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16. Abstract

Recent Clean Air Act legislation banned the use of leaded fuels however, due to significant safety concerns, the EPA has not enforced compliance on the general aviation community. Nonetheless, significant economic pressures will continue to mount concerning the purchase, handling, and shipping of lead containing fuels and the disposal of lead tainted engine oils. This is driving the need to develop a high Motor Octane unleaded alternative to the current leaded stock. The cost to develop this alternative is expected to be exponentially proportional to the motor octane number of the fuel. Historically, safety margins were determined by ensuring that the particular engine be without limiting detonation throughout its operating envelope on a particular aviation fuel. There is very limited data on the actual motor octane requirement of the majority of the fleet. A Coordinating Research Council Subcommittee has been formed to address the development of an unleaded fuel, with the current focus being the determination of the minimum motor octane number required for knock free operation of the majority of the piston engine fleet.

This report details ongoing FAA efforts toward this effort. Data from both ground based engine testing and in-flight testing are included. The findings suggest that greater than 100 motor octane number will be required with lean fuel flow schedule conditions requiring substantially greater motor octane numbers. The data also suggest that significant decrease in octane requirement can be obtained by substantial power deration for the large turbocharged engines.

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LIST OF DEFINITIONS/ABBREVIATIONS/SYMBOLS

Unless otherwise specified, the following is used as defined below throughout this report:

AN	Amine Number equal to the weight percentage of Meta-Toluidine in a blend with reference grade isooctane
ASTM	American Society for Testing and Materials
BHP	Brake horsepower
BMEP	Brake mean effective pressure
C	Centigrade
CHT	Cylinder head temperature
cm	Centimeter
Critical Engine	The left engine on the Aerocommander 680E aircraft, whose failure would most adversely affect the performance or handling qualities of an aircraft.
Critical Altitude	Maximum altitude where it is possible to maintain a specified power or a specified manifold pressure.
EGT	Exhaust gas temperature
EPA	Environmental Protection Agency
F	Fahrenheit
F/R	Full-rich mixture setting
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
Flush	Without recess
FRR	Fuel return rate
FSR	Fuel supply rate
ft	Feet
FT	Full throttle
GSO	Geared, supercharged, horizontally opposed
Hk	Heavy knock condition

IO	Fuel injected, horizontally opposed
in	Inch
Kg	Kilogram
LBP	Lean to best power
lbsf	Pounds force
Lk	Light knock condition
LPE	Lean to Peak Exhaust Gas Temperature
M	Meter
MAP	Manifold absolute pressure
Meta-Toluidine	Amine blended with isooctane to develop greater than 100 MON fuels, $CH_3C_6H_4NH_2$
mil	Thousandth of an inch
Mk	Moderate knock condition
MON	Motor octane number
MTBE	Methyl tertiary butyl ether
No	No knock condition
NRP	Normal Rated Power
psig	Pounds per square inch gage
rpm	Revolutions per minute
RVP	Reid Vapor Pressure
S	Second
Test Fuel	High-octane unleaded candidate fuel
TIO	Turbocharged, fuel injected, horizontally opposed
TSIO	Turbosupercharged, fuel injected, horizontally opposed
100LL	100-Octane low-lead avgas

EXECUTIVE SUMMARY

The Environmental Protection Agency (EPA) has temporarily excused the general aviation community from compliance with recent clean air legislation banning the use of leaded fuels. However, it is doubtful that the EPA will continue to do so as general aviation has now become a leading source of airborne lead. As leaded fuel becomes more scarce and disposal of lead tainted oils becomes more restricted, increasing economic pressures will force the issue of replacing the current leaded stock with a high-octane, unleaded alternative.

The Unleaded Gasoline Program includes both ground-based and flight testing to address some of the key issues regarding lead replacement. The majority of the test cell research is performed under the direction of the Coordinating Research Council High-Octane Unleaded Aviation Gasoline Subcommittee. Current ground-based testing is focused on determining the minimum motor octane requirement that will satisfy various representative critical engines selected by the Coordinating Research Council. These critical engines represent the greatest challenge, in terms of octane requirement, to respective candidate replacement fuels. These results will yield a minimum motor octane requirement that will satisfy the majority of the piston engine fleet.

The flight test phase utilizes the William J. Hughes Technical Center AeroCommander 680-E aircraft (registration N-50). A Lycoming GSO-480-B1A6 test engine was test cell prepped, operated only on unleaded fuels, and installed in place of the right engine. Areas of testing include knock, in-flight engine restarts, and endurance performance. The results from the ground-based octane rating are compared to those of the in-flight octane ratings to determine if the ground-based test cell controlled environment can adequately approximate the severity of actual in-flight conditions.

Preliminary results from the flight tests suggest that actual altitude knock testing will not produce significantly different results than those of ground-based testing. Results from the ground-based octane requirement study will suggest what minimum motor octane will satisfy the majority of the general aviation piston aircraft fleet.

The GSO-480-B1A6 engine experienced a valve sticking problem during some of the testing. The source of the problem was never isolated, so no determination has been made as to the fuel's contribution to this event. No other engines being tested experienced any operational problem due to fuel characteristics.

1. PHASE 1: GROUND-BASED INVESTIGATION.

1.1 INTRODUCTION.

1.1.1 Purpose.

The purpose of this investigation is to determine the motor octane requirement of engines known to be the most octane demanding of the fleet. The minimum motor octane requirement of these engines will determine the minimum motor octane number (MON) that will satisfy the bulk of the fleet. These results are used as an initial target for the development of an unleaded alternative to the current leaded aviation gasoline.

1.1.2 Background.

A Coordinating Research Council (CRC) subcommittee encompassing regulatory agencies, user groups, engine and airframe manufacturers, and petroleum companies has been formed to address the goal of removal of lead from general aviation piston engine gasoline. The majority of the piston engine fleet currently operate on 100LL and will require a high-octane replacement for the leaded fuel. However, past certification required only that the manufacturers showed that the engine was detonation free on the fuel and did not require the exact determination of the motor octane requirement of the engine. The cost of any alternate fuel is expected to be directly proportional to the motor octane number of the fuel, rising significantly with higher required numbers. The current goal of the CRC subcommittee is to determine what MON is required to satisfy the chosen engines. This MON is the first of many targets that have to be met in determining what candidate fuels exist, or can be developed, as potential replacements for the current leaded stock.

1.1.3 Related Documents.

ASTM D 910, Standard Specification for Aviation Gasoline.

ASTM D 2700, Standard Test Method for Knock Characteristics of Motor and Aviation Fuels by the Motor Method.

ASTM Standard Practice for Octane Rating Normally Aspirated Aircraft Engines.

CRC Draft Knock Rating Technique.

FAA Advisory Circular 20-24B, Qualification of Fuels, Lubricants, and Additives for Aircraft Engines.

Note: Copies of the material safety data sheets (MSDS) for any test fuel have been circulated to the immediate parties directly involved in the unleaded aviation gasoline testing. Handling of the test fuel will follow the same precautions as are currently taken when handling 100 low-lead (100LL) avgas.

FAA Advisory Circular 33-47, Detonation Testing in Reciprocating Aircraft Engines.

Paulius Puzinauskus, SuperFlow Corp., "Examinations of Methods Used to Characterize Engine Knock," SAE Paper 920808, 1992.

1.2 DISCUSSION.

Several engines, such as a Continental IO-550-D, a Lycoming IO-540-K, a Lycoming IO-320-B, a Lycoming TIO-540-J, and a Continental TSIO-550-E, were prepared and tested. Both the TSIO-550-E and the TIO-540-J engines were octane rated at three separate maximum power configurations. The TIO-540-J was rated at the normal rated power of 350 brake horsepower (BHP) and at derated power configurations of 325 BHP and 310 BHP. The deration was completed by adjusting the density controller so as to attain the limiting manifold absolute pressure (MAP) at full throttle and maximum rpm with 60°F induction and cooling air temperatures. The TSIO-550-E engine was rated at the normal rated power of 350 BHP and at the derated power configurations of 325 BHP and 310 BHP. For the TSIO-550-E engine, the deration was performed by adjusting the sloped controller with 60°F induction and cooling air temperatures to attain the desired MAP.

In both of these cases, the full-rich mixture fuel flow was adjusted to attain the desired Brake Specific Fuel Consumption (BSFC), as indicated in the engine manufacturer's specifications. This fuel flow was adjusted to fall on the lean side of the BHP versus MAP curve. All lean percentages are calculated from this full-rich fuel flow.

All of the engines were broken in using multiviscosity mineral oil and operated only on unleaded, nonmetallic fuels. An eddy-current dynamometer was used for power absorption and only the accessories required to run the engine were installed.

Typically, oil consumption tests are first performed using isooctane as the operating fuel. After the oil consumption stabilizes, power baselines are performed. These baselines encompass a combination of manifold absolute pressure (MAP) settings and engine rpm settings over a practical operating envelope in set increments. The results from the baselines verify the health of the engine. A MAP setting is chosen and the engine power data are collected for each subsequent engine rpm setting. The MAP is then changed and the process repeated until the engine power production data have been collected for all combinations of MAP and revolutions per minute (rpm).

After the baselines, the cylinder assemblies are removed, drilled, and tapped in the fin area for the installation of a high-temperature, water-cooled, piezoelectric pressure transducer (see figure 1). One transducer is installed in the cylinder head of each cylinder. The optimum installation is to have the transducer face as flush with the cylinder cavity as possible. An angled or recessed installation may produce undesirable acoustic effects. It is also advisable that the opening of the drilled port be free of sharp edges and discontinuities to prevent the creation of an ignition source. The transducers are then connected to charge-to-voltage amplifiers and subsequently to a data acquisition system.

Analog pressure signals are then digitized at the rate of at least one data point for every 0.4 degree of crank rotation for each transducer. Engine parameter data are recorded at a rate of one full channel scan every 10 seconds. Examples of these parameters include cylinder head temperatures, exhaust gas temperatures, cooling air temperature, oil temperature, oil pressure, fuel metered and unmetered pressures, fuel flow rate, engine rpm, engine shaft torque, manifold absolute pressure, turbine inlet temperature, manifold temperature, induction air temperature, induction air relative humidity, and induction air pressure. Sensors used to measure these parameters are installed at the manufacturer's recommended locations whenever possible.

All sensors are calibrated to within 2% accuracy of full scale. The engine speed measurement must be accurate to within 5 rpm. The MAP must be accurate to within 2.5 mm Hg (0.1 in Hg). Also, the mixture cut-off and full-rich settings and the throttle stop and throw positions are checked.

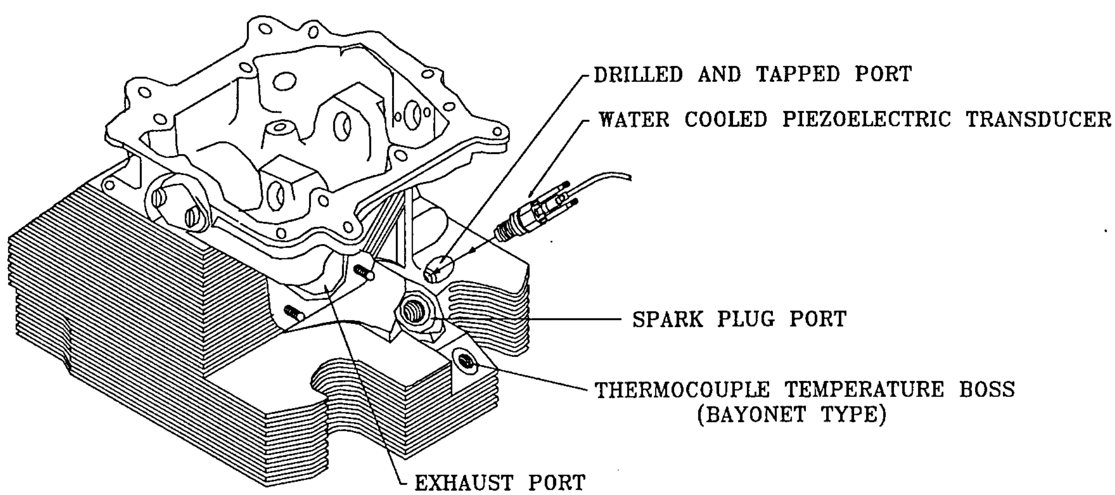

FIGURE 1. TYPICAL CYLINDER HEAD SHOWING THE FLUSH-MOUNTED TRANSDUCER INSTALLATION

The fuel system has the capability of switching between multiple fuel sources. One source contains the house fuel, and the other sources contain ASTM primary reference fuels of various MON and blends of reference grade ASTM specification isooctane with various weight percentages of Meta-Toluidine. These latter fuels were developed by the CRC to address motor octane numbers greater than 100. However these fuels will be named as AN numbers rather than MON, where 103 AN represents a reference fuel blend of isooctane and 3 weight % Meta-Toluidine. This was done to avoid using lead in the test engines thus avoiding the possibility of skewing the octane rating results. The AN number is not equivalent to a MON.

The integrity of the fuel system is checked prior to each run to ensure that cross contamination does not occur.

Typically, power settings representing the typical operating envelope are selected for testing. These points usually involve the wide-open throttle and maximum rpm setting, the maximum continuous power setting if different, a high manifold pressure climb power setting, and a high manifold pressure cruise power setting. The wide-open throttle and maximum rpm power, maximum continuous power, and climb power settings are all performed with the mixture at the full-rich position. The full-rich mixture fuel flow is set within the recommended fuel flow range as specified in the engine manufacturer's operator's manual. The cruise power setting is tested at the full-rich mixture configuration and at lean configurations ranging from full rich to peak EGT.

The test begins with starting the engine on house fuel and allowing time for warm-up. All instrumentation indications are checked to ensure they are within proper range and an ignition system check is conducted. Engine parameter settings listed in table 1 are maintained throughout the octane rating. Provided that knock does not develop, typically the power settings are adjusted on the house fuel (isooctane) and then the reference fuel is selected.

The test sequence should begin with an unleaded primary reference fuel of 100 MON. After selecting or changing a reference fuel, or changing the engine power setting, conditions must be allowed to stabilize. Enough time should be given to allow for the selected fuel to reach the engine and for cylinder head temperatures to stabilize. In situations where the engine rapidly enters into knock, the cylinder head temperatures (CHT's) will also rise rapidly and conditions may become unstable. In this situation, data should be collected as rapidly as possible and the engine power should be reduced to minimize damage to the engine.

TABLE 1. PARAMETER SETTINGS FOR OCTANE RATINGS

Parameter	Limit
Maximum Cylinder Head Temperature	Within 10°F of maximum recommended by manufacturer
All Other Cylinder Head Temperatures	Within 50°F of maximum cylinder head temperature
Induction Air Temperature	Within 4°F of 103°F
Induction Air Relative Humidity	Less than 30%
Oil Temperature	Within 10°F of engine manufacturer's recommended maximum

After switching to the rating fuel and the engine becomes stable, knock data are collected, and the presence and the severity of the knock (no, light, moderate, or heavy) are determined. The test engine is kept from operating under heavy knock for extended periods of time.

If knock occurred, the house fuel is selected and wide-open throttle and maximum rpm condition is retested with a higher-octane reference fuel than that on which it previously knocked. If knock did not occur, the house fuel is selected and the power on the test engine is set to the recommended climb power setting, or maximum continuous power setting, if appropriate. The mixture is maintained at the full-rich setting. The reference fuel is selected, knock data are recorded and the presence and severity of knock are again determined. If knock occurred at the climb power setting, the house fuel is selected and the climb power setting is retested with a higher-octane reference fuel. If knock is not detected, the house fuel is selected and the test engine is set to the cruise setting where the mixture can be leaned. The mixture is left at the full-rich position. The primary reference fuel is selected, and conditions are allowed to stabilize. Knock data are recorded. If knock is detected, the house fuel is selected and the cruise power setting is retested with a higher-octane reference fuel.

If knock is not detected while operating on the specific reference fuel, a 5% lean condition is then tested. Leaning is performed from the full-rich reading at the cruise power setting. Conditions are allowed to stabilize after adjusting the mixture. Knock data are then recorded. If knock is detected, the house fuel is selected and the cruise setting with a 5% lean mixture setting is retested using a higher octane reference fuel. If knock is not detected, the mixture is leaned by the 5% increment previously determined. This 5% increment leaning is continued until either knock is detected or peak EGT is eclipsed. After each leaning the engine is allowed to stabilize and knock data are recorded. If knock is detected, the house fuel is selected and the last power setting and lean condition is retried with a higher-octane reference fuel.

If knock is not detected, then lower MON fuel is tested at each power setting, if it hasn't been already. If a reference fuel of lower MON has already been found to produce knock at any power setting, then the minimum motor octane requirement is the MON of the last reference fuel tested. For example, if 99 MON is found to be knock free for all points and the engine knocked on 98 MON at the maximum power condition, then the engine is rated at 99 MON. Provided enough reference fuel is available, each power setting will be octane rated. This will provide valuable information concerning the possible deration of power to lower the motor octane requirement.

At the conclusion of the test, gradually reduce the power setting to allow the engine to cool. After shutdown, make sure the fuel selector valve does not leak. If the valve leaks, repair the valve and repeat the test to ensure the reference fuels were not contaminated.

Posttest processing of the knock data involves quantifying the knock level of each individual engine cycle collected for each power setting tested. The results from this postprocessing are used to determine the knock level of each power setting for a given MON. Typically the severity of any one knock event combined with the frequency of knocking cycles determines the severity of knock for that condition.

All knock ratings were performed with the use of either ASTM primary reference fuels or ASTM reference grade isooctane containing various weight percentages of Meta-Toluidine. Various ASTM reference fuels of 100 MON and below are made with the use of blends of reference grade isooctane and n-heptane with the MON of the blend being equal to the volume percent of isooctane in the blend. The MON of the blends is confirmed by ASTM standard D 2700.

1.3 ANALYSES.

Power baseline tests for the engines included in this report verified that the piezoelectric pressure transducer installations had negligible affect on cylinder integrity.

It was found, however, for the Lycoming IO-320 engine that the highest output power obtained was 147 BHP, corrected for standard day conditions. This output power was the same before the transducer installation as it was after the installation.

Various tables are presented which illustrate the octane requirements of the engines tested. Power settings listed in the first columns of the tables represent target settings of MAP, rpm, and BHP. Obviously, due to natural variations in barometer and slight fluctuations in rpm, the actual BHP and MAP varied slightly from these targets. For the power settings tested, takeoff (TO) power represented maximum allowed crankshaft rpm and wide-open throttle condition. For the climb point, typically 85% of the normal rated power (NRP) corrected for standard day barometer was utilized. A combination of high manifold absolute pressure and rpm that match this power was chosen. For the cruise point, 75% of the NRP was chosen. The combinations for both the cruise and climb points were chosen from power curves as found in the engine manufacturer's specifications. Typically, a combination of higher manifold pressure with a lower rpm will result in more severe knock conditions than a slightly higher rpm with lower MAP.

It is important to note that all lean conditions represent percentage reductions in fuel flow from the full-rich mixture position while operating on the particular rating fuel. For example, to test the cruise position at 5% lean condition on 98 MON reference fuel, it would require determining the full-rich fuel flow rate while operating on 98 MON reference fuel at the cruise position and then adjusting the mixture to reduce the fuel flow rate by 5%.

All of the engine operations were performed with unleaded fuels. The desire was to avoid the possibility of skewing the knock results due to either cylinder lead deposits or fuel system lead scavenging. The goal was to determine the minimum octane requirement of the engines without the introduction of additional variables into the rating process. Thus, 100 MON was the highest ASTM primary reference fuel that could be used as higher numbers would require the addition of lead. However, the CRC participating petroleum companies agreed to using various weight percentages of the amine Meta-Toluidine in reference grade isooctane to obtain higher than 100 MON rating fuels. Engines not satisfied with ASTM reference grade isooctane will be tested with these blends. These blends will be reported in AN numbers. For example 103 AN refers to reference grade isooctane containing 3 weight percent Meta-Toluidine.

Found in appendix A is the averaged data values for engine parameters either directly acquired or calculated. Many of the octane ratings required more than one test to fully map the engine; however, all of the engine parameter data that corresponds with the knock results found in this section can be found in the appendix.

Table 2 lists the rated power and compression ratio of each of the engines tested. Typically, for a given power output, the higher the compression ratio the higher the motor octane requirement due to higher cylinder Brake Mean Effective Pressures (BMEP). The 'IO' in the engine model description refers to fuel injection and opposed cylinder, the 'T' refers to turbocharged, and the numerical value of the model description refers to the cubic inch cylinder displacement. All of those listed are 6-cylinder engines except for the IO-320 which is a 4-cylinder engine.

TABLE 2. NORMAL RATED POWER AND CYLINDER COMPRESSION RATIOS

Engine Make and Model	Normal Rated Power (BHP)	Compression Ratio
Lycoming IO-320-B	160	8.5
Lycoming IO-540-K	300	8.7
Continental IO-550-D	300	8.5
Continental TSIO-550-E	350	7.5
Lycoming TIO-540-J	350	7.3

Following is a series of tables detailing the knock results of the engine tests. Refer to the List of Definitions/Abbreviations/Symbols section at the beginning of this document for an explanation of table symbols.

Table 3 contains the octane rating results for the Lycoming IO-320-B engine. The data indicate that 91 MON satisfied all of the power settings including the lean conditions. The climb power setting was satisfied with 87 MON. The full-rich cruise power setting was satisfied with a MON of 81, with a light knock condition present on 80 MON. It appears however, that the 5% lean cruise point was satisfied with 80 MON. The engine data does not offer any simple explanations. These results do fall within repeatability and accuracy limits expected. Leaning to 10% lean of full rich resulted in a MON requirement of 85, 4 MON higher than required at the 5% lean condition. Further leaning to the 15% condition resulted in another 4 MON higher requirement as the 15% condition required 89 MON for knock-free operation. Best power was found to reside between 15% and 17% lean of full rich. Leaning past best power to 20% lean resulted in a MON of 85 for knock-free operation, a drop of 4 MON requirement from the 15% lean condition. There does not appear to be any obvious explanation for this anomaly. It is also interesting to point out that for this engine, the maximum power condition with full-rich mixture required higher MON than the lean conditions.

Table 4 shows the power settings and knock results for the Continental IO-550-D engine. The table shows that for the full-rich mixture setting, at least light knock was detected on 100 MON at all of the power settings. As to be expected, the knock was lighter at the cruise and climb points than at the takeoff point. However, when leaning just 5% from the full-rich setting at the cruise configuration, the knock severity increased appreciably. The addition of 1 weight percent of Meta-Toluidine appeared to quench the development of knock at the maximum power condition. Leaning at the cruise configuration required at least one additional weight percent of Meta-Toluidine to suppress knock for each 5% decrease in fuel flow. The addition of at least 3 weight percent was required at the lean to best cruise power configuration to avoid knock development.

TABLE 3. OCTANE RATING RESULTS FOR THE LYCOMING IO-320-B ENGINE

Power Setting	Reference Fuel (MON)								
	91	89	88	87	86	85	83	81	80
TO (2700 rpm, Full Trottle, Full Rich)	No	Mk							
Climb (2600 rpm, 26.5 in Hg, F/R)				No	Mk	Mk			
Cruise (2500 rpm, 25 in Hg, F/R)								No	Mk
Cruise (2500 rpm, 25 in Hg, 5% lean)									No
Cruise (2500 rpm, 25 in Hg, 10% lean)						No	Mk	Hk	Hk
Cruise (2500 rpm, 25 in Hg, 15% lean)		No	Lk	Lk					
Cruise (2500 rpm, 25 in Hg, 20% lean)						No	Hk		

Lk-light knock
Mk-moderate knock
No-no knock

TABLE 4. OCTANE RATING RESULTS FOR THE CONTINENTAL IO-550-D ENGINE

Power Setting	Reference Fuel				
	104 AN	103 AN	102 AN	101 AN	100 MON
TO (2700 rpm, Full Trottle, Full Rich)				No	Mk
Climb (85% NRP, 2620 rpm, F/R)					Lk
Cruise (2500 rpm, 25 in Hg, F/R)					Lk
Cruise (2500 rpm, 25 in Hg, 5% lean)				Lk	Mk
Cruise (2500 rpm, 25 in Hg, 10% lean)		No	Lk	Lk	
Cruise (2500 rpm, 25 in Hg, 15% lean)		Lk	Lk		
Cruise (2500 rpm, 25 in Hg, LBP)	No	Lk	Lk		

LBP-lean to best power

Table 5 shows the data for the IO-540-K engine. At first glance, the takeoff power requirement of 105 AN seems to be askew when compared to that of the IO-550-D engine in table 4. However, several factors could have attributed to this. The IO-540-K engine has a slightly higher compression ratio, a lower BSFC at the maximum power condition, and a 15°F higher maximum allowed cylinder head temperature than for the IO-550-D. Leaning the engine to 10% lean of full rich drove the octane requirement at the cruise position from 103 AN to 106 AN, which was higher than the maximum power octane requirement. It is interesting to note that the 10% lean point fell slightly lean of best power.

Tables 6 through 8 detail the octane rating results for the Lycoming TIO-540 engine at various maximum horsepower configurations. The comparison of these settings can be found in table 9. The TIO-540-J2BD engine was first rated at its certified power of 350 BHP. The density controller was then adjusted to obtain the maximum takeoff power of 325 BHP (F model). The fuel flow schedule was set to match the BHP versus fuel flow curves for the F model. All adjustments were made while the engine was operating with 60°F induction and cooling air temperature. Consideration was also taken to ensure that the limiting manifold pressure was not eclipsed for each model. The engine was then rated again. Further adjustment to the 310 BHP maximum rated power (A model) was then completed using the same procedures. The engine was again rated. The purpose was to determine the effect of derating the maximum power on the minimum octane requirement.

