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Full-Scale Engine Detonation and Power Performance Evaluation of Swift Enterprises 702 Fuel

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The work of Anatoliy Ivanov of Syport Systems Incorporated was crucial to the successful completion of this test.

16\. Abstract

As of this writing, the Environmental Protection Agency (EPA) exemption for general aviation from compliance with the 1990 Clean Air Act Amendments regarding the use of leaded fuel is still in effect. Recent petitions to the EPA call for either a ban or the study of the health effects of lead in aviation gasoline. It is likely that environmental and cost pressures of using leaded fuels will continue to increase for the general aviation community. Past extensive testing by the Federal Aviation Administration (FAA) William J. Hughes Technical Center on an unleaded replacement for the current leaded 100 low-lead (100LL) aviation gasoline centered on the petroleum industry's use of specialty chemicals. Significant engine modifications may also be required on the high-compression, legacy fleet for operation on a lower-octane, unleaded fuel, which would likely result in changes to engine and aircraft performance and pilot-operating procedures. FAA testing has confirmed that significant detonation performance differences exist between unleaded and leaded fuels of the same octane.

The FAA William J. Hughes Technical Center entered into a Cooperative Research and Development Agreement (CRDA) with Swift Enterprises of Indiana. Under the CRDA, Swift developed a high-octane, high-heat-content, bio-renewable aviation fuel that has the potential for significant reduction in life-cycle CO_2 emissions and has the potential to be produced inexpensively on a mass scale. The Swift 702 fuel contains no alcohols or oxygenates.

FAA William J. Hughes Technical Center researchers performed detonation and power performance tests on the Swift 702 fuel as compared to a locally purchased 100LL in two of the highest octane requirement engines in the fleet. A Lycoming TIO-540-J2BD and a Lycoming IO-540-K were evaluated on both fuels. A power baseline and detonation test was run in the IO-540-K engine, comparing the performance of the Swift 702 fuel to 100LL fuel, and a detonation performance test was run in a Lycoming TIO-540-J2BD engine. A full laboratory analysis was performed on the Swift 702 fuel to compare its results to the current leaded aviation gasoline specification ASTM D 910. The 100LL was also evaluated for octane and lead content.

The engines produced more than 98% of the peak power on the Swift 702 fuel as they did on 100LL. The Swift 702 fuel contained 96.3% of the energy content per unit mass as the 100LL. On a volume basis, the Swift 702 fuel contained 13% more energy than the 100LL. Operation on the Swift 702 fuel resulted in an average decrease in volumetric fuel consumption of approximately 8%. The Swift 702 fuel met most of the current leaded aviation gasoline specification and outperformed the 100LL in detonation testing. Average exhaust gas temperatures were 50°F higher for the Swift 702 fuel. Further extensive endurance tests on the Swift 702 fuel are planned.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

BHP	Brake horsepower
BSFC	Brake-specific fuel consumption
BTDC	Before top-dead center
CDRA	Cooperative Research and Development Agreement
CHT	Cylinder head temperature
CRC	Coordinating Research Council
EGT	Exhaust gas temperature
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FBO	Fixed-base operator
FF	Fuel mass flow rate
FT	Full throttle
GA	General aviation
inHg	Inches of Mercury
MAP	Manifold absolute pressure
MON	Motor octane number per ASTM D 2700
ng/m^3	Nanograms per cubic meter
rpm	Engine crankshaft revolutions per minute
TDC	Top-dead center
TIT	Turbine inlet temperature
TO	Takeoff
WOT	Wide open throttle
100LL	100 low-lead

EXECUTIVE SUMMARY

Researchers at the Federal Aviation Administration (FAA) Propulsion and Fuels Systems Team Small-Engine Test Facility at the FAA William J. Hughes Technical Center have been providing full-scale engine test data on alternative fuels to facilitate the development of a safe, high-octane, unleaded aviation gasoline for spark-ignition, piston aircraft engines. Federal Clean Air Act Amendments prohibit the sale of leaded fuels for on-road vehicles but exempted the sale of leaded fuels for off-road vehicles, such as aircraft, racing vehicles, farm equipment, and marine engines. As a result, the general aviation community is the largest domestic consumer of leaded fuels and is responsible for 45% of the ambient air lead inventory. A group called the Bluewater Network recently filed a petition with the Environmental Protection Agency (EPA) that calls for either a complete ban on leaded aviation fuels or to commission a study of the effects of leaded aviation fuel on public health. This petition has increased domestic environmental pressures against the use of leaded fuels. In response to another suit, the EPA recently reduced the National Ambient Air Quality Standard for lead by 90% from 1500 nanograms per cubic meter (ng/m^3) to 150 ng/m^3. On a global scale, environmental and cost pressures on leaded fuels and lead-scavenging agents increase the uncertainty of the future of using leaded aviation gasoline for general aviation.

The FAA William J. Hughes Technical Center entered into a Cooperative Research and Development Agreement (CRDA) with Swift Enterprises of Indiana. Notably, the Swift Research Director is also a professor at Purdue University with more than 32 years of experience in the petroleum and energy industries.

Under the CRDA, Swift Enterprises engineered a fully bio-renewable, high-octane, high-heat-content aviation gasoline that has the potential to be produced inexpensively on a mass scale. The Swift 702 fuel consists of two pure chemical compounds and was supplied to the Technical Center in three 55 gallon drums. Full-scale engine detonation and power performance were compared with that of a 100 low-lead (100LL) aviation gasoline purchased from a local airport. The 100LL blends meet the current ASTM D 910 aviation specification.

The Swift 702 fuel had a motor octane number (MON) of 104.4, as determined by the international standard test ASTM D 2700, and the locally purchased 100LL had a tested 103.6 MON. The goal of this research was to compare the full-scale engine power and detonation performance of the Swift 702 blend to 100LL, in both a Lycoming IO-540-K engine and a Lycoming TIO-540-J2BD engine. Past FAA research determined that these engines were two of the highest-octane demand engines in the entire fleet. Any fuel that satisfies the octane demand of these engines will satisfy the octane demand of the majority of the fleet. Laboratory evaluation of both the Swift 702 and 100LL fuels were performed to compare the Swift 702 properties to those of the current leaded aviation gasoline specification ASTM D 910.

The Swift 702 fuel provided slightly better detonation performance than the 100LL in the full-scale engines. The Swift 702 fuel had an energy content that was 96.3% of the 100LL on a mass basis and produced greater than 98% of the power of 100LL. Operation on the Swift 702 fuel produced an average volumetric fuel consumption reduction of approximately 8% and an approximate average exhaust gas temperature increase of 50ºF. The Swift 702 fuel met most of

the current leaded aviation gasoline specification ASTM D 910, except for the 50%, 90%, end distillation points, and heat content.

Future evaluation of the Swift 702 is planned with a 150-hour endurance test and another longer endurance test to address wear, fuel distribution, deposit formation, and materials compatibility performance. The endurance test plan is being developed with engineers from both major aircraft engine manufacturers, Continental and Lycoming.

1. INTRODUCTION.

1.1 PURPOSE.

This research addressed the full-scale engine power and detonation performance of an unleaded, high-octane, high-heat-content, bio-renewable fuel compared to locally purchased 100 low-lead (100LL) aviation fuel in high-octane demand, normally aspirated and turbocharged engines.

1.2 BACKGROUND.

The Federal Aviation Administration (FAA) Propulsion and Fuel Systems Team Small-Engine Test Facility researchers have been instrumental in the recent and significant progress in the area of full-scale engine performance of unleaded aviation fuels. Recently, the FAA William J. Hughes Technical Center published research on the full-scale engine detonation performance of 47 unleaded blends [1].

Federal Clean Air Act Amendments prohibit the sale of leaded fuels for on-road vehicles but exempted the sale of leaded fuels for off-road vehicles, such as aircraft, racing cars, farm equipment, and marine engines. As a result, the general aviation (GA) community is the largest domestic consumer of leaded fuels and is responsible for 45% of the ambient air lead inventory. With environmental pressures increasing worldwide against the use of leaded fuels and lead-scavenging agents, the future of the Environmental Protection Agency exemption for GA is uncertain and is increasingly a subject of debate.

For more than a decade, the FAA Propulsion and Fuel Systems Team Small-Engine Test Facility at the William J. Hughes Technical Center has been a leading engine test facility providing full-scale engine test results and expertise to FAA certification officials, the petroleum industry, airframe and engine manufacturers, regulatory agencies, aircraft user and owners associations, universities, and chemical companies. One goal of the team is to facilitate the development of a safe, unleaded, high-octane alternative to the current 100LL aviation gasoline.

Traditionally, most GA spark ignition, reciprocating engines and airframes have been certified on leaded fuels that meet the ASTM D 910 standard aviation gasoline specification. FAA certification officials have viewed certification as an assessment of how the hardware performs on the given and widely accepted leaded aviation fuel. Use of unleaded alternative fuels will result in performance differences due not only to different fuel properties but combustion performance differences.

For safety reasons, any alternative unleaded fuel would have to meet the octane requirements of the majority of the aviation fleet that was certified on high-octane leaded fuels. Test data has made it clear that the detonation performance of leaded fuels can vary significantly from the performance of unleaded fuels with the same ASTM D 2700 motor octane number (MON), in a full-scale engine [2].

The objective of this research was to determine how the performance of an unleaded, bio-renewable aviation fuel compared to that of the existing 100LL leaded aviation gasoline in both detonation and power performance full-scale engine tests. The engines chosen in this research were determined from previous FAA full-scale engine detonation tests as the highest naturally aspirated and turbocharged engine octane requirement engines in the fleet. Any fuel satisfying the octane requirement of these two engines would satisfy the octane requirement of the majority of the piston, reciprocating engine fleet.

1.3 RELATED DOCUMENTS.

- ASTM D 909, "Standard Test Method for Knock Characteristics of Motor and Aviation Fuels by the Supercharge Method."
- 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 D 6424, "Standard Practice for Octane Rating Naturally Aspirated Spark Ignition Aircraft Engines."
- FAA Advisory Circular 20-24B, "Qualification of Fuels, Lubricants, and Additives for Aircraft Engines."
- FAA Advisory Circular 33-47, "Detonation Testing in Reciprocating Aircraft Engines."
- FAA Report DOT/FAA/AR-08/40, "Full-Scale Engine Detonation Tests of 47 Unleaded, High-Octane Blends," D. Atwood.
- FAA Report DOT/FAA/AR-TN07/5, "High-Octane and Mid-Octane Detonation Performance of Leaded and Unleaded Fuels in Naturally Aspirated, Piston, Spark Ignition Aircraft Engines," D. Atwood.
- FAA Report DOT/FAA/AR-04/25, "Full-Scale Engine Knock Tests of 30 Unleaded, High-Octane Blends," D. Atwood and A. Ivanov.
- FAA Report DOT/FAA/AR-99/70, "Evaluation of Reciprocating Aircraft Engines With Unleaded Fuels," D. Atwood and J. Canizales.
- "Unleaded Aviation Gasoline Development Program—Phase III Composition and MON Ratings of Experimental Fuels For Full-Scale Engine Tests at FAA Technical Center," Dixie Services Incorporated, M. Renz, 1997.

2. TEST PROCEDURES.

2.1 SWIFT 702 FUEL.

Three 55-gallon drums were received by the FAA Propulsion and Fuel Systems Team Small-Engine Test Facility researchers at the FAA William J. Hughes Technical Center. A sample from the drums was taken and sent to an independent laboratory for full ASTM D 910 analysis. The results of the ASTM D 910 analysis are shown in table 1.

Table 1. Swift 702 Unleaded Blend Component Specification

ASTM Test	Description	Value	Current ASTM D 910 Leaded Avgas Specification for 100LL
D 2700	Motor octane number	104.4	99.5 minimum
	(BRE/30.1in/300F)		
D 909	ASTM Supercharge rating, mL TEL/gal	1.6	
	Performance number	159.6	130.0 minimum
D 5059	Lead, mL/L	<0.01	0.53 maximum
D 2392	Color	Fail	Blue
D 4052	Density, 15°C, kg/m^3	819	Report
D 5191	Vapor pressure, 38°C, kPa	42.5	38.0-49.0
D 2386	Freezing point, °C	-63	-58 maximum
D 2622	Sulfur, mass %	0.0053	0.05 maximum
D 4809	Net heat of combustion, MJ/kg	41.9 (3.7% from spec)	43.5 minimum
D 130	Copper corrosion, 2 hrs., 100°C	1A	1 maximum
D 873	Potential residue, 5 hrs., 100°C		
	Precipitate, mg/100 mL	<0.1	3 maximum
	Potential gum, mg/100 mL	3	6 maximum
D 1094	Water reaction		
	Interface rating	1b	-
	Separation rating	2	-
	Volume change, mL	0.5	2
D 86	Distillation, % evaporated, °C		
	IBP	28.00	Report
	10%	58.00	75 maximum
	40%	161.00	75 minimum
	50%	161.00	105 maximum
	90%	161.50	135 maximum
	End	182.00	170 maximum
	Sum of 10+50%	219.00	135 minimum
	Recovery	99.00	97 minimum
	Residue	0.40	1.5 maximum
	Loss	0.60	1.5 maximum

Table 1. Swift 702 Unleaded Blend Component Specification (Continued)

ASTM Test	Description	Value	Current ASTM D 910 Leaded Avgas Specification for 100LL
GC–FID	Composition, mass %		
		0.01	
		0.02	
		14.31	
		0.06	
		0.15	
		84.96	
		0.02	
		0.38	
		0.09	

MJ = Mega Joules
kg/m^3 = Kilogram per cubic meter
kPa = kilopascal
mL = milliliter
BRE = Bracketing equilibrium method
TEL = Tetraethyl lead
GC = Gas chromatography
FID = Flame Ionization Detection

Table 1 shows that the Swift 702 fuel met almost all of the current ASTM D 910 leaded aviation gasoline specifications. The gas chromatography analysis showed that the fuel consists of two primary components, with all the other components comprising less than 1% by mass.

The fuel had a very high MON (104.4) and a very high performance number (159.6), which were well above the current required minimums. The Swift fuel heat content was 96.3% of the 100LL minimum specification. This would probably result in a slight drop in power. The T50, T90, and end distillation points were above the current specification limits. However, it should be noted that the high end of the distillation curve is where the high-octane components will lie. It will be very difficult to attain the same detonation performance of the current 100LL aviation gasoline without lead if the higher distillation points, typically expected with an aviation alkylate, are not increased. Previous FAA tests, in conjunction with the Coordinating Research Council (CRC), showed that equivalent detonation performance to the leaded 100LL was only attainable at least 10% volume-to-volume aromatic amine, or with a very high aromatic hydrocarbon-content fuel. It is unlikely that such a fuel will meet the distillation curve parameters chosen for the current performance of an aviation alkylate with lead. Future full-scale engine endurance tests will verify whether there will be issues with oil dilution, nozzle and fuel system deposits, bearing failure, induction varnish buildup, or cylinder and valve deposits from using Swift 702 fuel.

Table 2 shows the calculated stoichiometries of the Swift 702 and fixed-base operator (FBO) 100LL fuels.

Table 2. Stoichiometries of Fuels Tested

Fuel	Calculated Stoichiometric Air-to-Fuel Ratio
Swift 702	14.02
FBO 100LL	14.90

The Swift 702 fuel engine performance was compared with three different 100LL aviation gasolines. One of these was manufactured to meet the minimum allowable ASTM D 910 specification, while the other two 100LLs were purchased from the local airport. Table 3 shows the properties of the 100LL fuels tested.

Table 3. Properties of 100LL Fuels Tested

Fuel/Engine Tested	ASTM D 2700 MON	ASTM D 909 PN	Lead Content	Net Heat of Combustion ASTM D 4529, 25 C (MJ/kg)	Aromatics, ASTM D 1319 (vol %)
FBO 100LL 125538/IO-540-K	103.6	133.0 (1.51 mL TEL/gal)	1.70 mL TEL/gal	44.38	0.3
FBO 100LL 125713/TIO-540-J2BD	103.9	131.5 (1.39 mL TEL/gal)	1.88 mL TEL/gal	44.365	0.5
Minimum Specification 100LL from CRC MF2 testing/IO-540-K	100.6	130.9 (1.35 mL TEL/gal)	1.55 mL TEL/gal	-------	-------

PN = Performance number
MJ = Mega Joules
TEL = Tetraethyl lead

2.2 TEST ENGINES.

A Lycoming IO-540-K model engine, which was previously used to evaluate 77 unleaded fuel blends, was used as one of the test engines. The other engine was a non-intercooled Lycoming turbocharged TIO-540-J2BD. These engines were previously determined to be the highest octane requirement engines in the active fleet from research performed in conjunction with the Coordinating Research Council Aviation Gasoline Octane Rating Working Group.

These engines were originally broken-in using Phillips Type M nondispersant, 20W-50 mineral oil and operated only on unleaded fuels except for the brief test of leaded 100LL fuels. Evaluation of the Swift 702 fuel was performed prior to operating the engines on the 100LL so as to not skew the Swift results with lead deposits.

An eddy-current dynamometer was used for power absorption, and only the engine accessories required to operate the engine were installed. All engine testing and operation after the break-in period used an Aeroshell type W, 15W-50 ashless dispersant oil.

Table 4 lists the rated power and compression ratio of the Lycoming IO-540-K model engine. The IO in the engine model description refers to fuel injection and opposed cylinder, and the numerical value of the model description refers to the cubic inch cylinder displacement.

Table 4. Engine Model Specifications

Engine	Manufacturer	Rated Power	Rated rpm	No. Cylinders	Compression Ratio	Induction	Ignition Timing	Fuel Grade
TIO-540-J2BD	Lycoming	350	2575	6	7.3:1	Turbocharged/ non-intercooled	20º/20º	100/100LL
IO-540-K	Lycoming	300	2700	6	8.7:1	Natural	20º/20º	100/100LL

As part of the previous tests, the cylinder assemblies had been removed, drilled, and tapped in the fin area to install high-temperature, water-cooled piezoelectric pressure transducers. One transducer was installed in the cylinder head of each cylinder with the transducer face as flush as possible with the cylinder cavity. The transducers were connected to charge-to-voltage amplifiers, and the amplifiers were connected to a data acquisition system. Analog cylinder pressure signals were digitized at the rate of 50 kHz per channel. The pressure data was fed to a numerical knock quantification analyses routine, as detailed in ASTM D 6424.

The engine was also instrumented, and engine parameter data were recorded at a rate of one scan of all channels every 1 second. Sensors used to measure these parameters were installed at the manufacturer's recommended locations whenever possible and were calibrated prior to any engine test. After the instrumentation was calibrated, a series of maintenance runs were performed to verify the engine system's integrity and instrumentation accuracy. Prior to any engine operation, the mixture cutoff and full-rich settings and the throttle stop and throw positions were verified. The engine was instrumented with the following sensors:

- Cylinder head temperatures 1-6
- Exhaust gas temperatures 1-6
- Turbine inlet air temperature
- Intake air temperature
- Intake air pressure
- Mass air flow rate
- Air-to-fuel ratio
- Manifold absolute pressure
- Manifold air temperature
- Engine speed (rpm)
- Engine shaft torque
- Brake horsepower
- Fuel mass and volume flow rates

- Engine cowling air temperature and pressure
- Fuel temperature
- Fuel mass density
- Metered fuel pressure
- Fuel pump pressure
- Oil temperature
- Oil pressure

The fuel delivery system is designed to isolate multiple fuel sources, and the integrity of the fuel system was checked prior to each run to ensure that cross-contamination did not occur.

2.2.1 Power Baselines.

Using the Lycoming IO-540-K engine, a power baseline test was run, which compared the power developed by the Swift 702 fuel to the 100LL. Combinations of engine speeds ranging from 2700 to 2200 in 100-rpm increments, and manifold absolute pressures of wide open throttle (WOT) and 28 to 22 inches of Mercury (inHg) in 2-inHg increments were evaluated. Maximum cylinder head temperature (CHT) of 400ºF was maintained throughout the test along with an inlet air temperature of 60ºF. Standard engine ignition timing was used, and the fuels were run back to back on the same day to eliminate significant barometric variations. The mixture strength was adjusted from 0.600 brake-specific fuel consumption (BSFC) to 50ºF lean of peak exhaust gas temperature (EGT) or a maximum EGT of 1650ºF, whichever came first.

2.2.2 Detonation Tests.

The Swift 702 and 100LL blends were detonation tested in both the IO-540-K and the TIO-540-J2BD engines. Table 5 shows the conditions for the detonation tests.

Table 5. Engine Parameter Settings for Detonation Tests

Parameter	IO-540-K Engine	TIO-540-J2BD Engine
Maximum CHT (ºF)	475	470
All other cylinder head temperatures	Within 50°F of maximum cylinder head temperature	Within 50°F of maximum cylinder head temperature
Inlet air temperature (ºF)	103	103
Inlet oil temperature (ºF)	245	225
Inlet air pressure	±0.03 inHg of local	±0.03 inHg of local
Maximum inlet air humidity (Gr/lb)	1.0	1.0
Maximum EGT (ºF)	1650	-----
Maximum Turbine Inlet Temperature (ºF)	-----	1650
Manifold air temperature (ºF)	-----	Monitor
Compressor discharge pressure	-----	Monitor
Mixture start BSFC (lb/hp hr)	0.600	0.600 (0.700 at rated power)

Gr/lb = Grains of water per pounds of dry air

Table 6 shows the power settings tested. Takeoff (TO) is the condition of WOT and maximum-rated rpm. The horsepower and rpm combinations were chosen from the engine manufacturer's specifications. Tests were performed with the dynamometer controller operating in the speed mode so the engine load was varied to maintain the desired rpm.

Table 6. Power Settings for Detonation Tests

IO-540-K Engine rpm, MAP (inHg)	TIO-540-J2BD Engine rpm, power
2700, FT	2575, FT
2700, 28	2575, 85%
2700, 26	2575, 75%
2600, FT	2400, 80%
2600, 28	2200, 70%
2600, 26	-----
2600, 24	-----
2450, 28	-----
2450, 26	-----
2450, 24	-----
2350, 28	-----
2350, 26	-----
2350, 24	-----

MAP = Manifold absolute pressure
FT = Full throttle

When adjusting the part throttle power settings, the engine rpm was set, the mixture setting was adjusted to attain 0.600 BSFC in lb/hp hr, and the manifold absolute power (MAP) was adjusted until the desired power was attained. For the TIO-540-J2BD engine, the mixture was started at 0.700 BSFC at the rated power setting. These mixture settings are well rich of best power mixture and rich of detonation onset mixture strength.

The resulting MAP was then recorded, and any mixture leaning or enrichening from this condition at the same rpm was performed while maintaining constant MAP. Mixture adjustments were performed automatically at a rate of change less than 1 lb/hr/s. All analyses and figures presented in this report were determined using fuel mass flow rates and fuel volume flow rates.

The engine tests began with warming up the engine, ensuring that all instrumentation indications were within proper range, and performing an ignition systems check. At this time, the engine and environmental parameters, described in table 5, were set and maintained throughout the detonation tests. After selecting or changing a test blend or changing the engine power setting, conditions were allowed to stabilize. Enough time was given for the selected blend to reach the engine and for cylinder head temperatures to stabilize. All the Swift 702 fuel tests were done prior to testing the 100LL so as to not taint the Swift with leaded fuel.

