Temperature (°F)	102	102	102	102	103	103	103
Inlet Air Pressure (in. Hg)	30.02	30.04	30.03	30.04	30.02	30	30.01
Cowling Air Temperature (°F)	103	104	103	103	103	103	103
Cowling Air Pressure (in. H2O)	5.3	3.4	2.8	2.8	4.4	8.7	5.4
Fuel Inlet Temperature (°F)	85	85	85	84	84	83	83
Fuel Density (lb / gal)	5.84	5.84	5.83	5.84	5.84	5.85	5.85
Metered Fuel Pressure (psig)	3.4	2.7	3	3.1	3.3	4.2	4.1
Fuel Pump Outlet Pressure (psig)	25.4	25.6	25.2	25.6	25.7	25	25.3
CHT 1 (°F)	462	461	461	459	454	454	452
CHT 2 (°F)	480	479	476	479	477	480	473
CHT 3 (°F)	476	470	472	474	476	479	479
CHT 4 (°F)	472	466	469	469	469	473	472
EGT 1 (°F)	1430	1471	1453	1504	1455	1417	1381
EGT 2 (°F)	1393	1432	1412	1464	1421	1378	1336
EGT 3 (°F)	1401	1446	1436	1468	1429	1396	1365
EGT 4 (°F)	1435	1486	1472	1516	1470	1429	1388
Air-to-Fuel Ratio Right	14.46	15.09	14.75	14.88	14.76	14.38	14.17
Air-to-Fuel Ratio Left	14.61	15.41	14.75	15.06	15.18	14.55	14.39
Oil Inlet Temperature (°F)	248	233	227	236	236	230	233
Oil Pressure (psig)	57	60	60	60	60	60	60
Inlet Air Temperature - upstream (°F)	104	104	103	104	104	104	104
Humidity Ratio (gr / lb)	1.5	1.6	1.4	1.4	1.6	1.4	1.7
Relative Humidity (%)	1.6	1.8	1.6	1.6	1.8	1.5	1.8
Mass Air Flow (lb / hr)	1076	1008	1031	1110	1139	1196	1209
Calculated Air-to-Fuel Ratio	17.32	18.82	18.00	19.11	19.06	17.64	17.70

Table B-6. Variable Manifold Pressure Test Using 94 PRF

Test	T2_8_BJ	T2_8_BI	T2_8_BG	T2_8_BH	T2_8_BE	T2_8_BD	T2_8_BC
Fuel	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF
MAP (in. Hg)	27.02	27.22	27.42	27.74	27.18	27.39	27.99
rpm	2350	2350	2350	2350	2450	2450	2450
Fuel Mass Flow (lb / hr)	48	51.8	53.8	57.2	51.2	55.3	57.6
Corrected Power (HP)	109.5	112.6	113.3	115.3	115.6	117.9	122.4
Torque (ft lb)	236	243	244	248	239	244	253
Brake Horsepower (BHP)	105.6	108.5	109.2	111.2	111.5	113.7	118
Temperature Corrected BHP	110.2	113.3	114	116.1	116.4	118.8	123.2
Brake Mean Effective Pressure (psi)	98.6	101.3	101.9	103.8	99.8	101.9	105.7
Fuel Volume Flow (gal / hr)	8.4	9.1	9.5	10.1	9.0	9.7	10.1
Brake Specific Fuel Consumption (lb / hp hr)	0.455	0.48	0.49	0.51	0.459	0.486	0.488
Temperature Corrected BSFC (lb / hp hr)	0.435	0.46	0.47	0.49	0.44	0.466	0.467
Corrected BSFC (lb / hp hr)	0.438	0.46	0.47	0.5	0.443	0.469	0.47
Inlet Air Temperature (°F)	103	103	104	103	103	103	103
Inlet Air Pressure (in. Hg)	30.05	30.05	30.05	30.06	30.05	30.06	30.04
Cowling Air Temperature (°F)	104	104	104	104	104	104	103
Cowling Air Pressure (in. H2O)	1.9	2.2	2	2.1	3.6	2.1	3.4
Fuel Inlet Temperature (°F)	86	85	86	86	86	86	86
Fuel Density (lb / gal)	5.69	5.69	5.68	5.68	5.68	5.68	5.68
Metered Fuel Pressure (psig)	2.1	2.4	2.6	2.9	2.3	2.7	3
Fuel Pump Outlet Pressure (psig)	25.5	25.3	25.1	24.9	25.5	25.3	25.3
CHT 1 (°F)	450	453	456	454	452	452	451
CHT 2 (°F)	473	475	479	475	478	476	478
CHT 3 (°F)	472	476	476	477	473	478	476
CHT 4 (°F)	468	476	472	478	471	474	473
EGT 1 (°F)	1406	1365	1346	1317	1396	1361	1358
EGT 2 (°F)	1388	1344	1324	1295	1369	1333	1330
EGT 3 (°F)	1382	1343	1327	1299	1371	1341	1333
EGT 4 (°F)	1424	1381	1359	1331	1414	1377	1370
Air-to-Fuel Ratio Right	14.6	14.16	13.98	13.84	14.9	14.2	14.11
Air-to-Fuel Ratio Left	15.09	14.61	14.43	14.34	15	14.6	14.47
Oil Inlet Temperature (°F)	232	233	241	244	232	228	228
Oil Pressure (psig)	57	57	56	56	58	58	58
Inlet Air Temperature - upstream (°F)	103	103	104	104	103	104	104
Humidity Ratio (gr / lb)	1.4	1.6	1.6	1.7	1.5	1.6	1.6
Relative Humidity (%)	1.6	1.8	1.8	1.9	1.6	1.7	1.8
Mass Air Flow (lb / hr)	867	867	884	899	882	903	938
Calculated Air-to-Fuel Ratio	18.07	16.73	16.43	15.72	17.22	16.32	16.29