TABLE 5. OCTANE RATING RESULTS FOR THE LYCOMING IO-540-K ENGINE

Power Setting	Reference Fuel (AN)					
	106	105	104	103	102	101
TO (2700 rpm, FT, F/R)		No	Lk	Lk		
Climb (85% NRP; 2600 rpm, F/R)			No	Lk	Hk	
Cruise (75% NRP; 2450 rpm, F/R)				No	Lk	Lk
Cruise (75% NRP; 2450 rpm, 5% lean)			No	Lk	Lk	Mk
Cruise (75% NRP; 2450 rpm, 10% lean)	No	Lk	Lk			

Table 6 shows that for the 350 horsepower configuration the requirement was greater than 100 MON, even at the full-rich setting. A MON of 99 produced knock-free operation at the cruise setting with full-rich mixture; however, leaning to best power or peak EGT at this configuration resulted in a heavy knock condition while operating on 100 MON. It is also interesting that the lower rpm cruise for the same manifold pressure as the climb power resulted in a higher octane requirement.

TABLE 6. OCTANE RATING RESULTS FOR THE LYCOMING TIO-540 ENGINE, 350-BHP CONFIGURATION

Power Setting	Reference Fuel (MON)		
	100	99	98
TO (2575 rpm, FT, F/R)	Hk		Hk
Climb (2400 rpm, 40 in Hg, F/R)			No
Climb (2400 rpm, 40 in Hg, LBP)	Hk		
Cruise (2200 rpm, 40 in Hg, F/R)		No	Mk
Cruise (2200 rpm, 40 in Hg, LBP)	Hk	Hk	
Cruise (2200 rpm, 40 in Hg, LPE)	Hk		

LPE-lean to Peak Exhaust Gas Temperature

For the 325 horsepower configuration (see table 7), the engine was satisfied with 99 MON at all of the full-rich mixture settings. Knock-free operation was attained with 97 MON at the cruise power setting with full-rich mixture. Leaning to best power at this setting resulted in an increase in MON requirement of at least 4 MON.

TABLE 7. OCTANE RATING RESULTS FOR THE LYCOMING TIO-540 ENGINE, 325-BHP CONFIGURATION

Power Setting	Reference Fuel (MON)			
	100	99	98	97
TO (2575 rpm, FT, F/R)	No	No	Mk	Hk
Climb (2400 rpm, 40 in Hg, F/R)	No	No	No	No
Climb (2400 rpm, 40 in Hg, LBP)	Hk		Hk	
Cruise (2200 rpm, 40 in Hg, F/R)	No	No	No	No
Cruise (2200 rpm, 40 in Hg, LBP)	Hk		Hk	

For the 310 horsepower configuration (see table 8), the engine experienced light knock on 97 MON and was knock-free on 99 MON at the takeoff power setting. There was not enough of the 98 MON blend remaining to test the maximum power condition. The engine was knock-free on 97 MON at both the climb and cruise power settings. Leaning to best power at both the climb and cruise power settings resulted in a need for greater than 100 MON for knock-free operation. The manifold pressure was reduced by 5 in Hg increments to 30 in Hg at the climb power setting and the mixture was again adjusted to obtain best power. The engine still required greater than 100 MON for knock-free operation. Likewise the manifold absolute pressure was reduced from 40 in Hg to 30 in Hg at the cruise power setting and the mixture was again adjusted to obtain best power and the engine still required greater than 100 MON.

TABLE 8. OCTANE RATING RESULTS FOR THE LYCOMING TIO-540 ENGINE, 310-BHP CONFIGURATION

Power Setting	Reference Fuel (MON)			
	100	99	98	97
TO (2575 rpm, FT, F/R)	No	No		Lk
Climb (2400 rpm, 40 in Hg, F/R)	No	No		No
Climb (2400 rpm, 40 in Hg, LBP)	Hk			
Climb (2400 rpm, 35 in Hg, LBP)	Mk			
Climb (2400 rpm, 30 in Hg, LBP)	Lk			
Cruise (2200 rpm, 40 in Hg, F/R)	No	No	No	No
Cruise (2200 rpm, 40 in Hg, LBP)	Hk			
Cruise (2200 rpm, 30 in Hg, LBP)	Mk			

The summary results for the three separate maximum power configurations for the TIO-540 engine are listed in table 9. Decreasing the maximum horsepower from 350 to 325 resulted in at least a 2 MON reduction in requirement for the maximum power condition. Further reduction of the maximum power to 310 BHP resulted in an additional drop of 1 MON requirement. In all cases, leaning to best power at climb and cruise settings required greater than 100 MON for knock-free operation.

TABLE 9. SUMMARY OF OCTANE RATING RESULTS FOR THE LYCOMING TIO-540 ENGINE

Power Settings	Power Configuration		
	350 BHP	325 BHP	310 BHP
TO (FT, 2575 rpm, F/R)	100+	99	98
Climb (40 in Hg, 2400 rpm, F/R)	98-	97-	97-
Climb (40 in Hg, 2400 rpm, LBP)	100+	100+	100+
Climb (35 in Hg, 2400 rpm, LBP)	100+		100+
Climb (30 in Hg, 2400 rpm, LBP)			100+
Cruise (40 in Hg, 2400 rpm, F/R)	99	97-	97-
Cruise (40 in Hg, 2400 rpm, LBP)	100+	100+	100+
Cruise (35 in Hg, 2400 rpm, LBP)	100+		
Cruise (30 in Hg, 2400 rpm, LBP)			100+

Tables 10 through 12 show the results for the Continental TSIO-550 engine configured for 350 (E model), 325, and 310 (C model) BHP respectively. For the 350-BHP configuration (E model), the sloped controller was adjusted to the respective limiting absolute manifold pressure for this model. The fuel flow was set from the fuel flow versus brake horsepower curves found in the maintenance and engine operator's manual. Further adjustments were made to ensure that the resulting BSFC was in close proximity to the value given in the rpm versus BSFC curves and that the maximum BHP was at least that specified for the model. All of the above adjustments were made with 60°F induction and cooling air temperatures. Similar adjustments were performed for the other two model configurations.

A summary comparison of the ratings at the three separate power settings can be seen in table 13. It should also be noted that the limiting rpm and limiting MAP differed for each of the three model configurations for the TSIO-550 engine.

TABLE 10. OCTANE RATING RESULTS FOR THE CONTINENTAL TSIO-550-E ENGINE, 350-BHP CONFIGURATION

Power Setting	Reference Fuel (MON)					
	100	99	98	97	96	95
TO (2700 rpm, FT, F/R)	Lk	Mk				
Climb (2500 rpm, 36.0 in Hg, F/R)			No	Lk		
Cruise (2500 rpm, 32.3 in Hg, F/R)				No	Lk	Mk
Cruise (2500 rpm, 32.3 in Hg, 5% lean)			No	Lk		
Cruise (2500 rpm, 32.3 in Hg, 10% lean)	Lk					
Cruise (2500 rpm, 32.3 in Hg, 15% lean)	Mk					

TABLE 11. OCTANE RATING RESULTS FOR THE CONTINENTAL TSIO-550-E ENGINE, 325-BHP CONFIGURATION

Power Setting	Reference Fuel (MON)					
	100	99	98	97	96	95
TO (2600 rpm, FT, F/R)			No	Lk	Mk	
Climb (2500 rpm, 32.0 in Hg, F/R)				No	No	Hk
Cruise (2500 rpm, 28.5 in Hg, F/R)					No	No
Cruise (2500 rpm, 28.5 in Hg, 5% lean)					No	Mk
Cruise (2500 rpm, 28.5 in Hg, 10% lean)					Lk	
Cruise (2500 rpm, 28.5 in Hg, 15% lean)			No	Lk	Lk	
Cruise (2500 rpm, 28.5 in Hg, 20% lean)	Lk	Lk				
Cruise (2500 rpm, 28.5 in Hg, 25% lean)	Lk					

TABLE 12. OCTANE RATING RESULTS FOR THE CONTINENTAL TSIO-550-E ENGINE, 310-BHP CONFIGURATION

Power Setting	Reference Fuel (MON)					
	100	99	98	97	96	93
TO (2600 rpm, FT, F/R)			No	No	Lk	
Climb (2500 rpm, 31 in Hg, F/R)			No			No
Cruise (2500 rpm, 28 in Hg, F/R)			No			No
Cruise (2500 rpm, 28 in Hg, 5% lean)			No			
Cruise (2500 rpm, 28 in Hg, 10% lean)			No			
Cruise (2500 rpm, 28 in Hg, 15% lean)			No			
Cruise (2500 rpm, 28 in Hg, 20% lean)			No			
Cruise (2500 rpm, 28 in Hg, 25% lean)		No	Lk			
Cruise (2500 rpm, 28 in Hg, 30% lean)	Lk					
Cruise (2500 rpm, 28 in Hg, 35% lean)	Lk					

For the 350-BHP configuration, operation at the takeoff power setting, even at full-rich mixture condition, resulted in a light-knock condition with 100 MON reference fuel. Subsequent leaning to 10% or greater at the cruise configuration also required greater than 100 MON. Leaning from the full-rich cruise configuration by 5% resulted in a 1 MON increase in requirement while leaning to 10% resulted in at least an additional 3 MON requirement.

Derating the maximum power to 325-BHP decreased the MON requirement to 98 for the takeoff power setting. At the cruise configuration the engine was knock-free to a mixture setting of 15% lean on 98 MON. Further leaning to 20% lean at the cruise setting resulted in a greater than 100 MON requirement.

The engine was further derated to 310-BHP, as shown in table 12. At maximum power 97 MON satisfied the full-rich condition. At the cruise power setting, 99 MON satisfied the engine to the 25% lean configuration. However, continued leaning required greater than 100 MON.

The summary for the three separate maximum power configurations is illustrated in table 13. The table shows that a 25-BHP reduction in maximum power from 350 BHP results in at least a 2 MON drop in requirement. A 40-BHP reduction in maximum power resulted in a requirement drop of at least 3 MON. The full-rich climb and cruise conditions showed a much more dramatic response to rated power reduction.

TABLE 13. SUMMARY OF OCTANE RATING RESULTS FOR THE CONTINENTAL TSIO-550-E ENGINE

Power Setting	Maximum Power Configuration		
	350 HP	325 HP	310 HP
TO (F/R)	100+	98	97
Climb (F/R)	98	96	93-
Cruise (F/R)	97	95-	93-
Cruise (5% lean)	98	96	98-
Cruise (10% lean)	100+	96+	98-
Cruise (15% lean)		98	98-
Cruise (20% lean)		100+	98-
Cruise (25% lean)			99
Cruise (30% lean)			100+

2. PHASE 2: IN-FLIGHT INVESTIGATION.

2.1 INTRODUCTION.

2.1.1 Purpose.

In-flight octane rating results using ASTM primary reference fuels are to be compared to those of severe ground-based testing to determine the effectiveness of approximating worse-case conditions at sea level compared to actual in-flight conditions. The results from the knock tests, hot-fuel tests, in-flight engine restarts, and endurance tests address the usability of the unleaded fuels.

2.1.2 Background.

2.1.2.1 Test Fuel.

Test fuels include an unleaded aviation alkylate with 30% methyl tertiary butyl ether (MTBE) by volume and various ASTM primary reference fuels. These reference fuels consist of various amounts of isooctane and n-heptane as per the desired motor octane number (MON), with the volume percent of isooctane in the blend equaling the MON. The test fuel does not contain tetraethyl lead, ethylene dibromide, any metallic additives, nor any dyes. Each blend/batch of the aviation alkylate containing the MTBE has been tested in accordance with the procedures outlined in ASTM Standard D 4814 prior to shipping. Data on the MON of the MTBE containing test fuel was supplied and performed by ASTM Standard D 2700. Also required is the data on the energy density of the fuel. All documentation is kept on file for each fuel blend which allows for the traceability of the fuel.

Any opened drums which contain fuel are sealed and locked in a storage facility. Unless otherwise directed, any resealed drums are used first for the next servicing of the aircraft with test fuel. This is not the case when conducting either hot-fuel or detonation testing.

2.1.2.2 Test Engine.

An overhauled Lycoming GSO-480-B1A6 engine was built up and broken in under ground-based test cell operation and replaced a similar engine on an Aerocommander 680-E test aircraft (N-50). The break-in procedure followed the engine manufacturer's recommendations and was performed using unleaded fuels. All components of the test aircraft fuel and oil systems for the number two engine which may have been contaminated with lead build-up were replaced with new components.

Prior to installation of the engine on the airframe and after break-in on unleaded fuels, initial valve stem wear measurements were taken. Following the break-in, an initial octane requirement was performed using ASTM primary reference fuels.

The flight tests addressed issues such as hot-fuel, detonation testing, in-flight engine restarts at critical altitude, and endurance performance. Hot-fuel testing addressed volatility concerns with the use of the oxygenated test fuel. In-flight octane rating results are compared to those from the ground-based ratings to determine whether ground-based testing adequately approximates the severity of in-flight testing.

At the start of the flight testing the test engine had a total of 25 run hours of ground-based operation. Out of this time 6.5 run hours was for break-in, and 5 hours consisted of detonation testing. The rest of the hours consisted of either maintenance runs or operational check runs.

Standard maintenance manual procedures were used to set up mixture controls, throttle controls, and engine parameter ranges including pressure settings, magneto timing, engine starts, and system checks. The unleaded avgas group adjusted the carburetor to operate lean prior to any testing. Any adjustments were made such that the carburetor operates within limits specified by the manufacturer. This carburetor contains a self-leaning mixture; therefore the mixture is not manually leaned during engine operation.

2.1.2.3 Test Aircraft.

The fuel and oil systems were modified to ensure that the research and development engine did not ingest leaded test fuels. Modifications were also performed on the fuel vent system, fuel return system, and selector valve so as to prevent any unintentional cross contamination. This involved configuring the two auxiliary fuel bladders to handle unleaded test fuels only and configuring the system so the main bladder only held 100LL avgas for the critical engine.

Upon completion of the fuel system modifications, the fuel system supplying the test engine was flushed with test fuel. After flushing, the left and right auxiliary tanks were filled with test fuel and allowed to sit overnight. A fuel sample was taken from the auxiliary tanks and analyzed for lead content.

The right-side oil tank was flushed prior to installing the test engine on the airframe.

All original baffling was utilized so as to maintain proper engine cooling distribution and cowling pressure.

2.1.2.4 Operating Limitations.

All flights were conducted in accordance with applicable rules of FAR 91. The aircraft test engine records reflect the experimental run time on unleaded test fuel and standard octane rating reference fuels.

2.1.3 Related Documents.

ASTM D 2700, Standard Test Method for Knock Characteristics of Motor and Aviation Fuels by the Motor Method.

ASTM D 811, Chemical Analysis for Metals in New and Used Lubricating Oils.

ASTM D 323, Vapor Pressure of Petroleum Products (Reid Method).

ASTM D 873, Oxidation Stability of Aviation Fuels (Potential Residue Method).

ASTM D 910, Standard Specification for Aviation Gasoline.

ASTM D 4814, Standard Specification for Automotive Spark Ignition Engine Fuel.

ASTM Standard Practice for Octane Rating Normally Aspirated Aircraft Engines.

CRC Draft Knock Rating Technique.

FAA Advisory Circular 33-47, Detonation Testing in Reciprocating Aircraft Engines.

FAA Advisory Circular 20-24B, Qualification of Fuels, Lubricants, and Additives for Aircraft Engines.

FAA Advisory Circular 23.961, Procedures for Conducting Fuel System Hot-Weather Operation Tests.

FAR Part 33, Airworthiness Standards: Aircraft Engines.

FAR Part 91, Air Traffic and General Operating Rules.

Paulius Puzinauskus, SuperFlow Corp., "Examinations of Methods Used to Characterize Engine Knock," SAE Paper 920808, 1992.

2.2 DISCUSSION.

Flight testing includes octane ratings, in-flight engine restarts, hot-fuel, and endurance performance. The total flight time consists of at least 250 hours accrued in the following minimum block hour designations: 2.5 hours at takeoff power, 10 hours at maximum continuous power, 225 hours at cruise power, and 12.5 hours at idle. This is one-half the number of hours per block hour designation as suggested in Advisory Circular 20-24B.

Table 14 gives the engine power settings used throughout the various flight tests unless specifically stated otherwise.

TABLE 14. POWER SETTINGS, FUEL CONSUMPTION, AND CRITICAL ALTITUDES FOR THE LYCOMING GSO-480-B1A6 ENGINE

Power Setting	Engine Speed rpm	Manifold Absolute Pressure mm Hg [in Hg]	Average Fuel Consumption* L/Hr [Gal/Hr]	Approximate Critical Altitude M [Ft]
Warm-Up	1100	510 [20]	38 [10]	N/A
Ignition Systems Ground Check	2400	530 [21]	45 [12]	N/A
Takeoff	3400	1220 [48]	197 [52]	1830 [6000]
Maximum Continuous (rated power)	3200	1140 [45]	174 [46]	2440 [8000]
Climb (85% rated power)	3000	990 [39]	136 [36]	3050 [10000]
Cruise (75% rated power)	2750	914 [36]	83 [22]	3660 [12000]
Performance Cruise (65% rated power)	2600	890 [35]	68 [18]	4500 [14800]
Approach/Descent	2500	760 [20]	45 [12]	N/A

* at sea level

All climb rates are derived from the Aircraft Flight Manual and are based on a 38°C (100°F) day, 3400-kg (7500-lbs) gross aircraft weight, flaps down 1/4, gear up, and a calibrated airspeed of 193 km/hr (104 KCAS). Climb rate variation with altitude is taken into consideration when calculating fuel consumption and time required to attain altitude. For altitudes below 2440 m (8000 ft), the aircraft typically climbs with both engines set at maximum continuous power. For altitudes above 2440 m (8000 ft) the aircraft climbs with both engines set at climb power.

All descent rates are based on a minimum descent of 150 m/min (500 ft/min). The power setting for the approach/descent is 510 mm Hg (20 in Hg) MAP and 2500 rpm in order to prevent rapid cooling of the engines.

In determining critical altitude the power setting is set and the pilot advances the throttle while climbing until the desired MAP can no longer be maintained. The aircraft levels off at this point and the data point begins.

The total fuel capacity of the auxiliary tank modification allows for 254 liters (67 gallons) of usable test fuel. A ½-hour flight safety margin reduces the total usable test fuel quantity to 201 liters (53 gallons, 26.5 gallons/auxiliary tank). The ½-hour fuel reserve is calculated considering a 12-minute 75 percent rated power setting, a 12-minute cruise power setting, and a 6-minute approach/landing.

The critical engine always operates on 100LL throughout the full series of tests. Any fuel selector switching described herein refers to the fuel supply system for the test engine and does not affect the critical engine.

Prior to any flight test, the pilot conducts a normal preflight inspection and the fuel and oil quantities are checked. A fuel sample is drawn from the main and auxiliary tanks into a clear container. The sample is inspected for water/debris contamination. Fuel/oil consumption and inspection results are recorded.

Following are procedures that are based on the Advisory Circulars for each particular test.

2.2.1 Endurance Testing/General Maintenance/Scheduled Inspections.

Endurance tests are performed to monitor for any unusual wear characteristics. Prior to flight testing the engine had 25 hours of test cell operation.

The total number of hours generated from any knock testing, hot-fuel testing, and in-flight engine restarts are applied to the desired total number of hours detailed in the discussion section. The particular power settings and hour requirements are determined by the power settings and hours accrued on the test engine due to previous flight tests. This requires approximately 175 series of tests.

Tables 15 and 16 show the endurance test sequence and the corresponding total amount of flight time accrued. This sequence and total time accrued are based on the completion of the previously mentioned testing using their respective test sequences. The total amount of fuel used at the completion of the flight testing is approximately 22460 liters (5940 gal).

The procedures are as follows. The pilot conducts a warm-up and ignition system grounding check. Once minimum operating temperatures are attained, the pilot conducts a takeoff for approximately 40 seconds with an initial climb rate of at least 400 m/min (1310 ft/min.). The

TABLE 15. POWER SETTINGS, MAXIMUM TIME PER POINT, AND FUEL USAGE FOR ENDURANCE TESTING

Power Setting	Time minutes	Fuel Use liters [gal]	Time for 175 Tests hours	Fuel Use for 175 Tests liters [gal]
Idle/Warm-up	10.0	6.4 [1.7]	29.2	1104.0 [292]
Ignition Systems Ground Check	5.0	3.8 [1.0]	14.6	661.7 [175]
Takeoff	40 sec	2.3 [0.6]	1.9	381.9 [101]
Max Cont. to 4000 ft.	3.2	9.1 [2.4]	9.2	1599.4 [423]
Cruise (65% rated power)	77.4	87.7 [23.2]	225.8	15366.0 [4064]
Descent/Approach/ Landing	12.0	9.1 [2.4]	35.0	1588.0 [420]
Idle/Shut Down	10.0	6.4 [1.7]	29.2	1104.0 [292]
Total	118.2	124.8 [33.0]	344.9	21805.0 [5761]

TABLE 16. ESTIMATED TOTAL FLIGHT TIME AFTER COMPLETION OF ALL TESTING

Setting	Total Time hours	Minimum Time Required hours	Remaining Time hours
Takeoff	2.5	2.5	0
Maximum Continuous	10.0	10.0	0
75 Percent Power	0.6	N / A	N / A
65 Percent Power	226.1	225.0	-1.1
Approach/Descent	38.6	N / A	N / A
Ignition System Ground Check	15.3	N / A	N / A
Idle/Warm-up	61.3	12.5	-48.8
Total	354.4	250.0	-49.9

pilot then reduces the power to maximum continuous and continues climbing to and levels off at an altitude of 1220 m (4000 ft). At this point the pilot sets both engines to 65 percent rated power and maintains a cruise setting for approximately 1.5 hours. Once the time has elapsed the pilot begins a descent, approach, and commences normal landing procedures.

The unleaded avgas program conducts preflight and postflight maintenance checks on the test engine that involve oil and fuel servicing and visual inspections. Any fuel servicing requires a fuel sample be taken from the auxiliary tanks. The sample is taken in a clear container and visually inspected for water and other contaminates. Observations are recorded.

The unleaded avgas program uses Aeroshell 15W-50 multiviscosity oil only in the test engine. Any servicing of the engine with oil is recorded.

Throughout the period of flight testing, scheduled inspections are critical to the safety of the mission. As specified in the aircraft maintenance manual, periodic inspections are strictly adhered to by the unleaded avgas program.

2.2.1.1 Fifty-Hour Inspections.

After every 50 hours of engine operation a scheduled inspection that includes the following is performed.

The carburetor air filter covers are removed to access the filtering elements. These items are inspected for deformed mesh, obstructed air passages, and foreign matter. Once inspected, they are cleaned with Varsol and allowed to dry thoroughly. They are then saturated with SAE 10 oil, allowed to drain, and then reinstalled.

The right main fuel strainer is inspected for evidence of corrosion, security, cleanliness, foreign material, and overall condition. The strainer is removed, cleaned, and reinstalled using new packing if necessary. Once reinstalled the system is pressurized and inspected for possible leaks.

The carburetor fuel inlet screen (finger screen) is removed, cleaned, reinstalled, and safety wired. The system is then pressure checked for evidence of leaks at the sealing gasket.

The engine cylinder assembly is inspected for evidence of overheating, leakage between exhaust ports and pipes, and warped exhaust port flanges. Baffling is inspected for condition and security.

The carburetor mixture control is inspected for freedom of movement, security, condition, lubrication, and clearance of carburetor web.

During this inspection, an oil sample is taken and analyzed. Oil analyses are performed to ASTM Standard D 811 specifications and include the range of tests therein.

The oil system is drained and engine sump plug removed. The oil pump scavenge screen is also removed and inspected for metal particles and contamination. The screen is then thoroughly cleaned, reinstalled, and safety wired. New gaskets are installed. The system is then serviced to the proper level with Aeroshell 15W-50 multiviscosity oil.

All fluid carrying lines are inspected for possible leaks or chafing. Electrical wiring is inspected for proper connections, security, and evidence of chafing as well.

The auxiliary fuel tanks are inspected for possible leaks. The modified fuel line interconnecting the right and left auxiliary tanks is inspected for security and evidence of chafing. The main and auxiliary fuel vent system are inspected as well.

Upon completion of the inspection, the engine cowling is reinstalled and a performance run-up completed. At this time, the engine is inspected for evidence of fuel/oil leaks and proper operation.

2.2.1.2 Special Twenty-Hour Inspections.

At 20-hour intervals of engine operation, a special inspection to monitor cylinder valve wear is performed. The cylinder baffling attached to the valve covers are removed to gain access to the valve stem heads. The valve covers and any valve cover gasket material are removed from the cylinder head. This ensures an accurate measuring surface is obtained. The rocker pin access covers located on the sides of the cylinders are removed, the pins pulled out, and the rocker arms taken away.

To ensure the valves are properly seated, a rubber mallet is used to carefully tap the valve stem heads. A special measurement plate is mounted to the cylinder head (see figure 2). This allows the ability to obtain the total valve train measurement through guide holes utilizing a depth gauge. The data are recorded as valve wear history.

A compression check is conducted to document the condition of the cylinder assembly. A run-up is performed and then the compression check is performed with the engine warm. It is then recorded and monitored in the log records.

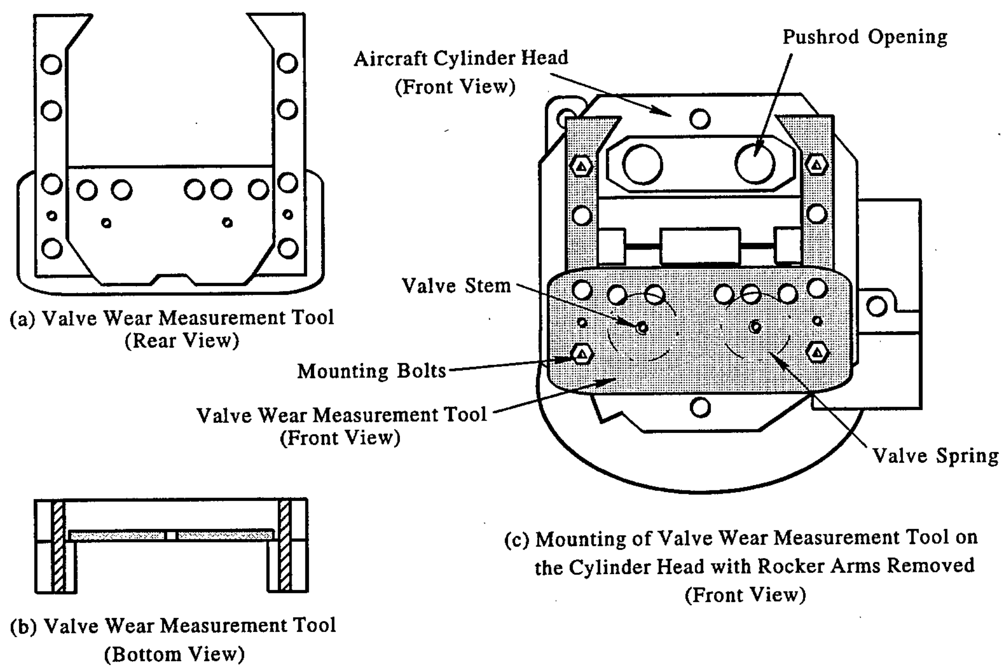

FIGURE 2. VALVE WEAR MEASUREMENT TOOL AND MOUNTING

Once the valve train measurements are recorded and the compression check completed, the rocker assembly is reinstalled. The valve covers are mounted to the cylinder heads and the baffling secured to the engine.