The fuel mixture was leaned from a richer, nonknocking setting, until heavy detonation, maximum allowable EGT, maximum allowable turbine inlet temperature (TIT), or 50ºF past peak EGT was reached. Careful attention was paid to the individual EGT and CHT spreads, and two exhaust gas Lambda sensors were used, one for each bank of cylinders. It was ensured that the CHT and EGT spreads and air-to-fuel reading differentials were minimal to prevent gross mixture imbalances between cylinders and cylinder banks. Mixture adjustments were automated by a computer algorithm to ensure fuel flow changes were slow and repeatable.

3. RESULTS AND DISCUSSIONS.

Table 7 shows the measured fuel mass density for the fuels tested. The Swift 702 fuel was roughly 1.01 lb/gal heavier (or 17.5%) than the 100LL at 87°F. However, since the Swift 702 fuel had 96.3% of the energy density on a mass basis as the 100LL, the Swift 702 fuel has approximately 13% higher energy per gallon of fuel than 100LL. On a fuel mass flow basis, the Swift 702 fuel will produce slightly less power than the 100LL; however, on a fuel volume flow basis, which is typically more of a concern to a pilot, the fuel will produce more power than the 100LL. Therefore, the same number of gallons of fuel will weigh more for the Swift 702 fuel than the 100LL, but will provide a greater range of flight.

Table 7. Measured Average Fuel Density of Swift 702 Fuel and 100LL at 87°F

Fuel	Measured Average Fuel Density at 87ºF (lb/gal)	Calculated Stoichiometric Air-to-Fuel Ratio
Swift 702	6.72	14.02
FBO 100LL	5.71	14.90

3.1 LYCOMING IO-540-K ENGINE POWER BASELINES.

The Lycoming IO-540-K engine was first tested in a series of power baseline runs at standard, sea-level induction air temperatures and normal CHTs using both the Swift 702 fuel and the 100LL FBO fuel. Table 8 shows there was excellent precision in test conditions for the power baseline tests.

Table 8. Engine Test Parameter Precision

Parameters	Target	Mean	Standard Deviation	Maximum	Minimum
IAT (ºF)	60	60	0.7	62	58
Maximum CHT (ºF)	400	399	3.5	409	385
Minimum CHT (ºF)	>350	361	3.4	370	352
IAP (inHg)	±0.03	0.00	0.03	0.09	-0.06
Inlet Air Humidity Ratio (Gr/lb)	<1.0	0.7	0.1	0.9	0.6
OilT (ºF)	200	201	5	211	192

IAP = Intake air pressure
OilT = Oil temperature
IAT = Intake air temperature

Figure 1 shows that the peak power mixture setting at the maximum power setting the engine produced 98.7% of the 100LL peak horsepower on Swift 702 fuel. This was the 100LL that was purchased from the local airport. At this mixture, the average EGTs were 39ºF higher on the Swift 702 fuel than the 100LL. The location of peak power, in relation to air-to-fuel ratio, occurred at richer mixture settings on the Swift 702 fuel than on the 100LL fuel. This was due to the lower stoichiometric air-to-fuel ratio for the Swift 702 fuel, as shown in table 7.

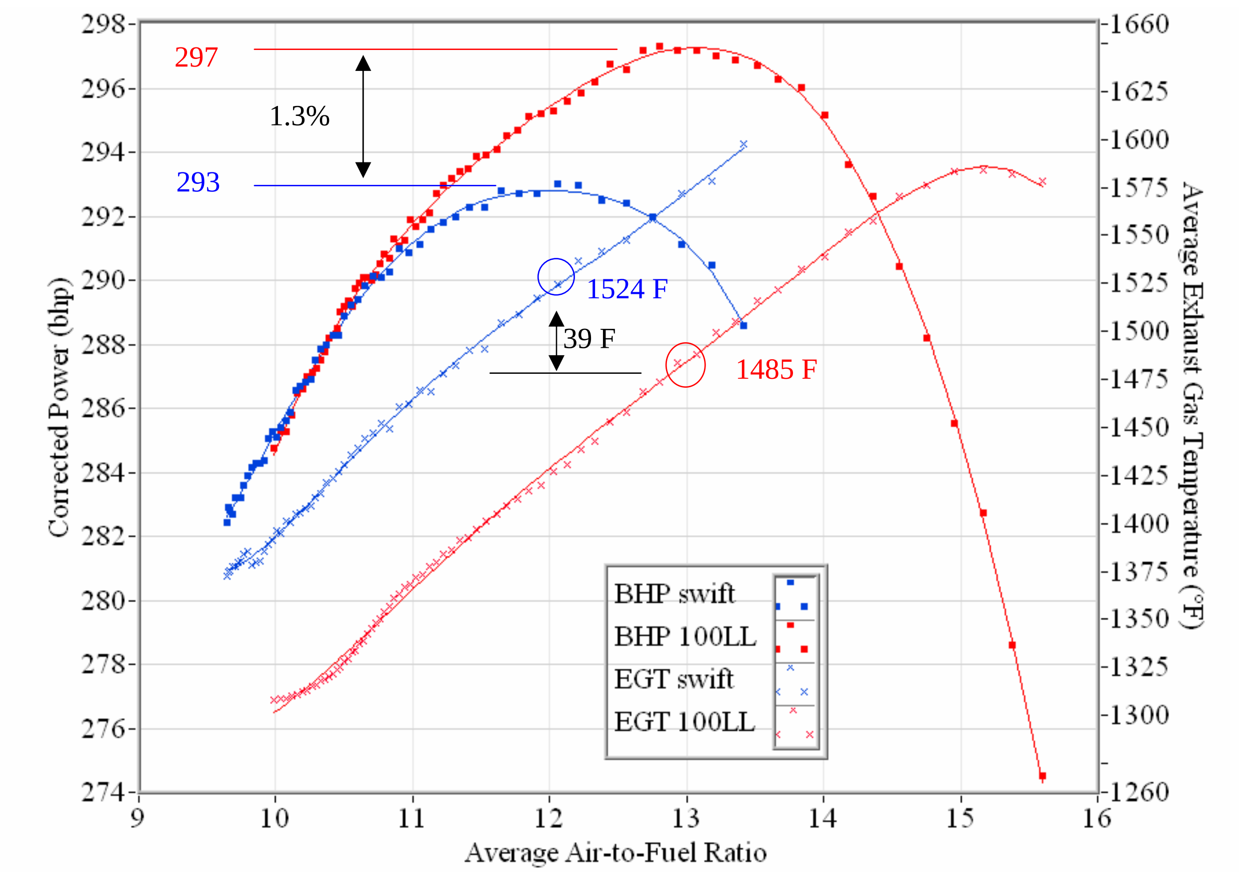


Figure 1. Swift 702 Fuel and 100LL Power Performance; FT, 2700 rpm

Figure 2 shows the power performance comparison at 2400 rpm, 24 inHg MAP. The Swift 702 fuel produced 98.2% of the peak power of the 100LL from the local airport and produced average EGTs 58ºF higher at peak power. The peak EGT was 50ºF higher on average for the Swift 702 fuel than for the 100LL. Again, due to the lower stoichiometric air-to-fuel ratio for the Swift 702 fuel, the air-to-fuel ratio at peak power and peak EGT was at richer mixtures.

Figure 3 shows the power performance data at TO corrected by the respective stoichiometric air-to-fuel ratio. As expected, peak power occurred at approximately the same equivalence ratio and was approximately 1.3% lower for the Swift 702 fuel. The chart shows that the average EGT was approximately 50ºF higher for the Swift 702 fuel than for the 100LL fuel.

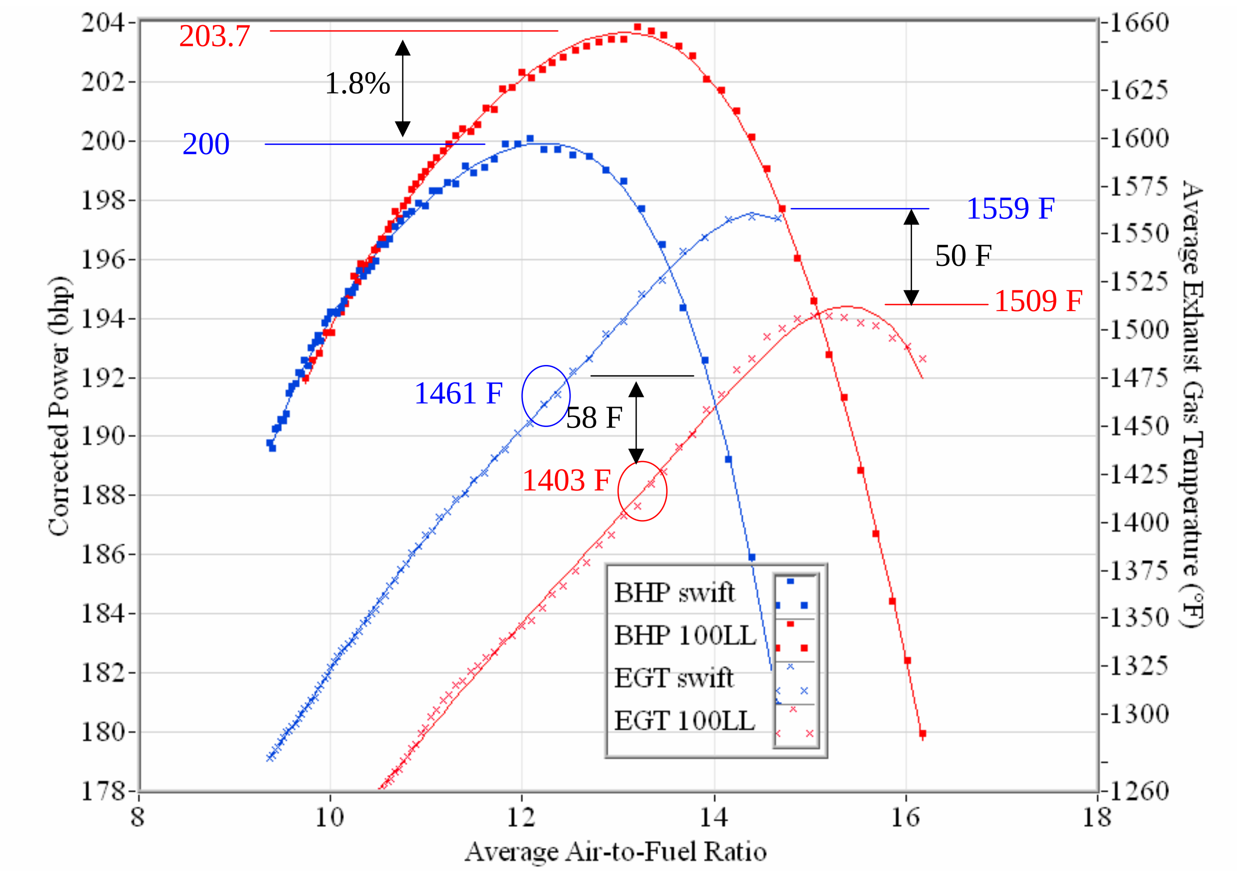


Figure 2. Swift 702 Fuel and 100LL Power Performance; 24 inHg, 2400 rpm

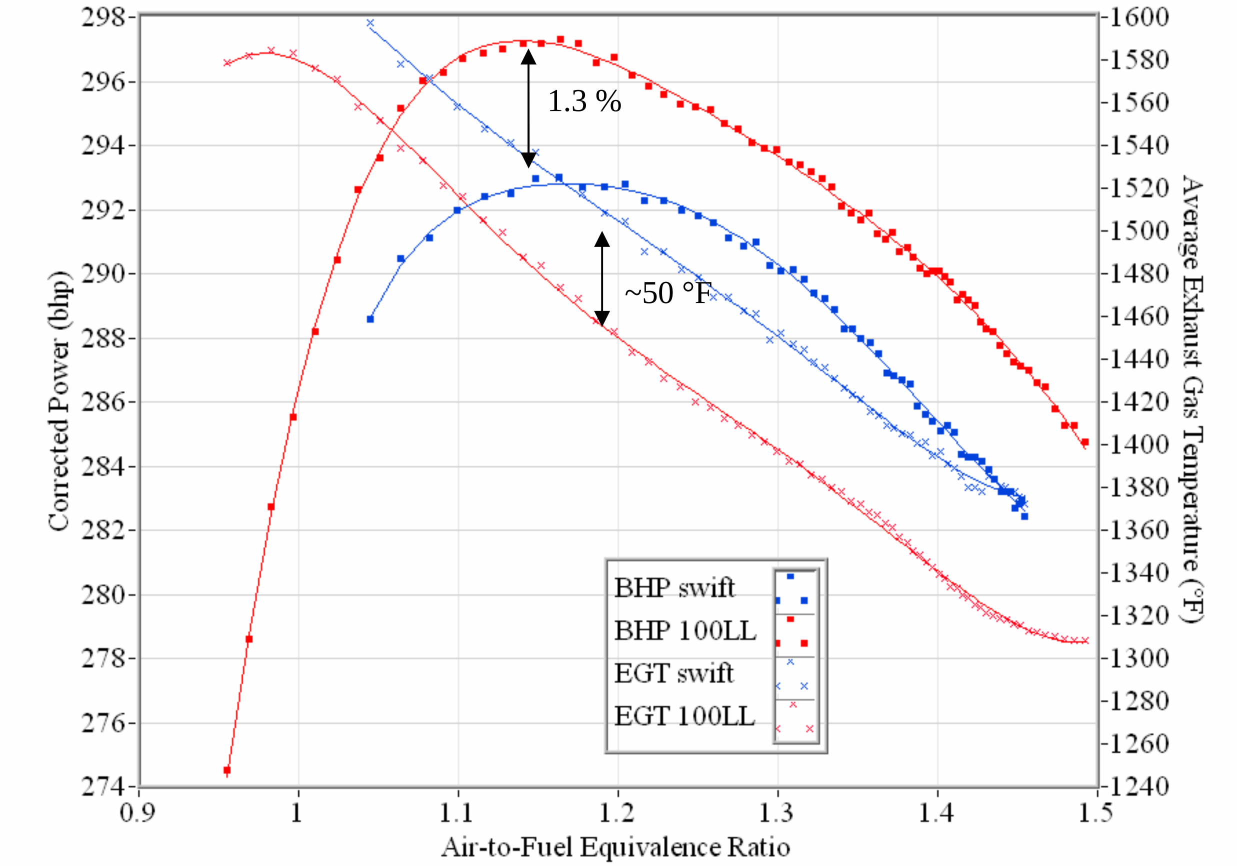


Figure 3. Swift 702 Fuel and 100LL Power Performance Based on Equivalence Ratio; FT, 2700 rpm

Figure 4 shows the equivalence ratio data for the 2600-rpm, 25-inHg MAP setting. The Swift 702 fuel produced 1.9% reduced horsepower and 54ºF higher average EGTs. At all engine speeds and manifold pressures, the Swift 702 fuel produced more than 98% of the horsepower as the 100LL and produced an average increase in EGT of approximately 50ºF.

Figure 5 shows the power performance mixture lean-outs based on fuel mass flow. The figure shows higher fuel mass flow rates (FF) for the Swift 702 fuel. This is due to the 1.0 lb/gal higher mass density. When the data is plotted against fuel volume flow rates, as in figure 6, the Swift 702 fuel shows a significantly reduced fuel consumption compared to 100LL. This is because for a given volume of fuel, the Swift 702 has a much higher mass and a higher energy content. The net result would be a slightly higher payload, 30 lb for a 30-gallon aircraft, but an increased range for the same amount of fuel.

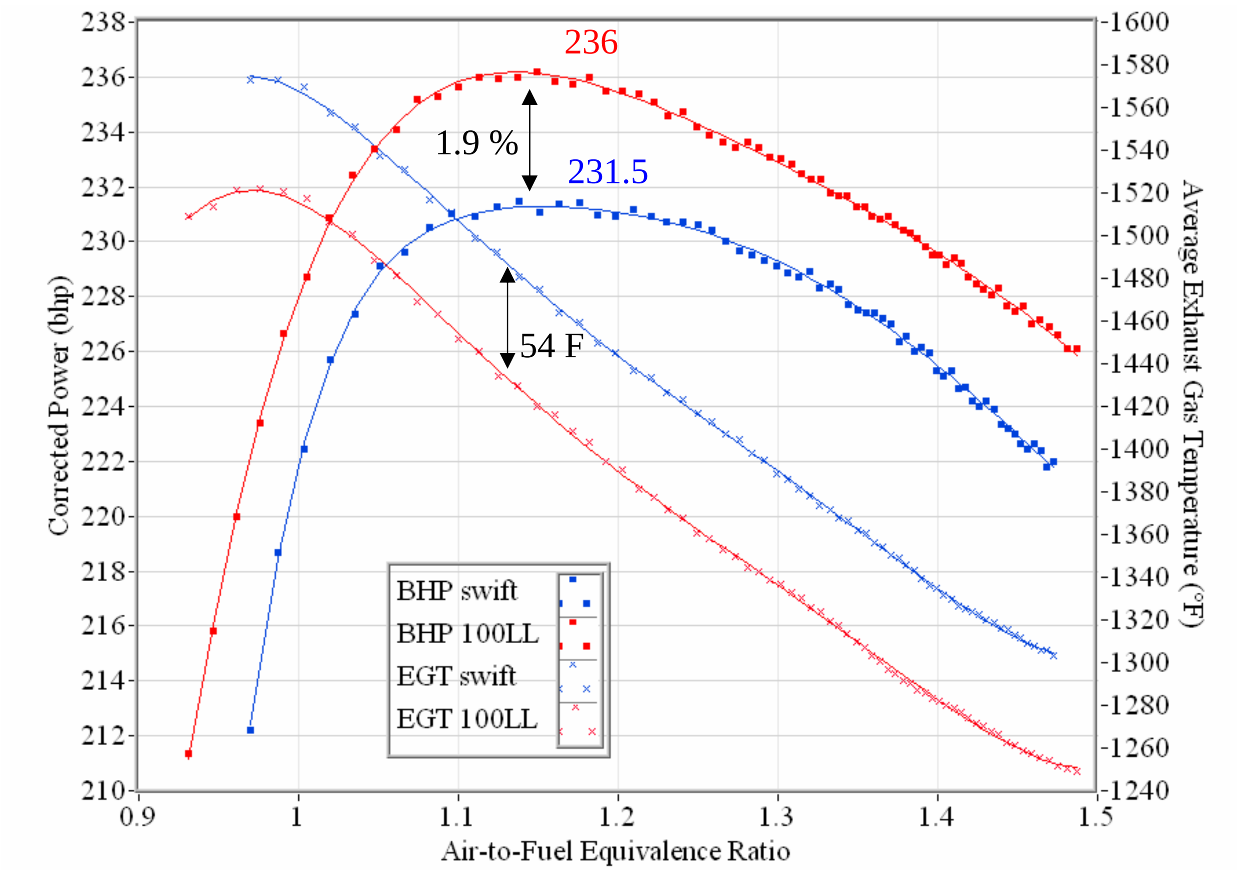


Figure 4. Swift 702 Fuel and 100LL Power Performance Based on Equivalence Ratio; 26 inHg, 2500 rpm

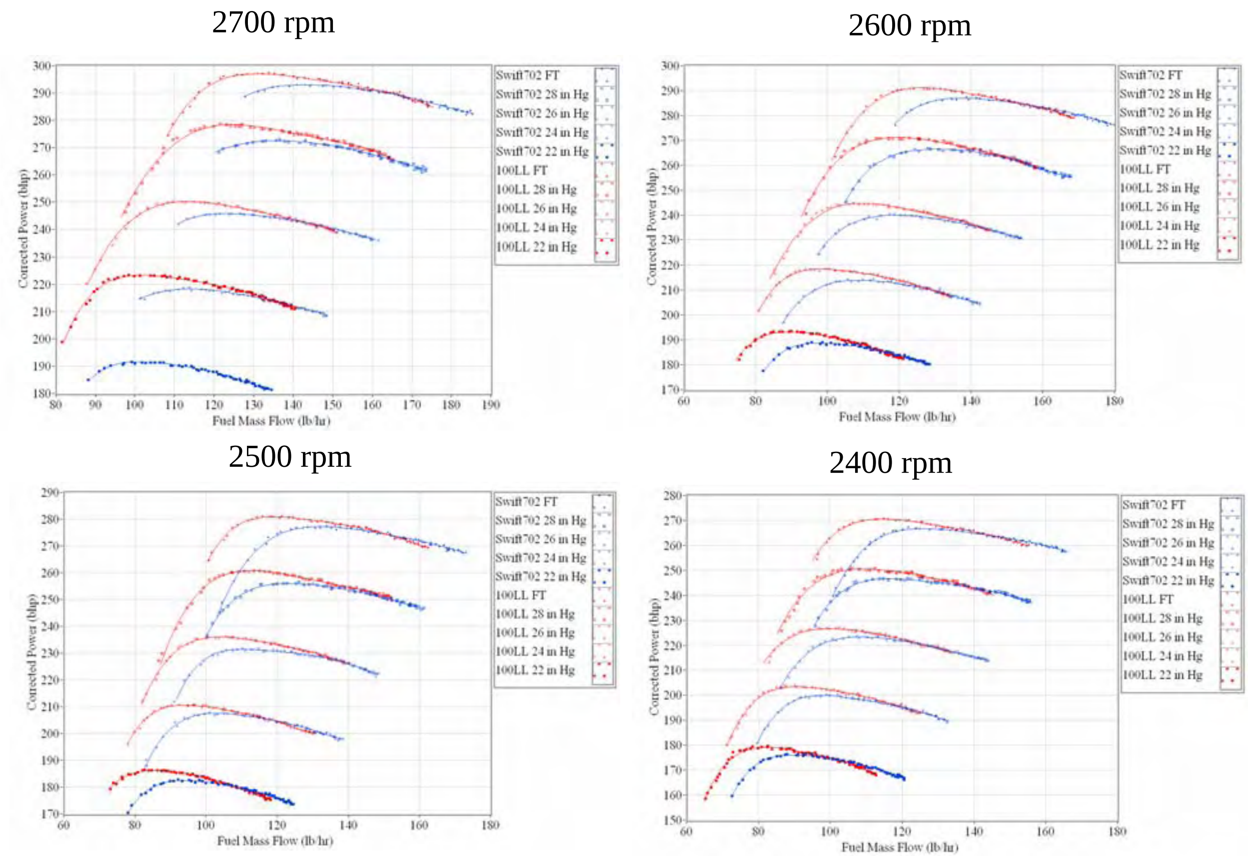


Figure 5. Swift 702 Fuel and 100LL Power Performance Based on Fuel Mass Flow

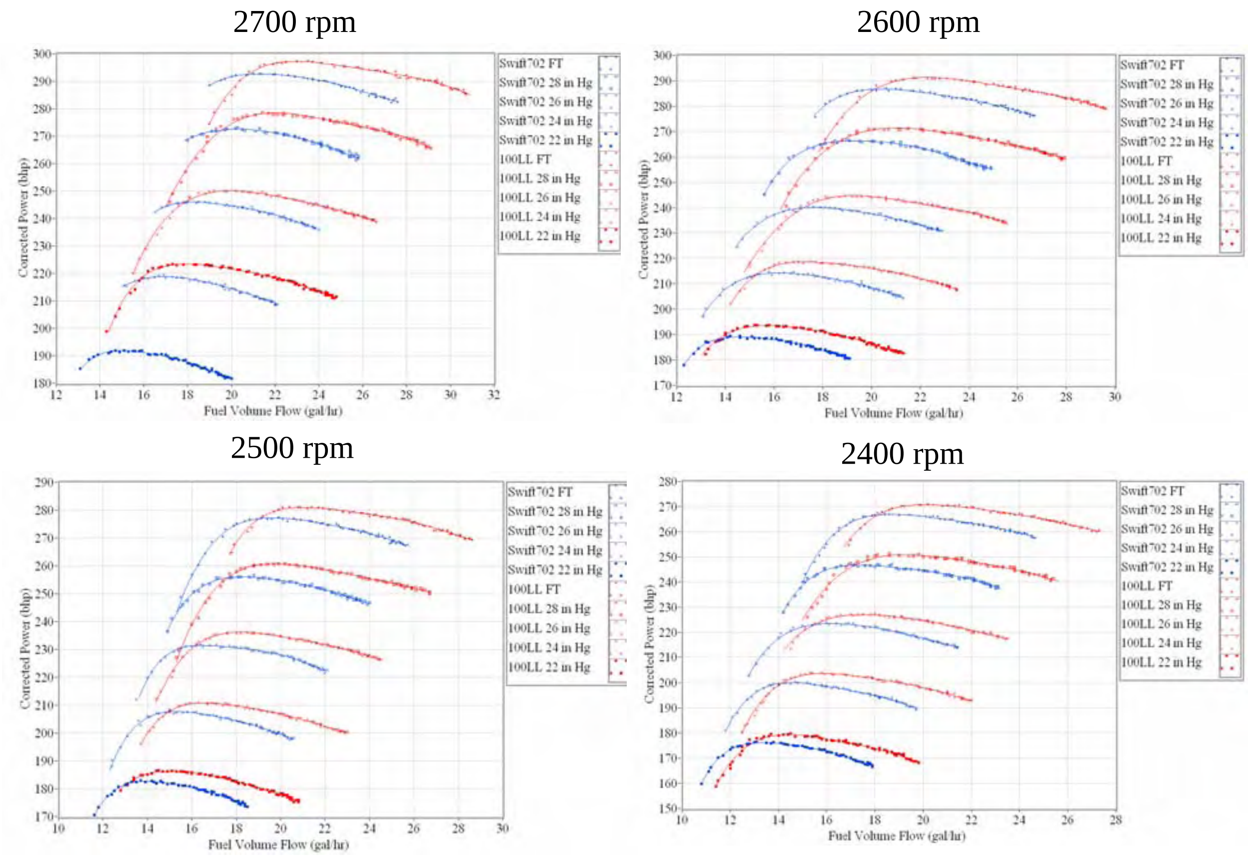


Figure 6. Swift 702 Fuel and 100LL Power Performance Based on Fuel Volume Flow

Appendix A contains the power performance mixture adjustment data for brake horsepower (BHP), equivalence ratio, air-to-fuel ratio, fuel mass flow, fuel volume flow, average EGT, and BSFC.