Table B-6. Variable Manifold Pressure Test Using 94 PRF (Continued)

Test	T2_8_BA	T2_8_BB	T2_9_BN	T2_9_BR	T2_8_AR	T2_9_BM	T2_9_Y
Fuel	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF
MAP (in. Hg)	28.4	29.23	27.64	28.08	27.36	27.36	26.95
rpm	2450	2450	2450	2451	2450	2450	2601
Fuel Mass Flow (lb / hr)	61.6	68	55	57.7	54.4	53.9	54.9
Corrected Power (HP)	124.7	130.3	120.7	122.7	118	117.9	122.9
Torque (ft lb)	258	269	249	253	244	244	239
Brake Horsepower (BHP)	120.2	125.6	116.4	118.3	113.9	113.8	118.5
Temperature Corrected BHP	125.5	131.1	121.5	123.5	118.9	118.7	123.7
Brake Mean Effective Pressure (psi)	107.7	112.4	104.2	105.9	102.0	101.9	99.9
Fuel Volume Flow (gal / hr)	10.8	12.0	9.7	10.2	9.6	9.5	9.7
Brake Specific Fuel Consumption (lb / hp hr)	0.512	0.541	0.473	0.488	0.478	0.474	0.463
Temperature Corrected BSFC (lb / hp hr)	0.491	0.519	0.453	0.467	0.458	0.454	0.444
Corrected BSFC (lb / hp hr)	0.494	0.522	0.456	0.47	0.461	0.457	0.447
Inlet Air Temperature (°F)	103	103	103	103	103	103	103
Inlet Air Pressure (in. Hg)	30.04	30.02	30.04	30.04	30.06	30.06	30.04
Cowling Air Temperature (°F)	104	104	103	103	104	104	104
Cowling Air Pressure (in. H2O)	2.8	2.7	4.6	8.8	2.1	2.1	7.1
Fuel Inlet Temperature (°F)	86	86	89	89	85	85	90
Fuel Density (lb / gal)	5.68	5.68	5.67	5.67	5.68	5.68	5.66
Metered Fuel Pressure (psig)	3.4	4.2	2.8	3.2	2.7	2.6	2.8
Fuel Pump Outlet Pressure (psig)	25.1	24.5	25.3	25	25.1	25.4	25.5
CHT 1 (°F)	453	450	456	455	443	443	456
CHT 2 (°F)	478	474	478	483	465	465	480
CHT 3 (°F)	477	477	475	480	471	471	477
CHT 4 (°F)	475	478	475	480	466	467	476
EGT 1 (°F)	1325	1290	1388	1360	1319	1323	1420
EGT 2 (°F)	1296	1258	1360	1334	1283	1288	1379
EGT 3 (°F)	1303	1275	1369	1343	1295	1300	1390
EGT 4 (°F)	1333	1297	1405	1378	1325	1330	1436
Air-to-Fuel Ratio Right	13.56	13.18	14.28	14.1	14.36	14.53	14.76
Air-to-Fuel Ratio Left	14.03	13.8	14.65	14.46	14.62	14.56	14.92
Oil Inlet Temperature (°F)	229	242	233	236	243	242	229
Oil Pressure (psig)	58	57	58	58	57	57	60
Inlet Air Temperature - upstream (°F)	104	104	104	104	103	103	104
Humidity Ratio (gr / lb)	1.5	1.6	1.4	1.5	1.6	1.7	1.6
Relative Humidity (%)	1.6	1.8	1.6	1.7	1.8	1.8	1.8
Mass Air Flow (lb / hr)	946	1004	910	926	914	914	957
Calculated Air-to-Fuel Ratio	15.36	14.77	16.54	16.05	16.81	16.97	17.44