Upon completion of the inspection, the engine cowling is reinstalled and a performance run-up completed. At this time, the engine is inspected for evidence of oil leaks and proper operation.

2.2.2 Knock Testing.

Each cylinder has one extended-reach spark plug of the proper heat rating and associated piezoelectric washer sensor that connects to a charge amplifier. The amplified charge is then supplied to a high-speed data acquisition unit and recorded. Knock levels are distinguished post-test and correspond with any previous ground-based knock testing performed at the William J. Hughes Technical Center with the Lycoming GSO-480 engine so as to maintain data consistency.

The power settings and critical altitudes tested are takeoff, maximum continuous power, cruise, and performance cruise. These are the same power settings addressed in the test cell with the addition of a cruise point. Ground-based altitude simulation and sea level testing confirm that the test engine's minimum octane requirement is 99 MON when using standard reference fuels. The test engine was also found to be knock-free when operating on test fuel at sea level and simulated altitude conditions.

Detonation testing is conducted on a hot day unless time constraints dictate otherwise. Carburetor heat is used on the test engine to develop induction air temperatures for a standard hot day for the particular altitude. Carburetor heat for the critical engine is used at the pilot's discretion. All test fuel used for detonation testing is supplied from unopened barrels. Resealed drums are not used.

For knock testing with candidate test fuel, both auxiliary tanks are serviced with the test fuel. Testing is performed while waiting for motor octane test results, performed to ASTM Standard D 2700 specifications.

The procedures are as follows. The test engine is started, with the selector switch for the right engine on the right auxiliary tank, allowed to warm-up, and an ignition system grounding check is performed. The critical engine is started and the same operational check procedures are followed.

Once the operational checks are performed, takeoff power is set on both engines for the time required to takeoff and climb to 15 m (50 ft). This takes roughly 25 seconds. A suggested time of 15 minutes is allotted for warm-up, ignition check, and takeoff. Normal pilot operations are followed.

After takeoff, the power settings for both engines are reduced to maximum continuous power and the aircraft is set for an initial climb rate of at least 400 m/min (1310 ft/min.). While climbing through 1680 m (5500 ft) altitude the fuel selector switch for the test engine is set to the left auxiliary tank. It is suggested that the test engine boost pump be turned on prior to switching the fuel selector setting. If the boost pump is used while switching tanks, it is turned off once the engine is operating smoothly. The test engine is then set to takeoff power and the pilot climbs to critical takeoff altitude. The maximum time allowed at takeoff power is five minutes. The pilot levels off upon reaching critical altitude. The pilot adjusts the carburetor heat for the test engine to attain an induction air temperature of 28°C-0°C (82°F-0°F). When the cylinder head temperatures stabilize, the data acquisition operator determines the level of knock and subsequently collects cylinder pressure data of at least 50 consecutive engine cycles for each cylinder at a sample rate of 50 kHz. After completing the data point the data acquisition operator notifies the pilot and flight engineer to continue to the next point. The carburetor heat for the test engine is returned to full cold. The maximum time allowed to climb to altitude, stabilize, and obtain data is 7 minutes.

The test engine power is reduced to maximum continuous, and the pilot climbs at a best rate (at least 380 m/min or 1245 ft/min) and levels off upon reaching the critical altitude for maximum continuous power. The carburetor heat for the test engine is adjusted to attain an induction air temperature of 21°C-0°C (70°F-0°F). When the cylinder head temperatures stabilize, the data acquisition operator observes for the presence of knock and collects cylinder pressure data. At the completion of the test point, the data acquisition operator notifies the pilot and project engineer to continue to the next point. The carburetor heat for the test engine is adjusted to full cold. The maximum time allowed to climb from 1830 m (6000 ft) to 2440 m (8000 ft), stabilize, and obtain data is 4 minutes.

Due to the fact that maximum continuous power can no longer be maintained above this altitude, both engine power settings are reduced to 75 percent rated power. The pilot climbs and levels off upon locating the critical altitude for the 75 percent power setting with an initial climb rate of at least 360 m/min (1175 ft/min.). The carburetor heat for the test engine is adjusted to attain an induction air temperature of 13°C-0°C (55°F-0°F). The test engine is held at the 75 percent rated power setting while allowing temperatures to stabilize. The data acquisition operator observes for the presence of knock and collects cylinder pressure data. At the completion of the test point, the data acquisition operator notifies the pilot and flight engineer to continue to the next point. The carburetor heat for the test engine is returned to full cold. The maximum time allowed to climb from 2440 m (8000 ft) to 36600 m (12000 ft), stabilize, and obtain data is 4 minutes.

Both engine power settings are reduced to 65 percent rated power. The pilot climbs and levels off at the critical altitude for the 65 percent power setting with an initial climb rate of at least 350 m/min (1150 ft/min.). The carburetor heat for the test engine is adjusted to attain an induction air temperature of 7°C-0°C (44°F-0°F). Temperatures are allowed to stabilize. The data acquisition operator observes for the presence of knock and collects cylinder pressure data. The maximum time allowed to the end of the point is 4 minutes.

At this time this test is complete. The carburetor heat is returned to full cold. It is recommended that the test engine boost pump be activated while switching the selector valve to the right auxiliary tank. Once the engine is operating smoothly, the boost pump is turned off and both engine power settings are reduced to descent power. The pilot commences procedures to descend, approach, and land.

Table 17 shows the maximum time per test point allowed for the completion of the total test sequence mentioned above and includes the amount of fuel used.

TABLE 17. POWER SETTINGS, MAXIMUM TIME PER POINT, AND FUEL USAGE FOR KNOCK TESTING

Power Setting	Time per Point minutes	Right Aux. Fuel Usage liters [gal]	Left Aux. Fuel Usage liters [gal]	Fuel Usage for 4 Tests liters [gal]
Idle/Warm-Up	10	6.4 [1.7]	-------	25.6 [6.8]
Ignition System Ground Check	5	3.8 [1.0]	-------	15.2 [4.0]
Takeoff	0.5	1.5 [0.4]	-------	6.0 [1.6]
Max. Continuous Climb to 1680 m (5500 ft)/Switch to Left Aux.	4.5	12.5 [3.3]	-------	50.0 [13.2]
Takeoff Power Climb to 1830 m (6000 ft), Stabilize/Obtain Data	2	-------	6.4 [1.7]	25.6 [6.8]
Max. Continuous Climb to 2440 m (8000 ft), Stabilize/Obtain Data	4	-------	11.7 [3.1]	46.8 [12.4]
75 % Rated Power Climb to 3660 m (12000 ft), Stabilize/Obtain Data	4	-------	9.1 [2.4]	36.4 [9.6]
65 % Rated Power Climb to 4510 m (14800 ft), Stabilize/Obtain Data	4	-------	4.5 [1.2]	18.0 [4.8]
Descend/Approach/Land	30	41.6 [11.0]	-------	166.4 [44.0]
Idle/Shut Down	10	6.4 [1.7]	-------	25.6 [6.8]
Total	74	72.2 [19.1]	31.7 [8.4]	415.6 [186.4]

After knock testing with the test fuel, ASTM standard reference fuel is used. It is desired to determine whether the engine is knock-free while operating on 99 MON reference fuel as was the case with the ground-based altitude simulation testing.

To prevent contamination, the fuel selector valve for the right engine is verified that it does not leak. If enough fuel is available the left auxiliary tank is flushed with 98 MON standard rating fuel prior to servicing.

The first reference fuel to be tested is isooctane. The left auxiliary tank is serviced with 100 MON primary reference fuel and the right auxiliary tank is serviced with test fuel.

The same knock testing procedures as previously described are followed. If the engine is found to be knock-free while operating on 100 MON standard octane rating fuel, the procedures are repeated with 99 MON reference fuel.

Occurrence of knock on 99 MON at any power setting indicates a requirement of 100 MON reference fuel.

Knock-free operation on 99 MON requires utilizing 98 MON reference fuel. The left auxiliary tanks are defueled and serviced with 98 MON reference fuel. The right auxiliary tanks are serviced with test fuel and these procedures are repeated.

The lowest "knock-free" MON reference fuel tested is considered the motor octane requirement.

In the highly unlikely event that the engine experiences heavy knock coupled with rapid cylinder head temperature increases, the pilot will abort the immediate test and begin procedures to descend, approach, and land. Extensive test cell testing indicates that this will not occur.

2.2.3 In-Flight Engine Restarts.

Test engine restarts are conducted at the critical altitude for takeoff (1830 m or 6000 ft), maximum continuous power (2440 m or 8000 ft), 75% rated power (3660 m or 12000 ft), and will follow standard operator's manual procedures.

Table 18 contains the power settings, maximum time, and fuel consumption for the in-flight engine restarts.

TABLE 18. POWER SETTINGS, MAXIMUM TIME PER POINT, AND FUEL USAGE FOR IN-FLIGHT ENGINE RESTARTS

Power Setting	Time per Point minutes	Fuel Usage liters [gal]	Time for Two Tests minutes	Fuel Usage for Two Tests liters [gal]
Idle/Warm-Up	10.0	6.4 [1.7]	20.0	12.9 [3.4]
Ignition Systems Grounding Check	5.0	3.8 [1.0]	10.0	7.6 [2.0]
Takeoff.	0.5	1.5 [0.4]	1.0	3.0 [0.8]
Maximum Continuous to 1830 m (6000 ft)	4.7	13.6 [3.6]	9.4	27.2 [7.2]
Reduce Power to High Idle/Stabilize	2.0	1.1 [0.3]	4.0	2.3 [0.6]
Maximum Continuous to 2440 m (8000 ft)	1.6	4.5 [1.2]	3.2	9.1 [2.4]
Reduce Power to High Idle/Stabilize	2.0	1.1 [0.3]	4.0	2.3 [0.6]
75 Percent Power to 3660 m (12000 ft)	3.6	7.6 [2.0]	7.2	15.1 [4.0]
Reduce Power to High Idle/Stabilize	2.0	1.1 [0.3]	4.0	2.3 [0.6]
Descend/Approach/Land	24.0	33.3 [8.8]	48.0	66.5 [17.6]
Idle/Shut Down	10.0	6.4 [1.7]	20.0	12.9 [3.4]
Total	65.4	80.4 [21.3]	130.8	161.2 [42.6]

The pilot conducts a warm-up and an ignition system grounding check. Once minimum operating temperatures are attained, the pilot conducts a takeoff for approximately 25 seconds with an initial climb rate of at least 400 m/min (1310 ft/min.). The pilot then reduces power to maximum continuous and continues climbing and levels off at 1830 m (6000 ft). Once arriving at the predetermined altitude the critical engine is adjusted to 75-90 percent rated power, and the pilot maintains an airspeed of at least 100 knots. The project power including the data acquisition unit is powered down at this point. The test engine restart procedures as outlined in the flight manual are then followed at this time. The fuel selector switch has been placarded to notify the pilot of the modifications to the fuel selector settings.

After the engine has been restarted, the pilot will set both engines to 75 percent rated power and climb to and level off at 2440 m (8000 ft). The engine restart procedures as per the operator's manual are conducted at this altitude.

After restarting at the 2440 m (8000 ft) altitude both engines are returned to 75 percent power and the pilot will climb to 3660 m (12000 ft) altitude. The restart procedures are again followed. After the engine is restarted at this altitude, this series of restarts is completed.

Once the engine restarts are completed, the pilot reduces both engine power settings to begin a descent and commence normal landing procedures. Any difficulty in engine restarts is noted and requires that the immediate point be reevaluated.

If engine restarts occurred in a normal manner, then the test is repeated for a second time to obtain a two point confirmation under slightly varied altitude conditions.

2.2.4 Hot-Fuel Testing.

Hot-fuel testing addresses the vapor lock characteristics of the test fuel in hot climates. Recommendations provided in Advisory Circular 23.961 for conducting hot-weather operation tests are used as a guideline throughout this series of testing.

Vapor lock is most evident with the fluctuation of engine fuel pressure. Vapor lock is said to occur when the fuel pressure falls below minimums set forth by the engine manufacturer or the engine does not operate satisfactorily. Unless time constraints dictate otherwise, the testing is performed on a clear day with a sea level ambient temperature greater than 29°C (85°F). An outside air temperature below 29°C (85°F) may have significant effects on test results. This ambient temperature is measured 1.2 to 1.8 m (4 to 6 ft) above the runway surface to minimize ground surface heat radiation effects.

Precautions are taken to minimize effects which may act to lower the volatility of the test fuel. The project test fuel is stored in sealed drums and locked in a fuel shed, a relatively cool environment. Care is taken to minimize agitation of the fuel when being transferred from the container to the aircraft. The right auxiliary tank is serviced from a previously unopened drum. Fuel in resealed barrels or that has sat for a long period of time is not used to service the right auxiliary tank. All safety precautions are adhered to while servicing the aircraft. Once the aircraft is serviced with fuel, a sample is taken from the right auxiliary tank in order to obtain a preheated Reid Vapor Pressure (RVP) measurement as per ASTM Standard D 323.

A portable heating unit is utilized to distribute hot air on the bottom wing surface of the section covering the two right auxiliary tanks. The top surface of the wing is covered with black plastic or other type of dark material and exposed to direct sunlight. The temperature of the fuel in the tank is monitored by connecting the thermocouple probe, which extends into the tank, to a hand-held temperature reading device. The attempt is to develop a fuel tank temperature of 43°C (110°F) +3/-0°C.

The time required to heat the fuel should not exceed 180 minutes; however, care is taken not to achieve the fuel temperature sooner than 90 minutes. Caution is also taken to avoid temperature discontinuities or large temperature gradients on the wing surface. The entire flight is conducted utilizing heated fuel in the right auxiliary tank. The test fuel in the left auxiliary tank is not heated.

Immediately after the fuel is heated to the recommended temperature the pilot conducts a warm-up and ignition system grounding check. Once minimum operating temperatures are attained the pilot conducts a takeoff with the test engine boost pump turned off. The pilot maintains a takeoff power setting on the test engine with an initial climb rate of at least 400 m/min (1310 ft/min) until an altitude of 1680 m (5500 ft) is attained. The time at takeoff power for the test engine is kept less than 5 continuous minutes. After takeoff the critical engine is maintained at maximum continuous power. While climbing through the 1680 m (5500 ft) altitude the test engine is reduced to maximum continuous power and the pilot continues climbing to 2440 m (8000 ft). At this altitude both engines are reduced to 75 percent rated power and the pilot continues climbing at a rate of at least 370 m/min (1210 ft/min.) to 3660 m (12000 ft) altitude. Engine parameters are monitored throughout the duration of testing. It should take less than 4 minutes to reach the 3660 m (12000 ft) altitude.

At this altitude both engines are reduced to 65 percent power with a climb rate of at least 360 m/min (1170 ft/min). The pilot continues climbing to 4510 m (14800 ft) altitude.

In the event of engine operation instability at any time during the hot-fuel testing, the test engine boost pump is turned ON in conjunction with selecting the left auxiliary tank, which contains the unheated test fuel. Once engine operation stabilizes, the right auxiliary tank, containing the heated test fuel, is selected and the testing procedures are continued. After the completion of this test another test is performed. Any difficulties in engine restart is documented.

At the end of each hot-fuel test, a fuel sample from the right auxiliary tank is taken in order to correlate the pretest heated RVP with the posttest heated RVP. All heated fuel in the right auxiliary tanks is drained and disposed of.

In the event of vapor lock the selector switch for the right engine is switched from the right auxiliary supply to the cold fuel in the left auxiliary supply and the right boost pump is turned on.

2.2.5 Data Acquisition.

The unleaded avgas program utilizes a 32 channel, high-speed, data acquisition system. This unit is rack mounted in the cabin and configured to monitor and collect engine parameter data at fixed intervals throughout the testing from takeoff to landing. Cylinder pressures are collected only at specific times. A display appears at the bottom of the screen that updates the average of each of

18 engine parameters in 10 second intervals. Cylinder pressure traces are continuously displayed on the screen; however, data are not collected unless specifically desired.

Various pressure and temperature readings are recorded for subsequent analysis. The aircraft is equipped with a data acquisition unit to capture various data points while in flight. Table 19 details the engine parameters that are collected.

TABLE 19. PARAMETER INFORMATION FOR THE DATA ACQUISITION UNIT

Parameter	Type of Sensor	Location of Measurement	Power Requirement	Signal Range
CHT #1-4 & 6	J-Type Thermocouple	Bayonet Fitting	Watch Battery	0-20 mV
CHT #5	J-Type Thermocouple	Washer Under Bottom Plug	Watch Battery	0-20 mV
EGT #1-6	K-Type Thermocouple	Exhaust Stack	Watch Battery	0-40 mV
Induction Air Temperature	J-Type Thermocouple	Air Box	Watch Battery	0-20 mV
Manifold Air Temperature	J-Type Thermocouple	Manifold Duct	Watch Battery	0-20 mV
Altitude Temp.	J-Type Thermocouple	Cabin Air Duct	Watch Battery	0-20 mV
Tank Fuel Temperature	J-Type Thermocouple	Carburetor Return	Watch Battery	0-20 mV
Fuel Line Temp.	J-Type Thermocouple	Fuel Strainer	Watch Battery	0-20 mV
Engine Oil Temperature	J-Type Thermocouple	Adjacent to Aircraft Pickup	Watch Battery	0-20 mV
Engine Oil Pressure	Pressure Transducer	Parallel to Aircraft Pickup	28 Vdc	0-5 V
Cylinder Pressure	Pressure Transducer	Top Spark Plug	Charge Amp (+15,-15 Vdc)	0-10 V
Engine RPM	Magnetic Tachometer Unit	Below Tachometer Generator	None	Frequency
Fuel Supply Rate	Fuel Flow Transducer	Downstream of Fuel Strainer	12 Vdc	Frequency
Fuel Return Rate	Fuel Flow Transducer	End of Fuel Return Line	12 Vdc	Frequency
MAP	Pressure Transducer	Baggage Compartment	28 Vdc	0-5 V
Metered Fuel Pressure	Pressure Transducer	Parallel to Aircraft Pickup	28 Vdc	0-5 V
Pressure Altitude	Pressure Transducer	Pickups in Baggage Compartment	28 Vdc	0-5 V
Airspeed	Pressure Transducer	Pickups in Baggage Compartment	28 Vdc	0-5 V
Fuel Flow (Net)	N/A	Calculation (FSR-FRR)	N/A	N/A

The cylinder pressures are monitored throughout the flight testing to prevent continued operation under knocking conditions. Each cylinder of the Lycoming GSO-480 test engine has a piezoelectric transducer shaped like a washer that fits under the spark plug. The top spark plug is replaced with a long-reach spark plug which meets the required temperature range for its respective operation. This method is currently the safest and most effective means of directly measuring cylinder pressure during a flight test.

Various temperature readings are required to monitor engine performance. The cylinder head temperature readings are supplied by bayonet-type thermocouples installed in each cylinder with the exception of the number five position. This cylinder temperature is monitored in the cockpit by the pilot. Therefore a washer-type thermocouple is installed under the bottom spark plug for test purposes.

An exhaust gas temperature probe (EGT) is installed in each exhaust pipe to monitor exhaust gas temperature. The induction air temperature is monitored by a thermocouple installed in the airbox to the carburetor. The present induction air box is modified with an aluminum boss welded to the under surface which accommodates this temperature probe. The manifold air temperature probe measures the temperature after the supercharger. This probe is located at the manifold pressure duct.

Once the instrumentation installation is completed the instruments are calibrated.

2.2.6 Posttest Breakdown.

Upon completion of all flight testing, the test engine is to be removed and sent back to the original equipment manufacturer (OEM) to be torn down and measured for excessive wear, including at least the cylinder diameter, piston diameter (major and minor) of each cylinder, valve stem diameter for each valve, valve guide diameter for each valve, ring dimensions (both compression and oil rings) for each cylinder, ring groove dimensions (both compression and oil rings) for each cylinder, and crankshaft journal dimensions (both main and rod).

The aircraft fuel system in contact with the test fuel is to be inspected and flushed after removal of the experimental engine. The inspection will determine if any evidence of unusual wear characteristics such as excessive swell, brittleness, softness, deterioration, and leakage has occurred. The left and right auxiliary bladders are to be removed and sent back to the manufacturer to be cleaned, scrubbed, inspected, and recertified The oil system will also be inspected.

2.3 ANALYSES.

2.3.1 Endurance Testing.

Table 20 shows the flight time breakdown for the total accumulation of 250 hours of engine operation at the various power settings. Prior to beginning the flight test hour log, the GSO-480 experimental engine had 24.8 total hours of test cell operation. All of that operation time was with the use of unleaded fuels and is not included in the table. The following table shows that roughly 219 out of 250 required total hours have been accumulated on the GSO-480 engine to date. Due to time limits at takeoff power, excess total flight time is required to meet the minimum required hours at takeoff power. Due to this, roughly 45 hours of total engine operation time remains to meet the required minimums.

TABLE 20. REQUIRED AND ACCUMULATED ENGINE OPERATING HOURS TO DATE

Power Setting	Accumulated Time (Hrs)	Minimum Time Required (Hrs)	Remaining / Excess Time (Hrs)
Takeoff	1.9	2.5	0.6
Maximum Continuous	7.2	10	2.8
65% Rated Power	149.2	225	75.8
Approach/Descent	13.9	N/A	N/A
Idle/Mag Check/Shut Down	46.6	12.5	-34.1
Totals	218.8	250.0	45.1

Table 21 provides a detailed description of the valve seat wear for both the intake and exhaust valves. The first column labeled HOUR gives both the time from the last measurement in 20 or 25 engine hour increments and the time from the first measurement. The numbers in the table represent inches. The leak down row shows the results from cylinder compression checks with 80 psi of applied pressure.

All of the engine operation hours for the following table occurred while using the test fuel composed of 70% aviation alkylate and 30% methyl tertiary butyl ether (MTBE). There has been some concern that removal of lead may result in accelerated valve seat wear. So far there has been no evidence of accelerated wear with the use of the unleaded fuels. Both the wear and the compression checks have tapered off after the initial break-in period indicating negligible compression loss.

The table indicates the measured valve seat recession up until the engine component failure. Stuck valves are suspected to have occurred causing a hydraulic tappet body to fail, resulting in significant damage to the crank case, push rod, lifter, and cam surface. The engine was repaired and testing continued; however the fuel, laden with a high amount of ether, was suspected to have been a major contributing factor to the valve sticking. It is thought that the high oxygenate content accelerated the formation of gums in the intake system. Visual inspection of the intake manifold revealed a buildup of a varnish-like substance. Both the intake and exhaust valves for the damaged cylinder appeared to be sticking.

Fuel samples were sent and analyzed for gum formation as per ASTM Standard D 873, and were also analyzed for thermal stability. Fuel samples from unopened drums and from the aircraft bladder were tested. The results from those tests were within acceptable ranges, however, the fuel did appear to have a high end point in the distillation test. This heavy component may be causing a varnish like substance to form. The unleaded avgas program is in the process of configuring a generator for the sole purpose of performing valve stick tests on the fuel. Potential problems with use of this fuel will continue to be investigated. In the meanwhile, for safety considerations, testing was resumed with the use of isooctane in place of the ether-laden fuel.