The tabular comparison of peak power, fuel consumption, fuel efficiency, and average EGT for both the Swift 702 fuel and the 100LL are shown in table 9 for the maximum power setting.

Table 9. Peak Power Comparison Between Swift 702 Fuel and FBO 100LL at FT, 2700 rpm

Power Setting	Fuel	FF (lb/hr)	FF (gal/hr) [% reduction from 100LL]	BHP	BSFC (lb/hp hr) [gal/hp hr]	Air-to-Fuel Ratio	Equivalence Ratio	Average EGT (°F)
Peak Power	Swift 702	143.1	21.3 [7.4]	292.9	0.488 [0.073]	12.055	1.163	1524
	FBO 100LL	131.0	23.0	297.1	0.441 [0.077]	13.071	1.14	1485

At peak power mixture at the maximum power setting, the Swift 702 fuel consumed 7.4% less fuel volume and showed an increase in volumetric consumption efficiency. The average EGT increased 39°F while the peak power decreased by 4.2 horsepower (1.4%) at the maximum power setting.

Table 10 shows the same data as table 9 for the performance cruise setting at both the peak power and best economy mixture settings.

Table 10. Peak Power Comparison Between Swift 702 Fuel and 100LL at 24 inHg, 2400 rpm

Power Setting	Fuel	FF (lb/hr)	FF (gal/hr) [% reduction from 100LL]	BHP	BSFC (lb/hp hr) [gal/hp hr]	Air-to-Fuel Ratio	Equivalence Ratio	Average EGT (°F)
Peak Power	Swift 702	97.7	14.5 [9.4]	200.1	0.489 [0.072]	12.223	1.147	1461
	FBO 100LL	90.9	16.0	203.7	0.448 [0.079]	13.062	1.141	1403
Best Economy	Swift 702	81.5	12.1 [8.3]	185.9	0.439 [0.065]	14.398	0.974	1559
	FBO 100LL	75.3	13.2	191.5	0.392 [0.069]	15.362	0.97	1509

The Swift 702 fuel produced 3.6 less horsepower (1.8%) than the 100LL at peak power mixture but required 9.4% less volumetric fuel (1.5 gal/hr) to do so. The result was a lower specific fuel consumption or better fuel volumetric efficiency. The average EGT increased 58ºF at this mixture setting.

At the best economy mixture setting, the Swift 702 fuel produced 97% of the power of 100LL at a reduced volumetric fuel flow of 8.3% (1.1 gal/hr), but produced an average of 50ºF higher EGTs.

The net horsepower reduction was typically less than 1.8% when operating on the Swift 702 fuel compared to the 100LL, and the EGTs were typically 50ºF higher for operation on the Swift 702 fuel. Further endurance testing is required to determine the significance of operating with 50°F higher EGTs.

3.2 DETONATION TESTS.

Detonation mixture lean-out tests were performed on (1) two separate FBO 100LL fuels purchased from the local airport, (2) a minimum specification 100LL that was specially blended to meet minimum specification and maximum allowable lead, and (3) the Swift 702 fuel in two different engines (see table 3). A naturally aspirated Lycoming IO-540-K engine and a turbocharged TIO-540-J2BD engine were used (see table 4). The engine parameters listed in table 5 were maintained throughout the tests. Power settings ranging from TO to economy cruise were evaluated (see table 6).

3.2.1 Lycoming IO-540-K.

Table 11 shows the precision of the environmental controls on the test parameters. The tests showed that the precision was excellent.

Table 11. Engine Test Parameter Precision for the Detonation Tests Using the Lycoming IO-540-K Engine

Parameter	Target	Mean	Standard Deviation	Maximum	Minimum
IAT (°F)	103	104	0.4	105	103
Maximum CHT (°F)	475	471	7	480	443
Minimum CHT (°F)	>425	428	6	446	409
IAP (inHg)	<0.03	0.02	0.01	0.06	-0.01
Inlet air humidity ratio (Gr/lb)	<1.0	0.6	0.1	0.8	0.4
OilT (°F)	245	236	6	247	223

IAP = Intake air pressure
OilT = Oil temperature
IAT = Intake air temperature

Table 12 shows the repeatability of the detonation onset data for the IO-540-K engine tests. The tests showed excellent repeatability with the average relative standard deviation less than 1.6% of the mean.

Table 12. Detonation Onset Repeatability for the Detonation Tests Using the Lycoming IO-540-K Engine

Statistic	FF (lb/hr)	Equivalence Ratio	Air-to-Fuel Ratio	BSFC (lb/hp hr)	EGT (°F)
Average standard deviation	1.6	0.02	0.19	0.006	10
Maximum standard deviation	5.4	0.05	0.61	0.020	29
Average difference (maximum-minimum)	2.3	0.02	0.26	0.008	15
Maximum difference (maximum-minimum)	7.6	0.07	0.86	0.028	42
Average relative standard deviation (% of mean)	1.6	1.4	1.4	1.3	1
Maximum relative standard deviation (% of mean)	4.8	4.5	4.4	4.6	2

Figures 7 and 8 show the detonation onset mixture lean-outs on a mass fuel flow and a volumetric fuel flow basis at the TO power setting. The data points on the curves represent the richest mixture setting where detonation occurred. The further the fuel mixture strength could be leaned, the better the detonation performance of the fuel.

Figure 7 shows that the Swift 702 fuel outperformed both the high-lead minimum specification 100LL and the FBO 100LL on a fuel mass flow basis.

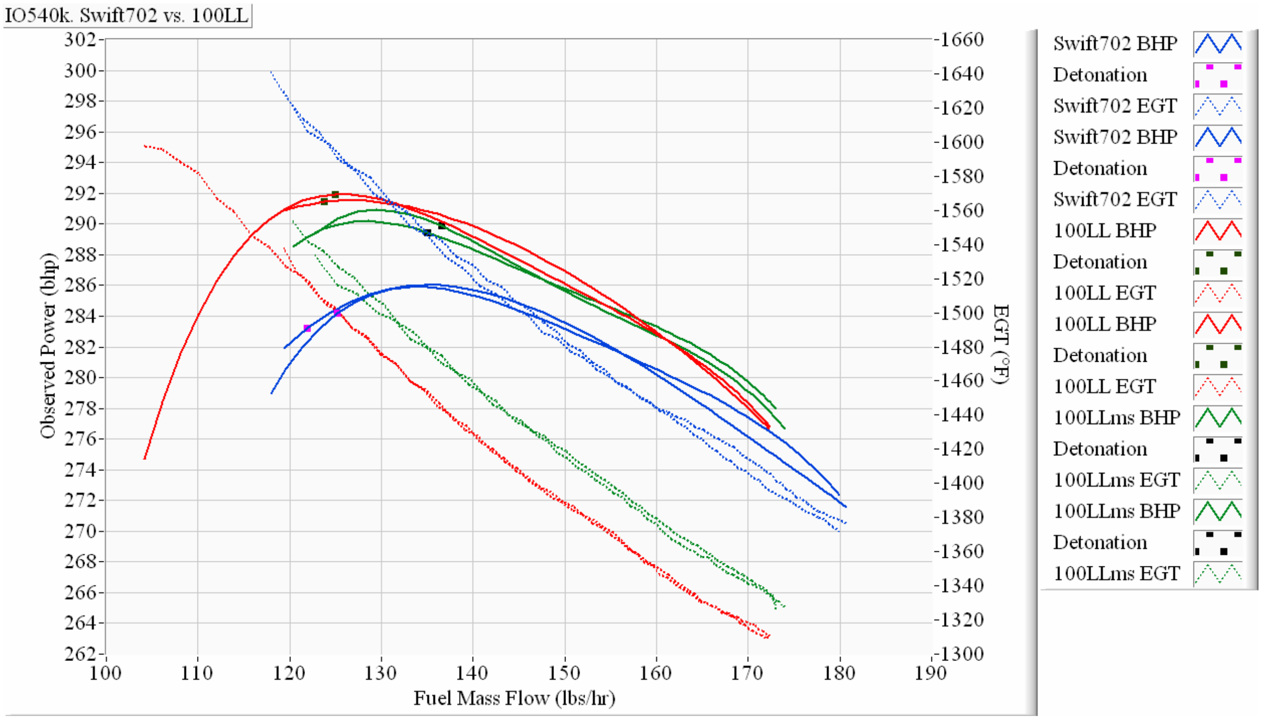


Figure 7. IO-540-K Detonation Tests Comparing Swift 702 Fuel to FBO 100LL and the Minimum Specification 100LL; FT, 2700 rpm

Figure 8 shows the same data plotted on a volumetric fuel flow basis; the Swift 702 fuel significantly outperformed both the 100LL fuels. Again, both figures show that the Swift 702 fuel produced approximately 6 horsepower less at the maximum power setting.

Figures 9 through 11 show the same data for the part throttle points, ranging from climb to economy cruise. All of these figures show that the Swift 702 fuel outperformed the FBO 100LL fuel in the detonation tests. Figure 10 shows that the detonation onset occurred at a slightly richer mixture for the Swift 702 fuel due to the lower stoichiometric air-to-fuel ratio. Figure 11 shows the data normalized by the stoichiometric air-to-fuel ratio. For operation of the IO-540-K engine, the mixture was able to be leaned to leaner relative mixtures prior to detonation onset on the Swift 702 fuel than the FBO 100LL.

All the detonation data mixture lean-out curves for the IO-540-K engine at all the data points tested are provided in appendices B and D. Appendix C provides the tabular data for the detonation onset and the peak power data for the IO-540-K detonation tests at all the power settings tested.

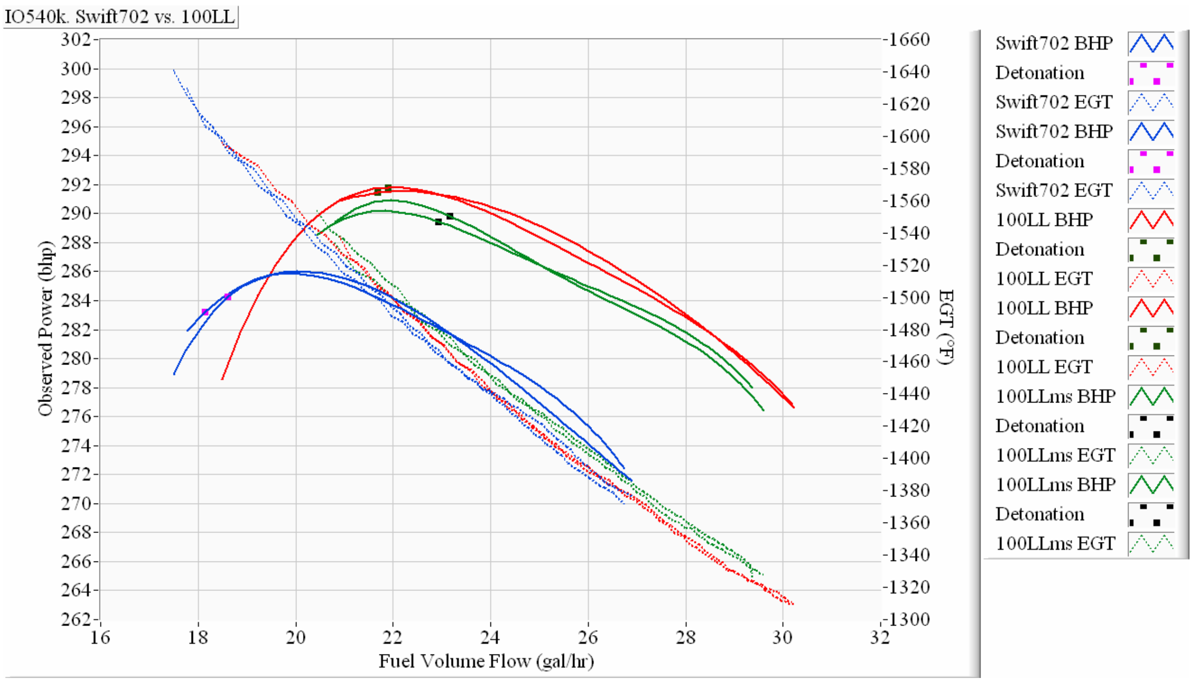


Figure 8. Detonation Tests Comparing Swift 702 Fuel to FBO 100LL and the Minimum Specification 100LL; FT, 2700 rpm

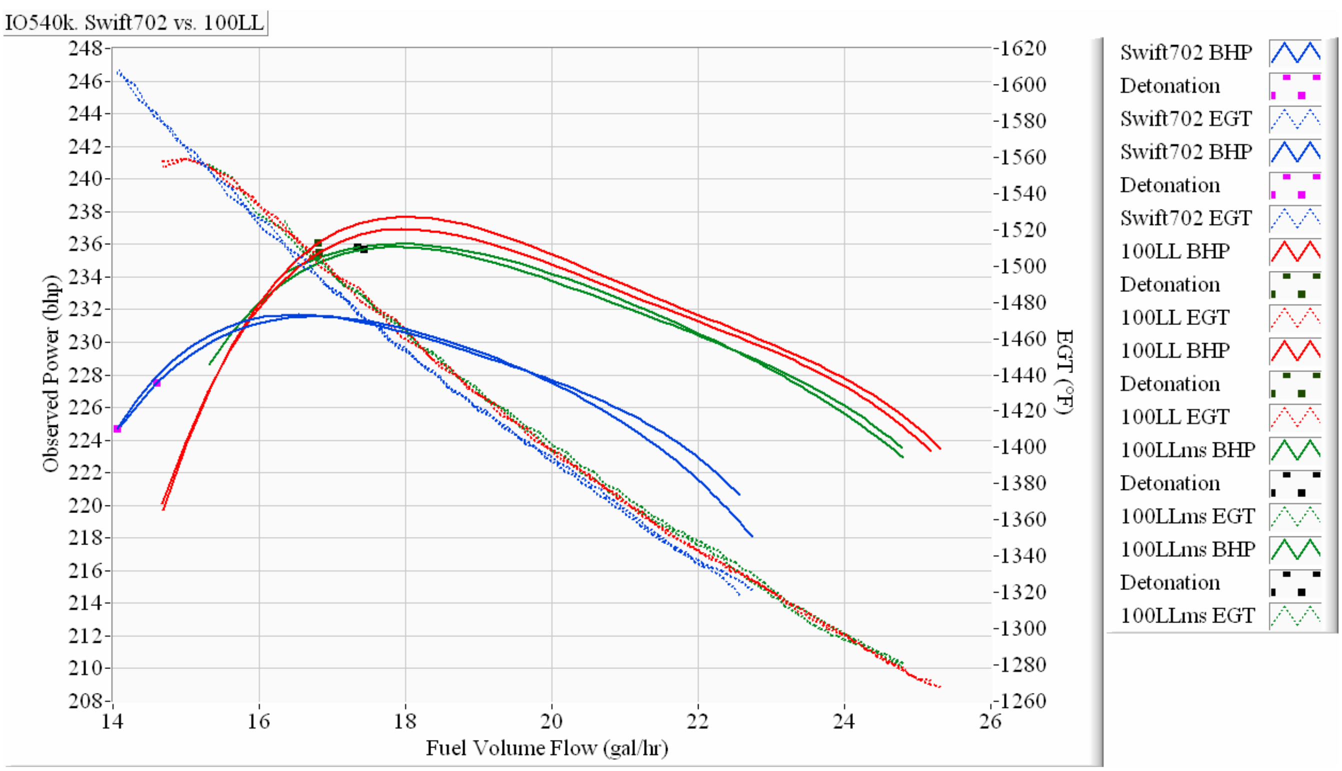


Figure 9. Detonation Tests Comparing Swift 702 Fuel to FBO 100LL and the Minimum Specification 100LL; 26 InHg MAP, 2600 rpm

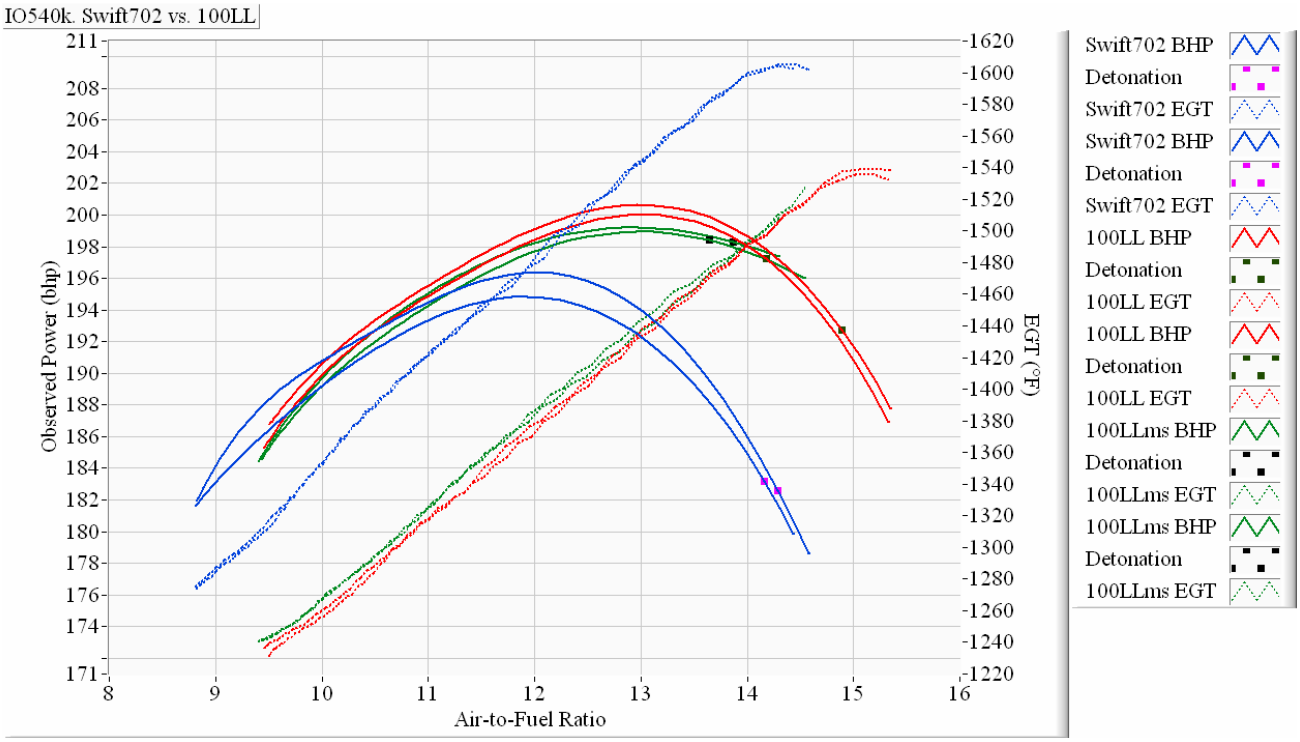


Figure 10. Detonation Tests Comparing Swift 702 Fuel to FBO 100LL and the Minimum Specification 100LL; 24 InHg MAP, 2450 rpm

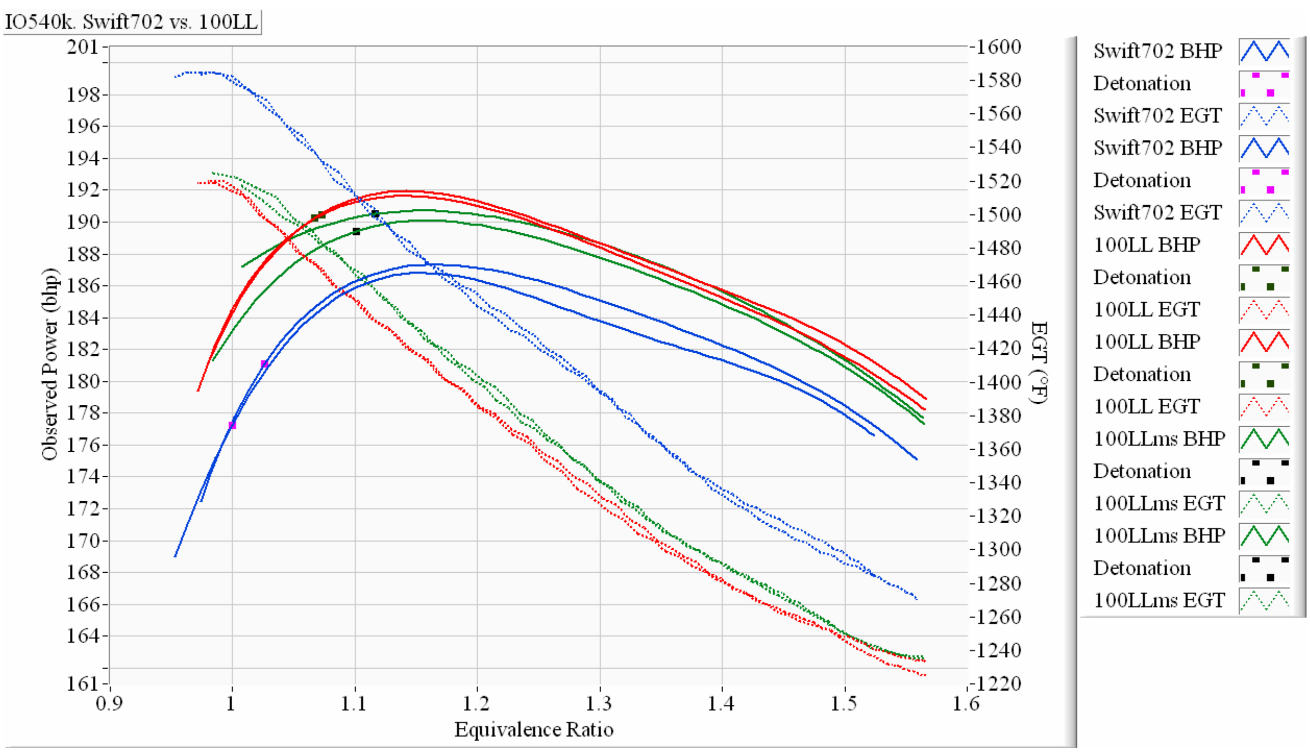


Figure 11. Detonation Tests Comparing Swift 702 Fuel to FBO 100LL and the Minimum Specification 100LL; 24 inHg MAP, 2350 rpm

3.2.2 Lycoming TIO-540-J2BD.

Table 13 shows the precision of the environmental controls on the test parameters. The tests showed that the precision of control of the environmental test factors was excellent.