Table B-6. Variable Manifold Pressure Test Using 94 PRF (Continued)

Test	T2_8_AZ	T2_8_AX	T2_8_AW	T2_8_AY	T2_9_BQ	T2_8_AQ	T2_9_W
Fuel	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF
MAP (in. Hg)	27.27	27.85	28.22	29.21	28.56	28.17	26.93
rpm	2600	2600	2600	2600	2601	2601	2700
Fuel Mass Flow (lb / hr)	58	61.8	67.2	74.4	68.2	67.3	57.9
Corrected Power (HP)	125.6	129.7	132.5	139.1	135.8	132.7	127.7
Torque (ft lb)	245	253	258	271	264	258	240
Brake Horsepower (BHP)	121.1	125	127.6	134	130.8	127.9	123.2
Temperature Corrected BHP	126.5	130.5	133.2	139.9	136.6	133.6	128.5
Brake Mean Effective Pressure (psi)	102.2	105.5	107.7	113.0	110.4	107.9	100.1
Fuel Volume Flow (gal / hr)	10.2	10.9	11.8	13.1	12.0	11.8	10.2
Brake Specific Fuel Consumption (lb / hp hr)	0.479	0.494	0.526	0.555	0.521	0.526	0.47
Temperature Corrected BSFC (lb / hp hr)	0.459	0.474	0.504	0.532	0.499	0.504	0.45
Corrected BSFC (lb / hp hr)	0.462	0.477	0.507	0.535	0.502	0.507	0.453
Inlet Air Temperature (°F)	103	103	103	103	103	103	103
Inlet Air Pressure (in. Hg)	30.06	30.04	30.03	30.02	30.02	30.04	30.04
Cowling Air Temperature (°F)	103	104	103	104	103	103	104
Cowling Air Pressure (in. H2O)	3.9	8.7	3.1	2.3	2.1	2.3	7.4
Fuel Inlet Temperature (°F)	86	86	86	86	88	85	89
Fuel Density (lb / gal)	5.68	5.68	5.68	5.68	5.67	5.69	5.67
Metered Fuel Pressure (psig)	3	3.6	4	4.8	4	3.8	3.1
Fuel Pump Outlet Pressure (psig)	25.4	25	24.9	24.5	25	24.9	25.3
CHT 1 (°F)	450	455	451	450	449	445	458
CHT 2 (°F)	473	477	473	470	474	469	481
CHT 3 (°F)	474	482	477	477	475	475	480
CHT 4 (°F)	468	476	471	471	474	469	477
EGT 1 (°F)	1402	1391	1335	1303	1333	1303	1426
EGT 2 (°F)	1361	1341	1283	1258	1291	1257	1392
EGT 3 (°F)	1375	1362	1309	1281	1310	1282	1398
EGT 4 (°F)	1411	1396	1333	1301	1341	1300	1444
Air-to-Fuel Ratio Right	14.36	14.19	13.64	13.14	13.69	13.71	14.74
Air-to-Fuel Ratio Left	14.44	14.44	13.96	13.58	14.01	14.16	14.8
Oil Inlet Temperature (°F)	241	248	233	230	228	245	244
Oil Pressure (psig)	59	57	59	60	60	58	59
Inlet Air Temperature - upstream (°F)	104	104	104	104	103	104	103
Humidity Ratio (gr / lb)	1.6	1.5	1.4	1.6	1.5	1.5	1.4
Relative Humidity (%)	1.8	1.6	1.6	1.8	1.7	1.7	1.5
Mass Air Flow (lb / hr)	985	1018	1049	1141	1083	1062	1026
Calculated Air-to-Fuel Ratio	16.98	16.48	15.62	15.34	15.87	15.79	17.72

Table B-6. Variable Manifold Pressure Test Using 94 PRF (Continued)