TABLE 21. VALVE STEM WEAR PRIOR TO ENGINE REPAIR

Hour	Intake Valves (cylinder numbers) #1	#2	#3	#4	#5	#6	Exhaust Valves (cylinder numbers) #1	#2	#3	#4	#5	#6
0	0.744	0.755	0.751	0.749	0.7445	0.7495	0.76	0.7605	0.7625	0.7625	0.7555	0.761
Leak Down	78/80	74/80	76/80	78/80	74/80	78/80	78/80	74/80	76/80	78/80	74/80	78/80
20	0.742	0.751	0.751	0.748	0.742	0.7475	0.759	0.758	0.76	0.761	0.754	0.76
Wear/20	0.002	0.004	0	0.001	0.0025	0.002	0.001	0.0025	0.0025	0.0015	0.0015	0.001
Average 20-Hour Wear				0.0019			Average 20-Hour Wear				0.0017	
40	0.739	0.747	0.752	0.749	0.74	0.748	0.762	0.761	0.764	0.763	0.757	0.7625
Wear/20	0.003	0.004	-0.001	-0.001	0.002	-0.0005	-0.003	-0.003	-0.004	-0.002	-0.003	-0.0025
Wear/40	0.005	0.008	-0.001	0	0.0045	0.0015	-0.002	-0.0005	-0.0015	-0.0005	-0.0015	-0.0015
Leak Down	76/80	78/80	77/80	78/80	78/80	77/80	76/80	78/80	77/80	78/80	78/80	77/80
Average 20-Hour Wear				0.0011			Average 20-Hour Wear				-0.0029	
60	0.7435	0.746	0.752	0.749	0.744	0.748	0.7605	0.7545	0.7635	0.7615	0.7535	0.761
Wear/20	-0.0045	0.001	0	0	-0.004	0	0.0015	0.0065	0.0005	0.0015	0.0035	0.0015
Wear/60	0.0005	0.009	-0.001	0	0.0005	0.0015	-0.0005	0.006	-0.001	0.001	0.002	0
Leak Down	79/80	79/80	79/80	79/80	79/80	79/80	79/80	79/80	79/80	79/80	79/80	79/80
Average 20-Hour Wear				-0.0013			Average 20-Hour Wear				0.0025	
80	0.7435	0.745	0.752	0.7485	0.7435	0.7475	0.7595	0.7585	0.7635	0.7625	0.7535	0.7605
Wear/20	0	0.001	0	0.0005	0.0005	0.0005	0.001	-0.004	0	-0.001	0	0.0005
Wear/80	0.0005	0.01	-0.001	0.0005	0.001	0.002	0.0005	0.002	-0.001	0	0.002	0.0005
Leak Down	78/80	79/80	78/80	79/80	79/80	78/80	78/80	79/80	78/80	79/80	79/80	78/80
Average 20-Hour Wear				0.0004			Average 20-Hour Wear				-0.0006	
100	0.7435	0.745	0.752	0.7485	0.7435	0.7475	0.7595	0.7585	0.76	0.7625	0.7535	0.7605
Wear/20	0	0	0	0	0	0	0	0	0.0035	0	0	0
Wear/100	0.0005	0.01	-0.001	0.0005	0.001	0.002	0.0005	0.002	0.0025	0	0.002	0.0005
Leak Down	78/80	79/80	77/80	79/80	79/80	79/80	78/80	79/80	77/80	79/80	79/80	79/80
Average 20-Hour Wear				0.0000			Average 20-Hour Wear				0.0006	
120	0.7435	0.746	0.752	0.749	0.7445	0.7475	0.758	0.7555	0.759	0.756	0.75	0.7575
Wear/20	0	-0.001	0	-0.0005	-0.001	0	0.0015	0.003	0.001	0.0065	0.0035	0.003
Wear/120	0.0005	0.009	-0.001	0	0	0.002	0.002	0.005	0.0035	0.0065	0.0055	0.0035
Leak Down	79/80	78/80	79/80	78/80	78/80	77/80	79/80	78/80	79/80	78/80	78/80	77/80
Average 20-Hour Wear				-0.0004			Average 20-Hour Wear				0.0031	

Table 22 continues the wear analyses data after the engine was repaired and returned to service. The hour was set back to zero since some of the valve seat surfaces were resurfaced at the time of repair which would skew the results. All of the data in this chart indicate the time the engine operated on isooctane. This table also shows that there is very little wear occurring and that the compression remains very high. All oil analyses indicate that normal engine wear is occurring.

TABLE 22. VALVE STEM WEAR AFTER ENGINE REPAIR

	Intake Valves (cylinder numbers)						Exhaust Valves (cylinder numbers)					
Hour	#1	#2	#3	#4	#5	#6	#1	#2	#3	#4	#5	#6
0	0.752	0.7475	0.7485	0.737	0.7345	0.742	0.7315	0.741	0.737	0.732	0.7335	0.7405
Leak Down	75/80	77/80	75/80	78/80	78/80	76/80	75/80	77/80	75/80	78/80	78/80	76/80
25	0.726	0.7475	0.747	0.737	0.7325	0.741	0.731	0.739	0.736	0.731	0.7275	0.739
Wear/25	0.026	0	0.0015	0	0.002	0.001	0.0005	0.002	0.001	0.001	0.006	0.0015
Leak Down	77/80	78/80	78/80	77/80	76/80	78/80	77/80	78/80	78/80	77/80	76/80	78/80
Average 25-Hour Wear				0.0051			Average 25-Hour Wear				0.0020	
50	0.724	0.7455	0.7465	0.7355	0.7325	0.7405	0.7295	0.737	0.7335	0.7285	0.7255	0.7375
Wear/25	0.002	0.002	0.0005	0.0015	0	0.0005	0.0015	0.002	0.0025	0.0025	0.002	0.0015
Wear/50	0.028	0.002	0.002	0.0015	0.002	0.0015	0.002	0.004	0.0035	0.0035	0.008	0.003
Leak Down	78/80	78/80	78/80	78/80	77/80	76/80	78/80	78/80	78/80	78/80	77/80	76/80
Average 25-Hour Wear				0.0011			Average 25-Hour Wear				0.0020	
75	0.724	0.7455	0.7465	0.7355	0.7315	0.7405	0.728	0.7345	0.731	0.727	0.7235	0.736
Wear/25	0	0	0	0	0.001	0	0.0015	0.0025	0.0025	0.0015	0.002	0.0015
Wear/75	0.028	0.002	0.002	0.0015	0.003	0.0015	0.0035	0.0065	0.006	0.005	0.01	0.0045
Leak Down	74/80	78/80	77/80	75/80	74/80	78/80	74/80	78/80	77/80	75/80	74/80	78/80
Average 25-Hour Wear				0.0002			Average 25-Hour Wear				0.0019	
100	0.724	0.7455	0.747	0.735	0.7315	0.74	0.727	0.734	0.7305	0.7265	0.7225	0.7345
Wear/25	0	0	-0.0005	0.0005	0	0.0005	0.001	0.0005	0.0005	0.0005	0.001	0.0015
Wear/100	0.028	0.002	0.0015	0.002	0.003	0.002	0.0045	0.007	0.0065	0.0055	0.011	0.006
Leak Down	77/80	79/80	77/80	78/80	79/80	78/80	77/80	79/80	77/80	78/80	79/80	78/80
Average 25-Hour Wear				0.0001			Average 25-Hour Wear				0.0008	
125	0.723	0.7445	0.7445	0.734	0.73	0.7395	0.7245	0.7305	0.727	0.7235	0.719	0.7315
Wear/25	0.001	0.001	0.0025	0.001	0.0015	0.0005	0.0025	0.0035	0.0035	0.003	0.0035	0.003
Wear/125	0.029	0.003	0.004	0.003	0.0045	0.0025	0.007	0.0105	0.01	0.0085	0.0145	0.009
Leak Down	77/80	79/80	77/80	78/80	79/80	78/80	77/80	79/80	77/80	78/80	79/80	78/80
Average 25-Hour Wear				0.0012			Average 25-Hour Wear				0.0032	
150	0.723	0.744	0.745	0.7335	0.73	0.7395	0.7245	0.7305	0.7285	0.725	0.7195	0.7313
Wear/25	0	0.0005	-0.0005	0.0005	0	0	0	0	-0.0015	-0.0015	-0.0005	0.0003
Wear/150	0.029	0.0035	0.0035	0.0035	0.0045	0.0025	0.007	0.0105	0.0085	0.007	0.014	0.0093
Leak Down	78/80	79/80	78/80	78/80	78/80	78/80	78/80	79/80	78/80	78/80	78/80	78/80
Average 25-Hour Wear				0.0001			Average 25-Hour Wear				-0.0005	

The fuel screen inspection revealed a brown substance in the bottom of the bladder. This substance did not appear until after the use of the isooctane. The first impression suggests that it is a bacteria since a clear water separation boundary is present in which the substance resides. Fuel samples with the substance were collected and sent out to an independent laboratory for identification. The results indicated that the brown substance was not due to fungus nor a microbial organism.

2.3.2 Knock Testing.

In the following procedures, the term "knock" refers to a knock level of incipient or greater in any individual cylinder and "knock-free" refers to the condition where less than incipient knock is occurring in all of the cylinders. These levels have been distinguished in accordance with Advisory Circular 33-47.

The following table shows the ground-based, altitude-simulated detonation results. These results are to be compared to those of actual in-flight tests to determine if the ground-based simulation can approximate a worse-case condition than those of actual flight. The altitude is simulated by drawing down the intake pressure to that equivalent at the desired altitude based on standard day conditions. However, the test facilities do not have the ability to draw down the exhaust to the same level, thus limiting the simulated altitude that can be achieved.

TABLE 23. GROUND-BASED ALTITUDE SIMULATION KNOCK RESULTS FOR THE LYCOMING GSO-480-B1A6 ENGINE

Point Description	MAP (in Hg)	Engine Speed (rpm)	Referenc e Fuel (MON)	Knock Condition
Takeoff power - sea level	ft	3400	95	Hk
Takeoff power - sea level	ft	3400	97	Mk
Takeoff power - sea level	ft	3400	98	Lk
Takeoff power - sea level	ft	3400	99	No
Takeoff power - 5500 feet	ft	3400	98	Mk
Takeoff power - 6000 feet	ft	3400	99	No
Max Continuous - sea level	45	3200	98	Mk
Max Continuous - sea level	45	3200	99	No
Cruise power - sea level	35	2600	98	No

The results from these tests indicate a minimum MON requirement of 99 when using reference fuels for sea level, knock-free operation. The results also indicate that the altitude simulation suggests that the same minimum octane is required. However, the highest altitude in the ground-based simulation for takeoff power was 6000 feet. The in-flight condition is performed at critical altitude for the particular day and may suggest different results.

Preparation for in-flight detonation tests are currently underway.

2.3.3 In-Flight Engine Restarts.

In-flight engine restarts were performed at each of several altitudes for two separate flights. The restarts occurred at altitudes of 10.5, 8.5, 6.5, and 4.5 thousand feet. In each case some altitude was lost before restart occurred. In all cases, restarting took a couple of attempts before success. In light of the high ether content of the fuel, these findings do not appear to suggest a significant restart problem exists with the use of high ether content fuels.

2.3.4 Hot-Fuel Testing.

It was desired to test the vapor lock effect of a high ether content fuel. Oxygenated fuels tend to skew the results of standard RVP tests typically used to project the vapor lock behavior of the fuel. Until the valve tests have been performed using this test fuel, the hot-fuel tests have been indefinitely postponed. If the valve sticking tests clear the test fuel the hot-fuel testing may be resumed. Use of the alternate test fuel, isooctane, for hot-fuel testing will offer little since isooctane is a single boiling point, low-volatility fuel.

3. CONCLUSIONS.

3.1 GROUND-BASED TESTING.

Any mixture leaning, such as typically performed during cruise operation for fuel efficiency, appears to have a substantial effect on motor octane requirement when using unleaded fuels. For most of the engines tested, the lean cruise configuration required the greatest octane requirement, even greater than for the maximum power configuration. However, this was not the case for the lower power IO-320 engine.

The data indicate that a MON greater than 100 would be needed to satisfy the majority of the fleet for full-rich operations. Significant power derating of the large turbocharged engines may enable knock-free operation on 100 MON. However, while derating the TIO-540-J and TSIO-550 engines did appear to lower the full-rich MON requirements, there was still very little tolerance for mixture leaning. With substantial power deration, knock-free operation can be obtained with less than 100 MON, even during moderate leaning. This suggests that for knock-free operation on a fuel of 100 MON or below there may have to be changes in both pilot procedures coupled with power reduction.

For the IO-320 engine, reducing the fuel flow by 10% at the cruise condition increased the octane requirement by 4 MON and reducing the fuel flow another 5% to 15% lean increased the MON requirement by another 4 MON. Typically, each 5% reduction in fuel flow rate resulted in a requirement increase of at least 2 MON. This requirement increase was also seen with the higher powered engines. Leaning both the IO-540-K and IO-550-D engines to best power at the cruise configurations resulted in an increase of at least 3 AN in both cases.

Immediate future testing will address octane rating the large turbocharged engines with the amine-laden reference grade isooctane to obtain full characterizations. It is suggested that after all octane ratings have been performed using unleaded reference fuels these high octane engines should be rated with leaded ASTM reference fuels. This will present a characterization of the requirement in terms of an established and known standard. It should be pointed out that use of amine-laden reference grade isooctane may produce different octane requirement results than those found with primary reference fuels containing tetra-ethyl lead.

3.2 IN-FLIGHT TESTING.

High ether content fuels may be more susceptible to the formation of gums due to their high oxygen content. This area is under further investigation by the unleaded avgas group. Valve sticking tests will be performed with the use of a single-cylinder generator and the oxygenated test fuel.

Use of unleaded fuels has not resulted in undue valve seat wear or the acceleration of normal wear.

APPENDIX A—AVERAGED DATA VALUES FOR ENGINE PARAMETERS

A.1 IO-320-B ENGINE PARAMETER DATA.

Engine Parameters	Data Points					
	A	B	C	D	E	F
Reference Fuel Motor Octane Number	93	92	91	90	89	88
#1 Cylinder Head Temperature (Deg F)	469	481	485	479	478	473
#2 Cylinder Head Temperature (Deg F)	481	493	496	496	490	485
#3 Cylinder Head Temperature (Deg F)	495	506	506	504	504	495
#4 Cylinder Head Temperature (Deg F)	497	507	510	508	505	500
#1 Exhaust Gas Temperature (Deg F)	1277	1285	1286	1282	1284	1282
#2 Exhaust Gas Temperature (Deg F)	1252	1260	1258	1254	1256	1255
#3 Exhaust Gas Temperature (Deg F)	1273	1279	1279	1273	1271	1275
#4 Exhaust Gas Temperature (Deg F)	1299	1306	1305	1304	1304	1302
Oil Temperature (Deg F)	246	243	241	240	248	247
Oil Pressure (psig)	59	58	58	58	58	58
Engine Induction Air Temperature (Deg F)	103	102	103	103	102	102
Combustion Air Temperature (Deg F)	127	128	128	128	126	127
Cooling Air Temperature (Deg F)	112	113	111	106	106	99
Cooling Air Pressure (in H_2O)	3	3	2	2	2	2
Unmetered Fuel Pressure (psig)	24	24	24	24	24	24
Metered Fuel Pressure (psig)	4.3	4.2	4.2	4.2	4.2	4.2
Manifold Absolute Pressure (in Hg)	29.3	29.3	29.3	29.3	29.4	29.4
Engine Speed (rpm)	2704	2704	2704	2704	2704	2704
Produced Engine Torque (ft/lbs)	253	253	252	253	254	254
Observed Brake Horse Power (BHP)	130	130	130	130	131	131
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.612	0.610	0.613	0.614	0.606	0.609
Mass Fuel Flow (Pounds/Hr)	80	79	80	80	79	80
Fuel Density (Pounds/Gallon)	5.60	5.58	5.58	5.57	5.59	5.58
Fuel Flow Rate (Gallons/Hour)	14	14	14	14	14	14
Fuel Tank Temperature (Deg F)	85	86	86	86	86	87
Fuel Line Temperature (Deg F)	108	111	112	113	110	111
Humidity Ratio (Grains/Pound)	81	81	81	82	82	83
Relative Humidity (%)	27	27	27	27	27	28
Sea Level Barometer During Test (in Hg)	29.97	29.97	29.97	29.97	29.97	29.97
Test Cell Ambient Temperature (Deg F)	99	99	99	99	99	99
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	F/R
Airflow (Pounds of Air per Hour)	2181	2198	2178	2186	2199	2188
Fuel to Air Ratio	0.145	0.146	0.147	0.145	0.147	0.145
Air to Fuel Ratio	11.5	11.6	11.7	11.6	11.6	11.6
Description of Points						
A	Takeoff 100%, 2700 rpm, wide open throttle, F/R, 93 MON					
B	Takeoff 100%, 2700 rpm, wide open throttle, F/R, 92 MON					
C	Takeoff 100%, 2700 rpm, wide open throttle, F/R, 91 MON					
D	Takeoff 100%, 2700 rpm, wide open throttle, F/R, 90 MON					
E	Takeoff 100%, 2700 rpm, wide open throttle, F/R, 89 MON					
F	Takeoff 100%, 2700 rpm, wide open throttle, F/R, 88 MON					

Engine Parameters	Data Points					
	G	H	I	J	K	L
Reference Fuel Motor Octane Number	87	87	86	85	81	80
#1 Cylinder Head Temperature (Deg F)	478	491	489	490	487	486
#2 Cylinder Head Temperature (Deg F)	489	496	495	495	496	495
#3 Cylinder Head Temperature (Deg F)	503	501	501	501	496	495
#4 Cylinder Head Temperature (Deg F)	507	506	503	504	501	501
#1 Exhaust Gas Temperature (Deg F)	1279	1314	1308	1310	1300	1300
#2 Exhaust Gas Temperature (Deg F)	1255	1280	1280	1280	1279	1279
#3 Exhaust Gas Temperature (Deg F)	1256	1294	1283	1286	1285	1285
#4 Exhaust Gas Temperature (Deg F)	1297	1320	1317	1319	1311	1311
Oil Temperature (Deg F)	239	246	248	247	241	242
Oil Pressure (psig)	58	56	56	56	56	55
Engine Induction Air Temperature (Deg F)	103	103	103	103	103	103
Combustion Air Temperature (Deg F)	126	132	131	131	137	137
Cooling Air Temperature (Deg F)	102	103	98	100	103	102
Cooling Air Pressure (in H_2O)	3	1	2	2	1	1
Unmetered Fuel Pressure (psig)	24	25	25	25	25	25
Metered Fuel Pressure (psig)	4.3	3.1	3.1	3.0	2.4	2.4
Manifold Absolute Pressure (in Hg)	29.3	26.5	26.5	26.5	25.0	25.0
Engine Speed (rpm)	2704	2604	2604	2604	2504	2504
Produced Engine Torque (ft/lbs)	254	217	218	217	195	195
Observed Brake Horse Power (BHP)	131	108	108	108	93	93
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.606	0.604	0.599	0.602	0.623	0.623
Mass Fuel Flow (Pounds/Hr)	79	65	65	65	58	58
Fuel Density (Pounds/Gallon)	5.56	5.56	5.56	5.57	5.58	5.58
Fuel Flow Rate (Gallons/Hour)	14	12	12	12	10	10
Fuel Tank Temperature (Deg F)	88	88	88	89	93	92
Fuel Line Temperature (Deg F)	115	116	115	114	112	112
Dew Point (Deg F)						
Humidity Ratio (Grains/Pound)	82	82	82	80	76	76
Relative Humidity (%)	27	27	27	27	25	25
Percent Power Produced (%)	99	80	80	80	69	69
Sea Level Barometer During Test (in Hg)	29.96	29.96	29.96	29.95	29.91	29.91
Test Cell Ambient Temperature (Deg F)	99	99	99	99	99	99
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	F/R
Airflow (Pounds of Air per Hour)	2215	1733	1719	1717	1458	1471
Fuel to Air Ratio	0.146	0.189	0.189	0.187	0.212	0.212
Air to Fuel Ratio	11.5	12.3	12.2	12.1	12.3	12.3
Description of Points						
G	Takeoff 100%, 2700 rpm, wide open throttle, F/R, 87 MON					
H	Climb 80%, 2600 rpm, 26.5", F/R, 87 MON					
I	Climb 80%, 2600 rpm, 26.5", F/R, 86 MON					
J	Climb 80%, 2600 rpm, 26.5", F/R, 85 MON					
K	Cruise 70%, 2500 rpm, 25", F/R, 81 MON					
L	Cruise 70%, 2500 rpm, 25", F/R, 80 MON					

Engine Parameters	Data Points					
	M	N	O	P	Q	R
Reference Fuel Motor Octane Number	79	80	80	81	82	83
#1 Cylinder Head Temperature (Deg F)	491	495	498	487	492	488
#2 Cylinder Head Temperature (Deg F)	496	498	500	492	496	497
#3 Cylinder Head Temperature (Deg F)	505	502	513	509	507	499
#4 Cylinder Head Temperature (Deg F)	506	508	509	495	504	503
#1 Exhaust Gas Temperature (Deg F)	1291	1333	1340	1333	1340	1358
#2 Exhaust Gas Temperature (Deg F)	1270	1306	1331	1328	1328	1335
#3 Exhaust Gas Temperature (Deg F)	1262	1316	1306	1300	1311	1340
#4 Exhaust Gas Temperature (Deg F)	1304	1344	1364	1362	1358	1369
Oil Temperature (Deg F)	251	247	246	249	241	241
Oil Pressure (psig)	55	56	55	55	56	55
Engine Induction Air Temperature (Deg F)	103	104	104	104	104	104
Combustion Air Temperature (Deg F)	137	137	138	139	137	137
Cooling Air Temperature (Deg F)	102	102	103	102	102	101
Cooling Air Pressure (in H_2O)	1	1	5	9	2	2
Unmetered Fuel Pressure (psig)	25	25	25	25	25	25
Metered Fuel Pressure (psig)	2.4	2.2	2.0	2.2	2.0	2.0
Manifold Absolute Pressure (in Hg)	25.0	25.0	25.0	24.9	25.1	25.0
Engine Speed (rpm)	2504	2503	2504	2504	2504	2503
Produced Engine Torque (ft/lbs)	193	194	194	194	196	197
Observed Brake Horse Power (BHP)	92	93	93	93	94	94
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.626	0.591	0.550	0.586	0.554	0.549
Mass Fuel Flow (Pounds/Hr)	58	55	51	54	52	52
Fuel Density (Pounds/Gallon)	5.57	5.57	5.57	5.57	5.57	5.57
Fuel Flow Rate (Gallons/Hour)	10	10	9	10	9	9
Fuel Tank Temperature (Deg F)	93	95	94	94	95	95
Fuel Line Temperature (Deg F)	113	114	114	114	114	115
Dew Point (Deg F)						
Humidity Ratio (Grains/Pound)	78	78	79	80	80	79
Relative Humidity (%)	26	26	26	27	27	26
Percent Power Produced (%)	68	69	69	69	69	70
Sea Level Barometer During Test (in Hg)	29.91	29.90	29.90	29.90	29.90	29.90
Test Cell Ambient Temperature (Deg F)	99	99	99	99	99	99
Percent Lean (%)	F/R	-4.8	-11.5	-5.7	-9.8	-10.2
Airflow (Pounds of Air per Hour)	1458	1459	1456	1461	1483	1451
Fuel to Air Ratio	0.212	0.235	0.271	0.246	0.263	0.262
Air to Fuel Ratio	12.2	12.9	13.8	13.4	13.6	13.5

Description of Points	
M	Cruise 70%, 2500 rpm, 25", F/R, 79 MON
N	Cruise 70%, 2500 rpm, 25", 5% Lean, 80 MON
O	Cruise 70%, 2500 rpm, 25", 10% Lean, 80 MON
P	Cruise 70%, 2500 rpm, 25", 10% Lean, 81 MON
Q	Cruise 70%, 2500 rpm, 25", 10% Lean, 82 MON
R	Cruise 70%, 2500 rpm, 25", 10% Lean, 83 MON

Engine Parameters	Data Points					
	S	T	U	V	W	X
Reference Fuel Motor Octane Number	84	85	90	89	88	87
#1 Cylinder Head Temperature (Deg F)	492	493	489	488	487	490
#2 Cylinder Head Temperature (Deg F)	500	500	498	497	497	500
#3 Cylinder Head Temperature (Deg F)	499	500	496	496	492	497
#4 Cylinder Head Temperature (Deg F)	507	508	504	503	502	505
#1 Exhaust Gas Temperature (Deg F)	1354	1367	1390	1390	1388	1391
#2 Exhaust Gas Temperature (Deg F)	1333	1343	1365	1366	1366	1368
#3 Exhaust Gas Temperature (Deg F)	1335	1352	1372	1374	1373	1374
#4 Exhaust Gas Temperature (Deg F)	1367	1376	1401	1402	1400	1401
Oil Temperature (Deg F)	246	243	248	246	247	247
Oil Pressure (psig)	55	56	56	56	55	56
Engine Induction Air Temperature (Deg F)	104	104	104	104	104	104
Combustion Air Temperature (Deg F)	137	138	138	138	138	138
Cooling Air Temperature (Deg F)	102	103	102	103	101	101
Cooling Air Pressure (in H_2O)	1	1	2	2	1	2
Unmetered Fuel Pressure (psig)	25	25	25	25	25	25
Metered Fuel Pressure (psig)	2.0	2.0	1.9	1.9	1.9	1.9
Manifold Absolute Pressure (in Hg)	25.0	25.0	25.0	25.0	25.0	25.0
Engine Speed (rpm)	2505	2504	2504	2504	2504	2503
Produced Engine Torque (ft/lbs)	197	197	197	197	198	198
Observed Brake Horse Power (BHP)	94	94	94	94	94	94
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.550	0.545	0.522	0.525	0.518	0.517
Mass Fuel Flow (Pounds/Hr)	52	51	49	49	49	49
Fuel Density (Pounds/Gallon)	5.58	5.58	5.58	5.58	5.57	5.57
Fuel Flow Rate (Gallons/Hour)	9	9	9	9	9	9
Fuel Tank Temperature (Deg F)	95	95	96	96	97	97
Fuel Line Temperature (Deg F)	113	114	114	114	115	115
Humidity Ratio (Grains/Pound)	79	78	78	77	78	78
Relative Humidity (%)	26	26	26	26	26	26
Percent Power Produced (%)	70	70	70	70	70	70
Sea Level Barometer During Test (in Hg)	29.90	29.90	29.89	29.89	29.89	29.89
Test Cell Ambient Temperature (Deg F)	99	99	99	99	99	99
Percent Lean (%)	-10.0	-10.9	-14.6	-14.1	-15.0	-15.0
Airflow (Pounds of Air per Minute)	24	24	25	25	25	25
Airflow (Pounds of Air per Hour)	1463	1469	1476	1495	1491	1478
Fuel to Air Ratio	0.264	0.266	0.285	0.285	0.291	0.292
Air to Fuel Ratio	13.6	13.6	14.0	14.1	14.2	14.3

Description of Points	
S	Cruise 70%, 2500 rpm, 25", 10% Lean, 84 MON
T	Cruise 70%, 2500 rpm, 25", 10% Lean, 85 MON
U	Cruise 70%, 2500 rpm, 25", 15% Lean, 90 MON
V	Cruise 70%, 2500 rpm, 25", 15% Lean, 89 MON
W	Cruise 70%, 2500 rpm, 25", 15% Lean, 88 MON
X	Cruise 70%, 2500 rpm, 25", 15% Lean, 87 MON