Table 13. Engine Test Parameter Precision for the Detonation Tests Using the Lycoming TIO-540-J2BD Engine

Parameter	Target	Mean	Standard Deviation	Maximum	Minimum
IAT (ºF)	103	103	1	105	102
Maximum CHT (°F)	470	471	1	478	469
Minimum CHT (°F)	>425	442	4	454	433
IAP (inHg)	<0.03	0.01	0.01	0.04	-0.04
Inlet air humidity ratio (Gr/lb)	<1.0	0.9	0.1	1.1	0.7
OilT (°F)	245	221	7	236	204

IAP = Intake air pressure
OilT = Oil temperature
IAT = Intake air temperature

Table 14 shows the repeatability of the detonation onset data for the TIO-540-J2BD engine tests. The tests showed excellent repeatability with the average relative standard deviation less than 1.0% of the mean.

Table 14. Detonation Onset Repeatibility for the Detonation Tests Using the Lycoming TIO-540-J2BD Engine

Statistic	FF (lb/hr)	Equivalence Ratio	Air-to-Fuel Ratio	BSFC (lb/hp hr)	EGT (°F)
Average standard deviation	1.7	0.01	0.16	0.005	9
Maximum standard deviation	2.0	0.02	0.17	0.006	10
Average difference (maximum-minimum)	2.4	0.02	0.24	0.008	13
Maximum difference (maximum-minimum)	3.2	0.03	0.31	0.011	19
Average relative standard deviation (% of mean)	1.0	1.0	1.0	0.9	0.4
Maximum relative standard deviation (% of mean)	1.5	1.3	1.3	1.2	0.6

Figures 12 through 17 compare the detonation performance of the Swift 702 fuel to the FBO 100LL based on detonation onset fuel mass flow, fuel volume flow, and equivalence ratio. Figure 12 shows that the Swift 702 fuel performed as well as the FBO 100LL fuel at the TO power setting on a fuel mass flow basis even though it weighs 1.0 lb/gal more than the 100LL. Both fuels showed detonation onset just rich of best power mixture setting. As observed with the IO-540-K engine tests, the average EGT, and hence, the TIT, was higher on the Swift 702 fuel. Figure 15 shows the peak power average EGT to be approximately 40ºF higher with the Swift 702 fuel.

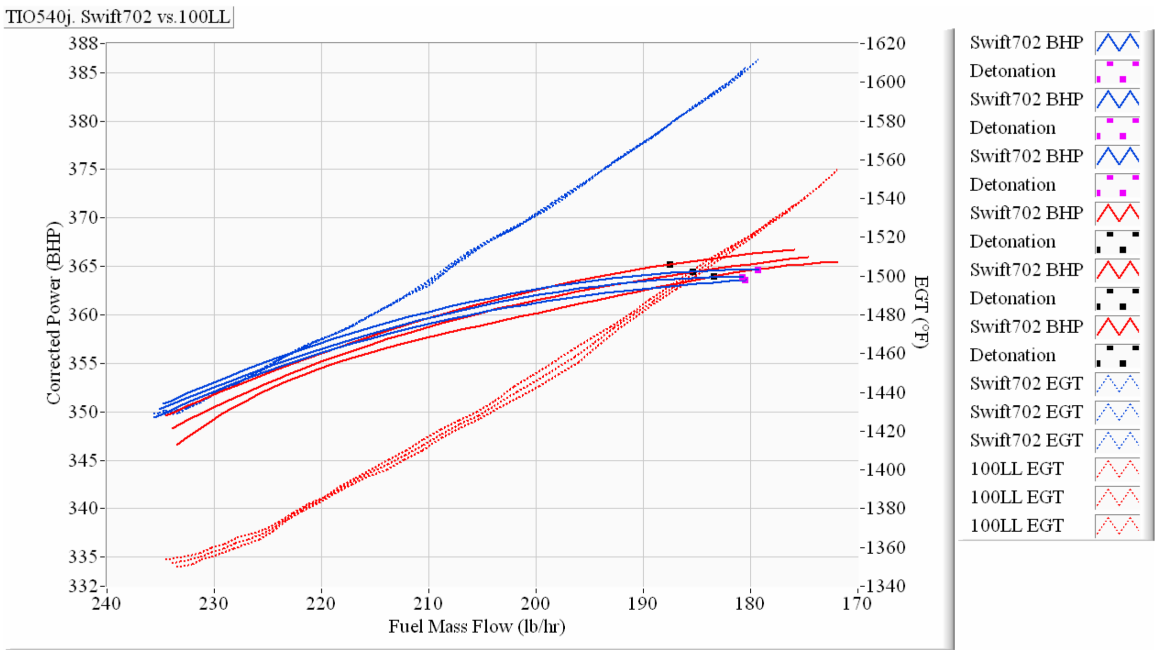


Figure 12. Swift 702 Fuel and 100LL Detonation Performance Based on Fuel Mass Flow; 2575 rpm, TO

Figure 13 shows the fuel comparison on a fuel volume flow basis. The Swift 702 fuel developed detonation onset at a significantly reduced fuel volume flow (approximately 6 gal/hr less).

As shown in figures 12 and 13, the mixture adjustments were stopped because either the maximum allowable TIT was reached or moderate to heavy detonation was reached.

Figures 14 and 15 show part throttle comparisons based on fuel volume flow. Again, the Swift 702 fuel performed better than the FBO 100LL fuel. In figure 14, the mixture adjustment with the Swift 702 fuel was stopped because maximum allowable TIT was reached.

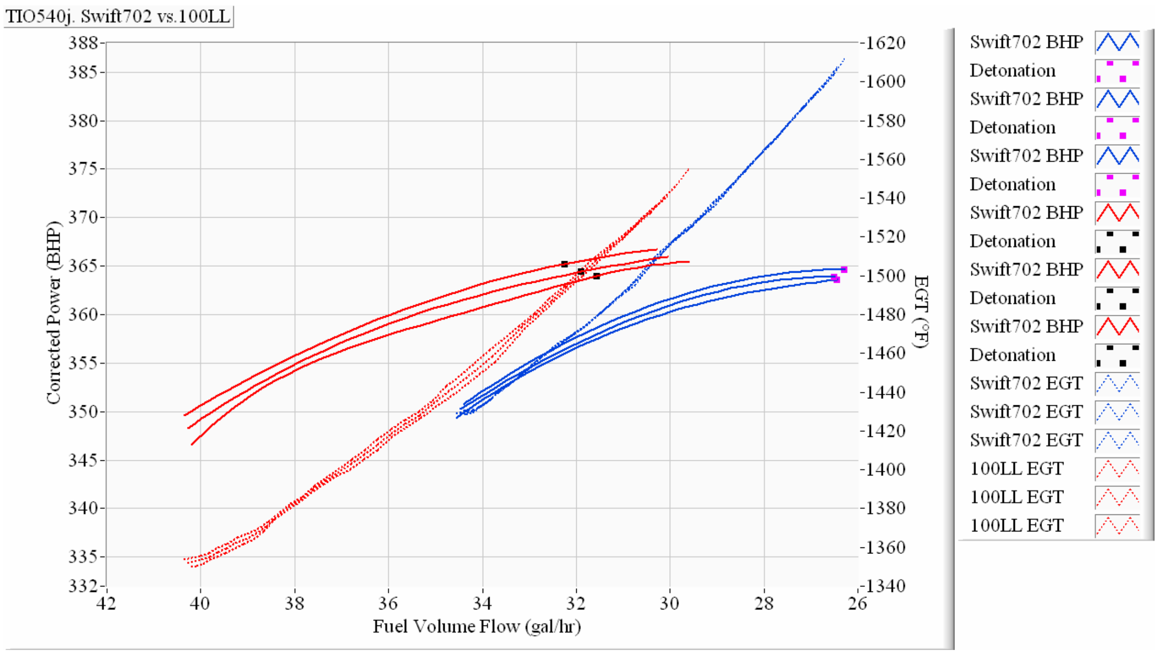


Figure 13. Swift 702 Fuel and 100LL Power Performance Based on Fuel Volume Flow; 2575 rpm, TO

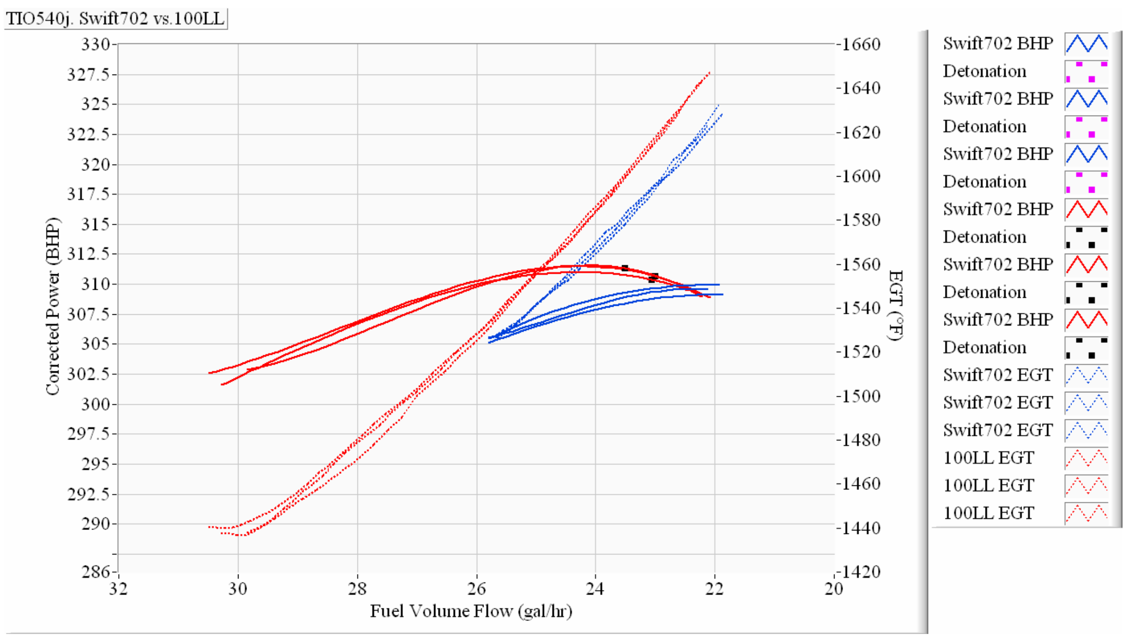


Figure 14. Swift 702 Fuel and 100LL Power Performance Based on Fuel Volume Flow; 2575 rpm, 85% Power

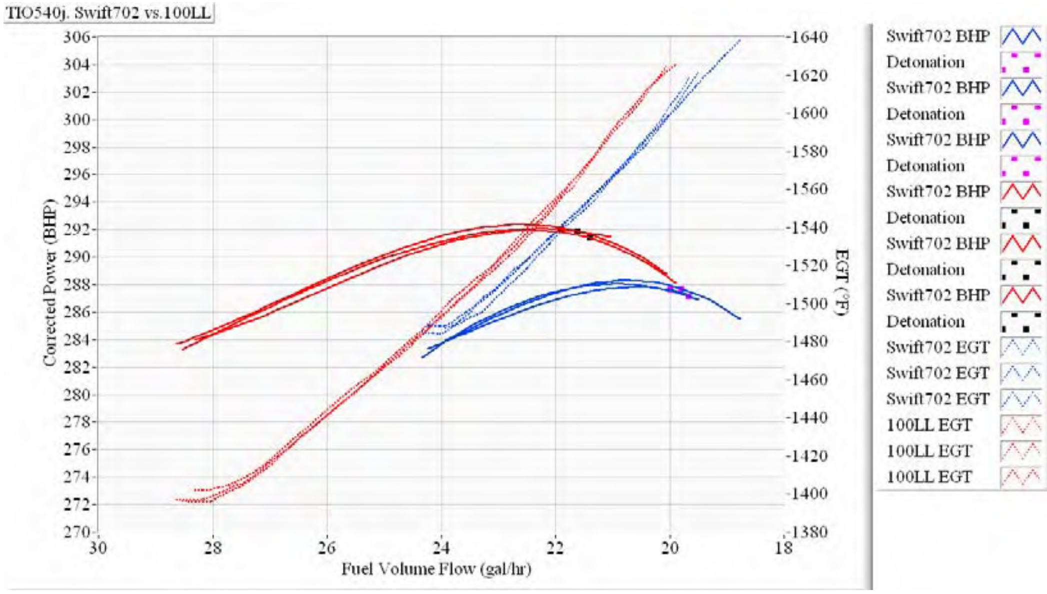


Figure 15. Swift 702 Fuel and 100LL Power Performance Based on Fuel Volume Flow, 2400 rpm, 80% Power

It should be noted that at the 85% power setting, mixture leaning is typically not permitted on this engine, according to the engine operator's manual. Mixture leaning adjustments at power settings above 75% rated power were performed to provide data for comparison. Based on equivalence ratio, the Swift 702 fuel outperformed the FBO 100LL fuel at the TO power setting, as shown in figure 16. The average EGT was found to be approximately 40°F higher for the Swift 702 fuel. Mixture adjustments on the Swift 702 fuel were stopped because they reached the maximum allowable TIT at the TO power setting.

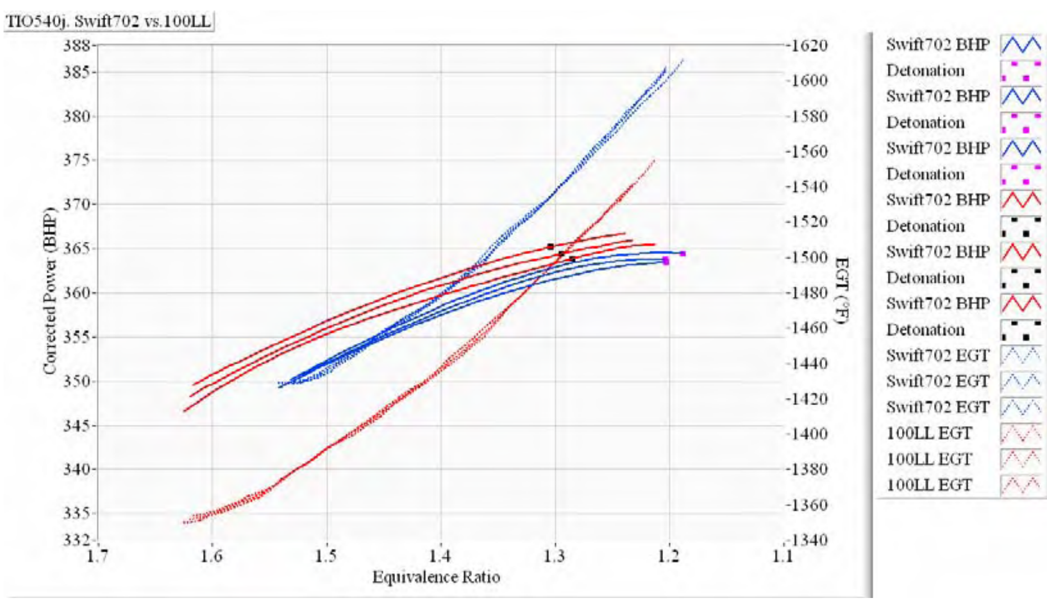


Figure 16. Swift 702 Fuel and 100LL Power Performance Based on Equivalence Ratio; 2575 rpm, TO

Figure 17 shows that, at low-cruise power setting, the FBO 100LL outperformed the Swift 702 fuel.

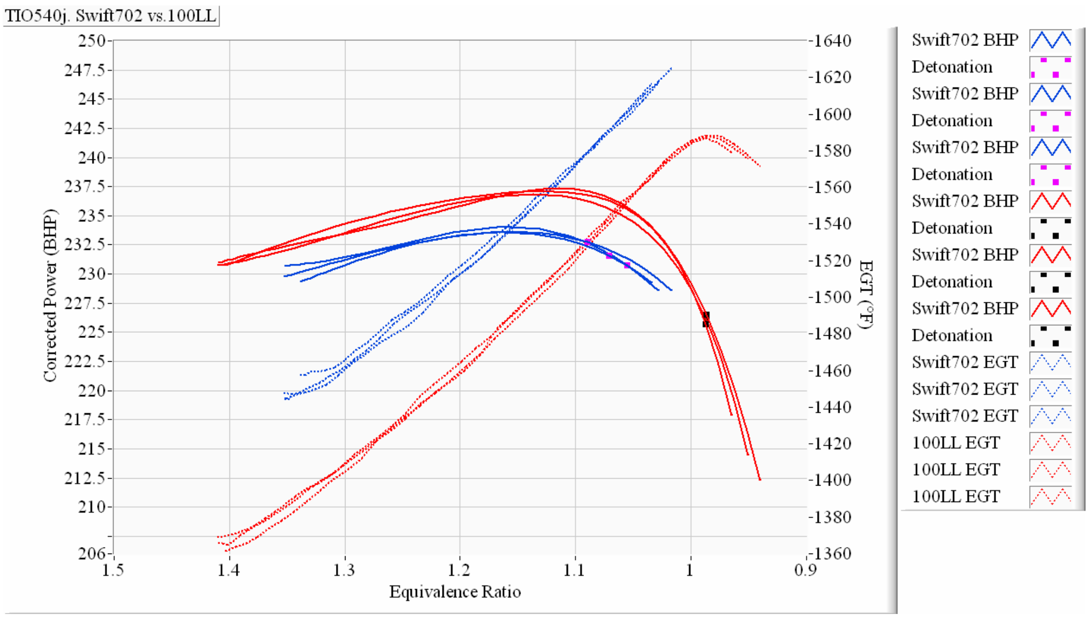


Figure 17. Swift 702 Fuel and 100LL Power Performance Based on Equivalence Ratio; 2200 rpm, 65% Power

The FBO 100LL fuel reached peak EGT prior to onset of detonation, whereas the mixture adjustments on the Swift 702 fuel were stopped when the maximum allowable TIT was reached. At the part throttle setting the peak power average EGT was approximately 40ºF higher for the Swift 702 fuel than the FBO 100LL fuel.

All the detonation onset graphs are provided in appendices E and G. Appendix F provides tabular data for detonation onset and best power data.

3.2.3 Lycoming IO-540-K Ignition Timing Change Effects.

The slightly reduced horsepower and elevated EGTs experienced with both the IO-540-K and the TIO-540-J2BD engines suggested that the burn rate for the Swift 702 fuel was slightly slower than the 100LL fuel. This would explain the slightly reduced power output but higher average EGTs as more heat was released later in the combustion cycle. The IO-540-K engine was used to collect 250 consecutive engine pressure cycles for all six cylinders at four different power settings at the standard ignition timing of 20 degrees before top-dead center (BTDC), at 3 degrees timing advance and at 6 degrees timing advance. The average peak cylinder pressure and its location with respect to top-dead center (TDC) of the compression stroke were measured and compared for both the Swift 702 fuel and the FBO 100LL fuel.

Figure 18 shows the TO power setting peak pressure. Figure 19 shows the location of peak pressure for the Swift 702 fuel at TO power setting for the three ignition timing settings and the FBO 100LL at the standard ignition timing of 20° BTDC. The Swift 702 fuel produced lower peak pressures (approximately 7 bar or 102 psi) than the 100LL at the standard ignition timing of 20° BTDC and occurred approximately 3 degrees of crankshaft rotation later in the cycle. Advancing the timing by 3 degrees resulted in peak pressures much closer to those of the 100LL and at a location relative to TDC close to the FBO 100LL. Advancing the ignition timing by another 3 degrees resulted in slightly higher peak pressures on the Swift 702 fuel than the FBO 100LL at standard ignition timing, but at a location much closer to TDC.