Test	T2_8_AV	T2_8_AU	T2_8_AT	T2_9_BP	T2_8_AP	T2_9_BO
Fuel	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF	94 PRF
MAP (in. Hg)	27.39	27.78	29.19	28.27	29.23	29.24
rpm	2700	2700	2701	2700	2700	2701
Fuel Mass Flow (lb / hr)	61.9	67.8	75.2	69.2	77	76.8
Corrected Power (HP)	131.7	134.6	143.6	138.7	144.2	143.8
Torque (ft lb)	247	252	269	260	270	269
Brake Horsepower (BHP)	127	129.8	138.2	133.6	138.9	138.4
Temperature Corrected BHP	132.6	135.5	144.3	139.6	145.1	144.5
Brake Mean Effective Pressure (psi)	103.2	105.5	112.3	108.6	112.9	112.5
Fuel Volume Flow (gal / hr)	10.9	11.9	13.2	12.2	13.5	13.5
Brake Specific Fuel Consumption (lb / hp hr)	0.487	0.522	0.544	0.518	0.554	0.554
Temperature Corrected BSFC (lb / hp hr)	0.467	0.5	0.521	0.496	0.53	0.531
Corrected BSFC (lb / hp hr)	0.47	0.503	0.524	0.499	0.534	0.534
Inlet Air Temperature (°F)	103	103	103	103	103	103
Inlet Air Pressure (in. Hg)	30.05	30.04	30.01	30.03	30.02	30.01
Cowling Air Temperature (°F)	104	104	104	103	104	103
Cowling Air Pressure (in. H2O)	3.4	6.3	8.9	3.6	3	5.3
Fuel Inlet Temperature (°F)	86	86	86	88	84	89
Fuel Density (lb / gal)	5.68	5.68	5.68	5.67	5.69	5.67
Metered Fuel Pressure (psig)	3.5	4.2	5.2	4.3	5.1	5.1
Fuel Pump Outlet Pressure (psig)	25	24.8	24.4	24.4	24.4	24.8
CHT 1 (°F)	454	460	462	453	447	454
CHT 2 (°F)	475	474	475	474	472	476
CHT 3 (°F)	477	482	482	476	479	479
CHT 4 (°F)	470	475	475	471	470	474
EGT 1 (°F)	1418	1357	1337	1370	1299	1293
EGT 2 (°F)	1370	1311	1297	1329	1259	1257
EGT 3 (°F)	1383	1333	1315	1344	1280	1280
EGT 4 (°F)	1424	1356	1338	1379	1299	1295
Air-to-Fuel Ratio Right	14.07	13.77	13.58	13.81	13.24	13.43
Air-to-Fuel Ratio Left	14.4	14.21	13.72	14.13	13.6	14.03
Oil Inlet Temperature (°F)	247	230	231	227	230	237
Oil Pressure (psig)	58	60	60	61	60	60
Inlet Air Temperature - upstream (°F)	104	104	104	104	104	104
Humidity Ratio (gr / lb)	1.6	1.5	1.4	1.3	1.5	1.4
Relative Humidity (%)	1.7	1.7	1.6	1.4	1.6	1.5
Mass Air Flow (lb / hr)	1063	1094	1194	1118	1211	1210
Calculated Air-to-Fuel Ratio	17.16	16.14	15.87	16.15	15.74	15.77