Engine Parameters	Data Points					
	Y	Z	A2	B2	C2	D2
Reference Fuel Motor Octane Number	87	86	85	84	85	84
#1 Cylinder Head Temperature (Deg F)	489	491	493	492	489	489
#2 Cylinder Head Temperature (Deg F)	494	497	500	499	500	501
#3 Cylinder Head Temperature (Deg F)	489	490	498	498	499	498
#4 Cylinder Head Temperature (Deg F)	502	504	507	505	505	506
#1 Exhaust Gas Temperature (Deg F)	1391	1399	1397	1379	1449	1428
#2 Exhaust Gas Temperature (Deg F)	1369	1375	1371	1363	1422	1402
#3 Exhaust Gas Temperature (Deg F)	1376	1381	1375	1356	1426	1408
#4 Exhaust Gas Temperature (Deg F)	1406	1413	1407	1397	1469	1447
Oil Temperature (Deg F)	245	243	244	246	247	241
Oil Pressure (psig)	57	56	56	56	56	56
Engine Induction Air Temperature (Deg F)	100	101	102	102	102	102
Combustion Air Temperature (Deg F)	134	135	135	136	133	135
Cooling Air Temperature (Deg F)	105	105	107	107	100	99
Cooling Air Pressure (in H_2O)	1	2	2	2	2	2
Unmetered Fuel Pressure (psig)	25	25	25	25	25	25
Metered Fuel Pressure (psig)	2.0	2.0	1.9	1.9	1.8	1.8
Manifold Absolute Pressure (in Hg)	25.0	25.0	24.9	25.0	25.1	25.0
Engine Speed (rpm)	2503	2503	2503	2503	2503	2503
Produced Engine Torque (ft/lbs)	199	199	198	197	198	197
Observed Brake Horse Power (BHP)	95	95	94	94	94	94
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.519	0.511	0.515	0.515	0.483	0.486
Mass Fuel Flow (Pounds/Hr)	49	49	49	48	46	46
Fuel Density (Pounds/Gallon)	5.61	5.60	5.59	5.59	5.60	5.61
Fuel Flow Rate (Gallons/Hour)	9	9	9	9	8	8
Fuel Tank Temperature (Deg F)	84	84	87	86	86	87
Fuel Line Temperature (Deg F)	106	108	109	110	109	106
Humidity Ratio (Grains/Pound)	73	73	74	74	75	76
Relative Humidity (%)	24	24	24	24	25	25
Percent Power Produced (%)	70	70	69	69	70	69
Sea Level Barometer During Test (in Hg)	29.97	29.97	29.96	29.96	29.96	29.96
Test Cell Ambient Temperature (Deg F)	99	99	99	99	99	99
Percent Lean (%)	-14.6	-15.7	-15.7	-16.1	-20.9	-20.7
Airflow (Pounds of Air per Hour)	1468	1460	1463	1456	1473	1431
Fuel to Air Ratio	0.287	0.301	0.293	0.294	0.336	0.332
Air to Fuel Ratio	14.1	14.6	14.2	14.2	15.3	15.2

Description of Points	
Y	Cruise 70%, 2500 rpm, 25", 15% Lean, 87 MON
Z	Cruise 70%, 2500 rpm, 25", 15% Lean, 86 MON
A2	Cruise 70%, 2500 rpm, 25", 15% Lean, 85 MON
B2	Cruise 70%, 2500 rpm, 25", 15% Lean, 84 MON
C2	Cruise 70%, 2500 rpm, 25", 20% Lean, 85 MON
D2	Cruise 70%, 2500 rpm, 25", 20% Lean, 84 MON

Engine Parameters	Data Points
	E2
Reference Fuel Motor Octane Number	83
#1 Cylinder Head Temperature (Deg F)	494
#2 Cylinder Head Temperature (Deg F)	501
#3 Cylinder Head Temperature (Deg F)	501
#4 Cylinder Head Temperature (Deg F)	507
#1 Exhaust Gas Temperature (Deg F)	1405
#2 Exhaust Gas Temperature (Deg F)	1398
#3 Exhaust Gas Temperature (Deg F)	1387
#4 Exhaust Gas Temperature (Deg F)	1438
Oil Temperature (Deg F)	247
Oil Pressure (psig)	56
Engine Induction Air Temperature (Deg F)	101
Combustion Air Temperature (Deg F)	135
Cooling Air Temperature (Deg F)	98
Cooling Air Pressure (in H_2O)	2
Unmetered Fuel Pressure (psig)	25
Metered Fuel Pressure (psig)	1.8
Manifold Absolute Pressure (in Hg)	25.0
Engine Speed (rpm)	2503
Produced Engine Torque (ft/lbs)	198
Observed Brake Horse Power (BHP)	94
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.494
Corrected BSFC (CBSFC)	0.456
Mass Fuel Flow (Pounds/Hr)	47
Fuel Density (Pounds/Gallon)	5.60
Fuel Flow Rate (Gallons/Hour)	8
Fuel Tank Temperature (Deg F)	87
Fuel Line Temperature (Deg F)	107
Humidity Ratio (Grains/Pound)	76
Relative Humidity (%)	25
Percent Power Produced (%)	69
Sea Level Barometer During Test (in Hg)	29.96
Test Cell Ambient Temperature (Deg F)	99
Percent Lean (%)	-19.1
Airflow (Pounds of Air per Minute)	24
Airflow (Pounds of Air per Hour)	1466
Fuel to Air Ratio	0.320
Air to Fuel Ratio	14.9
Description of Points	
E2	Cruise 70%, 2500 rpm, 25", 20% Lean, 83 MON

A.2 CONTINENTAL IO-550-D ENGINE PARAMETER DATA.

Engine Parameters	Data Points					
	G	H	I	J	K	L
Reference Fuel Motor Octane Number	99	100	101	102	103	99
#1 Cylinder Head Temperature (Deg F)	444	433	438	441	442	458
#2 Cylinder Head Temperature (Deg F)	467	467	467	467	468	466
#3 Cylinder Head Temperature (Deg F)	409	406	408	407	409	420
#4 Cylinder Head Temperature (Deg F)	406	404	406	406	407	408
#5 Cylinder Head Temperature (Deg F)	459	458	459	457	457	467
#6 Cylinder Head Temperature (Deg F)	449	446	448	446	448	457
#1 Exhaust Gas Temperature (Deg F)	1339	1339	1342	1343	1351	1375
#2 Exhaust Gas Temperature (Deg F)	1362	1364	1367	1367	1369	1390
#3 Exhaust Gas Temperature (Deg F)	1358	1362	1362	1361	1365	1392
#4 Exhaust Gas Temperature (Deg F)	1334	1334	1337	1335	1339	1357
#5 Exhaust Gas Temperature (Deg F)	1310	1310	1312	1311	1313	1347
#6 Exhaust Gas Temperature (Deg F)	1320	1322	1325	1323	1324	1350
Oil Temperature (Deg F)	241	238	236	246	240	242
Oil Pressure (psig)	34	34	34	34	34	34
Engine Induction Air Temperature (Deg F)	102	103	101	101	101	102
Cooling Air Temperature (Deg F)	103	99	104	102	102	104
Cooling Air Pressure (in H_2O)	5.4	5.4	5.5	5.1	5.5	2.8
Unmetered Fuel Pressure (psig)	34	34	34	34	35	34
Metered Fuel Pressure (psig)	20	20	20	20	20	15
Manifold Absolute Pressure (in Hg)	28.7	28.6	28.6	28.6	28.6	25.7
Engine Speed (rpm)	2704	2702	2704	2703	2702	2621
Produced Engine Torque (ft/lbs)	547	548	549	549	549	473
Observed Brake Horse Power (BHP)	281	282	283	282	283	236
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.531	0.531	0.537	0.538	0.539	0.516
Mass Fuel Flow (Pounds/Hr)	149.6	149.6	151.7	152.0	152.2	121.8
Fuel Density (Pounds/Gallon)	5.57	5.59	5.63	5.64	5.67	5.58
Fuel Flow Rate (Gallons/Hour)	26.9	26.8	27.0	27.0	26.9	21.8
Fuel Line Temperature (Deg F)	105	102	99	101	101	104
Dew Point (Deg F)	51	52	53	52	51	50
Percent Power Produced (%)	101	101	101	101	101	85
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	F/R
Airflow (Pounds of Air per Hour)	2092	2099	2064	2051	2073	1700
Fuel to Air Ratio	0.071	0.071	0.074	0.074	0.073	0.072
Air to Fuel Ratio	13.99	14.03	13.61	13.49	13.62	13.96

Description of Points	
G	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 99 MON
H	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 100 MON
I	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 101 MON
J	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 102 MON
K	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 103 MON
L	Climb, 85%, 2620 rpm, F/R, 99 MON

Engine Parameters	Data Points					
	M	N	O	P	Q	R
Reference Fuel Motor Octane Number	99	101	100	102	101	103
#1 Cylinder Head Temperature (Deg F)	450	448	444	456	451	448
#2 Cylinder Head Temperature (Deg F)	456	461	459	462	463	456
#3 Cylinder Head Temperature (Deg F)	416	425	422	421	423	418
#4 Cylinder Head Temperature (Deg F)	403	409	406	410	411	404
#5 Cylinder Head Temperature (Deg F)	463	470	472	472	475	466
#6 Cylinder Head Temperature (Deg F)	452	459	456	460	462	454
#1 Exhaust Gas Temperature (Deg F)	1375	1418	1425	1462	1471	1466
#2 Exhaust Gas Temperature (Deg F)	1390	1434	1439	1477	1485	1482
#3 Exhaust Gas Temperature (Deg F)	1389	1431	1439	1473	1482	1477
#4 Exhaust Gas Temperature (Deg F)	1357	1396	1405	1439	1448	1441
#5 Exhaust Gas Temperature (Deg F)	1341	1381	1382	1426	1427	1428
#6 Exhaust Gas Temperature (Deg F)	1343	1388	1393	1432	1439	1436
Oil Temperature (Deg F)	239	241	240	243	238	238
Oil Pressure (psig)	34	34	34	34	34	35
Engine Induction Air Temperature (Deg F)	102	103	103	103	102	103
Combustion Air Temperature (Deg F)						
Cooling Air Temperature (Deg F)	102	107	102	104	104	103
Cooling Air Pressure (in H_2O)	2.8	2.7	2.8	2.8	2.8	2.8
Unmetered Fuel Pressure (psig)	32	31	30	30	30	30
Metered Fuel Pressure (psig)	13	12	12	11	11	11
Manifold Absolute Pressure (in Hg)	25.0	25.0	25.0	25.1	25.1	25.1
Engine Speed (rpm)	2506	2504	2504	2504	2505	2504
Produced Engine Torque (ft/lbs)	455	457	458	459	459	461
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.510	0.475	0.471	0.453	0.441	0.448
Mass Fuel Flow (Pounds/Hr)	110.8	103.6	103.0	99.1	96.6	98.4
Fuel Density (Pounds/Gallon)	5.56	5.58	5.55	5.60	5.57	5.63
Fuel Flow Rate (Gallons/Hour)	19.9	18.6	18.6	17.7	17.3	17.5
Fuel Tank Temperature (Deg F)						
Fuel Line Temperature (Deg F)	109	109	110	109	111	110
Dew Point (Deg F)	50	51	51	51	51	50
Percent Power Produced (%)	78	78	79	79	79	79
Percent Lean (%)	F/R	-6.5	-7.0	-10.5	-12.8	-11.2
Airflow (Pounds of Air per Hour)	1501	1506	1517	1500	1499	1523
Fuel to Air Ratio	0.074	0.069	0.068	0.066	0.064	0.065
Air to Fuel Ratio	13.55	14.54	14.73	15.13	15.51	15.48

Description of Points	
M	Cruise, 25", 2500 rpm, F/R, 99 MON
N	Cruise, 25", 2500 rpm, -5%, 101 MON
O	Cruise, 25", 2500 rpm, -5%, 100 MON
P	Cruise, 25", 2500 rpm, -10%, 102 MON
Q	Cruise, 25", 2500 rpm, -10%, 101 MON
R	Cruise, 25", 2500 rpm, -10%, 103 MON

Engine Parameters	Data Points					
	S	T	U	V	W	X
Reference Fuel Motor Octane Number	102	101	103	102	103	104
#1 Cylinder Head Temperature (Deg F)	440	448	444	439	446	449
#2 Cylinder Head Temperature (Deg F)	454	455	452	448	456	452
#3 Cylinder Head Temperature (Deg F)	413	415	412	408	417	413
#4 Cylinder Head Temperature (Deg F)	402	402	401	398	404	403
#5 Cylinder Head Temperature (Deg F)	465	466	464	464	469	465
#6 Cylinder Head Temperature (Deg F)	454	453	452	450	454	455
#1 Exhaust Gas Temperature (Deg F)	1495	1486	1489	1514	1525	1526
#2 Exhaust Gas Temperature (Deg F)	1514	1502	1504	1531	1537	1546
#3 Exhaust Gas Temperature (Deg F)	1507	1498	1500	1525	1537	1537
#4 Exhaust Gas Temperature (Deg F)	1470	1461	1462	1486	1495	1502
#5 Exhaust Gas Temperature (Deg F)	1454	1442	1448	1463	1478	1489
#6 Exhaust Gas Temperature (Deg F)	1465	1456	1458	1480	1493	1498
Oil Temperature (Deg F)	241	238	236	242	239	244
Oil Pressure (psig)	34	35	35	34	34	34
Engine Induction Air Temperature (Deg F)	102	103	103	102	103	101
Combustion Air Temperature (Deg F)						
Cooling Air Temperature (Deg F)	104	102	102	102	103	102
Cooling Air Pressure (in H_2O)	2.8	2.8	3.2	2.8	5.4	4.6
Unmetered Fuel Pressure (psig)	30	30	30	29	29	30
Metered Fuel Pressure (psig)	11	11	11	10	10	10
Manifold Absolute Pressure (in Hg)	25.1	25.1	25.1	25.0	25.0	25.1
Engine Speed (rpm)	2505	2505	2504	2505	2504	2506
Produced Engine Torque (ft/lbs)	461	461	461	460	457	461
Observed Brake Horse Power (BHP)	220	220	220	220	218	220
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.423	0.429	0.429	0.415	0.408	0.415
Corrected BSFC (CBSFC)	0.396	0.400	0.401	0.388	0.380	0.388
Mass Fuel Flow (Pounds/Hr)	93.2	94.2	94.4	91.1	88.9	91.2
Fuel Density (Pounds/Gallon)	5.60	5.57	5.62	5.60	5.63	5.68
Fuel Flow Rate (Gallons/Hour)	16.6	16.9	16.8	16.3	15.8	16.1
Fuel Line Temperature (Deg F)	110	111	111	110	111	103
Dew Point (Deg F)	50	50	51	50	51	51
Percent Power Produced (%)	79	79	79	79	78	79
Percent Lean (%)	-15.9	-15.0	-14.8	-17.8	-19.8	-17.7
Airflow (Pounds of Air per Hour)	1508	1514	1516	1506	1523	1521
Fuel to Air Ratio	0.062	0.062	0.062	0.060	0.058	0.060
Air to Fuel Ratio	16.18	16.07	16.06	16.53	17.14	16.68

Description of Points	
S	Cruise, 25", 2500 rpm, -15%, 102 MON
T	Cruise, 25", 2500 rpm, -15%, 101 MON
U	Cruise, 25", 2500 rpm, -15%, 103 MON
V	Cruise, 25", 2500 rpm, -LBP, 102 MON
W	Cruise, 25", 2500 rpm, -LBP, 103 MON
X	Cruise, 25", 2500 rpm, -LBP, 104 MON

Engine Parameters	Data Points				
	Y	Z	A2	B2	C2
Reference Fuel Motor Octane Number	104	105	106	107	108
#1 Cylinder Head Temperature (Deg F)	443	446	446	443	444
#2 Cylinder Head Temperature (Deg F)	467	471	471	467	468
#3 Cylinder Head Temperature (Deg F)	414	416	413	408	410
#4 Cylinder Head Temperature (Deg F)	408	410	409	406	406
#5 Cylinder Head Temperature (Deg F)	465	462	464	458	458
#6 Cylinder Head Temperature (Deg F)	449	449	450	446	447
#1 Exhaust Gas Temperature (Deg F)	1354	1351	1350	1343	1347
#2 Exhaust Gas Temperature (Deg F)	1378	1372	1370	1365	1367
#3 Exhaust Gas Temperature (Deg F)	1362	1362	1359	1355	1357
#4 Exhaust Gas Temperature (Deg F)	1347	1345	1342	1337	1335
#5 Exhaust Gas Temperature (Deg F)	1321	1314	1309	1305	1306
#6 Exhaust Gas Temperature (Deg F)	1328	1328	1325	1322	1322
Oil Temperature (Deg F)	244	238	239	245	237
Oil Pressure (psig)	34	36	34	34	34
Engine Induction Air Temperature (Deg F)	98	103	105	105	105
Cooling Air Temperature (Deg F)	105	102	100	104	102
Cooling Air Pressure (in H_2O)	2.9	2.9	2.9	5.1	3.5
Unmetered Fuel Pressure (psig)	35	35	35	36	36
Metered Fuel Pressure (psig)	20	20	20	21	21
Manifold Absolute Pressure (in Hg)	28.7	28.7	28.7	28.7	28.7
Engine Speed (rpm)	2700	2706	2705	2706	2705
Produced Engine Torque (ft/lbs)	550	546	546	547	546
Observed Brake Horse Power (BHP)	283	282	281	282	281
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.541	0.545	0.551	0.550	0.556
Corrected BSFC (CBSFC)	0.509	0.509	0.512	0.511	0.517
Mass Fuel Flow (Pounds/Hr)	153.1	153.6	154.9	154.9	156.5
Fuel Density (Pounds/Gallon)	5.67	5.72	5.74	5.76	5.79
Fuel Flow Rate (Gallons/Hour)	27.0	26.8	27.0	26.9	27.0
Fuel Line Temperature (Deg F)	103	100	101	101	101
Dew Point (Deg F)	50	52	52	52	52
Percent Power Produced (%)	101	101	101	102	102
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R
Airflow (Pounds of Air per Hour)	2085	2074	2088	2073	2082
Fuel to Air Ratio	0.073	0.074	0.074	0.075	0.075
Air to Fuel Ratio	13.62	13.51	13.48	13.39	13.31

Description of Points	
Y	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 104 MON
Z	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 105 MON
A2	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 106 MON
B2	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 107 MON
C2	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 108 MON

Engine Parameters	Data Points					
	A	B	C	D	E	F
Reference Fuel Motor Octane Number	100	99	99	100	100	100
#1 Cylinder Head Temperature (Deg F)	429	444	444	442	441	432
#2 Cylinder Head Temperature (Deg F)	461	460	461	460	459	456
#3 Cylinder Head Temperature (Deg F)	403	410	417	416	417	413
#4 Cylinder Head Temperature (Deg F)	397	402	406	404	404	398
#5 Cylinder Head Temperature (Deg F)	447	458	463	465	463	459
#6 Cylinder Head Temperature (Deg F)	440	448	456	456	455	446
#1 Exhaust Gas Temperature (Deg F)	1349	1373	1378	1405	1379	1373
#2 Exhaust Gas Temperature (Deg F)	1372	1402	1402	1430	1408	1405
#3 Exhaust Gas Temperature (Deg F)	1367	1395	1399	1425	1399	1397
#4 Exhaust Gas Temperature (Deg F)	1344	1368	1370	1395	1372	1369
#5 Exhaust Gas Temperature (Deg F)	1308	1348	1346	1367	1346	1350
#6 Exhaust Gas Temperature (Deg F)	1331	1364	1358	1384	1361	1363
Oil Temperature (Deg F)	244	244	238	238	245	238
Oil Pressure (psig)	35	35	35	35	35	35
Engine Induction Air Temperature (Deg F)	104	103	104	105	104	105
Cooling Air Temperature (Deg F)	106	102	105	103	104	100
Cooling Air Pressure (in H_2O)	5	3	2	2	4	3
Unmetered Fuel Pressure (psig)	34	34	31	31	31	34
Metered Fuel Pressure (psig)	20	15	13	12	13	15
Manifold Absolute Pressure (in Hg)	28.7	25.9	25.0	25.0	25.0	26.0
Engine Speed (rpm)	2703	2622	2504	2505	2506	2622
Produced Engine Torque (ft/lbs)	538	472	445	446	447	474
Observed Brake Horse Power (BHP)	277	236	212	213	213	237
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.538	0.518	0.516	0.496	0.513	0.516
Corrected BSFC (CBSFC)	0.502	0.483	0.480	0.462	0.478	0.480
Mass Fuel Flow (Pounds/Hr)	149	122	109	106	109	122
Fuel Density (Pounds/Gallon)	5.58	5.56	5.54	5.54	5.55	5.56
Fuel Flow Rate (Gallons/Hour)	26.7	22.0	19.7	19.1	19.7	22.0
Fuel Line Temperature (Deg F)	104	108	113	113	111	109
Dew Point (Deg F)	46	44	43	40	39	38
Percent Power Produced (%)	100	85	76	77	77	85
Sea Level Barometer During Test (in Hg)	30.0	30.0	30.0	30.0	30.0	30.0
Test Cell Ambient Temperature (Deg F)	66	66	66	66	66	66
Percent Lean (%)	F/R	F/R	F/R	-3.5	F/R	F/R
Airflow (Pounds of Air per Minute)	35	28	25	25	25	29
Airflow (Pounds of Air per Hour)	2076	1704	1522	1497	1523	1720
Fuel to Air Ratio	0.072	0.072	0.072	0.071	0.072	0.071
Air to Fuel Ratio	13.9	13.9	13.9	14.2	13.9	14.1
Description of Points						
A	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 100 MON					
B	Climb, 85%, 2620 rpm, F/R, 99 MON					
C	Cruise, 25", 2500 rpm, F/R, 99 MON					
D	Cruise, 25", 2500 rpm, -5%, 100 MON					
E	Cruise, 25", 2500 rpm, F/R, 100 MON					
F	Climb, 85%, 2620 rpm, F/R, 100 MON					

Engine Parameters	Data Points					
	G	H	I	J	K	L
Reference Fuel Motor Octane Number	98	97	98	97	98	99
#1 Cylinder Head Temperature (Deg F)	442	440	445	440	411	409
#2 Cylinder Head Temperature (Deg F)	460	459	461	456	441	443
#3 Cylinder Head Temperature (Deg F)	416	409	417	410	382	383
#4 Cylinder Head Temperature (Deg F)	401	400	406	399	376	377
#5 Cylinder Head Temperature (Deg F)	459	459	464	460	427	426
#6 Cylinder Head Temperature (Deg F)	449	447	456	451	419	421
#1 Exhaust Gas Temperature (Deg F)	1377	1376	1381	1378	1357	1354
#2 Exhaust Gas Temperature (Deg F)	1406	1401	1410	1405	1371	1373
#3 Exhaust Gas Temperature (Deg F)	1399	1398	1403	1398	1371	1374
#4 Exhaust Gas Temperature (Deg F)	1372	1372	1375	1370	1347	1350
#5 Exhaust Gas Temperature (Deg F)	1351	1347	1350	1342	1310	1312
#6 Exhaust Gas Temperature (Deg F)	1366	1364	1364	1358	1337	1340
Oil Temperature (Deg F)	241	244	245	245	238	234
Oil Pressure (psig)	35	35	35	35	36	36
Engine Induction Air Temperature (Deg F)	105	104	104	104	104	106
Cooling Air Temperature (Deg F)	105	102	106	104	103	99
Cooling Air Pressure (in H_2O)	2	2	3	2	7	5
Unmetered Fuel Pressure (psig)	33	33	31	31	33	33
Metered Fuel Pressure (psig)	15	15	13	13	19	19
Manifold Absolute Pressure (in Hg)	26.0	26.0	25.0	24.9	28.7	28.7
Engine Speed (rpm)	2622	2622	2503	2502	2696	2700
Produced Engine Torque (ft/lbs)	475	475	447	444	548	548
Observed Brake Horse Power (BHP)	237	237	213	212	282	282
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.513	0.513	0.510	0.511	0.523	0.523
Corrected BSFC (CBSFC)	0.477	0.478	0.475	0.476	0.487	0.486
Mass Fuel Flow (Pounds/Hr)	122	122	109	108	147	147
Fuel Density (Pounds/Gallon)	5.56	5.56	5.55	5.55	5.58	5.59
Fuel Flow Rate (Gallons/Hour)	21.9	21.9	19.6	19.5	26.4	26.4
Fuel Line Temperature (Deg F)	109	110	112	112	106	106
Dew Point (Deg F)	34	34	33	34	35	35
Percent Power Produced (%)	86	86	77	76	101	102
Sea Level Barometer During Test (in Hg)	30.0	30.0	30.0	30.0	30.0	30.0
Test Cell Ambient Temperature (Deg F)	66	66	66	66	66	66
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	F/R
Airflow (Pounds of Air per Hour)	1726	1714	1521	1523	2070	2053
Fuel to Air Ratio	0.070	0.071	0.071	0.071	0.071	0.072
Air to Fuel Ratio	14.2	14.1	14.0	14.1	14.1	13.9

Description of Points	
G	Climb, 85%, 2620 rpm, F/R, 98 MON
H	Climb, 85%, 2620 rpm, F/R, 97 MON
I	Cruise, 25", 2500 rpm, F/R, 98 MON
J	Cruise, 25", 2500 rpm, F/R, 97 MON
K	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 98 MON
L	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 99 MON

Engine Parameters	Data Points
	M
Reference Fuel Motor Octane Number	100
#1 Cylinder Head Temperature (Deg F)	406
#2 Cylinder Head Temperature (Deg F)	440
#3 Cylinder Head Temperature (Deg F)	383
#4 Cylinder Head Temperature (Deg F)	376
#5 Cylinder Head Temperature (Deg F)	425
#6 Cylinder Head Temperature (Deg F)	419
#1 Exhaust Gas Temperature (Deg F)	1353
#2 Exhaust Gas Temperature (Deg F)	1373
#3 Exhaust Gas Temperature (Deg F)	1369
#4 Exhaust Gas Temperature (Deg F)	1346
#5 Exhaust Gas Temperature (Deg F)	1310
#6 Exhaust Gas Temperature (Deg F)	1335
Oil Temperature (Deg F)	236
Oil Pressure (psig)	36
Engine Induction Air Temperature (Deg F)	105
Cooling Air Temperature (Deg F)	100
Cooling Air Pressure (in H_2O)	4
Unmetered Fuel Pressure (psig)	33
Metered Fuel Pressure (psig)	19
Manifold Absolute Pressure (in Hg)	28.7
Engine Speed (rpm)	2701
Produced Engine Torque (ft/lbs)	548
Observed Brake Horse Power (BHP)	282
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.524
Corrected BSFC (CBSFC)	0.487
Mass Fuel Flow (Pounds/Hr)	148
Fuel Density (Pounds/Gallon)	5.59
Fuel Flow Rate (Gallons/Hour)	26.4
Fuel Line Temperature (Deg F)	104
Dew Point (Deg F)	35
Percent Power Produced (%)	102
Sea Level Barometer During Test (in Hg)	30.0
Test Cell Ambient Temperature (Deg F)	66
Percent Lean (%)	F/R
Airflow (Pounds of Air per Hour)	2113
Fuel to Air Ratio	0.070
Air to Fuel Ratio	14.3
Description of Points	
M	Takeoff, 100%, wide open throttle, 2700 rpm, F/R, 100 MON

A.3 IO-540-K ENGINE PARAMETER DATA.