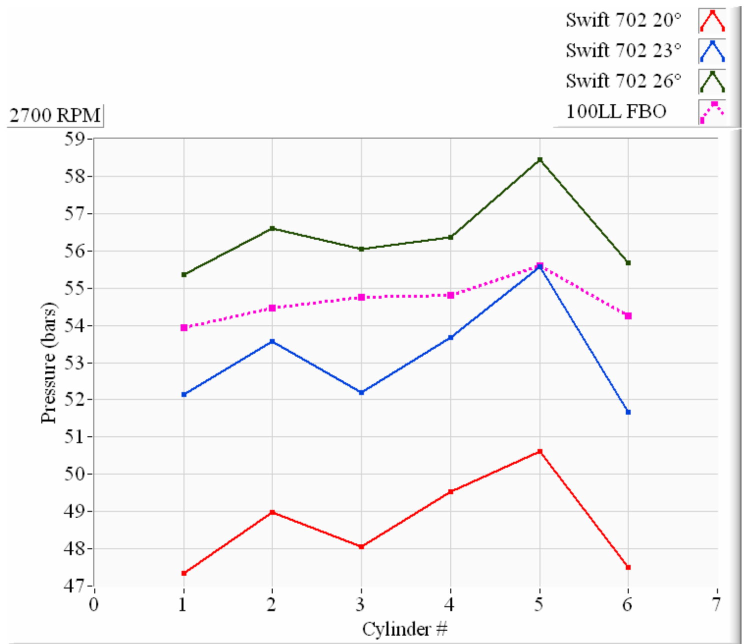


Figure 18. Peak Pressure, 2700 rpm

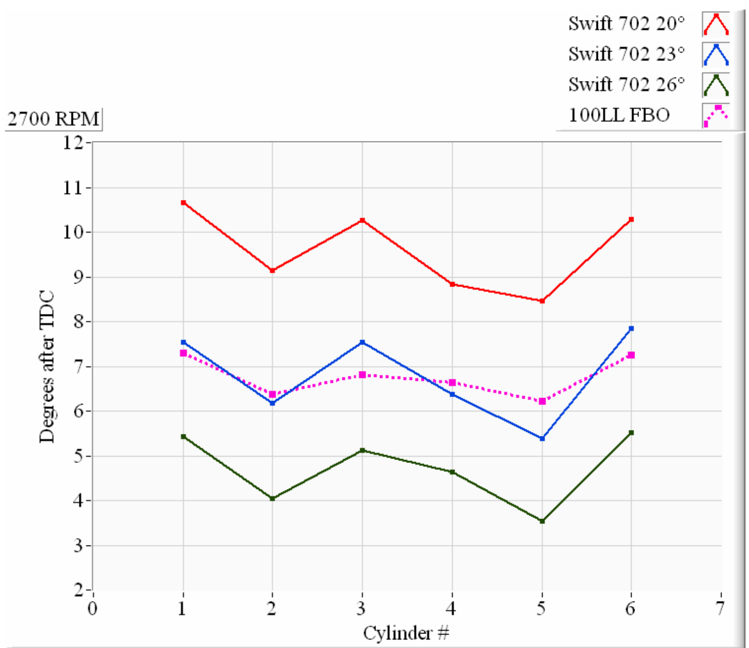


Figure 19. Location of Peak Pressure, 2700 rpm

The same effects are shown in figures 20 and 21, which show a performance cruise power setting. All cylinder peak pressure and location of peak pressure data for all power settings from the adjustments in ignition timing are provided in appendix H.

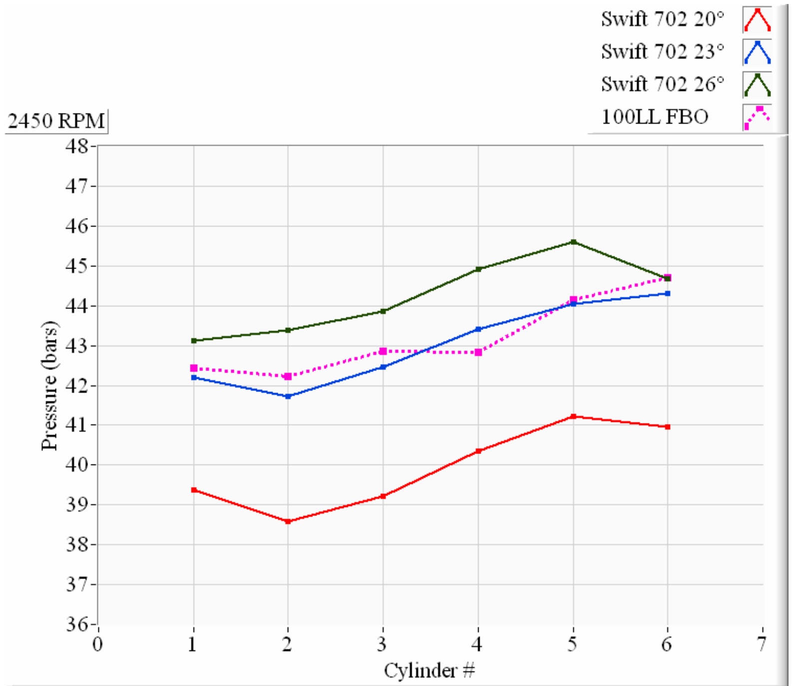


Figure 20. Peak Pressure, 2450 rpm

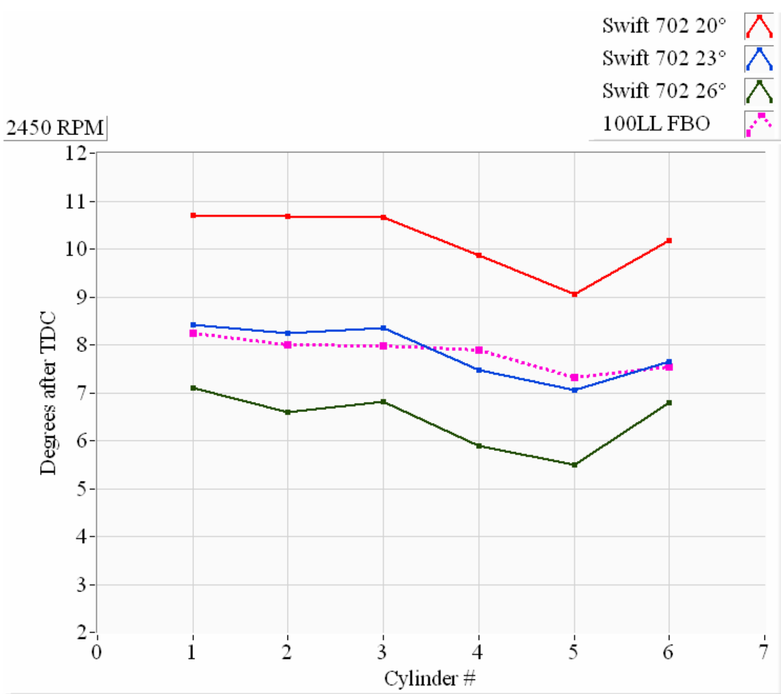


Figure 21. Location of Peak Pressure, 2450 rpm

The effects of the ignition timing changes on detonation and average EGT were investigated. For a given fuel, advancing the ignition timing would result in lower average EGT and increased brake power. This is due to more heat being released earlier in the cycle, resulting in higher peak pressures and more heat transferring through the head and pistons.

Figure 22 shows the detonation onset curves for the ignition timing changes of the Swift 702 fuel at the TO power setting, and figure 23 shows the economy cruise setting. The data points on the curves are the locations of richest mixture setting where detonation occurred. This data shows that advancing the ignition timing by 3 degrees from the standard setting resulted in a slight increase in power, but the reduction in average EGT was minimal. There was also a slight degradation in detonation performance with the 3-degree ignition timing advance. At the economy cruise setting, the detonation onset mixture setting was shifted rich of peak EGT for the 3-degree advanced ignition timing.

Advancing another 3 degrees to a 6-degree total advance resulted in an increase of 2 to 3 horsepower on average but only an approximate reduction in average EGT of 15ºF. This data shows that the slight loss in power and increase in average EGT has more to do with the greater amount of heat released per unit of air consumed over a greater period of time for the Swift 702 fuel than the FBO 100LL.

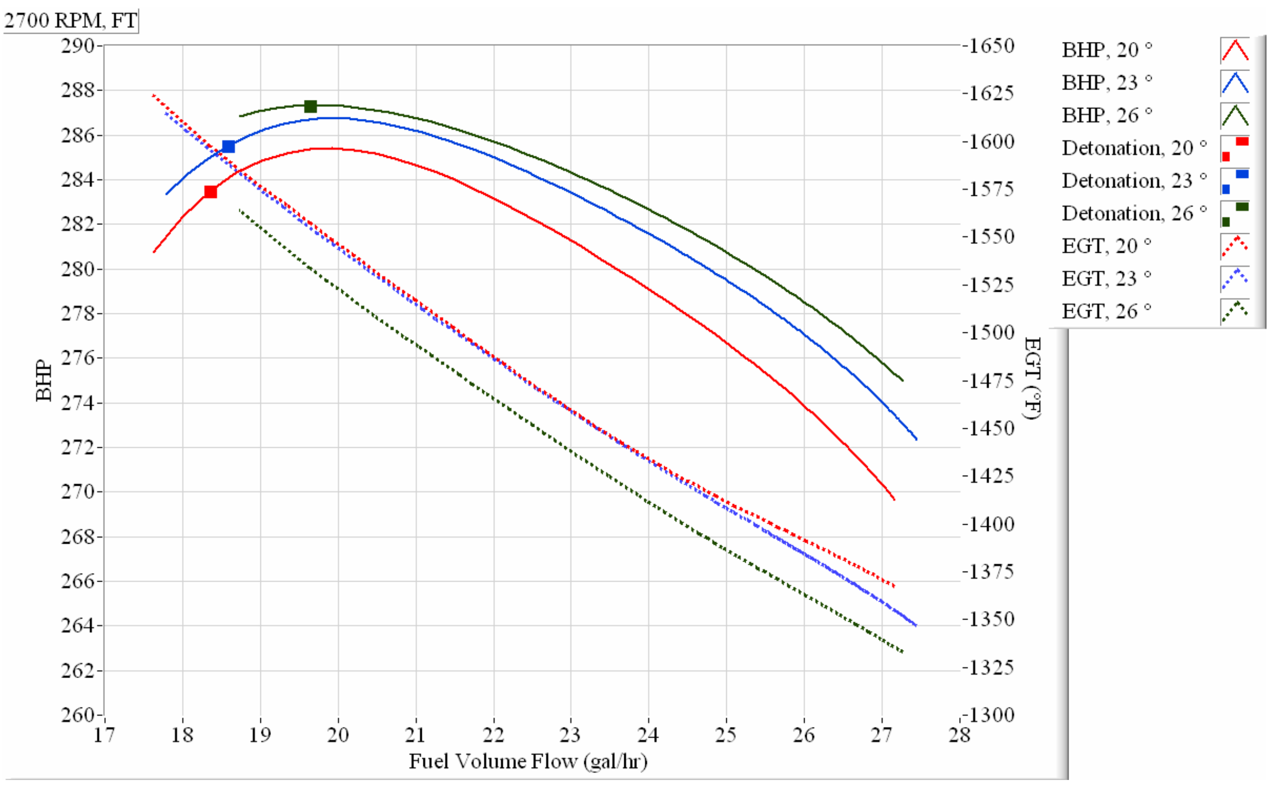


Figure 22. Effect of Ignition Timing Changes on Peak Power, Average EGT, and Detonation Onset; 2700 rpm, FT

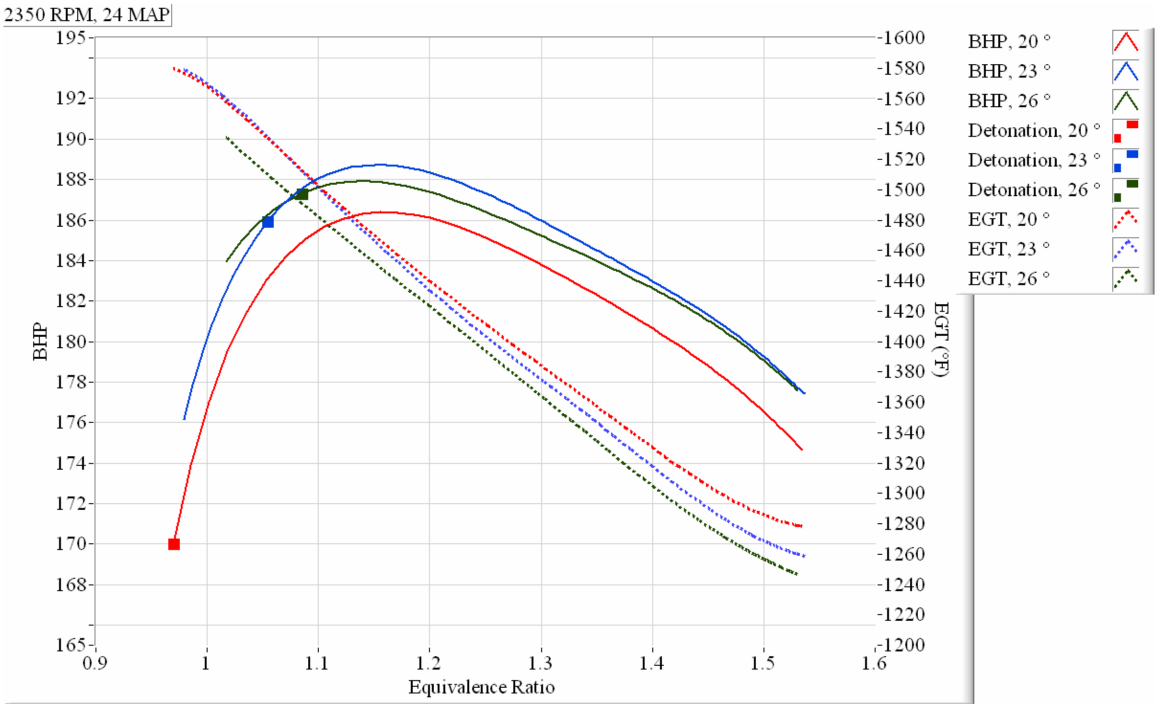


Figure 23. Effect of Ignition Timing Changes on Peak Power, Average EGT, and Detonation Onset; 2350 rpm, 24 inHg MAP

All the mixture adjustment detonation onset data curves for the timing changes to the IO-540-K engine are provided in appendix I.

4. CONCLUSIONS AND RECOMMENDATIONS.

The Swift 702 fuel was compared to a locally purchased 100 low-lead (100LL) aviation fuel in both a naturally aspirated, six-cylinder, Lycoming IO-540-K engine and a turbocharged, six-cylinder Lycoming TIO-540-J2BD engine. These engines have been identified in previous Federal Aviation Administration (FAA) tests as the highest octane demand engines for their respective engine class. Power performance and detonation performance tests were performed in the IO-540-K engine and detonation performance tests were performed in the TIO-540-J2BD engine. Furthermore, full ASTM D 910 laboratory tests were performed on the Swift 702 fuel and compared to the current leaded aviation gasoline specification, ASTM D 910.

The Swift 702 fuel met all the current ASTM D 910 specifications, other than the mandatory lead requirement and dye, except for the following two items:

1. The net heat of combustion was 41.9 MJ/kg compared to a minimum specification value of 43.5 MJ/kg. This is a 3.7% reduction in specific energy content. The Swift 702 fuel was found to have a mass density that was 1.0 lb/gal higher than 100LL at 87ºF (6.7 lb/gal for Swift 702 versus 5.7 lb/gal for 100LL). On a per gallon basis, the Swift 702 fuel contains 127.6 MJ/gal versus 112.7 MJ/gal for 100LL, a 13% higher heat content for the Swift 702 fuel.

2. The Swift 702 fuel did not meet the 50%, 90%, or end point of the distillation curves. This was due to the high aromatic hydrocarbon content of the fuel. Previous and extensive FAA tests determined that an unleaded fuel could meet the current detonation performance of the current ASTM D 910 100LL leaded aviation gasoline only if it contained at least 10% of a specific aromatic amine or it contained a very high concentration of aromatic hydrocarbon. In either case, it is highly unlikely that any such fuel would meet the distillation specification for an aviation alkylate-based fuel. Further tests are planned on the Swift 702 fuel using two separate high-power engines, a Continental and a Lycoming, for long-duration tests. This testing will be in coordination with engineers from both Continental and Lycoming engine manufacturers.

Operation on the Swift 702 fuel resulted in lower air-to-fuel ratios, or richer mixtures, for peak power and peak exhaust gas temperature (EGT) locations than the 100LL. This is due to the lower stoichiometric mass-based air-to-fuel ratio for the Swift 702 fuel (14 versus 15 for 100LL). Swift 702 fuel provided greater than 98% of the power of 100LL at approximately 8% lower volumetric fuel consumption. As a rough estimate, 30 gallons of Swift 702 fuel would increase the weight of an aircraft by 30 lb but would increase the range by approximately 8%.

The Swift 702 fuel, having an ASTM D 2700 motor octane number (MON) of 104.4, provided slightly better detonation performance than a 100LL fuel of 103.6 MON purchased from a local airport. The better performance became increasingly evident when accounting for the different stoichiometries and mass densities of the fuels.

Swift 702 produced, on average, a 50°F higher average EGT than the fixed-base operator (FBO) 100LL. Further planned extensive endurance tests, previously mentioned, will address if there is any noticeable effect on engine wear due to the slightly elevated temperatures.

Swift 702 operation resulted in approximately 100 psi reduction in average peak cylinder pressure and shifted the location of peak cylinder pressure by 3 degrees retard with respect to crank shaft compression cycle top-dead center.

Advancing the ignition timing by 3 degrees before top-dead center (BTDC) on the Swift 702 fuel resulted in a 2-3 brake horsepower (BHP) increase with a minimal decrease in average EGT and a slight degradation in detonation performance. At 3-degree advanced timing, the detonation onset mixture setting at economy cruise shifted rich of peak EGT for the Swift 702 fuel. Advancing the ignition timing by 6 degrees BTDC on the Swift 702 fuel resulted in significant detonation performance degradation with minimal decrease in average EGT. Some of the higher EGTs are due to the high aromatic hydrocarbon content of the fuel, resulting in a greater heat release per unit of air consumed.

Further testing of the Swift 702 fuel will address long-term endurance wear performance of the fuel. This test plan will be derived in cooperation with both major aviation piston engine manufacturers, Continental and Lycoming. Engine tear-down measurements will be taken of all the high-stress parts of the engine, both before and after testing. Fuel injector nozzle and combustion deposits, along with intake varnish buildup will be recorded and documented.

Results from these tests will address concerns about the high-end distillation performance and the lubricity of the fuel.

5. REFERENCES.

1. Atwood, David, "Full-Scale Engine Detonation Tests of 47 Unleaded, High-Octane Blends," FAA report DOT/FAA/AR-08/40, September 2008.

2. Atwood, David, "High-Octane and Mid-Octane Detonation Performance of Leaded and Unleaded Fuels in Naturally Aspirated, Piston, Spark Ignition Aircraft Engines," FAA report DOT/FAA/AR-TN07/5, March 2007.

APPENDIX A—LYCOMING IO-540-K POWER BASELINE MIXTURE ADJUSTMENT DATA

The graphical data contained in this appendix shows the power performance with mixture adjustment of the Swift 702 fuel compared to the locally purchased 100LL aviation gasoline.