Table B-7. Variable Manifold Pressure Test Using 94/98 UL

Test	T2_9_T	T2_9_S	T2_9_R	T2_9_O
Fuel	94/98 UL	94/98 UL	94/98 UL	94/98 UL
MAP (in. Hg)	28.7	29.18	29.33	28.48
rpm	2350	2349	2351	2450
Fuel Mass Flow (lb / hr)	49	51	53.3	51.9
Corrected Power (HP)	118.4	121.8	126.1	122.1
Torque (ft lb)	255	262	271	252
Brake Horsepower (BHP)	114.1	117.3	121.5	117.6
Temperature Corrected BHP	119	122.5	126.8	122.8
Brake Mean Effective Pressure (psi)	106.5	109.5	113.4	105.4
Fuel Volume Flow (gal / hr)	8.4	8.8	9.1	8.9
Brake Specific Fuel Consumption (lb / hp hr)	0.43	0.435	0.438	0.441
Temperature Corrected BSFC (lb / hp hr)	0.412	0.416	0.42	0.423
Corrected BSFC (lb / hp hr)	0.414	0.419	0.422	0.425
Inlet Air Temperature (°F)	103	103	103	103
Inlet Air Pressure (in. Hg)	30.02	30.02	30.01	30.02
Cowling Air Temperature (°F)	103	103	104	104
Cowling Air Pressure (in. H2O)	2.3	2.6	2.4	5.2
Fuel Inlet Temperature (°F)	89	88	88	87
Fuel Density (lb / gal)	5.82	5.82	5.82	5.83
Metered Fuel Pressure (psig)	2.5	2.5	2.7	2.7
Fuel Pump Outlet Pressure (psig)	25.5	25.6	25.5	25.6
CHT 1 (°F)	459	453	457	456
CHT 2 (°F)	480	472	477	477
CHT 3 (°F)	479	474	480	476
CHT 4 (°F)	477	474	481	476
EGT 1 (°F)	1465	1431	1405	1464
EGT 2 (°F)	1439	1409	1386	1432
EGT 3 (°F)	1424	1408	1386	1429
EGT 4 (°F)	1466	1449	1430	1471
Air-to-Fuel Ratio Right	15.27	15.34	14.69	15.47
Air-to-Fuel Ratio Left	15.06	15.17	14.78	15.24
Oil Inlet Temperature (°F)	228	232	228	240
Oil Pressure (psig)	58	57	58	57
Inlet Air Temperature - upstream (°F)	103	104	104	103
Humidity Ratio (gr / lb)	1.6	1.4	1.5	1.6
Relative Humidity (%)	1.8	1.6	1.7	1.8
Mass Air Flow (lb / hr)	934	970	972	956
Calculated Air-to-Fuel Ratio	19.05	19.02	18.24	18.41

Table B-7. Variable Manifold Pressure Test Using 94/98 UL (Continued)

Test	T2_9_M	T2_9_K	T2_9_J	T2_9_G
Fuel	94/98 UL	94/98 UL	94/98 UL	94/98 UL
MAP (in. Hg)	29.1	28.36	28.78	29.2
rpm	2450	2601	2600	2699
Fuel Mass Flow (lb / hr)	56	53.9	56.3	56.8
Corrected Power (HP)	129.6	127.8	133	133.6
Torque (ft lb)	267	249	259	250
Brake Horsepower (BHP)	124.8	123.1	128	128.5
Temperature Corrected BHP	130.3	128.5	133.6	134.2
Brake Mean Effective Pressure (psi)	111.7	103.8	108.0	104.5
Fuel Volume Flow (gal / hr)	9.6	9.2	9.7	9.7
Brake Specific Fuel Consumption (lb / hp hr)	0.449	0.438	0.44	0.442
Temperature Corrected BSFC (lb / hp hr)	0.43	0.419	0.422	0.423
Corrected BSFC (lb / hp hr)	0.432	0.422	0.424	0.425
Inlet Air Temperature (°F)	103	103	103	103
Inlet Air Pressure (in. Hg)	30.01	30.01	30	30
Cowling Air Temperature (°F)	104	104	104	104
Cowling Air Pressure (in. H2O)	8.8	2.4	5.6	2.3
Fuel Inlet Temperature (°F)	86	86	86	85
Fuel Density (lb / gal)	5.83	5.83	5.83	5.84
Metered Fuel Pressure (psig)	3.1	2.7	2.9	2.8
Fuel Pump Outlet Pressure (psig)	25.4	25.6	25.3	25.6
CHT 1 (°F)	454	454	453	452
CHT 2 (°F)	474	478	481	475
CHT 3 (°F)	477	469	472	467
CHT 4 (°F)	479	469	472	464
EGT 1 (°F)	1406	1492	1465	1528
EGT 2 (°F)	1376	1450	1428	1486
EGT 3 (°F)	1386	1455	1437	1461
EGT 4 (°F)	1431	1504	1485	1509
Air-to-Fuel Ratio Right	15.01	15.18	15.39	15.58
Air-to-Fuel Ratio Left	15.12	15.4	15.43	15.44
Oil Inlet Temperature (°F)	229	230	231	237
Oil Pressure (psig)	58	60	59	59
Inlet Air Temperature - upstream (°F)	104	104	103	104
Humidity Ratio (gr / lb)	1.3	1.6	1.4	1.4
Relative Humidity (%)	1.6	1.7	1.5	1.5
Mass Air Flow (lb / hr)	994	1049	1080	1187
Calculated Air-to-Fuel Ratio	17.73	19.47	19.17	20.91