Engine Parameters	Data Points					
	A	B	C	D	E	F
Reference Fuel	107AN	105AN	104AN	103AN	102AN	100Pure
#1 Cylinder Head Temperature (Deg F)	474	478	479	483	475	478
#2 Cylinder Head Temperature (Deg F)	447	453	455	457	448	447
#3 Cylinder Head Temperature (Deg F)	456	463	464	469	459	458
#4 Cylinder Head Temperature (Deg F)	438	445	447	450	442	440
#5 Cylinder Head Temperature (Deg F)	471	478	481	485	475	483
#6 Cylinder Head Temperature (Deg F)	470	476	477	485	473	479
#1 Exhaust Gas Temperature (Deg F)	1464	1473	1467	1456	1449	1394
#2 Exhaust Gas Temperature (Deg F)	1441	1450	1445	1436	1432	1393
#3 Exhaust Gas Temperature (Deg F)	1460	1467	1463	1454	1447	1398
#4 Exhaust Gas Temperature (Deg F)	1458	1470	1461	1451	1445	1406
#5 Exhaust Gas Temperature (Deg F)	1461	1470	1460	1453	1444	1372
#6 Exhaust Gas Temperature (Deg F)	1489	1496	1492	1478	1470	1409
Left Turbine Inlet Temperature (Deg F)						
Right Turbine Inlet Temperature (Deg F)						
Oil Temperature (Deg F)	234	233	233	229	235	238
Oil Pressure (psig)	74	74	74	74	74	73
Engine Induction Air Temperature (Deg F)	97	103	103	104	104	102
Combustion Air Temperature (Deg F)						
Cooling Air Temperature (Deg F)	103	107	103	106	98	102
Cooling Air Pressure (in H_2O)	2.5	2.2	3.3	1.4	1.5	3.4
Unmetered Fuel Pressure (psig)	21.7	21.6	21.7	21.6	21.6	21.5
Metered Fuel Pressure (psig)	7.9	7.6	7.7	7.8	7.8	8.2
Manifold Absolute Pressure (in Hg)	29.8	29.8	29.8	29.8	29.8	29.8
Engine Speed (rpm)	2705	2707	2706	2702	2703	2701
Produced Engine Torque (ft/lbs)	522	528	526	527	529	524
Observed Brake Horse Power (BHP)	269	272	271	271	272	270
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.52	0.50	0.50	0.51	0.50	0.52
Mass Fuel Flow (Pounds/Hr)	139	136	136	138	137	140
Fuel Density (Pounds/Gallon)	5.77	5.73	5.70	5.69	5.66	5.61
Fuel Flow Rate (Gallons/Hour)	24.2	23.7	23.9	24.3	24.3	24.9
Fuel Line Temperature (Deg F)	75	72	73	71	71	70
Dew Point (Deg F)	26	31	31	30	29	30
Percent Power Produced (%)	95	97	97	97	97	96
Sea Level Barometer During Test (in Hg)	30.5	30.5	30.5	30.5	30.5	30.5
Test Cell Ambient Temperature (Deg F)	41	41	41	41	41	41
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	F/R
Airflow (Pounds of Air per Hour)	2297	2285	2278	2290	2292	2278
Fuel to Air Ratio	0.061	0.060	0.060	0.060	0.060	0.061
Air to Fuel Ratio	16.5	16.8	16.7	16.6	16.7	16.3

Description of Points	
A	Takeoff, 2700 rpm, FT, F/R, Sample #107AN
B	Takeoff, 2700 rpm, FT, F/R, Sample #105AN
C	Takeoff, 2700 rpm, FT, F/R, Sample #104AN
D	Takeoff, 2700 rpm, FT, F/R, Sample #103AN
E	Takeoff, 2700 rpm, FT, F/R, Sample #102AN
F	Takeoff, 2700 rpm, FT, F/R, House

Engine Parameters	Data Points					
	G	H	I	J	K	L
Reference Fuel	100	100	100	102AN	102AN	103AN
#1 Cylinder Head Temperature (Deg F)	480	478	475	473	481	477
#2 Cylinder Head Temperature (Deg F)	456	447	453	450	455	451
#3 Cylinder Head Temperature (Deg F)	465	459	461	461	465	459
#4 Cylinder Head Temperature (Deg F)	450	438	448	443	450	447
#5 Cylinder Head Temperature (Deg F)	486	485	479	477	481	475
#6 Cylinder Head Temperature (Deg F)	479	474	474	471	481	475
#1 Exhaust Gas Temperature (Deg F)	1383	1464	1447	1446	1433	1457
#2 Exhaust Gas Temperature (Deg F)	1374	1467	1435	1422	1413	1429
#3 Exhaust Gas Temperature (Deg F)	1392	1466	1454	1444	1433	1453
#4 Exhaust Gas Temperature (Deg F)	1400	1470	1443	1434	1433	1449
#5 Exhaust Gas Temperature (Deg F)	1373	1434	1441	1438	1427	1448
#6 Exhaust Gas Temperature (Deg F)	1405	1477	1466	1463	1457	1479
Oil Temperature (Deg F)	235	231	237	228	240	229
Oil Pressure (psig)	74	73	70	74	74	75
Engine Induction Air Temperature (Deg F)	105	105	103	104	103	104
Cooling Air Temperature (Deg F)	109	110	114	102	105	106
Cooling Air Pressure (in H_2O)	3.3	3.4	2.2	2.8	3.3	3.3
Unmetered Fuel Pressure (psig)	21.4	21.4	21.3	21.5	21.6	21.5
Metered Fuel Pressure (psig)	8.4	5.6	4.7	6.2	7.9	7.7
Manifold Absolute Pressure (in Hg)	29.7	28.1	26.8	28.1	29.7	29.7
Engine Speed (rpm)	2702	2608	2452	2605	2707	2705
Produced Engine Torque (ft/lbs)	520	478	448	485	525	525
Observed Brake Horse Power (BHP)	267	237	209	241	271	270
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.54	0.47	0.48	0.49	0.51	0.51
Mass Fuel Flow (Pounds/Hr)	143	110	100	119	138	137
Fuel Density (Pounds/Gallon)	5.58	5.56	5.58	5.60	5.62	5.63
Fuel Flow Rate (Gallons/Hour)	25.6	19.9	18.0	21.3	24.6	24.3
Fuel Line Temperature (Deg F)	78	84	81	84	78	81
Dew Point (Deg F)	30	31	30	30	31	33
Percent Power Produced (%)	96	85	75	86	97	97
Sea Level Barometer During Test (in Hg)	30.5	30.5	30.5	30.5	30.5	30.5
Test Cell Ambient Temperature (Deg F)	53	53	53	53	53	53
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	F/R
Airflow (Pounds of Air per Hour)	2268	1795	1548	1821	2300	2299
Fuel to Air Ratio	0.063	0.062	0.065	0.065	0.060	0.059
Air to Fuel Ratio	15.8	16.2	15.5	15.3	16.6	16.8

Description of Points	
G	Takeoff, 2700 rpm, FT, F/R, Sample #100
H	Climb, 2600 rpm, 26", F/R, Sample #100
I	Cruise, 2450 rpm, 25", F/R, Sample #100
J	Climb, 2600 rpm, 26", F/R, Sample #102AN
K	Takeoff, 2700 rpm, FT, F/R, Sample #102AN
L	Climb, 2600 rpm, 26", F/R, Sample #103AN

Engine Parameters	Data Points					
	M	N	O	P	Q	R
Reference Fuel	103AN	104AN	104AN	107AN	105AN	104AN
#1 Cylinder Head Temperature (Deg F)	474	478	476	481	475	474
#2 Cylinder Head Temperature (Deg F)	453	455	452	462	458	453
#3 Cylinder Head Temperature (Deg F)	460	461	458	462	457	455
#4 Cylinder Head Temperature (Deg F)	447	450	448	456	453	450
#5 Cylinder Head Temperature (Deg F)	477	475	474	478	476	473
#6 Cylinder Head Temperature (Deg F)	471	472	474	472	469	467
#1 Exhaust Gas Temperature (Deg F)	1487	1510	1458	1522	1492	1465
#2 Exhaust Gas Temperature (Deg F)	1457	1481	1432	1490	1459	1434
#3 Exhaust Gas Temperature (Deg F)	1484	1510	1458	1524	1491	1465
#4 Exhaust Gas Temperature (Deg F)	1470	1491	1453	1502	1471	1448
#5 Exhaust Gas Temperature (Deg F)	1479	1505	1453	1509	1482	1452
#6 Exhaust Gas Temperature (Deg F)	1502	1528	1480	1542	1510	1482
Oil Temperature (Deg F)	229	231	232	239	241	239
Oil Pressure (psig)	72	72	74	69	68	69
Engine Induction Air Temperature (Deg F)	103	103	104	103	103	102
Cooling Air Temperature (Deg F)	109	107	105	107	107	105
Cooling Air Pressure (in H_2O)	1.5	1.4	3.0	2.4	2.8	1.4
Unmetered Fuel Pressure (psig)	21.5	21.5	21.5	21.5	21.4	21.4
Metered Fuel Pressure (psig)	5.8	5.6	7.6	4.4	4.7	4.9
Manifold Absolute Pressure (in Hg)	28.2	28.2	29.7	27.0	27.1	27.0
Engine Speed (rpm)	2608	2608	2706	2457	2454	2453
Produced Engine Torque (ft/lbs)	486	486	521	450	456	453
Observed Brake Horse Power (BHP)	241	241	268	211	213	212
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.48	0.47	0.51	0.46	0.47	0.49
Mass Fuel Flow (Pounds/Hr)	116	113	136	97	101	103
Fuel Density (Pounds/Gallon)	5.64	5.67	5.66	5.74	5.71	5.67
Fuel Flow Rate (Gallons/Hour)	20.6	20.0	24.0	16.9	17.7	18.2
Fuel Line Temperature (Deg F)	81	80	82	80	80	82
Dew Point (Deg F)	33	30	33	31	31	31
Percent Power Produced (%)	86	87	96	75	76	76
Sea Level Barometer During Test (in Hg)	30.5	30.5	30.5	30.5	30.5	30.5
Test Cell Ambient Temperature (Deg F)	53	53	53	53	53	53
Percent Lean (%)	F/R	F/R	F/R	5.7	1.7	-1.6
Airflow (Pounds of Air per Hour)	1820	1829	2295	1556	1555	1550
Fuel to Air Ratio	0.064	0.062	0.059	0.062	0.065	0.067
Air to Fuel Ratio	15.7	16.1	16.9	16.0	15.4	15.0

Description of Points	
M	Climb, 2600 rpm, 26", F/R, Sample #103AN
N	Climb, 2600 rpm, 26", F/R, Sample #104AN
O	Takeoff, 2700 rpm, FT, F/R, Sample #104AN
P	Cruise, 2450 rpm, 25", LBP, Sample #107AN
Q	Cruise, 2450 rpm, 25", LBP, Sample #105AN
R	Cruise, 2450 rpm, 25", LBP, Sample #104AN

Engine Parameters	Data Points
	S
Reference Fuel	105AN
#1 Cylinder Head Temperature (Deg F)	475
#2 Cylinder Head Temperature (Deg F)	452
#3 Cylinder Head Temperature (Deg F)	461
#4 Cylinder Head Temperature (Deg F)	447
#5 Cylinder Head Temperature (Deg F)	473
#6 Cylinder Head Temperature (Deg F)	472
#1 Exhaust Gas Temperature (Deg F)	1416
#2 Exhaust Gas Temperature (Deg F)	1392
#3 Exhaust Gas Temperature (Deg F)	1416
#4 Exhaust Gas Temperature (Deg F)	1399
#5 Exhaust Gas Temperature (Deg F)	1412
#6 Exhaust Gas Temperature (Deg F)	1438
Left Turbine Inlet Temperature (Deg F)	
Right Turbine Inlet Temperature (Deg F)	
Oil Temperature (Deg F)	237
Oil Pressure (psig)	71
Engine Induction Air Temperature (Deg F)	103
Combustion Air Temperature (Deg F)	
Cooling Air Temperature (Deg F)	109
Cooling Air Pressure (in H_2O)	1.5
Unmetered Fuel Pressure (psig)	21.5
Metered Fuel Pressure (psig)	6.8
Manifold Absolute Pressure (in Hg)	28.1
Engine Speed (rpm)	2602
Produced Engine Torque (ft/lbs)	477
Observed Brake Horse Power (BHP)	236
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.54
Mass Fuel Flow (Pounds/Hr)	128
Fuel Density (Pounds/Gallon)	5.70
Fuel Flow Rate (Gallons/Hour)	22.5
Fuel Tank Temperature (Deg F)	
Fuel Line Temperature (Deg F)	80
Dew Point (Deg F)	31
Humidity Ratio (Grains/Pound)	
Relative Humidity (%)	
Percent Power Produced (%)	85
Sea Level Barometer During Test (in Hg)	30.5
Test Cell Ambient Temperature (Deg F)	53
Percent Lean (%)	-13.4
Airflow (Standard Cubic Feet per Minute)	
Airflow (Pounds of Air per Minute)	30
Airflow (Pounds of Air per Hour)	1817
Fuel to Air Ratio	0.071
Air to Fuel Ratio	14.2
Description of Points	
S	Climb, 2600 rpm, 26", LBP, Sample #105AN

Engine Parameters	Data Points					
	A	B	C	D	E	F
Reference Fuel	104AN	103AN	103AN	102AN	104AN	103AN
#1 Cylinder Head Temperature (Deg F)	480	483	470	470	469	468
#2 Cylinder Head Temperature (Deg F)	445	446	436	434	439	437
#3 Cylinder Head Temperature (Deg F)	452	461	457	457	459	458
#4 Cylinder Head Temperature (Deg F)	446	448	441	444	439	438
#5 Cylinder Head Temperature (Deg F)	491	495	484	483	484	483
#6 Cylinder Head Temperature (Deg F)	469	470	460	459	459	459
#1 Exhaust Gas Temperature (Deg F)	1469	1463	1455	1455	1486	1486
#2 Exhaust Gas Temperature (Deg F)	1446	1443	1433	1438	1457	1454
#3 Exhaust Gas Temperature (Deg F)	1471	1468	1459	1458	1491	1491
#4 Exhaust Gas Temperature (Deg F)	1465	1466	1458	1462	1470	1470
#5 Exhaust Gas Temperature (Deg F)	1467	1457	1451	1452	1481	1481
#6 Exhaust Gas Temperature (Deg F)	1493	1489	1480	1481	1506	1503
Oil Temperature (Deg F)	238	236	237	243	226	243
Oil Pressure (psig)	67	68	68	68	67	67
Engine Induction Air Temperature (Deg F)	106	106	101	101	102	103
Cooling Air Temperature (Deg F)	105	105	103	102	102	103
Cooling Air Pressure (in H_2O)	0.7	3.5	3.5	3.5	3.5	3.5
Unmetered Fuel Pressure (psig)	20.9	21.0	20.9	20.9	21.0	21.0
Metered Fuel Pressure (psig)	6.3	6.2	6.0	5.9	4.7	4.7
Manifold Absolute Pressure (in Hg)	29.5	29.5	29.4	29.4	27.6	27.6
Engine Speed (rpm)	2695	2695	2695	2695	2595	2595
Produced Engine Torque (ft/lbs)	533	538	540	542	491	493
Observed Brake Horse Power (BHP)	273	276	277	278	243	243
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.49	0.48	0.49	0.48	0.48	0.47
Mass Fuel Flow (Pounds/Hr)	135	134	137	135	116	114
Fuel Density (Pounds/Gallon)	5.58	5.54	5.66	5.63	5.69	5.64
Fuel Flow Rate (Gallons/Hour)	23.9	24.1	24.2	23.9	20.3	20.3
Fuel Tank Temperature (Deg F)	100	101	103	102	105	107
Fuel Line Temperature (Deg F)	130	131	103	104	104	108
Relative Humidity (%)	11	11	9	9	9	8
Percent Power Produced (%)	99	100	99	99	87	87
Sea Level Barometer During Test (in Hg)	29.92	29.92	29.91	29.91	29.91	29.91
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	F/R

Description of Points	
A	Takeoff, 2700 rpm, F/R, 104AN
B	Takeoff, 2700 rpm, F/R, 103AN
C	Takeoff, 2700 rpm, F/R, 103AN
D	Takeoff, 2700 rpm, F/R, 102AN
E	Climb, 255 HP, 2600 rpm, F/R, 104AN
F	Climb, 255 HP, 2600 rpm, F/R, 103AN

Engine Parameters	Data Points					
	G	H	I	J	K	L
Reference Fuel	102AN	101AN	102AN	101AN	100AN	101AN
#1 Cylinder Head Temperature (Deg F)	467	468	462	466	464	466
#2 Cylinder Head Temperature (Deg F)	435	437	433	438	436	440
#3 Cylinder Head Temperature (Deg F)	456	457	451	455	454	456
#4 Cylinder Head Temperature (Deg F)	434	436	436	440	438	442
#5 Cylinder Head Temperature (Deg F)	482	485	478	484	482	484
#6 Cylinder Head Temperature (Deg F)	458	458	453	457	456	458
#1 Exhaust Gas Temperature (Deg F)	1488	1474	1472	1456	1458	1507
#2 Exhaust Gas Temperature (Deg F)	1455	1446	1441	1425	1431	1476
#3 Exhaust Gas Temperature (Deg F)	1486	1475	1478	1459	1459	1512
#4 Exhaust Gas Temperature (Deg F)	1472	1465	1460	1441	1447	1496
#5 Exhaust Gas Temperature (Deg F)	1480	1461	1464	1440	1441	1495
#6 Exhaust Gas Temperature (Deg F)	1503	1493	1493	1473	1470	1524
Oil Temperature (Deg F)	227	230	239	232	226	243
Oil Pressure (psig)	68	67	65	66	66	65
Engine Induction Air Temperature (Deg F)	103	103	103	103	103	102
Cooling Air Temperature (Deg F)	103	103	103	103	103	102
Cooling Air Pressure (in H_2O)	2.4	3.5	0.7	3.5	3.5	3.5
Unmetered Fuel Pressure (psig)	20.9	20.9	20.8	20.8	20.8	20.8
Metered Fuel Pressure (psig)	4.6	4.8	3.8	4.0	3.9	3.7
Manifold Absolute Pressure (in Hg)	27.6	27.6	26.3	26.3	26.3	26.3
Engine Speed (rpm)	2595	2594	2445	2445	2445	2445
Produced Engine Torque (ft/lbs)	492	491	463	463	463	462
Observed Brake Horse Power (BHP)	243	242	216	216	215	215
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.47	0.48	0.46	0.47	0.46	0.44
Mass Fuel Flow (Pounds/Hr)	115	115	99	102	100	95
Fuel Density (Pounds/Gallon)	5.60	5.60	5.64	5.60	5.60	5.62
Fuel Flow Rate (Gallons/Hour)	20.5	20.6	17.6	18.2	17.8	16.9
Fuel Tank Temperature (Deg F)	109	109	112	112	113	114
Fuel Line Temperature (Deg F)	115	109	103	109	104	105
Relative Humidity (%)	8	9	9	9	9	9
Percent Power Produced (%)	87	87	77	77	77	77
Sea Level Barometer During Test (in Hg)	29.91	29.91	29.92	29.92	29.92	29.92
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	-4.9
Description of Points						
G	Climb, 255 HP, 2600 rpm, F/R, 102AN					
H	Climb, 255 HP, 2600 rpm, F/R, 101AN					
I	Cruise, 225 HP, 2450 rpm, F/R, 102AN					
J	Cruise, 225 HP, 2450 rpm, F/R, 101AN					
K	Cruise, 225 HP, 2450 rpm, F/R, 100AN					
L	Cruise, 225 HP, 2450 rpm, Less 5%, 101AN					

Engine Parameters	Data Points	
	M	N
Reference Fuel	102AN	103AN
#1 Cylinder Head Temperature (Deg F)	466	463
#2 Cylinder Head Temperature (Deg F)	441	439
#3 Cylinder Head Temperature (Deg F)	457	453
#4 Cylinder Head Temperature (Deg F)	443	440
#5 Cylinder Head Temperature (Deg F)	484	478
#6 Cylinder Head Temperature (Deg F)	458	452
#1 Exhaust Gas Temperature (Deg F)	1514	1557
#2 Exhaust Gas Temperature (Deg F)	1482	1521
#3 Exhaust Gas Temperature (Deg F)	1516	1557
#4 Exhaust Gas Temperature (Deg F)	1496	1539
#5 Exhaust Gas Temperature (Deg F)	1502	1538
#6 Exhaust Gas Temperature (Deg F)	1534	1568
Oil Temperature (Deg F)	230	227
Oil Pressure (psig)	66	66
Engine Induction Air Temperature (Deg F)	103	104
Combustion Air Temperature (Deg F)		
Cooling Air Temperature (Deg F)	103	102
Cooling Air Pressure (in H_2O)	3.5	0.7
Unmetered Fuel Pressure (psig)	20.8	20.9
Metered Fuel Pressure (psig)	3.7	3.2
Manifold Absolute Pressure (in Hg)	26.3	26.3
Engine Speed (rpm)	2445	2444
Produced Engine Torque (ft/lbs)	461	452
Observed Brake Horse Power (BHP)	214	210
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.44	0.42
Mass Fuel Flow (Pounds/Hr)	94	89
Fuel Density (Pounds/Gallon)	5.64	5.63
Fuel Flow Rate (Gallons/Hour)	16.7	15.9
Fuel Tank Temperature (Deg F)	114	116
Fuel Line Temperature (Deg F)	104	114
Relative Humidity (%)	9	8
Percent Power Produced (%)	77	75
Sea Level Barometer During Test (in Hg)	29.92	29.92
Percent Lean (%)	-5.7	-10.6
Description of Points		
M	Cruise, 225 HP, 2450 rpm, Less 5%, 102AN	
N	Cruise, 225 HP, 2450 rpm, Less 10%, 103AN	

Engine Parameters	Data Points					
	A	B	C	D	E	F
Reference Fuel Motor Octane Number	105	103	104	103	104	105
#1 Cylinder Head Temperature (Deg F)	471	463	468	464	463	467
#2 Cylinder Head Temperature (Deg F)	435	435	445	438	438	444
#3 Cylinder Head Temperature (Deg F)	457	451	457	454	453	457
#4 Cylinder Head Temperature (Deg F)	439	438	444	442	441	445
#5 Cylinder Head Temperature (Deg F)	485	477	483	478	478	483
#6 Cylinder Head Temperature (Deg F)	463	452	458	457	453	458
#1 Exhaust Gas Temperature (Deg F)	1485	1471	1482	1518	1506	1522
#2 Exhaust Gas Temperature (Deg F)	1462	1440	1452	1484	1478	1497
#3 Exhaust Gas Temperature (Deg F)	1482	1474	1484	1517	1510	1527
#4 Exhaust Gas Temperature (Deg F)	1477	1453	1469	1503	1496	1509
#5 Exhaust Gas Temperature (Deg F)	1483	1458	1467	1503	1494	1511
#6 Exhaust Gas Temperature (Deg F)	1507	1485	1496	1532	1526	1544
Oil Temperature (Deg F)	228	235	240	227	226	227
Oil Pressure (psig)	68	65	65	65	65	65
Engine Induction Air Temperature (Deg F)	105	107	106	106	106	106
Cooling Air Temperature (Deg F)	106	105	106	106	106	106
Cooling Air Pressure (in H_2O)	3.5	0.8	3.5	1.3	1.9	3.5
Unmetered Fuel Pressure (psig)	21	21	21	21	21	21
Metered Fuel Pressure (psig)	6.0	3.8	3.9	3.6	3.7	3.6
Manifold Absolute Pressure (in Hg)	29.63	26.16	26.21	26.19	26.21	26.24
Engine Speed (rpm)	2699	2449	2450	2449	2449	2449
Produced Engine Torque (ft/lbs)	544	461	461	461	461	459
Observed Brake Horse Power (BHP)	280	215	215	215	215	214
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.48	0.46	0.46	0.44	0.44	0.44
Mass Fuel Flow (Pounds/Hr)	133.9	99.0	99.0	93.8	94.7	93.4
Fuel Density (Pounds/Gallon)	5.67	5.61	5.63	5.60	5.63	5.64
Fuel Flow Rate (Gallons/Hour)	23.6	17.7	17.6	16.7	16.8	16.6
Fuel Tank Temperature (Deg F)	90	93	94	97	96	99
Fuel Line Temperature (Deg F)	110	115	117	118	118	119
Relative Humidity (%)	5.9	6.3	6.4	6.2	6.4	6.3
Percent Power Produced (%)	100	77	77	77	77	77
Sea Level Barometer During Test (in Hg)	30.13	30.13	30.13	30.13	30.14	30.14
Percent Lean Mixture (%)	F/R	F/R	F/R	-5.3	-4.3	-5.7
Description of Points						
A	Takeoff, 300 HP, 2700 rpm, 105AN, F/R					
B	Cruise, 225 HP, 2450 rpm, 103AN, F/R					
C	Cruise, 225 HP, 2450 rpm, 104AN, F/R					
D	Cruise, 225 HP, 2450 rpm, 103AN, Less 5%					
E	Cruise, 225 HP, 2450 rpm, 104AN, Less 5%					
F	Cruise, 225 HP, 2450 rpm, 105AN, Less 5%					

Engine Parameters	Data Points		
	G	H	I
Reference Fuel Motor Octane Number	104	105	106
#1 Cylinder Head Temperature (Deg F)	462	464	463
#2 Cylinder Head Temperature (Deg F)	434	439	436
#3 Cylinder Head Temperature (Deg F)	452	454	454
#4 Cylinder Head Temperature (Deg F)	440	442	442
#5 Cylinder Head Temperature (Deg F)	477	478	478
#6 Cylinder Head Temperature (Deg F)	452	453	453
#1 Exhaust Gas Temperature (Deg F)	1556	1548	1561
#2 Exhaust Gas Temperature (Deg F)	1526	1519	1529
#3 Exhaust Gas Temperature (Deg F)	1558	1551	1561
#4 Exhaust Gas Temperature (Deg F)	1542	1536	1546
#5 Exhaust Gas Temperature (Deg F)	1535	1536	1536
#6 Exhaust Gas Temperature (Deg F)	1562	1564	1565
Oil Temperature (Deg F)	229	241	234
Oil Pressure (psig)	65	65	64
Engine Induction Air Temperature (Deg F)	104	105	105
Cooling Air Temperature (Deg F)	103	103	103
Cooling Air Pressure (in H_2O)	1.1	1.6	2.2
Unmetered Fuel Pressure (psig)	21	21	21
Metered Fuel Pressure (psig)	3.3	3.5	3.4
Manifold Absolute Pressure (in Hg)	26.20	26.23	26.23
Engine Speed (rpm)	2449	2448	2449
Produced Engine Torque (ft/lbs)	453	456	452
Observed Brake Horse Power (BHP)	211	213	211
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.42	0.43	0.42
Mass Fuel Flow (Pounds/Hr)	88.2	90.4	88.8
Fuel Density (Pounds/Gallon)	5.62	5.65	5.67
Fuel Flow Rate (Gallons/Hour)	15.7	16.0	15.7
Fuel Tank Temperature (Deg F)	100	101	101
Fuel Line Temperature (Deg F)	119	117	119
Relative Humidity (%)	6.0	5.7	5.7
Percent Power Produced (%)	76	76	75
Sea Level Barometer During Test (in Hg)	30.14	30.14	30.14
Percent Lean Mixture (%)	-10.9	-8.7	-10.3
Description of Points			
G	Cruise, 225 HP, 2450 rpm, 104AN, Less 10%		
H	Cruise, 225 HP, 2450 rpm, 105AN, Less 10%		
I	Cruise, 225 HP, 2450 rpm, 106AN, Less 10%		

A.4 TIO-540-J ENGINE PARAMETER DATA.