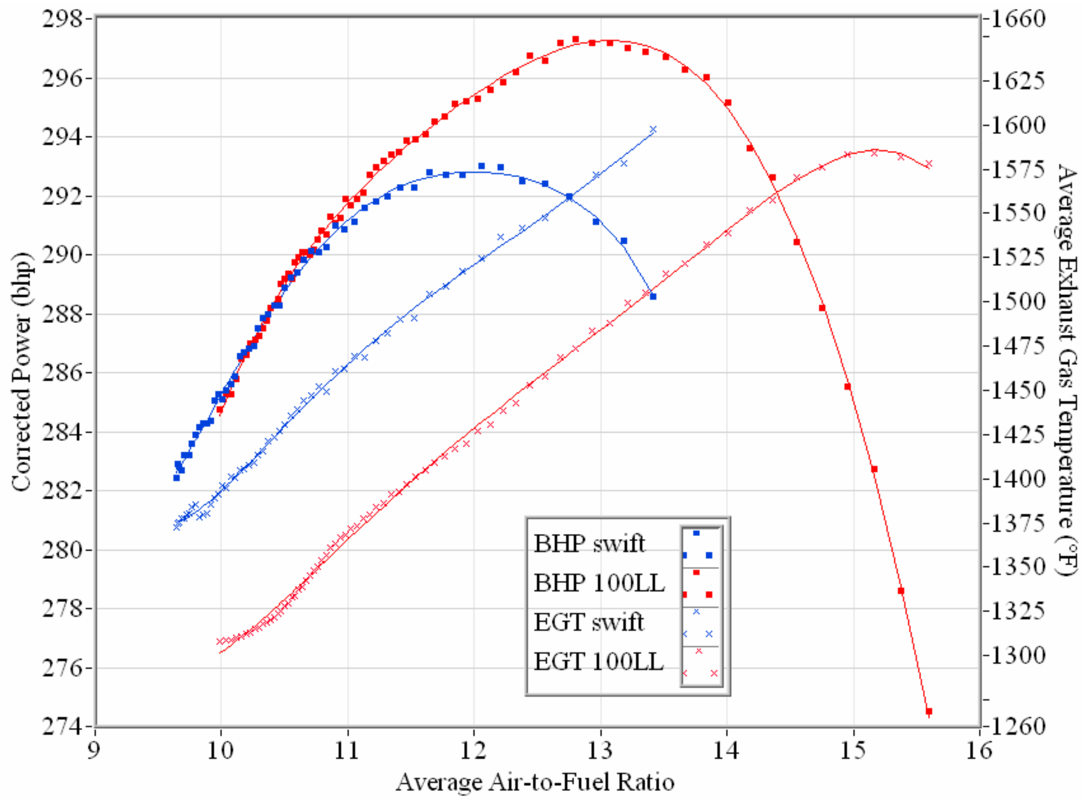


Figure A-1. Swift 702 Fuel Compared to 100LL; 2700 rpm, FT

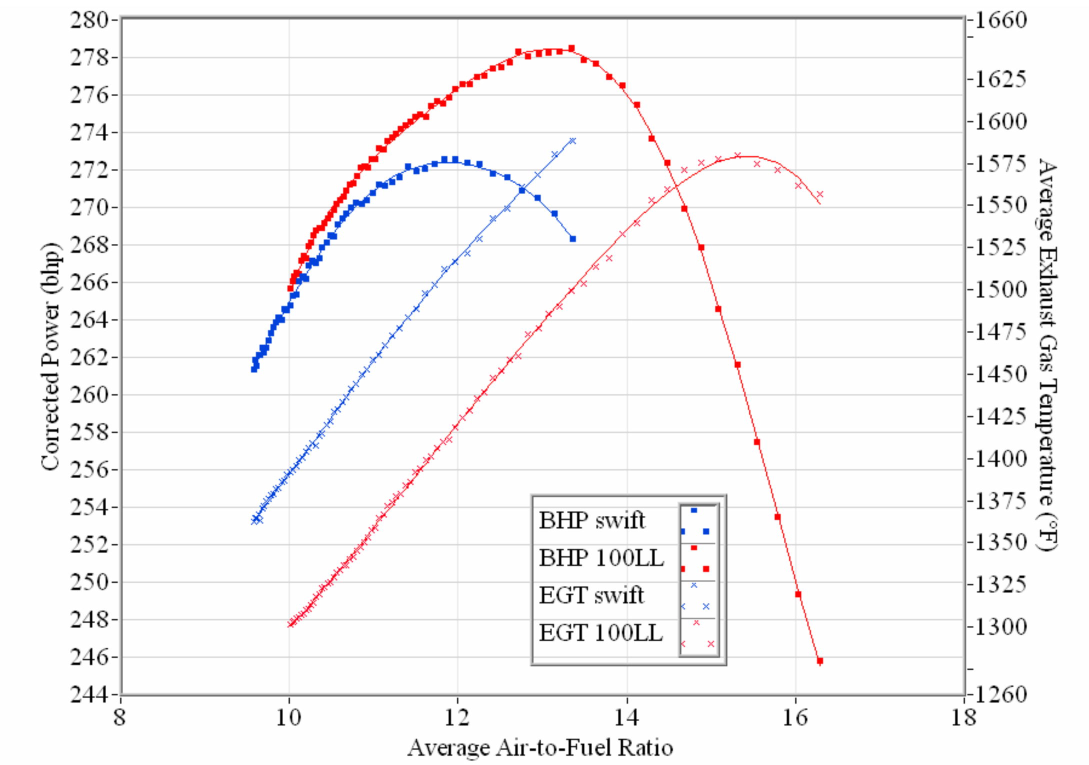


Figure A-2. Swift 702 Fuel Compared to 100LL; 2700 rpm, 28 inHg MAP

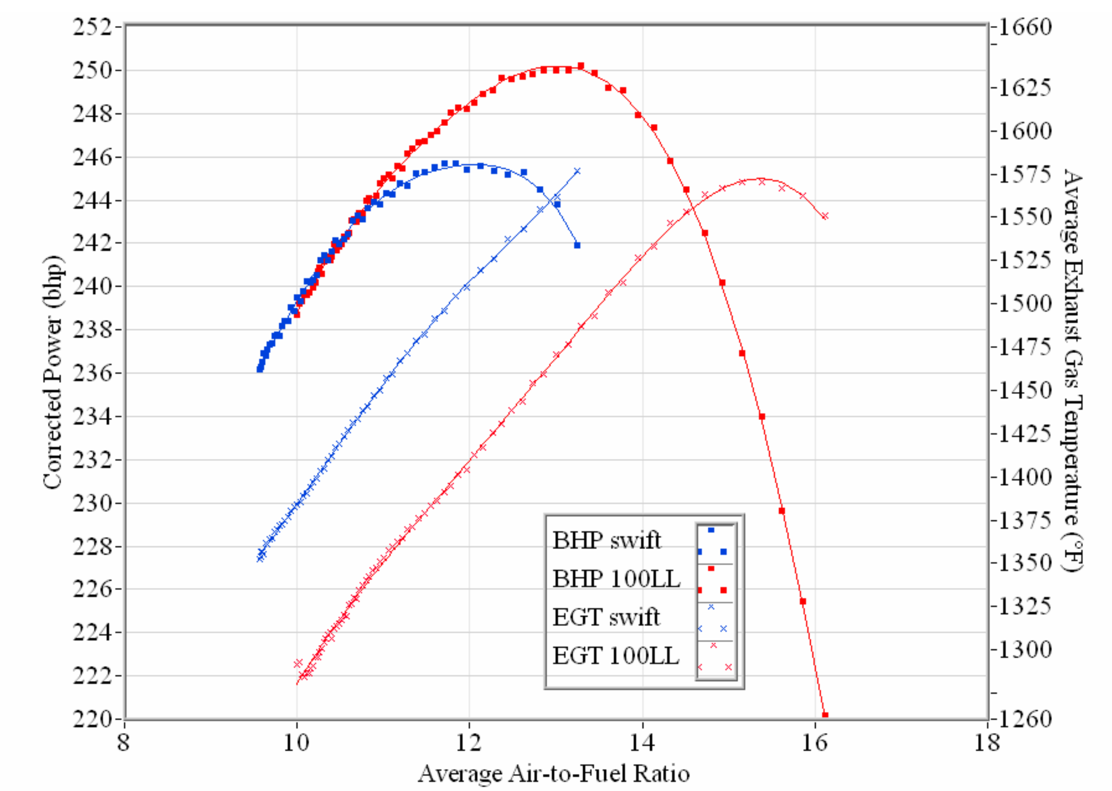


Figure A-3. Swift 702 Fuel Compared to 100LL; 2700 rpm, 26 inHg MAP

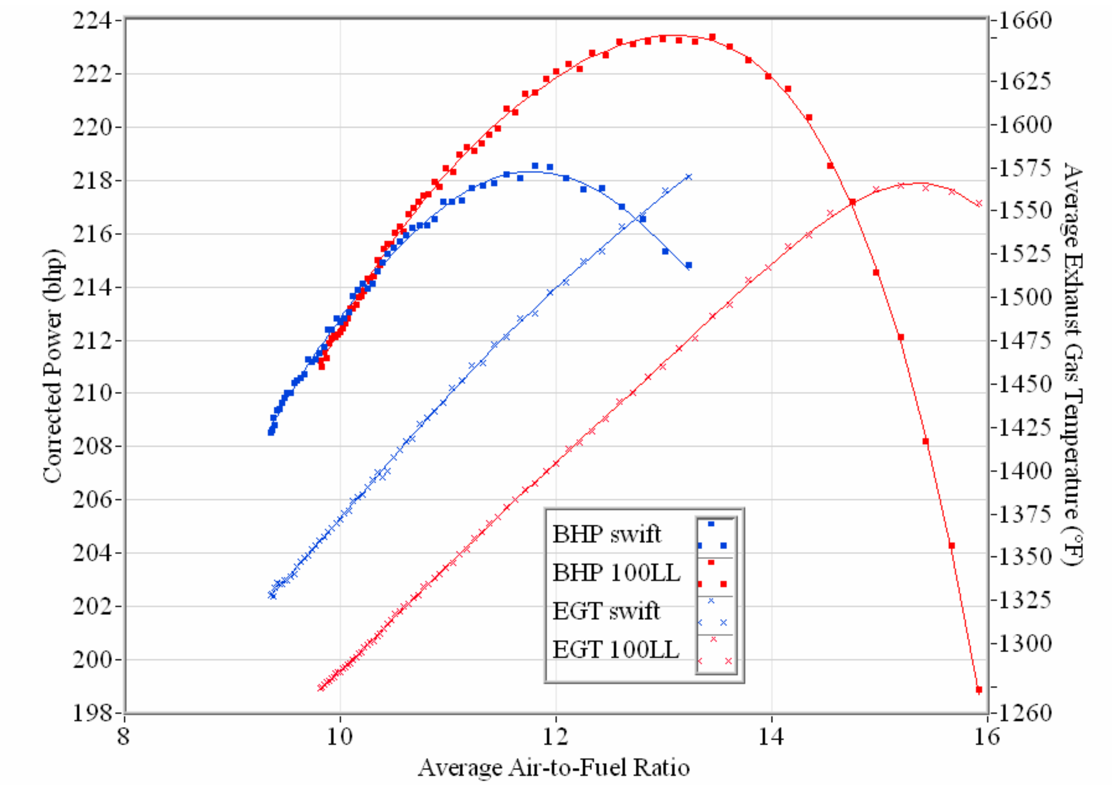


Figure A-4. Swift 702 Fuel Compared to 100LL; 2700 rpm, 24 inHg MAP

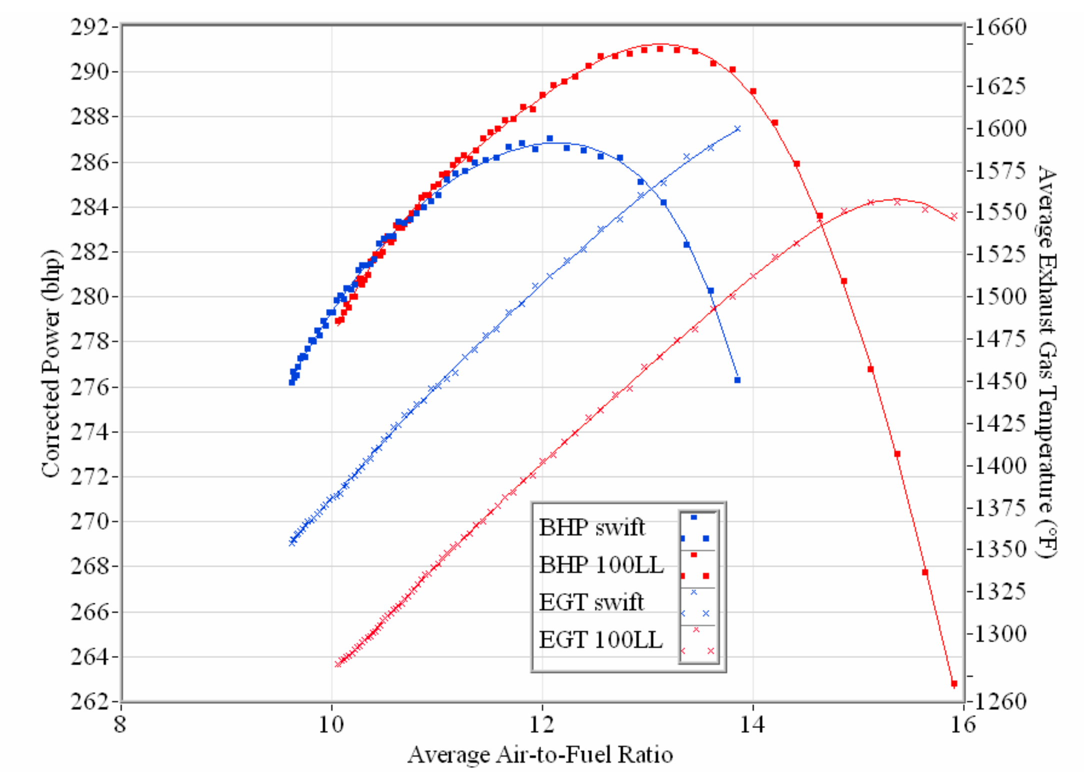


Figure A-5. Swift 702 Fuel Compared to 100LL; 2600 rpm, FT

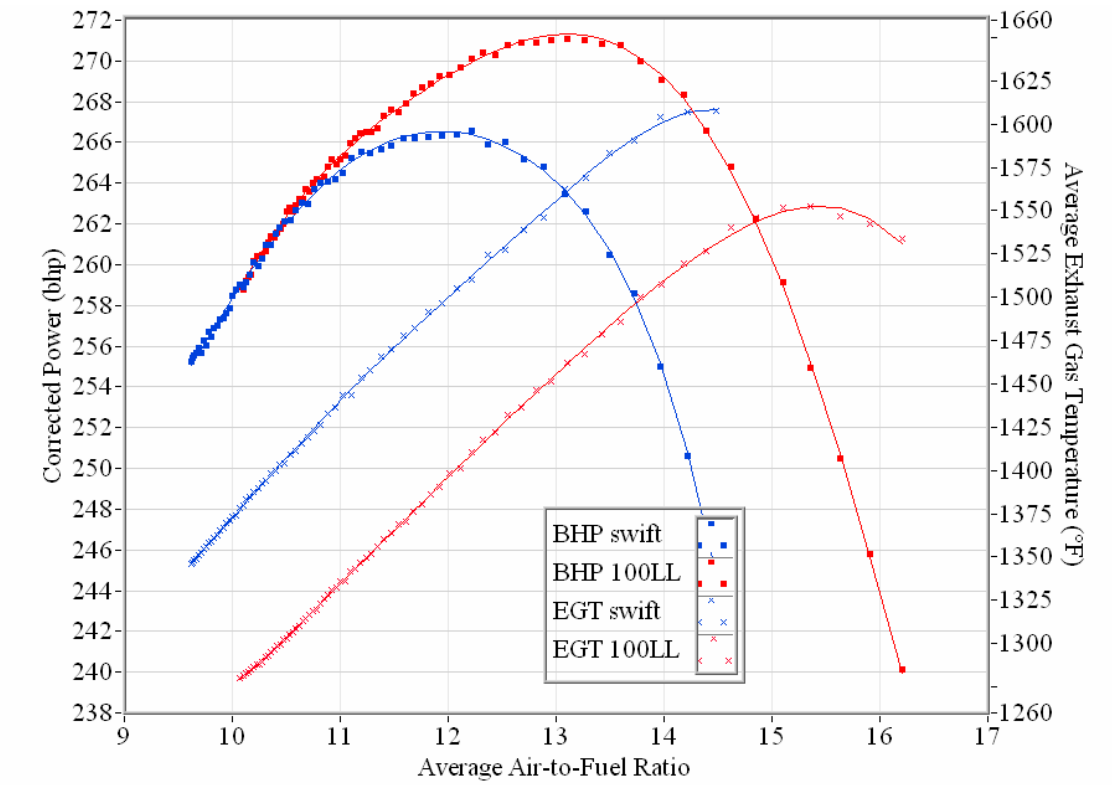


Figure A-6. Swift 702 Fuel Compared to 100LL; 2600 rpm, 28 inHg MAP

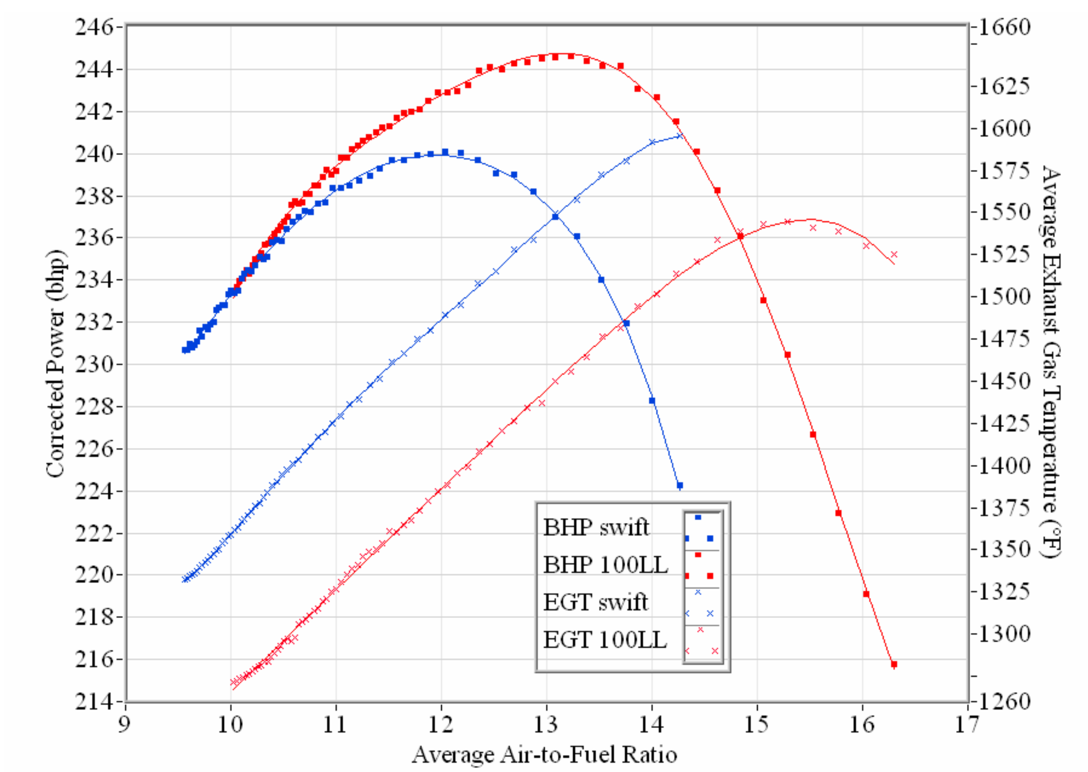


Figure A-7. Swift 702 Fuel Compared to 100LL; 2600 rpm, 26 inHg MAP

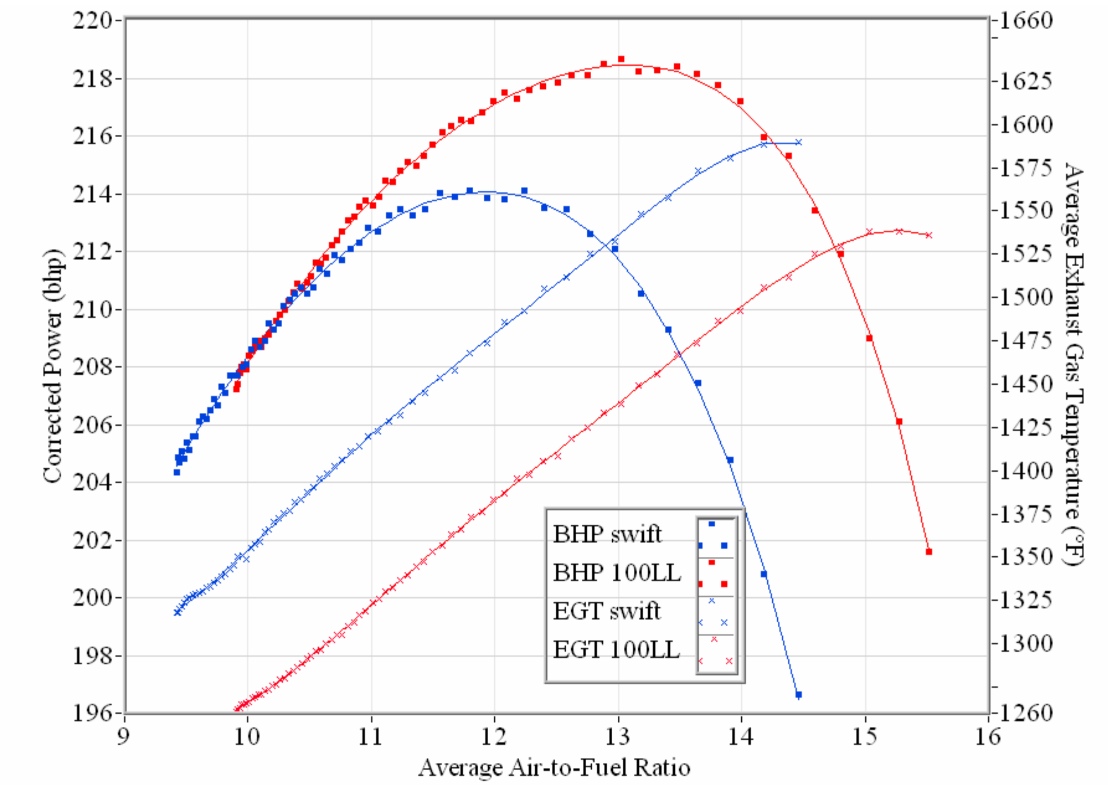


Figure A-8. Swift 702 Fuel Compared to 100LL; 2600 rpm, 24 inHg MAP

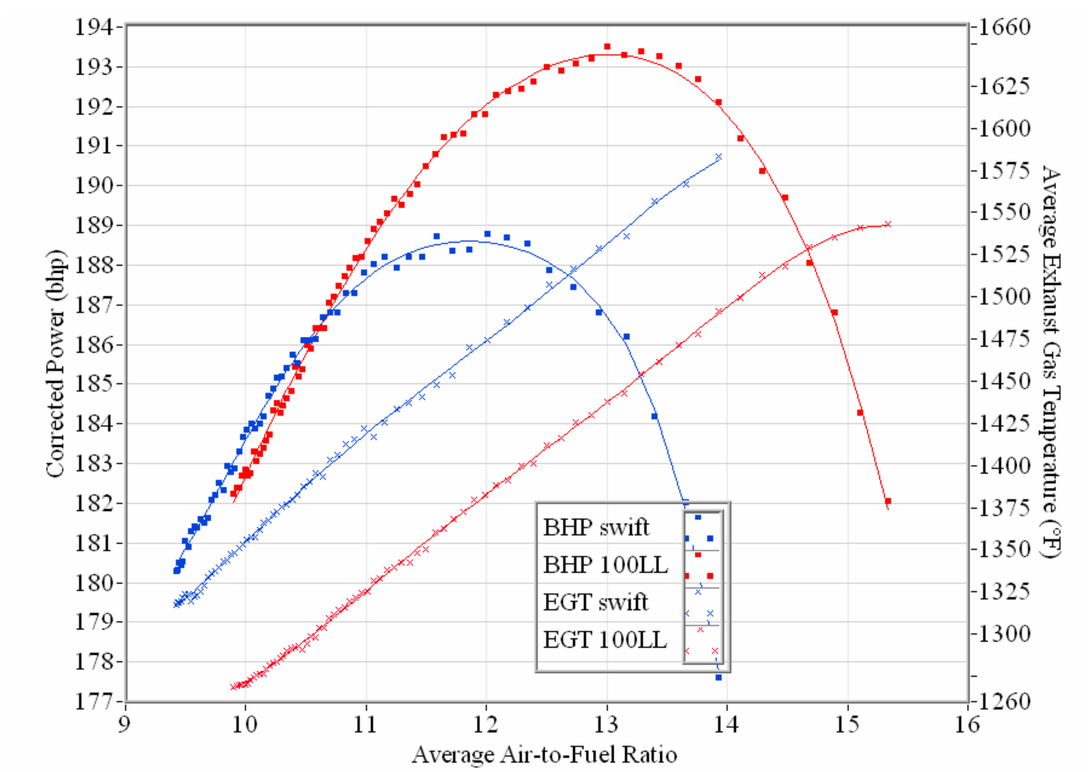


Figure A-9. Swift 702 Fuel Compared to 100LL; 2600 rpm, 22 inHg MAP