A.4.1 350 BHP Configuration.

Engine Parameters	Data Points				
	A	B	C	D	E
Reference Fuel Motor Octane Number	98	98	98	100	99
#1 Cylinder Head Temperature (Deg F)	487	473	466	465	467
#2 Cylinder Head Temperature (Deg F)	486	467	477	470	461
#3 Cylinder Head Temperature (Deg F)	475	465	467	462	456
#4 Cylinder Head Temperature (Deg F)	454	433	433	440	427
#5 Cylinder Head Temperature (Deg F)	475	459	460	462	449
#6 Cylinder Head Temperature (Deg F)	474	453	463	461	449
Oil Temperature (Deg F)	222	220	216	217	208
Oil Pressure (psig)	77	75	73	79	76
Cooling Air Temperature (Deg F)	107	115	118	105	100
Engine Induction Air Temperature (Deg F)	99	92	90	86	108
Manifold Temperature (Deg F)	200	177	173	179	185
#1 Exhaust Gas Temperature (Deg F)	1309	1265	1224	1303	1248
#2 Exhaust Gas Temperature (Deg F)	1309	1263	1218	1305	1254
#3 Exhaust Gas Temperature (Deg F)	1350	1281	1257	1334	1280
#4 Exhaust Gas Temperature (Deg F)	1331	1261	1232	1316	1259
#5 Exhaust Gas Temperature (Deg F)	1367	1299	1267	1349	1288
#6 Exhaust Gas Temperature (Deg F)	1361	1294	1262	1349	1282
Turbine Inlet Temperature (Deg F)	1404	1324	1300	1373	1327
Engine Speed (rpm)	2548	2403	2198	2576	2203
Fuel Flow Rate (Pounds/Hr)	251	216	197	255	191
Fuel Flow Rate (Gallons/Hr)	44	38	35	45	34
Produced Engine Torque (ft/lbs)	698	616	624	693	617
Manifold Absolute Pressure (in Hg)	45	40	40	44	40
Pressure Altitude (in Hg)	28.9	29.1	29.2	28.8	29.0
Observed Brake Horse Power (BHP)	339	282	261	340	259
Brake Specific Fuel Consumption (lbs/BHP Hr)	1	1	1	1	1
Dewpoint Temperature (Deg F)	42	37	36	39	90
Description of Points					
A	Takeoff, 2575 rpm, F/R, 98 MON				
B	Climb, 40 in Hg, 2400 rpm, 98 MON				
C	Climb, 40 in Hg, 2200 rpm, 98 MON				
D	Takeoff, 2575 rpm, F/R, 100 MON				
E	Cruise, 40 in Hg, 2200 rpm, F/R, 99 MON				

Engine Parameters	Data Points				
	F	G	H	I	J
Reference Fuel Motor Octane Number	99	100	100	100	100
#1 Cylinder Head Temperature (Deg F)	462	465	468	474	470
#2 Cylinder Head Temperature (Deg F)	468	467	469	468	460
#3 Cylinder Head Temperature (Deg F)	459	457	465	465	453
#4 Cylinder Head Temperature (Deg F)	428	429	436	434	426
#5 Cylinder Head Temperature (Deg F)	452	452	457	460	452
#6 Cylinder Head Temperature (Deg F)	454	453	459	451	442
Oil Temperature (Deg F)	219	219	219	221	222
Oil Pressure (psig)	73	73	73	75	76
Cooling Air Temperature (Deg F)	100	99	101	98	100
Engine Induction Air Temperature (Deg F)	102	102	105	106	108
Manifold Temperature (Deg F)	186	185	172	193	179
#1 Exhaust Gas Temperature (Deg F)	1280	1284	1322	1310	1321
#2 Exhaust Gas Temperature (Deg F)	1278	1287	1328	1308	1311
#3 Exhaust Gas Temperature (Deg F)	1307	1313	1349	1326	1334
#4 Exhaust Gas Temperature (Deg F)	1286	1292	1330	1307	1310
#5 Exhaust Gas Temperature (Deg F)	1318	1325	1364	1347	1357
#6 Exhaust Gas Temperature (Deg F)	1311	1317	1352	1340	1344
Turbine Inlet Temperature (Deg F)	1344	1346	1365	1363	1354
Engine Speed (rpm)	2206	2204	2207	2403	2412
Fuel Flow Rate (Pounds/Hr)	186	182	154	202	180
Fuel Flow Rate (Gallons/Hr)	33	32	27	N/A	31
Produced Engine Torque (ft/lbs)	621	628	541	623	536
Manifold Absolute Pressure (in Hg)	40	40	35	40	35
Pressure Altitude (in Hg)	29	29	29	29	29
Observed Brake Horse Power (BHP)	261	264	227	285	246
Brake Specific Fuel Consumption (lbs/BHP Hr)	1	1	1	1	1
Dewpoint Temperature (Deg F)	100	76	86	N/A	107
Description of Points					
F	Cruise, 40 in Hg, 2200 rpm, LBP, 99 MON				
G	Cruise, 40 in Hg, 2200 rpm, LBP, 100 MON				
H	Cruise, 35 in Hg, 2200 rpm, LPE, 100 MON				
I	Climb, 40 in Hg, 2400 rpm, LBP, 100 MON				
J	Cruise, 35 in Hg, 2400 rpm, LPE, 100 MON				

A.4.2 325 BHP Configuration.

Engine Parameters	Data Points					
	A	B	C	D	E	F
Reference Fuel Motor Octane Number	100	100	100	100	100	99
#1 Cylinder Head Temperature (Deg F)	474	473	474	486	481	475
#2 Cylinder Head Temperature (Deg F)	464	457	458	466	466	468
#3 Cylinder Head Temperature (Deg F)	455	460	465	474	457	460
#4 Cylinder Head Temperature (Deg F)	443	438	445	440	439	446
#5 Cylinder Head Temperature (Deg F)	465	459	460	465	458	467
#6 Cylinder Head Temperature (Deg F)	461	456	465	472	458	464
Oil Temperature (Deg F)	230	230	229	229	231	235
Oil Pressure (psig)	74	72	70	70	72	73
Cooling Air Temperature (Deg F)	105	108	109	107	108	105
#1 Exhaust Gas Temperature (Deg F)	1292	1258	1214	1332	1385	1293
#2 Exhaust Gas Temperature (Deg F)	1285	1251	1208	1340	1393	1289
#3 Exhaust Gas Temperature (Deg F)	1321	1280	1247	1371	1421	1324
#4 Exhaust Gas Temperature (Deg F)	1308	1257	1223	1355	1406	1303
#5 Exhaust Gas Temperature (Deg F)	1338	1292	1254	1384	1438	1339
#6 Exhaust Gas Temperature (Deg F)	1341	1294	1255	1382	1442	1343
Turbine Inlet Temperature (Deg F)	1368	1325	1301	1404	1429	1376
Engine Induction Air Temperature (Deg F)	99	103	101	101	102	101
Manifold Temperature (Deg F)	200	190	184	183	189	201
Dewpoint Temperature (Deg F)	67	67	68	68	68	67
Engine Speed (rpm)	2571	2402	2200	2203	2405	2574
Produced Engine Torque (ft/lbs)	657	583	591	624	631	658
Manifold Absolute Pressure (in Hg)	44.8	40.1	40.1	40	40.1	44.7
Observed Brake Horse Power (BHP)	322	267	247	262	289	323
Fuel Pump Pressure (psig)	43	43	43	44	44	43
Fuel Metered Pressure (psig)	26	18	15	10	10	25
Fuel Flow Rate (Gallons/HR)	48.1	40.1	37.1	30.2	32.1	47.7
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.85	0.86	0.86	0.66	0.63	0.84
Description of Points						
A	Takeoff, 2575 rpm, F/R, 100 MON					
B	Climb, 40 in Hg, 2400 rpm, F/R, 100 MON					
C	Cruise, 40 in Hg, 2200 rpm, F/R, 100 MON					
D	Cruise, 40 in Hg, 2200 rpm, LBP, 100 MON					
E	Climb, 40 in Hg, 2400 rpm, LBP, 100 MON					
F	Takeoff, 2575 rpm, F/R, 99 MON					

Engine Parameters	Data Points					
	G	H	I	J	K	L
Reference Fuel Motor Octane Number	99	99	98	97	98	97
#1 Cylinder Head Temperature (Deg F)	472	472	478	475	473	473
#2 Cylinder Head Temperature (Deg F)	463	459	468	464	456	457
#3 Cylinder Head Temperature (Deg F)	460	458	462	460	456	455
#4 Cylinder Head Temperature (Deg F)	436	432	446	439	435	430
#5 Cylinder Head Temperature (Deg F)	468	460	471	466	466	466
#6 Cylinder Head Temperature (Deg F)	458	461	465	458	453	452
Oil Temperature (Deg F)	232	229	231	232	230	230
Oil Pressure (psig)	72	70	74	74	72	72
Cooling Air Temperature (Deg F)	109	110	108	104	110	108
#1 Exhaust Gas Temperature (Deg F)	1254	1211	1288	1265	1250	1250
#2 Exhaust Gas Temperature (Deg F)	1249	1212	1287	1262	1246	1247
#3 Exhaust Gas Temperature (Deg F)	1277	1244	1322	1317	1276	1273
#4 Exhaust Gas Temperature (Deg F)	1254	1222	1303	1296	1250	1253
#5 Exhaust Gas Temperature (Deg F)	1288	1253	1336	1332	1288	1288
#6 Exhaust Gas Temperature (Deg F)	1291	1252	1340	1335	1290	1288
Turbine Inlet Temperature (Deg F)	1318	1289	1369	1376	1318	1315
Engine Induction Air Temperature (Deg F)	102	102	103	102	101	101
Manifold Temperature (Deg F)	190	185	203	201	189	188
Dewpoint Temperature (Deg F)	68	68	68	67	68	68
Engine Speed (rpm)	2404	2206	2573	2572	2398	2401
Produced Engine Torque (ft/lbs)	583	591	663	662	587	585
Manifold Absolute Pressure (in Hg)	40.1	40.2	45.1	44.8	40.1	39.9
Observed Brake Horse Power (BHP)	267	248	325	324	268	267
Fuel Pump Pressure (psig)	43	43	43	43	43	43
Fuel Metered Pressure (psig)	18	15	26	25	18	18
Fuel Flow Rate (Gallons/HR)	40.5	36.7	48	47.7	40.3	40.3
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.87	0.84	0.84	0.84	0.86	0.86

Description of Points	
G	Climb, 40 in Hg, 2400 rpm, F/R, 99 MON
H	Cruise, 40 in Hg, 2200 rpm, F/R, 99 MON
I	Takeoff, 2575 rpm, F/R, 98 MON
J	Takeoff, 2575 rpm, F/R, 97 MON
K	Climb, 40 in Hg, 2400 rpm, F/R, 98 MON
L	Climb, 40 in Hg, 2400 rpm, F/R, 97 MON

Engine Parameters	Data Points			
	M	N	O	P
Reference Fuel Motor Octane Number	98	97	98	98
#1 Cylinder Head Temperature (Deg F)	472	473	481	484
#2 Cylinder Head Temperature (Deg F)	452	459	470	475
#3 Cylinder Head Temperature (Deg F)	458	467	469	472
#4 Cylinder Head Temperature (Deg F)	434	439	444	442
#5 Cylinder Head Temperature (Deg F)	460	466	470	478
#6 Cylinder Head Temperature (Deg F)	456	462	468	463
Oil Temperature (Deg F)	227	228	227	231
Oil Pressure (psig)	70	70	70	72
Cooling Air Temperature (Deg F)	110	110	108	106
#1 Exhaust Gas Temperature (Deg F)	1210	1212	1315	1363
#2 Exhaust Gas Temperature (Deg F)	1211	1211	1325	1376
#3 Exhaust Gas Temperature (Deg F)	1245	1248	1354	1405
#4 Exhaust Gas Temperature (Deg F)	1221	1224	1348	1392
#5 Exhaust Gas Temperature (Deg F)	1253	1256	1378	1424
#6 Exhaust Gas Temperature (Deg F)	1253	1254	1378	1429
Turbine Inlet Temperature (Deg F)	1288	1292	1367	1418
Engine Induction Air Temperature (Deg F)	103	104	102	102
Manifold Temperature (Deg F)	186	188	185	189
Dewpoint Temperature (Deg F)	69	69	68	68
Engine Speed (rpm)	2207	2204	2210	2409
Produced Engine Torque (ft/lbs)	590	588	612	621
Manifold Absolute Pressure (in Hg)	40.1	40	39.7	39.9
Observed Brake Horse Power (BHP)	248	247	257	285
Fuel Pump Pressure (psig)	43	43	43	43
Fuel Metered Pressure (psig)	15	15	9	11
Fuel Flow Rate (Gallons/HR)	36.6	36.6	29.5	32.5
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.84	0.85	0.65	0.65
Description of Points				
M	Cruise, 40 in Hg, 2200 rpm, F/R, 98 MON			
N	Cruise, 40 in Hg, 2200 rpm, F/R, 97 MON			
O	Cruise, 40 in Hg, 2200 rpm, LBP, 98 MON			
P	Climb, 40 in Hg, 2400 rpm, LBP, 98 MON			

A.5 TSIO-550-E ENGINE PARAMETER DATA.

A.5.1 350 BHP Configuration.

Engine Parameters	Data Points					
	A	B	C	D	E	F
Reference Fuel Motor Octane Number	100	99	98	98	98	100
#1 Cylinder Head Temperature (Deg F)	454	455	431	433	436	430
#2 Cylinder Head Temperature (Deg F)	472	473	458	459	460	460
#3 Cylinder Head Temperature (Deg F)	455	464	448	451	453	448
#4 Cylinder Head Temperature (Deg F)	443	444	435	436	438	430
#5 Cylinder Head Temperature (Deg F)	422	417	404	405	407	401
#6 Cylinder Head Temperature (Deg F)	435	436	428	428	429	422
#1 Exhaust Gas Temperature (Deg F)	1421	1418	1431	1441	1489	1534
#2 Exhaust Gas Temperature (Deg F)	1436	1433	1445	1455	1505	1548
#3 Exhaust Gas Temperature (Deg F)	1406	1402	1418	1431	1474	1514
#4 Exhaust Gas Temperature (Deg F)	1398	1395	1407	1417	1464	1504
#5 Exhaust Gas Temperature (Deg F)	1371	1368	1377	1390	1435	1477
#6 Exhaust Gas Temperature (Deg F)	1372	1371	1369	1387	1430	1468
Left Turbine Inlet Temperature (Deg F)	1445	1442	1440	1442	1486	1529
Right Turbine Inlet Temperature (Deg F)	1450	1447	1449	1452	1496	1537
Oil Temperature (Deg F)	234	235	233	232	233	232
Oil Pressure (psig)	44	44	44	43	43	44
Cooling Air Temperature (Deg F)	112	111	104	109	109	101
Engine Induction Air Temperature (Deg F)	101	100	103	102	102	99
Combustion Air Temperature (Deg F)	145	143	133	128	129	122
Cooling Air Pressure (in H_2O)	4	4	2	4	4	4
Manifold Pressure (in Hg)	37.39	37.35	35.00	31.13	31.23	31.26
Engine Speed (rpm)	2703	2701	2501	2509	2503	2503
Produced Engine Torque (ft/lbs)	646	646	602	527	535	545
Observed Brake Horse Power (BHP)	332	332	287	252	255	260
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.68	0.69	0.65	0.64	0.59	0.55
Fuel Flow (gallons/hr @ 5.87 lbs/gallon)	38.7	38.9	31.6	27.3	25.8	24.4
Fuel Flow (lbs/hr)	227	229	186	160	151	143
Dew Point (Deg F)	28	28	29	28	29	28
Percent Power Produced (%)	98	98	85	75	76	77
Sea Level Barometer During Test (in Hg)	30	30	30	30	30	30
Test Cell Ambient Temperature (Deg F)	69	69	69	69	69	69
Percent Lean (%)	F/R	F/R	F/R	F/R	-5.4	-10.5
Description of Points						
A	Takeoff, 2700 rpm, F/R, 100 MON, 100% HP					
B	Takeoff, 2700 rpm, F/R, 99 MON, 100% HP					
C	Climb, 2500 rpm, F/R, 98 MON, 85% HP					
D	Cruise, 2500 rpm, F/R, 98 MON, 75% HP					
E	Cruise, 2500 rpm, -5%, 98 MON, 75% HP					
F	Cruise, 2500 rpm, -10%, 100 MON, 75% HP					

Engine Parameters	Data Points					
	G	H	I	J	K	L
Reference Fuel Motor Octane Number	100	97	97	96	97	96
#1 Cylinder Head Temperature (Deg F)	436	436	435	434	429	432
#2 Cylinder Head Temperature (Deg F)	465	460	459	458	457	457
#3 Cylinder Head Temperature (Deg F)	454	450	449	452	448	453
#4 Cylinder Head Temperature (Deg F)	437	439	437	436	430	433
#5 Cylinder Head Temperature (Deg F)	406	412	405	404	401	402
#6 Cylinder Head Temperature (Deg F)	427	432	427	426	421	423
#1 Exhaust Gas Temperature (Deg F)	1578	1441	1450	1448	1497	1490
#2 Exhaust Gas Temperature (Deg F)	1595	1455	1463	1463	1511	1504
#3 Exhaust Gas Temperature (Deg F)	1555	1423	1436	1437	1480	1475
#4 Exhaust Gas Temperature (Deg F)	1549	1415	1420	1422	1465	1465
#5 Exhaust Gas Temperature (Deg F)	1522	1390	1395	1398	1444	1441
#6 Exhaust Gas Temperature (Deg F)	1515	1382	1390	1394	1432	1436
Left Turbine Inlet Temperature (Deg F)	1575	1452	1446	1447	1490	1489
Right Turbine Inlet Temperature (Deg F)	1581	1458	1458	1458	1502	1496
Oil Temperature (Deg F)	232	233	233	232	233	234
Oil Pressure (psig)	44	44	43	43	44	43
Cooling Air Temperature (Deg F)	107	105	106	109	100	104
Engine Induction Air Temperature (Deg F)	100	101	103	101	102	103
Combustion Air Temperature (Deg F)	126	134	127	128	123	125
Cooling Air Pressure (in H_2O)	4	4	4	4	3	3
Unmetered Fuel Pressure (psig)	15	20	18	18	17	17
Metered Fuel Pressure (psig)	8	11	9	9	9	9
Manifold Pressure (in Hg)	31.3	34.9	31.1	31.1	31.1	31.2
Engine Speed (rpm)	2504	2503	2509	2510	2512	2512
Produced Engine Torque (ft/lbs)	544	599	529	530	537	535
Observed Brake Horse Power (BHP)	260	285	253	253	257	256
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.52	0.64	0.63	0.63	0.59	0.59
Fuel Flow (gallons/hr @ 5.87 lbs/gallon)	23.1	31.2	27.3	27.3	25.8	25.8
Fuel Flow (lbs/hr)	135	183	160	160	151	151
Dew Point (Deg F)	29	30	30	31	30	30
Percent Power Produced (%)	77	85	75	75	76	76
Sea Level Barometer During Test (in Hg)	30.4	30.4	30.4	30.4	30.4	30.4
Test Cell Ambient Temperature (Deg F)	69	69	69	69	69	69
Percent Lean (%)	-15.4	F/R	F/R	F/R	-5.5	-5.4

Description of Points	
G	Cruise, 2500 rpm, -15%, 100 MON, 75% HP
H	Climb, 2500 rpm, F/R, 97 MON, 85% HP
I	Cruise, 2500 rpm, F/R, 97 MON, 75% HP
J	Cruise, 2500 rpm, F/R, 96 MON, 75% HP
K	Cruise, 2500 rpm, -5%, 97 MON, 75% HP
L	Cruise, 2500 rpm, -5%, 96 MON, 75% HP

Engine Parameters	Data Points
	M
Reference Fuel Motor Octane Number	95
#1 Cylinder Head Temperature (Deg F)	435
#2 Cylinder Head Temperature (Deg F)	462
#3 Cylinder Head Temperature (Deg F)	464
#4 Cylinder Head Temperature (Deg F)	445
#5 Cylinder Head Temperature (Deg F)	407
#6 Cylinder Head Temperature (Deg F)	427
#1 Exhaust Gas Temperature (Deg F)	1431
#2 Exhaust Gas Temperature (Deg F)	1433
#3 Exhaust Gas Temperature (Deg F)	1395
#4 Exhaust Gas Temperature (Deg F)	1393
#5 Exhaust Gas Temperature (Deg F)	1388
#6 Exhaust Gas Temperature (Deg F)	1380
Left Turbine Inlet Temperature (Deg F)	1424
Right Turbine Inlet Temperature (Deg F)	1434
Oil Temperature (Deg F)	232
Oil Pressure (psig)	43
Cooling Air Temperature (Deg F)	107
Engine Induction Air Temperature (Deg F)	102
Combustion Air Temperature (Deg F)	127
Cooling Air Pressure (in H_2O)	4
Unmetered Fuel Pressure (psig)	19
Metered Fuel Pressure (psig)	9
Manifold Pressure (in Hg)	31.1
Engine Speed (rpm)	2511
Produced Engine Torque (ft/lbs)	519
Observed Brake Horse Power (BHP)	248
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.64
Fuel Flow (gallons/hr @ 5.87 lbs/gallon)	27.3
Fuel Flow (lbs/hr)	160
Dew Point (Deg F)	30
Percent Power Produced (%)	74
Sea Level Barometer During Test (in Hg)	30.4
Test Cell Ambient Temperature (Deg F)	69
Percent Lean (%)	F/R
Description of Points	
M	Cruise, 2500 rpm, F/R, 95 MON, 75% HP

A.5.2 325 BHP Configuration.

Engine Parameters	Data Points					
	A	B	C	D	E	F
Reference Fuel Motor Octane Number	100	99	98	97	96	97
#1 Cylinder Head Temperature (Deg F)	441	441	442	450	447	433
#2 Cylinder Head Temperature (Deg F)	455	455	456	459	459	454
#3 Cylinder Head Temperature (Deg F)	434	433	438	445	439	443
#4 Cylinder Head Temperature (Deg F)	419	418	421	425	422	431
#5 Cylinder Head Temperature (Deg F)	393	391	397	403	394	402
#6 Cylinder Head Temperature (Deg F)	411	408	414	417	413	420
#1 Exhaust Gas Temperature (Deg F)	1365	1380	1368	1380	1369	1398
#2 Exhaust Gas Temperature (Deg F)	1378	1393	1381	1392	1380	1400
#+A25 Exhaust Gas Temperature (Deg F)	1349	1361	1352	1359	1350	1383
#2 Exhaust Gas Temperature (Deg F)	1337	1350	1342	1350	1342	1365
#1 Exhaust Gas Temperature (Deg F)	1315	1325	1318	1328	1319	1346
#2 Exhaust Gas Temperature (Deg F)	1312	1320	1315	1322	1316	1330
Left Turbine Inlet Temperature (Deg F)	1382	1393	1386	1396	1386	1393
Right Turbine Inlet Temperature (Deg F)	1391	1403	1394	1405	1395	1411
Oil Temperature (Deg F)	234	234	234	235	234	234
Oil Pressure (psig)	44	44	44	43	44	43
Cooling Air Temperature (Deg F)	102	103	105	97	98	100
Engine Induction Air Temperature (Deg F)	104	104	103	103	104	104
Combustion Air Temperature (Deg F)	132	134	134	130	130	123
Cooling Air Pressure (in H_2O)	4	2	4	4	4	3
Unmetered Fuel Pressure (psig)	23	23	22	22	22	20
Metered Fuel Pressure (psig)	13	13	13	13	13	10
Manifold Absolute Pressure (in Hg)	35.3	35.4	35.4	35.3	35.3	31.8
Engine Speed (rpm)	2606	2604	2605	2599	2606	2510
Engine Torque (ft/lbs)	615	614	615	616	616	546
Observed Brake Horse Power (BHP)	305	304	305	305	306	261
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.702	0.696	0.700	0.692	0.697	0.660
Fuel Flow (gal/hr @ 5.87 lbs/gal)	36	36	36	36	36	29
Fuel Flow (lbs/hr)	214	212	214	211	213	172
Dew Point (Deg F)	29	29	29	28	28	28
Percent Power Produced (%)	100	99	99	99	100	85
Sea Level Barometer (in Hg)	30.7	30.7	30.7	30.7	30.7	30.7
Test Cell Ambient Temperature (Deg F)	54	54	54	54	54	54
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	F/R

Description of Points	
A	Takeoff, 2600 rpm, F/R, 100 MON, 100% HP
B	Takeoff, 2600 rpm, F/R, 99 MON, 100% HP
C	Takeoff, 2600 rpm, F/R, 98 MON, 100% HP
D	Takeoff, 2600 rpm, F/R, 97 MON, 100% HP
E	Takeoff, 2600 rpm, F/R, 96 MON, 100% HP
F	Climb, 2500 rpm, F/R, 97 MON, 85% HP

Engine Parameters	Data Points					
	G	H	I	J	K	L
Reference Fuel Motor Octane Number	96	95	96	95	95	96
#1 Cylinder Head Temperature (Deg F)	441	436	434	440	442	439
#2 Cylinder Head Temperature (Deg F)	458	459	453	459	459	456
#3 Cylinder Head Temperature (Deg F)	446	451	450	460	465	458
#4 Cylinder Head Temperature (Deg F)	440	441	428	436	435	432
#5 Cylinder Head Temperature (Deg F)	404	405	399	406	407	405
#6 Cylinder Head Temperature (Deg F)	426	424	414	420	421	418
#1 Exhaust Gas Temperature (Deg F)	1403	1385	1396	1389	1431	1427
#2 Exhaust Gas Temperature (Deg F)	1410	1381	1397	1390	1431	1430
#+A25 Exhaust Gas Temperature (Deg F)	1389	1357	1386	1379	1416	1415
#2 Exhaust Gas Temperature (Deg F)	1370	1343	1369	1362	1399	1401
#1 Exhaust Gas Temperature (Deg F)	1352	1334	1355	1350	1387	1384
#2 Exhaust Gas Temperature (Deg F)	1336	1321	1339	1334	1372	1368
Left Turbine Inlet Temperature (Deg F)	1400	1376	1381	1378	1414	1412
Right Turbine Inlet Temperature (Deg F)	1416	1393	1403	1400	1435	1432
Oil Temperature (Deg F)	235	234	234	235	235	235
Oil Pressure (psig)	43	43	42	42	42	42
Cooling Air Temperature (Deg F)	107	106	102	102	103	105
Engine Induction Air Temperature (Deg F)	102	105	101	105	104	104
Combustion Air Temperature (Deg F)	128	127	119	119	119	120
Cooling Air Pressure (in H_2O)	3	4	2	4	4	2
Unmetered Fuel Pressure (psig)	20	20	19	19	17	18
Metered Fuel Pressure (psig)	10	10	9	9	9	9
Manifold Absolute Pressure (in Hg)	31.8	31.8	28.6	28.6	28.7	28.7
Engine Speed (rpm)	2509	2510	2510	2511	2511	2511
Engine Torque (ft/lbs)	539	537	485	483	488	486
Observed Brake Horse Power (BHP)	257	257	232	231	233	232
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.669	0.672	0.661	0.662	0.622	0.628
Fuel Flow (gal/hr @ 5.87 lbs/gal)	29	29	26	26	25	25
Fuel Flow (lbs/hr)	172	173	153	153	145	146
Dew Point (Deg F)	29	29	29	28	29	29
Percent Power Produced (%)	84	84	75	75	76	76
Sea Level Barometer (in Hg)	30.7	30.7	30.7	30.7	30.7	30.7
Test Cell Ambient Temperature (Deg F)	54	54	54	54	54	54
Percent Lean (%)	F/R	F/R	F/R	F/R	-5%	-5%
Description of Points						
G	Climb, 2500 rpm, F/R, 96 MON, 85% HP					
H	Climb, 2500 rpm, F/R, 95 MON, 85% HP					
I	Cruise, 2500 rpm, F/R, 96 MON, 75% HP					
J	Cruise, 2500 rpm, F/R, 95 MON, 75% HP					
K	Cruise, 2500 rpm, -5%, 95 MON, 75% HP					
L	Cruise, 2500 rpm, -5%, 96 MON, 75% HP					

Engine Parameters	Data Points					
	M	N	O	P	Q	R
Reference Fuel Motor Octane Number	96	96	97	98	97	98
#1 Cylinder Head Temperature (Deg F)	439	447	441	439	441	439
#2 Cylinder Head Temperature (Deg F)	455	462	458	456	460	458
#3 Cylinder Head Temperature (Deg F)	458	461	464	448	453	449
#4 Cylinder Head Temperature (Deg F)	430	439	432	429	431	429
#5 Cylinder Head Temperature (Deg F)	404	406	404	403	404	403
#6 Cylinder Head Temperature (Deg F)	418	423	419	417	418	417
#1 Exhaust Gas Temperature (Deg F)	1478	1533	1523	1522	1574	1581
#2 Exhaust Gas Temperature (Deg F)	1485	1538	1529	1528	1579	1587
#+A25 Exhaust Gas Temperature (Deg F)	1466	1516	1507	1508	1552	1564
#2 Exhaust Gas Temperature (Deg F)	1449	1500	1494	1492	1540	1548
#1 Exhaust Gas Temperature (Deg F)	1433	1486	1476	1474	1523	1532
#2 Exhaust Gas Temperature (Deg F)	1419	1471	1462	1458	1509	1517
Left Turbine Inlet Temperature (Deg F)	1460	1514	1505	1502	1554	1561
Right Turbine Inlet Temperature (Deg F)	1480	1532	1522	1522	1571	1581
Oil Temperature (Deg F)	235	235	235	235	235	235
Oil Pressure (psig)	42	42	42	42	42	42
Cooling Air Temperature (Deg F)	105	101	101	105	97	97
Engine Induction Air Temperature (Deg F)	101	101	103	101	101	104
Combustion Air Temperature (Deg F)	120	117	117	119	115	115
Cooling Air Pressure (in H_2O)	2	4	4	2	4	4
Unmetered Fuel Pressure (psig)	16	15	15	15	14	14
Metered Fuel Pressure (psig)	8	8	8	8	8	8
Manifold Absolute Pressure (in Hg)	28.7	28.8	28.7	28.8	28.9	28.8
Engine Speed (rpm)	2511	2511	2512	2511	2512	2513
Engine Torque (ft/lbs)	492	497	499	497	505	504
Observed Brake Horse Power (BHP)	235	238	238	238	241	241
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.585	0.543	0.543	0.547	0.506	0.503
Corrected BSFC (CBSFC)	0.547	0.508	0.507	0.512	0.474	0.468
Fuel Flow (gal/hr @ 5.87 lbs/gal)	23	22	22	22	21	21
Fuel Flow (lbs/hr)	138	129	130	130	122	121
Dew Point (Deg F)	29	29	29	29	29	29
Percent Power Produced (%)	76	77	78	77	78	79
Sea Level Barometer (in Hg)	30.7	30.7	30.7	30.7	30.7	30.7
Test Cell Ambient Temperature (Deg F)	54	54	54	54	54	54
Percent Lean (%)	-10%	-16%	-15%	-15%	-20%	-21%

Description of Points	
M	Cruise, 2500 rpm, -10%, 96 MON, 75% HP
N	Cruise, 2500 rpm, -15%, 96 MON, 75% HP
O	Cruise, 2500 rpm, -15%, 97 MON, 75% HP
P	Cruise, 2500 rpm, -15%, 98 MON, 75% HP
Q	Cruise, 2500 rpm, -20%, 97 MON, 75% HP
R	Cruise, 2500 rpm, -20%, 98 MON, 75% HP

Engine Parameters	Data Points		
	S	T	U
Reference Fuel Motor Octane Number	99	0	100
#1 Cylinder Head Temperature (Deg F)	446	444	446
#2 Cylinder Head Temperature (Deg F)	463	462	465
#3 Cylinder Head Temperature (Deg F)	467	469	465
#4 Cylinder Head Temperature (Deg F)	437	435	435
#5 Cylinder Head Temperature (Deg F)	408	409	404
#6 Cylinder Head Temperature (Deg F)	423	423	421
#1 Exhaust Gas Temperature (Deg F)	1583	1582	1617
#2 Exhaust Gas Temperature (Deg F)	1588	1591	1627
#+A25 Exhaust Gas Temperature (Deg F)	1563	1565	1598
#2 Exhaust Gas Temperature (Deg F)	1547	1550	1583
#1 Exhaust Gas Temperature (Deg F)	1530	1531	1567
#2 Exhaust Gas Temperature (Deg F)	1517	1520	1552
Left Turbine Inlet Temperature (Deg F)	1563	1562	1599
Right Turbine Inlet Temperature (Deg F)	1581	1581	1615
Oil Temperature (Deg F)	235	235	234
Oil Pressure (psig)	42	42	42
Cooling Air Temperature (Deg F)	103	99	98
Engine Induction Air Temperature (Deg F)	101	104	102
Combustion Air Temperature (Deg F)	118	117	116
Cooling Air Pressure (in H_2O)	4	4	4
Unmetered Fuel Pressure (psig)	14	14	13
Metered Fuel Pressure (psig)	8	8	8
Manifold Absolute Pressure (in Hg)	28.8	28.8	28.9
Engine Speed (rpm)	2512	2513	2512
Engine Torque (ft/lbs)	499	501	504
Observed Brake Horse Power (BHP)	239	240	241
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.507	0.504	0.484
Fuel Flow (gal/hr @ 5.87 lbs/gal)	21	21	20
Fuel Flow (lbs/hr)	121	121	117
Dew Point (Deg F)	29	29	29
Percent Power Produced (%)	77	78	78
Sea Level Barometer (in Hg)	30.7	30.7	30.7
Test Cell Ambient Temperature (Deg F)	54	54	54
Percent Lean (%)	-21%	-21%	-24%
Description of Points			
S	Cruise, 2500 rpm, -20%, 99 MON, 75% HP		
T	Cruise, 2500 rpm, -20%, 100 MON, 75% HP		
U	Cruise, 2500 rpm, -25%, 100 MON, 75% HP		

A.5.3 310 BHP Configuration.

Engine Parameters	Data Points					
	A	B	C	D	E	F
Reference Fuel Motor Octane Number	100	99	98	98	98	98
#1 Cylinder Head Temperature (Deg F)	438	440	436	422	431	429
#2 Cylinder Head Temperature (Deg F)	453	452	454	451	450	450
#3 Cylinder Head Temperature (Deg F)	441	444	444	450	455	456
#4 Cylinder Head Temperature (Deg F)	417	416	414	423	421	421
#5 Cylinder Head Temperature (Deg F)	398	399	397	398	403	402
#6 Cylinder Head Temperature (Deg F)	413	412	415	421	417	416
#1 Exhaust Gas Temperature (Deg F)	1330	1335	1331	1366	1349	1394
#2 Exhaust Gas Temperature (Deg F)	1341	1346	1348	1375	1357	1404
#3 Exhaust Gas Temperature (Deg F)	1314	1319	1318	1357	1344	1389
#4 Exhaust Gas Temperature (Deg F)	1301	1307	1308	1341	1329	1376
#5 Exhaust Gas Temperature (Deg F)	1273	1281	1281	1317	1316	1359
#6 Exhaust Gas Temperature (Deg F)	1277	1284	1284	1306	1303	1350
Left Turbine Inlet Temperature (Deg F)	1343	1348	1348	1364	1338	1382
Right Turbine Inlet Temperature (Deg F)	1355	1361	1358	1382	1361	1405
Oil Temperature (Deg F)	231	234	233	233	233	232
Oil Pressure (psig)	45	44	44	43	42	42
Cooling Air Temperature (Deg F)	105	97	100	104	102	106
Engine Induction Air Temperature (Deg F)	101	101	99	102	102	100
Combustion Air Temperature (Deg F)	133	128	131	125	119	120
Cooling Air Pressure (in H_2O)	4	3	2	2	2	2
Unmetered Fuel Pressure (psig)	23	22	22	20	19	18
Metered Fuel Pressure (psig)	13	13	13	11	9	9
Manifold Pressure (in Hg)	34.3	34.2	33.9	30.8	27.7	27.8
Engine Speed (rpm)	2604	2601	2606	2504	2502	2504
Produced Engine Torque (ft/lbs)	588	591	583	519	460	468
Observed Brake Horse Power (BHP)	292	293	289	248	219	223
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.747	0.738	0.745	0.702	0.712	0.660
Fuel Flow (gallons/hr @ 5.87 lbs/gallon)	37	37	37	30	27	25
Fuel Flow (lbs/hr)	218	216	216	174	156	147
Dew Point (Deg F)	27	26	27	26	26	26
Percent Power Produced (%)	100	100	100	85	75	75
Sea Level Barometer During Test (in Hg)	30.2	30.2	30.2	30.2	30.2	30.2
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	-5.7%

Description of Points	
A	Takeoff, 2600 rpm, F/R, 100 MON, 100% HP
B	Takeoff, 2600 rpm, F/R, 99 MON, 100% HP
C	Takeoff, 2600 rpm, F/R, 98 MON, 100% HP
D	Climb, 2500 rpm, F/R, 98 MON, 85% HP
E	Cruise, 2500 rpm, F/R, 98 MON, 75% HP
F	Cruise, 2500 rpm, -5%, 98 MON, 75% HP

Engine Parameters	Data Points					
	G	H	I	J	K	L
Reference Fuel Motor Octane Number	98	98	98	98	99	100
#1 Cylinder Head Temperature (Deg F)	433	440	434	435	432	437
#2 Cylinder Head Temperature (Deg F)	453	462	457	464	456	461
#3 Cylinder Head Temperature (Deg F)	453	455	455	459	452	453
#4 Cylinder Head Temperature (Deg F)	423	430	424	428	423	424
#5 Cylinder Head Temperature (Deg F)	402	405	403	407	402	403
#6 Cylinder Head Temperature (Deg F)	417	423	418	423	416	418
#1 Exhaust Gas Temperature (Deg F)	1439	1491	1536	1595	1588	1637
#2 Exhaust Gas Temperature (Deg F)	1445	1502	1545	1603	1599	1649
#3 Exhaust Gas Temperature (Deg F)	1425	1479	1518	1574	1572	1618
#4 Exhaust Gas Temperature (Deg F)	1411	1464	1508	1561	1560	1606
#5 Exhaust Gas Temperature (Deg F)	1396	1447	1488	1545	1543	1586
#6 Exhaust Gas Temperature (Deg F)	1382	1437	1476	1529	1530	1573
Left Turbine Inlet Temperature (Deg F)	1420	1474	1517	1572	1569	1619
Right Turbine Inlet Temperature (Deg F)	1443	1495	1537	1594	1589	1636
Oil Temperature (Deg F)	233	233	233	233	233	233
Oil Pressure (psig)	42	42	42	42	43	43
Cooling Air Temperature (Deg F)	100	100	95	101	98	102
Engine Induction Air Temperature (Deg F)	100	103	101	103	102	102
Combustion Air Temperature (Deg F)	117	117	113	117	115	117
Cooling Air Pressure (in H_2O)	2	2	3	4	4	4
Unmetered Fuel Pressure (psig)	17	15	14	13	13	12
Metered Fuel Pressure (psig)	9	8	8	8	8	7
Manifold Pressure (in Hg)	27.8	27.9	28.0	28.1	28.1	28.1
Engine Speed (rpm)	2503	2503	2504	2504	2504	2504
Produced Engine Torque (ft/lbs)	474	477	488	487	489	486
Observed Brake Horse Power (BHP)	226	227	233	232	233	232
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.625	0.584	0.535	0.499	0.502	0.478
Fuel Flow (gallons/hr @ 5.87 lbs/gallon)	24	23	21	20	20	19
Fuel Flow (lbs/hr)	141	133	125	116	117	111
Dew Point (Deg F)	27	27	27	28	27	29
Percent Power Produced (%)	75	75	75	75	75	75
Sea Level Barometer During Test (in Hg)	30.2	30.2	30.2	30.2	30.2	30.2
Percent Lean (%)	-9.6%	-14.9%	-20.1%	-25.7%	-25.0%	-29.0%

Description of Points	
G	Cruise, 2500 rpm, -10%, 98 MON, 75% HP
H	Cruise, 2500 rpm, -15%, 98 MON, 75% HP
I	Cruise, 2500 rpm, -20%, 98 MON, 75% HP
J	Cruise, 2500 rpm, -25%, 98 MON, 75% HP
K	Cruise, 2500 rpm, -25%, 99 MON, 75% HP
L	Cruise, 2500 rpm, -30%, 100 MON, 75% HP

Engine Parameters	Data Points					
	M	N	O	P	Q	R
Reference Fuel Motor Octane Number	100	97	96	95	95	94
#1 Cylinder Head Temperature (Deg F)	440	444	441	434	426	430
#2 Cylinder Head Temperature (Deg F)	457	458	455	459	451	452
#3 Cylinder Head Temperature (Deg F)	456	445	438	451	453	453
#4 Cylinder Head Temperature (Deg F)	424	422	415	420	424	425
#5 Cylinder Head Temperature (Deg F)	409	400	399	402	399	399
#6 Cylinder Head Temperature (Deg F)	419	417	411	416	420	423
#1 Exhaust Gas Temperature (Deg F)	1668	1349	1349	1333	1366	1368
#2 Exhaust Gas Temperature (Deg F)	1668	1360	1361	1323	1373	1375
#3 Exhaust Gas Temperature (Deg F)	1657	1333	1334	1301	1353	1356
#4 Exhaust Gas Temperature (Deg F)	1617	1321	1323	1295	1335	1338
#5 Exhaust Gas Temperature (Deg F)	1640	1297	1298	1281	1314	1316
#6 Exhaust Gas Temperature (Deg F)	1600	1292	1295	1281	1301	1305
Left Turbine Inlet Temperature (Deg F)	1641	1363	1363	1334	1362	1364
Right Turbine Inlet Temperature (Deg F)	1680	1375	1373	1352	1378	1381
Oil Temperature (Deg F)	233	233	233	234	234	234
Oil Pressure (psig)	42	43	44	44	43	43
Cooling Air Temperature (Deg F)	101	101	101	100	103	104
Engine Induction Air Temperature (Deg F)	101	101	102	102	101	101
Combustion Air Temperature (Deg F)	118	131	130	128	124	125
Cooling Air Pressure (in H_2O)	3	3	2	4	2	2
Unmetered Fuel Pressure (psig)	11	22	22	22	20	20
Metered Fuel Pressure (psig)	7	13	12	12	10	10
Manifold Pressure (in Hg)	28.1	33.8	33.8	33.7	30.7	30.7
Engine Speed (rpm)	2504	2600	2606	2603	2508	2508
Produced Engine Torque (ft/lbs)	465	579	583	576	518	516
Observed Brake Horse Power (BHP)	222	286	289	286	248	246
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.451	0.743	0.739	0.739	0.707	0.712
Fuel Flow (gallons/hr @ 5.87 lbs/gallon)	17	36	36	36	30	30
Fuel Flow (lbs/hr)	100	213	214	211	175	175
Dew Point (Deg F)	29	28	29	29	29	29
Percent Power Produced (%)	75	100	100	100	85	85
Sea Level Barometer During Test (in Hg)	30.2	30.2	30.2	30.2	30.2	30.2
Percent Lean (%)	-36.0%	F/R	F/R	F/R	F/R	F/R
Description of Points						
M	Cruise, 2500 rpm, -35%, 100 MON, 75% HP					
N	Takeoff, 2600 rpm, F/R, 97 MON, 100% HP					
O	Takeoff, 2600 rpm, F/R, 96 MON, 100% HP					
P	Takeoff, 2600 rpm, F/R, 95 MON, 100% HP					
Q	Climb, 2500 rpm, F/R, 95 MON, 85% HP					
R	Climb, 2500 rpm, F/R, 94 MON, 85% HP					

Engine Parameters	Data Points					
	S	T	U	V	W	X
Reference Fuel Motor Octane Number	93	93	99	98	97	96
#1 Cylinder Head Temperature (Deg F)	433	434	445	445	443	445
#2 Cylinder Head Temperature (Deg F)	455	453	457	457	458	460
#3 Cylinder Head Temperature (Deg F)	445	452	453	439	437	439
#4 Cylinder Head Temperature (Deg F)	430	425	421	422	420	422
#5 Cylinder Head Temperature (Deg F)	402	403	401	400	399	407
#6 Cylinder Head Temperature (Deg F)	427	417	419	414	414	417
#1 Exhaust Gas Temperature (Deg F)	1368	1363	1382	1389	1391	1389
#2 Exhaust Gas Temperature (Deg F)	1375	1365	1394	1399	1401	1399
#3 Exhaust Gas Temperature (Deg F)	1355	1352	1367	1368	1370	1370
#4 Exhaust Gas Temperature (Deg F)	1340	1335	1354	1357	1360	1358
#5 Exhaust Gas Temperature (Deg F)	1318	1324	1328	1334	1337	1339
#6 Exhaust Gas Temperature (Deg F)	1308	1308	1326	1330	1332	1333
Left Turbine Inlet Temperature (Deg F)	1366	1346	1395	1401	1404	1402
Right Turbine Inlet Temperature (Deg F)	1381	1369	1406	1410	1413	1412
Oil Temperature (Deg F)	234	234	232	234	233	234
Oil Pressure (psig)	43	42	44	44	44	44
Cooling Air Temperature (Deg F)	108	106	104	105	101	103
Engine Induction Air Temperature (Deg F)	102	104	103	104	101	103
Combustion Air Temperature (Deg F)	128	121	134	132	129	130
Cooling Air Pressure (in H_2O)	2	2	3	4	4	4
Unmetered Fuel Pressure (psig)	20	19	21	21	21	20
Metered Fuel Pressure (psig)	10	9	12	12	12	12
Manifold Pressure (in Hg)	30.7	27.7	34.3	34.1	34.1	34.0
Engine Speed (rpm)	2508	2508	2604	2604	2605	2605
Produced Engine Torque (ft/lbs)	514	458	595	594	598	594
Observed Brake Horse Power (BHP)	245	219	295	295	297	295
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.717	0.715	0.696	0.686	0.681	0.686
Fuel Flow (gallons/hr @ 5.87 lbs/gallon)	30	27	35	34	34	34
Fuel Flow (lbs/hr)	176	156	205	202	202	202
Dew Point (Deg F)	28	28	21	26	28	28
Percent Power Produced (%)	85	75	100	100	100	100
Sea Level Barometer During Test (in Hg)	30.2	30.2	30.1	30.1	30.1	30.1
Test Cell Ambient Temperature (Deg F)						
Percent Lean (%)	F/R	F/R	F/R	F/R	F/R	F/R
Description of Points						
S	Climb, 2500 rpm, F/R, 93 MON, 85% HP					
T	Cruise, 2500 rpm, F/R, 93 MON, 75% HP					
U	Takeoff, 2600 rpm, F/R, 99 MON, 100% HP					
V	Takeoff, 2600 rpm, F/R, 98 MON, 100% HP					
W	Takeoff, 2600 rpm, F/R, 97 MON, 100% HP					
X	Takeoff, 2600 rpm, F/R, 96 MON, 100% HP					

Engine Parameters	Data Points	
	Y	Z
Reference Fuel Motor Octane Number	95	93
#1 Cylinder Head Temperature (Deg F)	452	437
#2 Cylinder Head Temperature (Deg F)	472	457
#3 Cylinder Head Temperature (Deg F)	449	450
#4 Cylinder Head Temperature (Deg F)	436	433
#5 Cylinder Head Temperature (Deg F)	411	405
#6 Cylinder Head Temperature (Deg F)	423	426
#1 Exhaust Gas Temperature (Deg F)	1362	1410
#2 Exhaust Gas Temperature (Deg F)	1351	1414
#3 Exhaust Gas Temperature (Deg F)	1325	1392
#4 Exhaust Gas Temperature (Deg F)	1324	1375
#5 Exhaust Gas Temperature (Deg F)	1319	1356
#6 Exhaust Gas Temperature (Deg F)	1312	1342
Left Turbine Inlet Temperature (Deg F)	1364	1403
Right Turbine Inlet Temperature (Deg F)	1382	1419
Oil Temperature (Deg F)	234	234
Oil Pressure (psig)	44	43
Cooling Air Temperature (Deg F)	107	103
Engine Induction Air Temperature (Deg F)	101	103
Combustion Air Temperature (Deg F)	132	124
Cooling Air Pressure (in H_2O)	4	3
Unmetered Fuel Pressure (psig)	20	18
Metered Fuel Pressure (psig)	12	10
Manifold Pressure (in Hg)	33.8	30.6
Engine Speed (rpm)	2603	2502
Produced Engine Torque (ft/lbs)	575	520
Observed Brake Horse Power (BHP)	285	248
Brake Specific Fuel Consumption (lbs/BHP Hr)	0.703	0.667
Fuel Flow (gallons/hr @ 5.87 lbs/gallon)	34	28
Fuel Flow (lbs/hr)	200	165
Dew Point (Deg F)	28	24
Percent Power Produced (%)	100	85
Sea Level Barometer During Test (in Hg)	30.1	30.1
Percent Lean (%)	F/R	F/R
Description of Points		
Y	Takeoff, 2600 rpm, F/R, 95 MON, 100% HP	
Z	Climb, 2500 rpm, F/R, 93 MON, 85% HP	