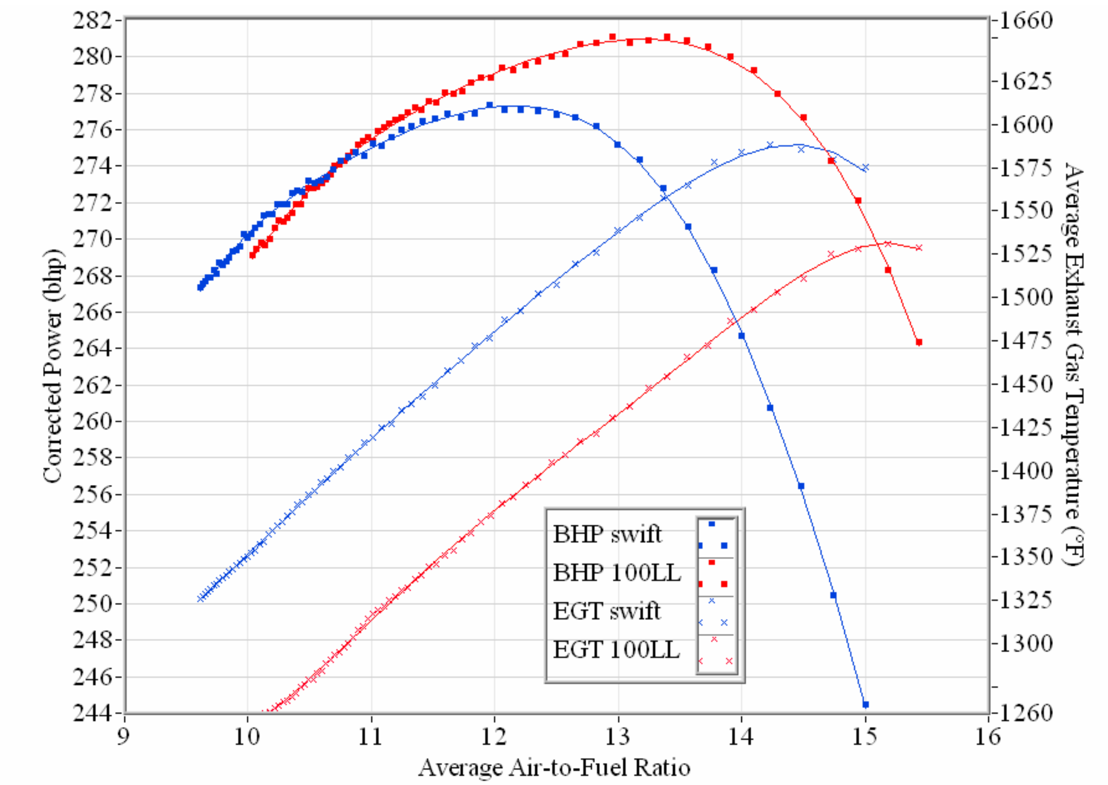


Figure A-10. Swift 702 Fuel Compared to 100LL; 2500 rpm, FT

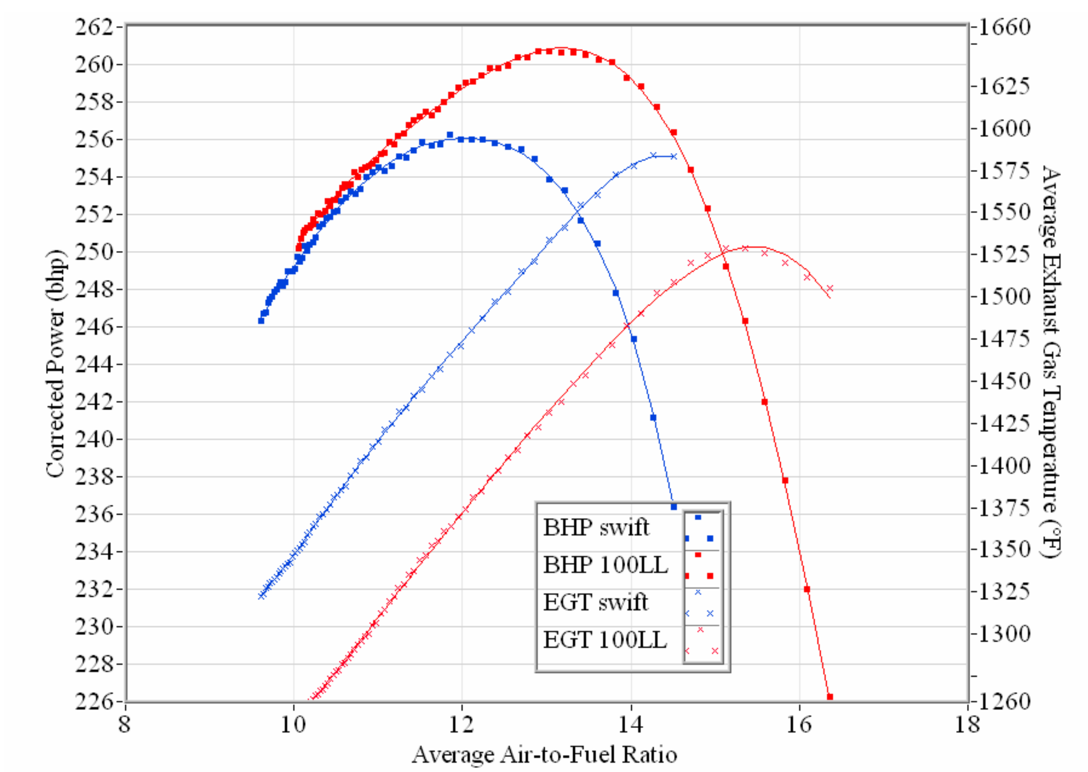


Figure A-11. Swift 702 Fuel Compared to 100LL; 2500 rpm, 28 inHg MAP

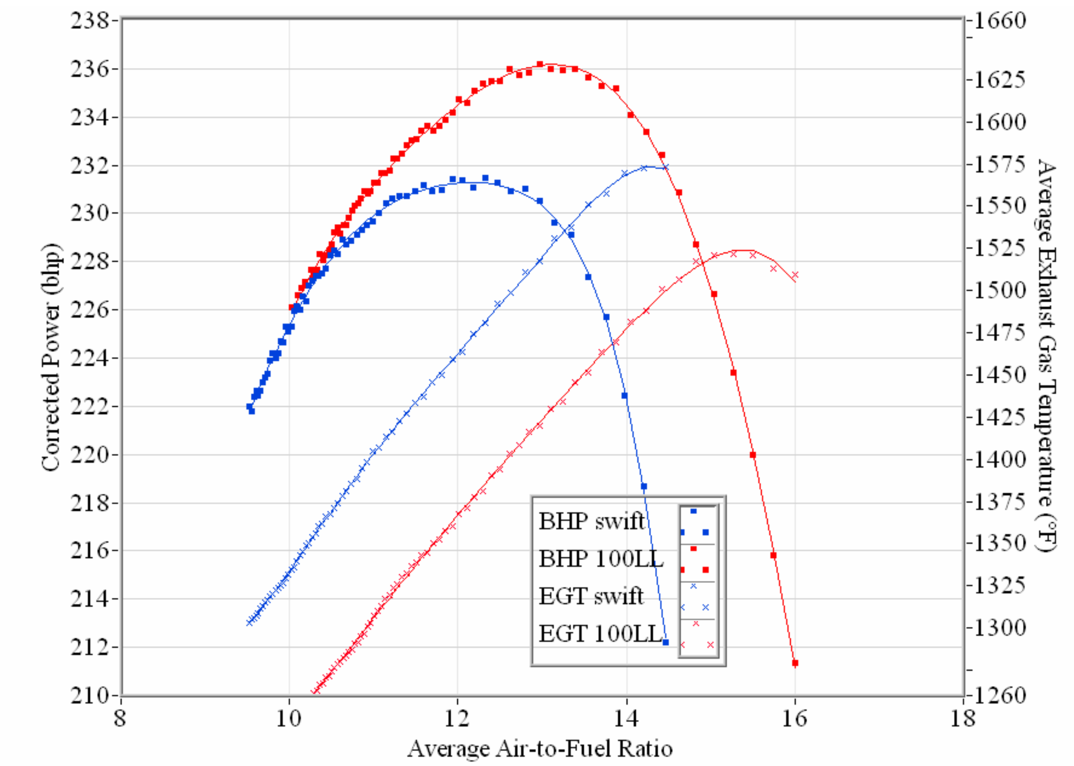


Figure A-12. Swift 702 Fuel Compared to 100LL; 2500 rpm, 26 inHg MAP

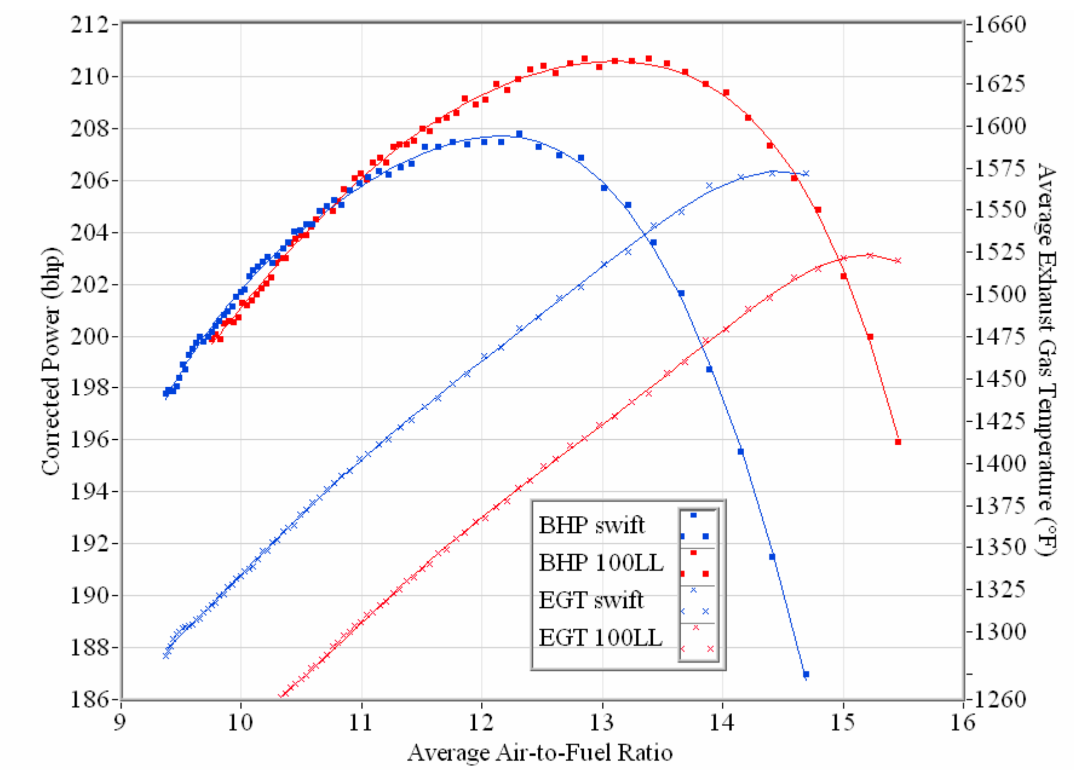


Figure A-13. Swift 702 Fuel Compared to 100LL; 2500 rpm, 24 inHg MAP

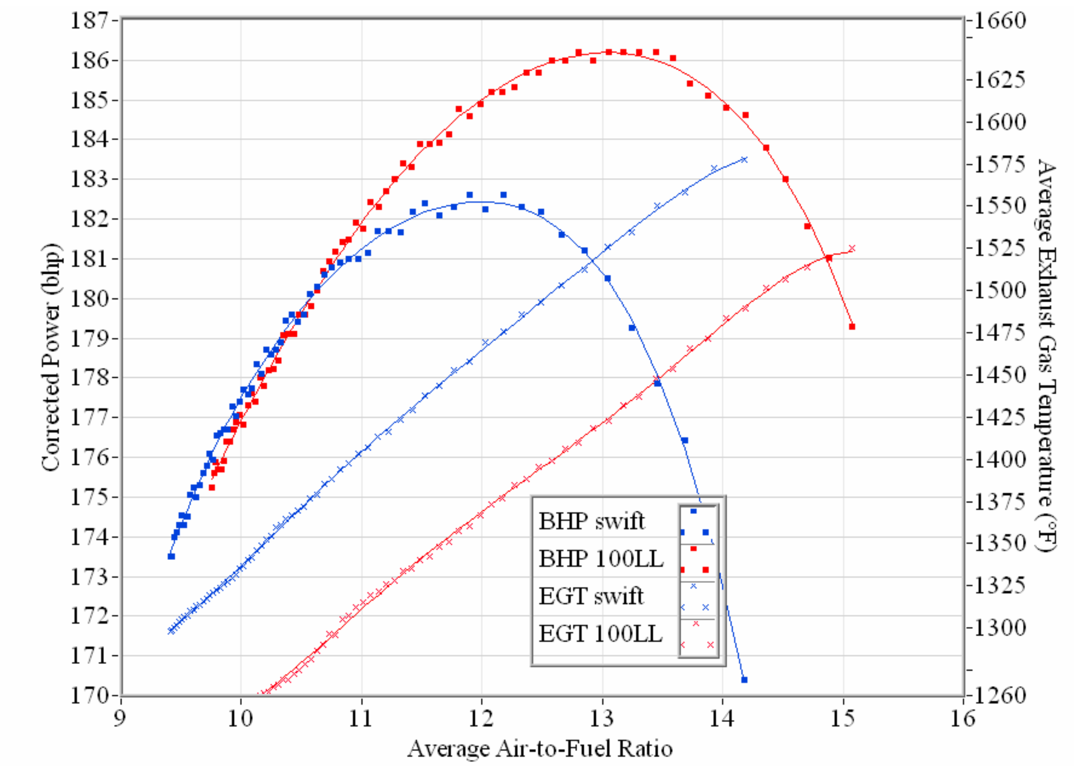


Figure A-14. Swift 702 Fuel Compared to 100LL; 2500 rpm, 22 inHg MAP

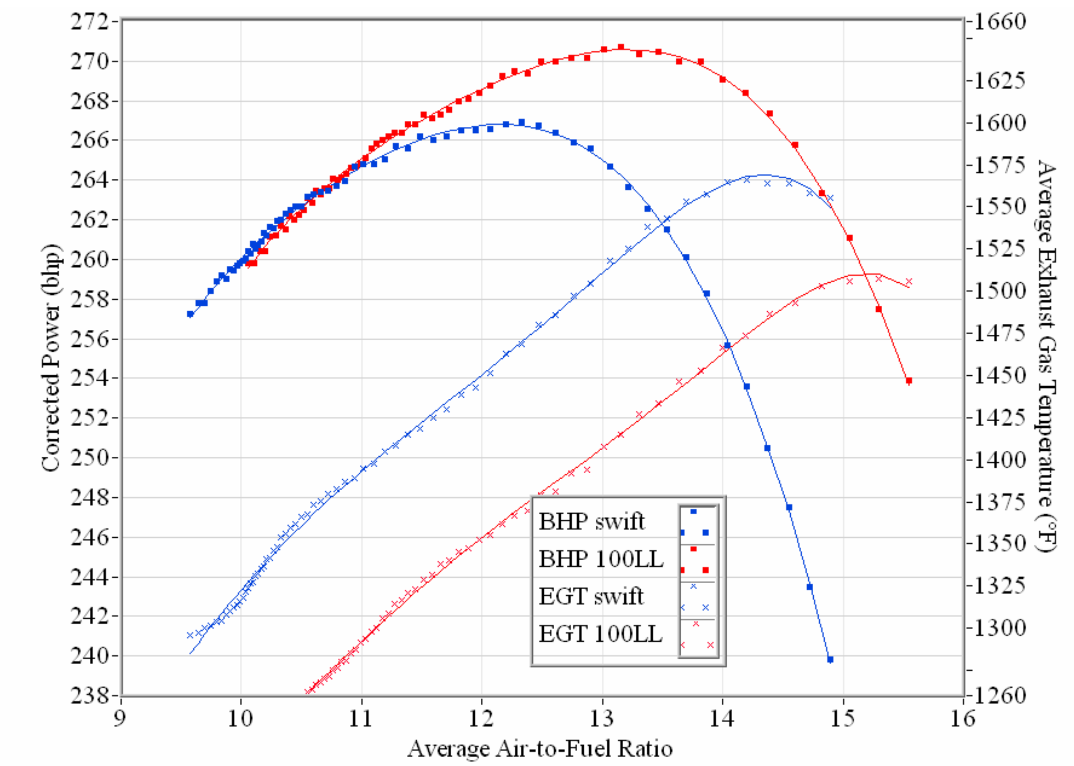


Figure A-15. Swift 702 Fuel Compared to 100LL; 2400 rpm, FT

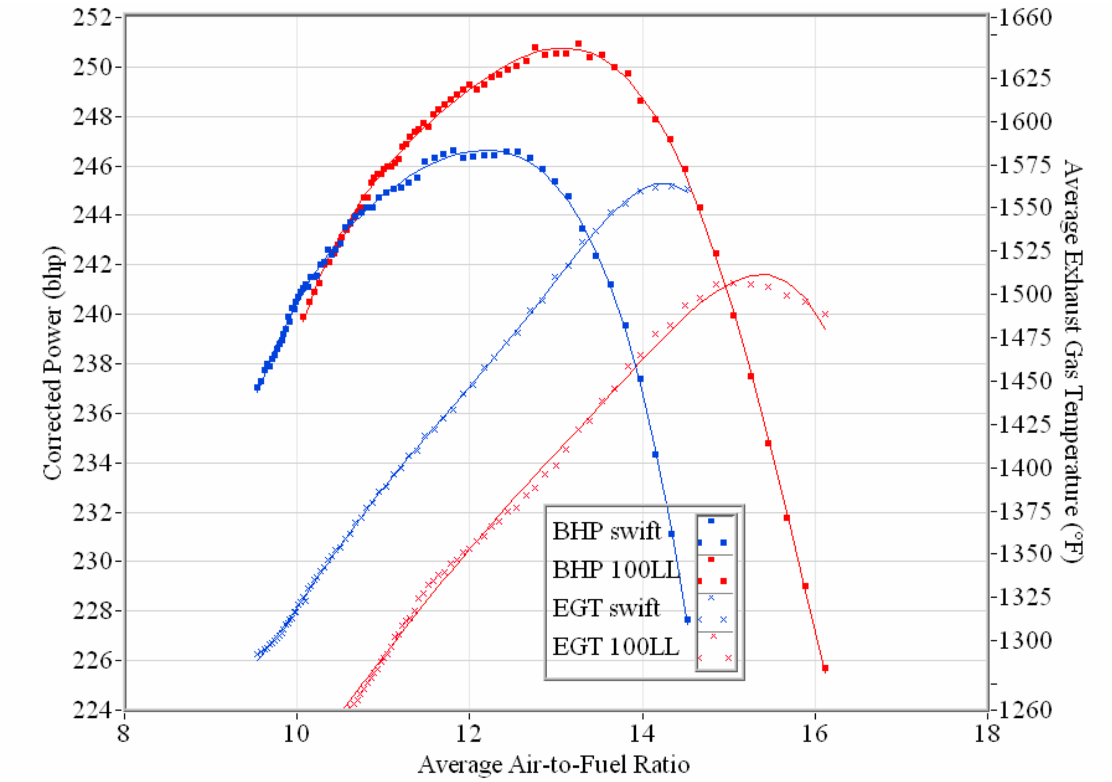


Figure A-16. Swift 702 Fuel Compared to 100LL; 2400 rpm, 28 inHg MAP

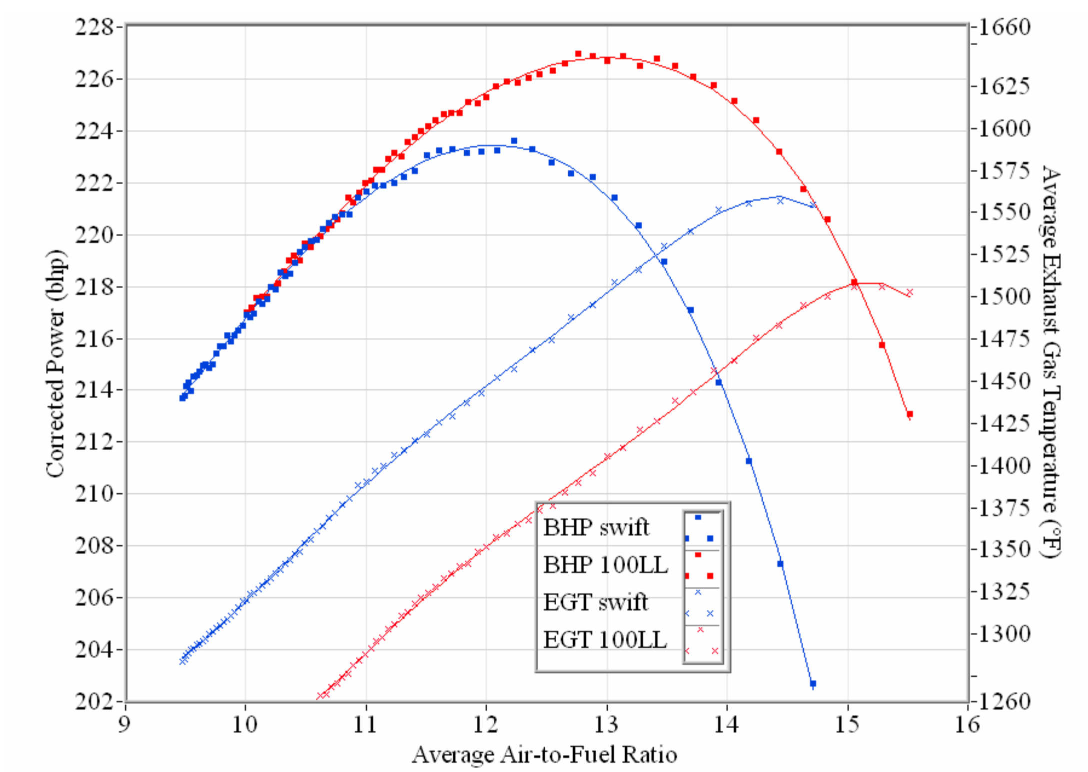


Figure A-17. Swift 702 Fuel Compared to 100LL; 2400 rpm, 26 inHg MAP

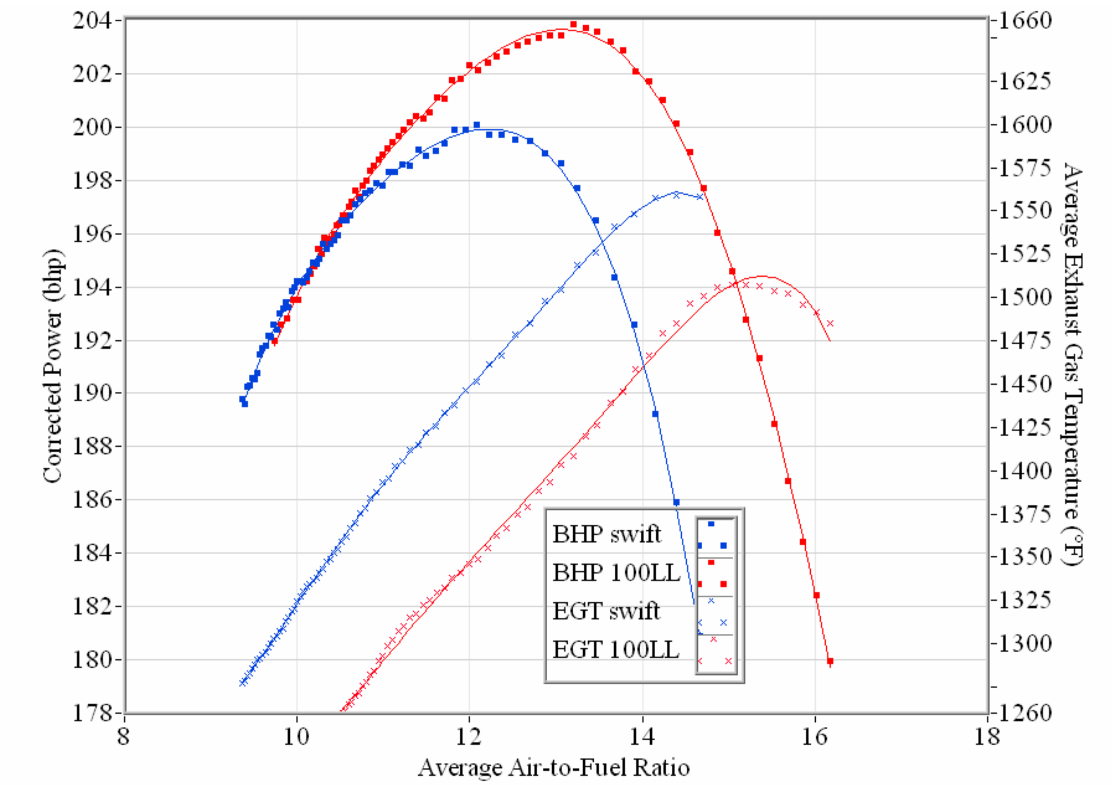


Figure A-18. Swift 702 Fuel Compared to 100LL; 2400 rpm, 24 inHg MAP

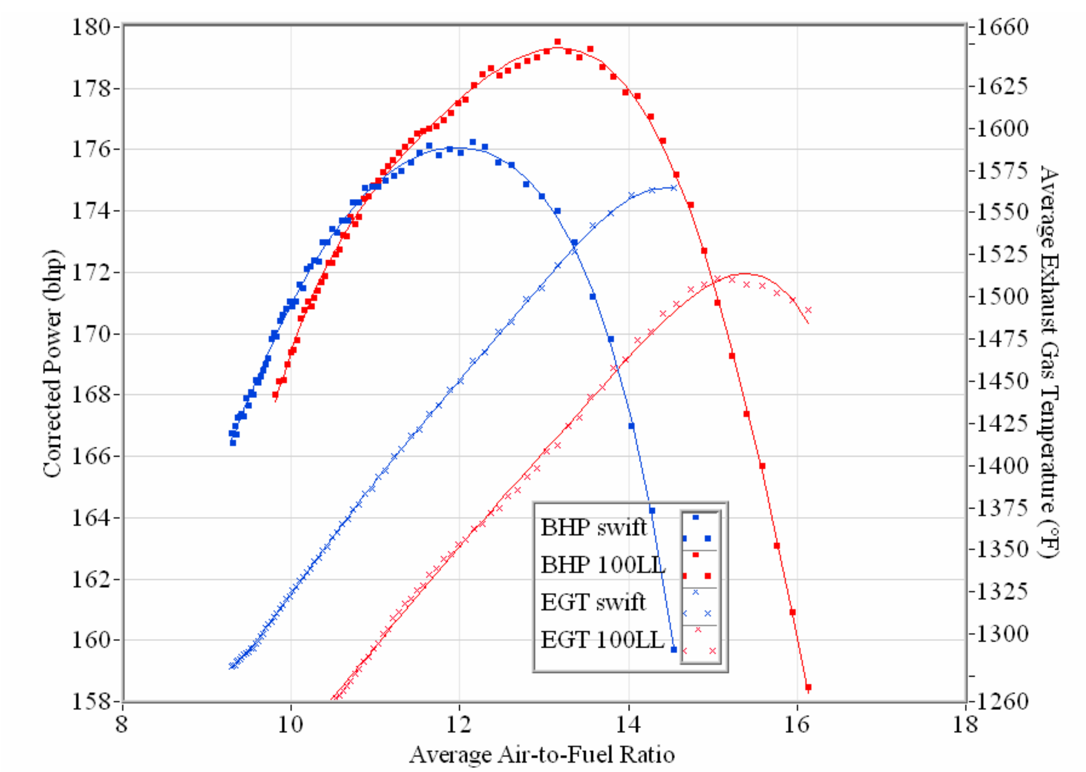


Figure A-19. Swift 702 Fuel Compared to 100LL; 2400 rpm, 22 inHg MAP

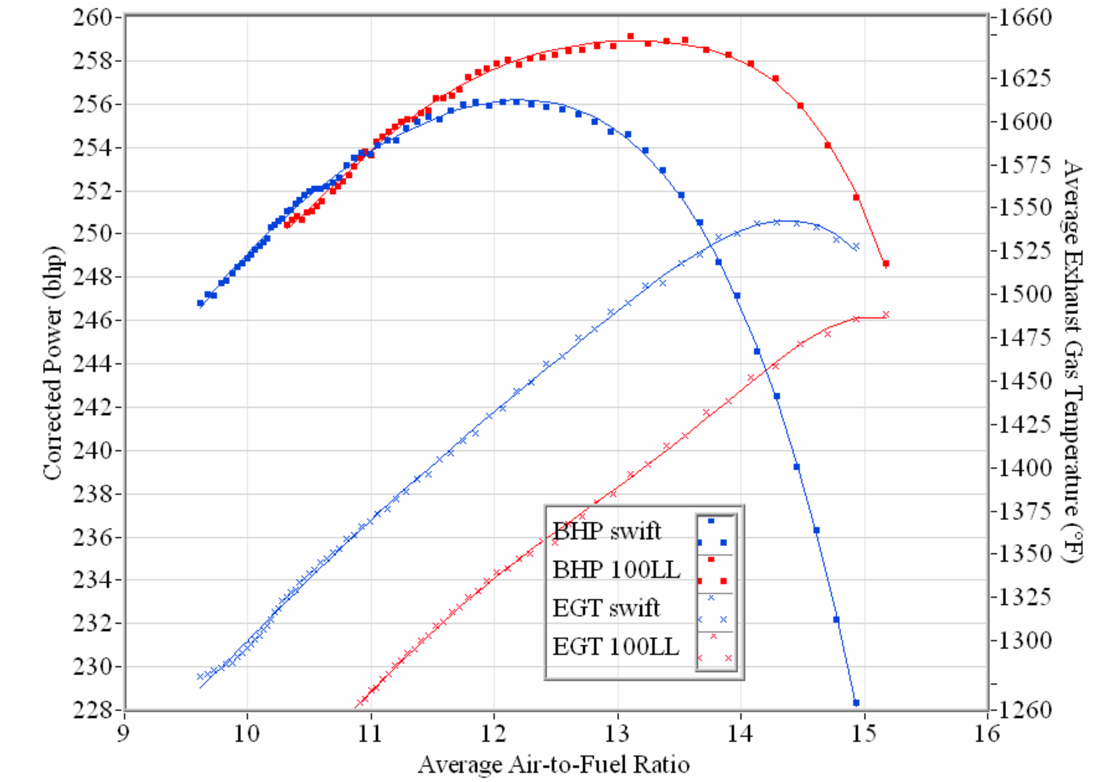


Figure A-20. Swift 702 Fuel Compared to 100LL; 2300 rpm, FT

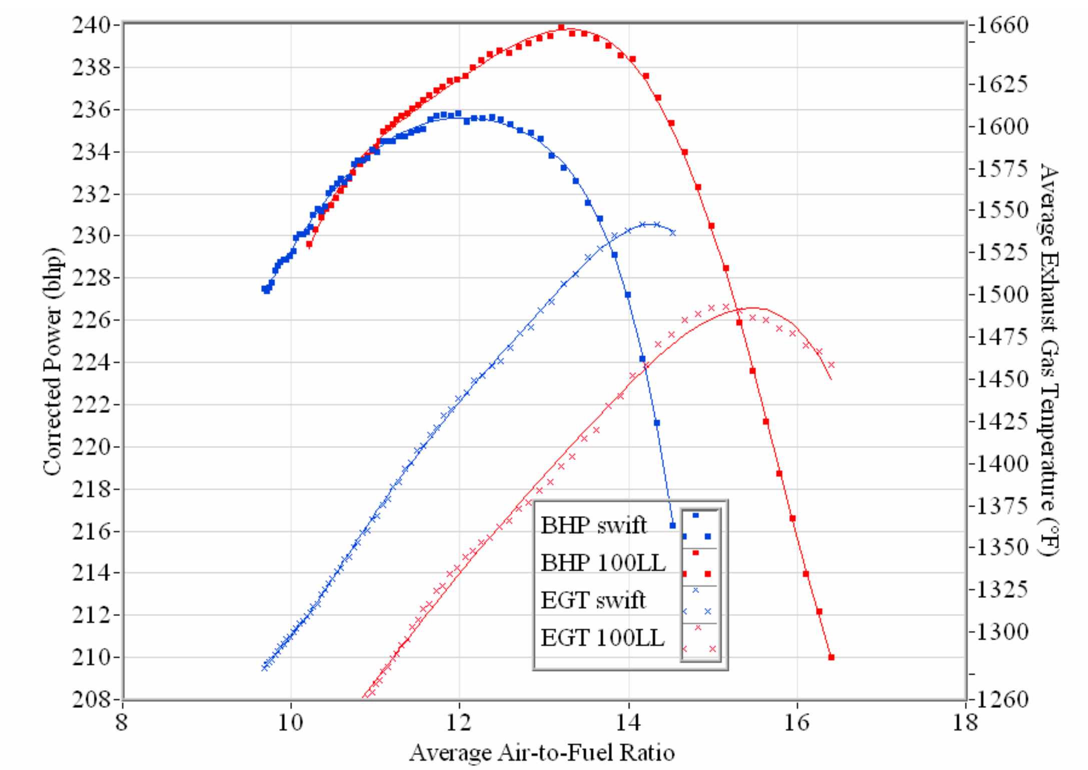


Figure A-21. Swift 702 Fuel Compared to 100LL; 2300 rpm, 28 inHg MAP

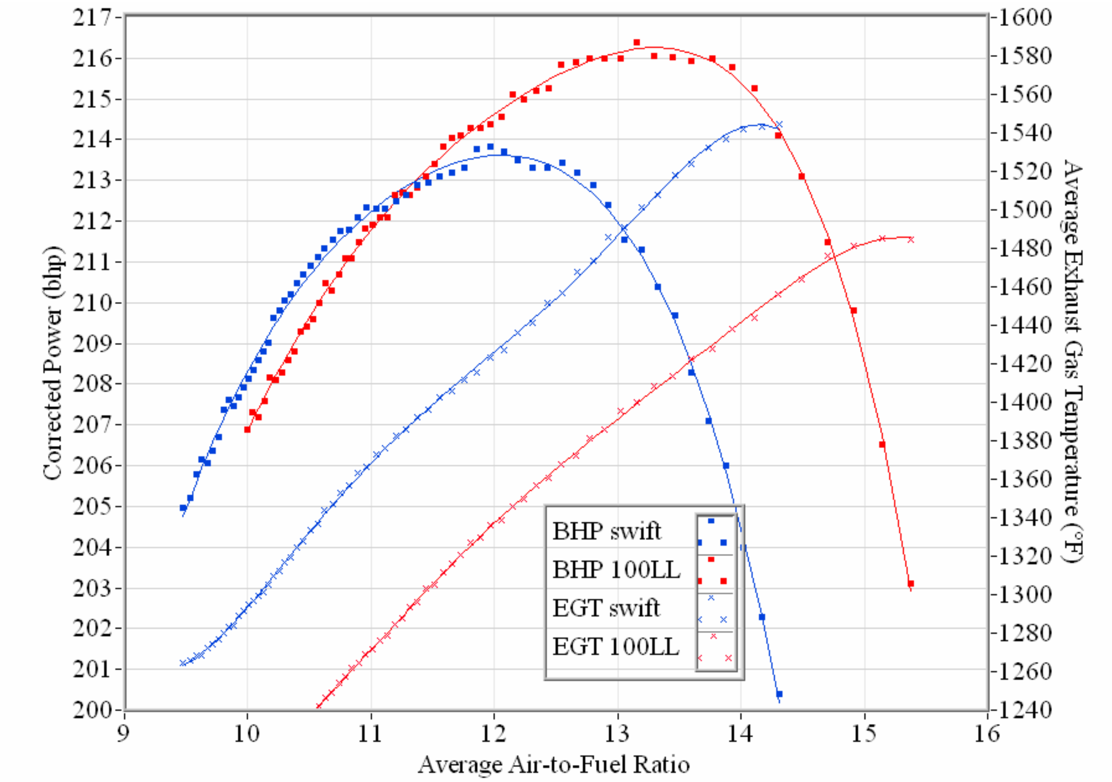


Figure A-22. Swift 702 Fuel Compared to 100LL; 2300 rpm, 26 inHg MAP

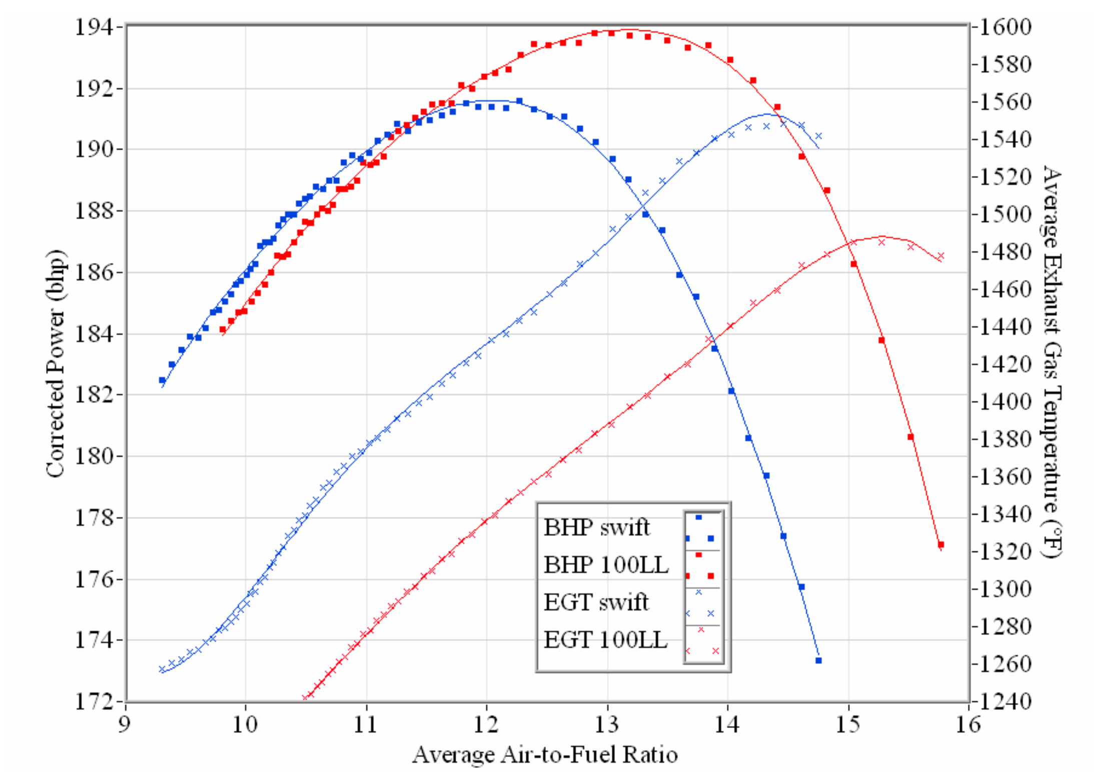


Figure A-23. Swift 702 Fuel Compared to 100LL; 2300 rpm, 24 inHg MAP

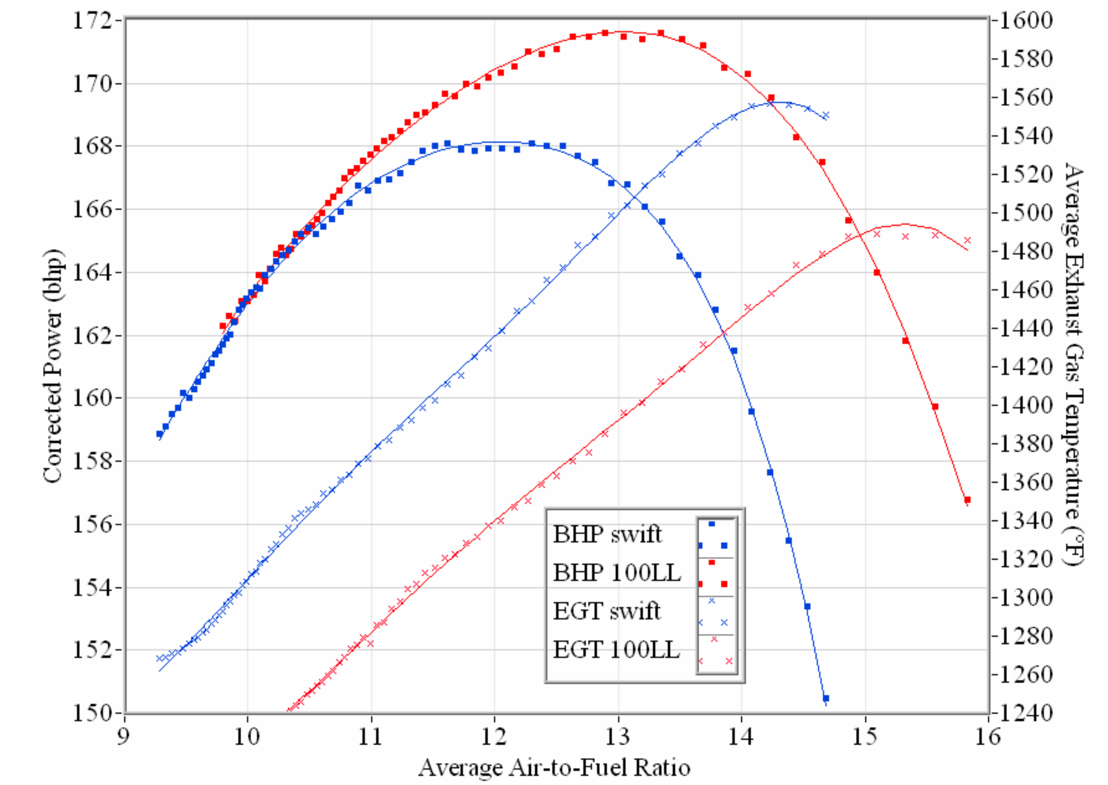


Figure A-24. Swift 702 Fuel Compared to 100LL; 2300 rpm, 22 inHg MAP

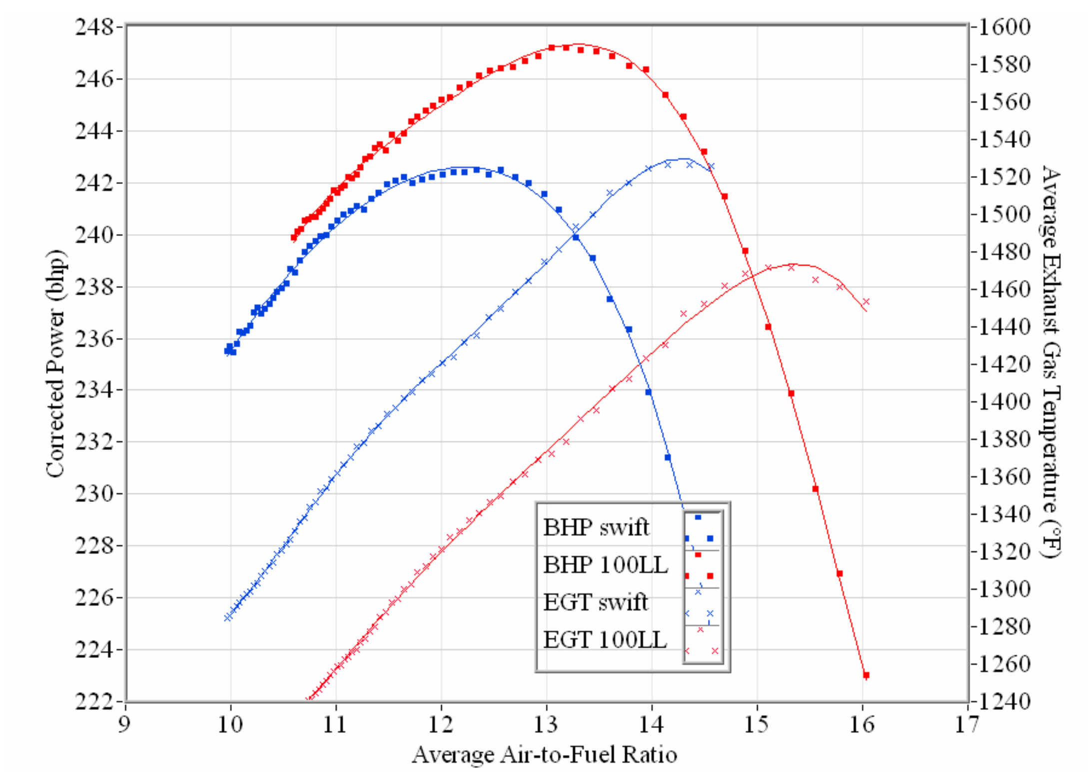


Figure A-25. Swift 702 Fuel Compared to 100LL; 2200 rpm, FT

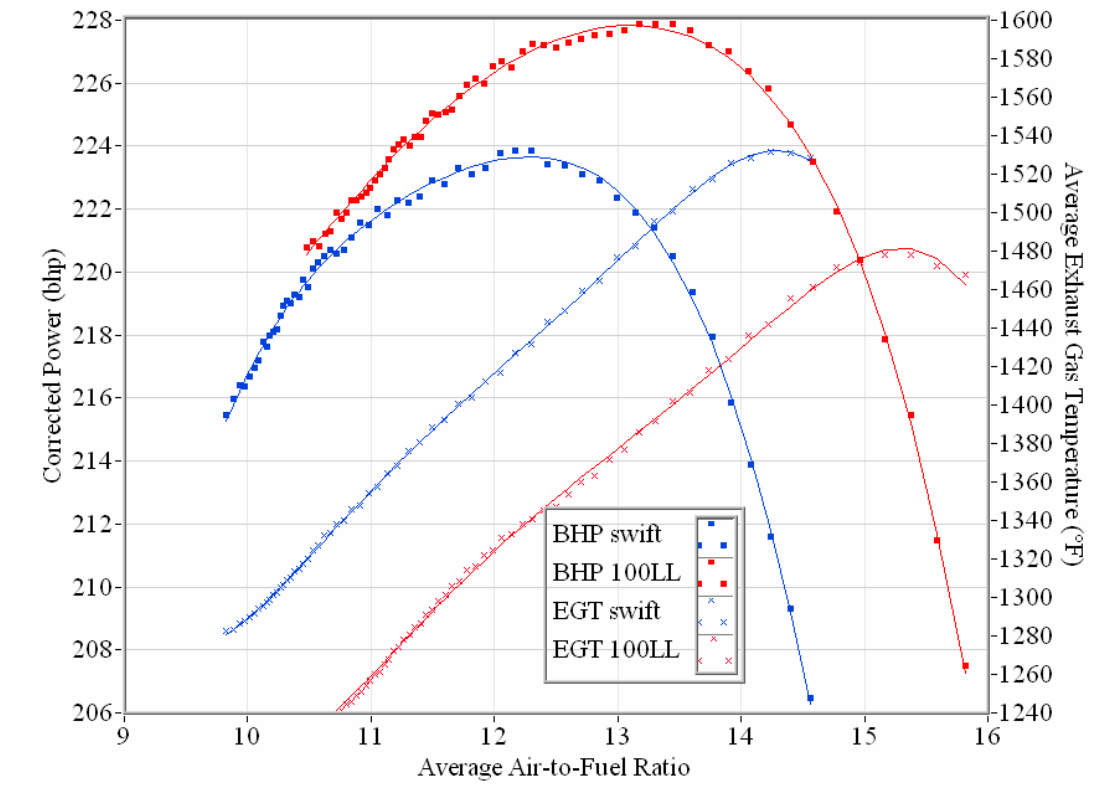


Figure A-26. Swift 702 Fuel Compared to 100LL; 2200 rpm, 28 inHg MAP

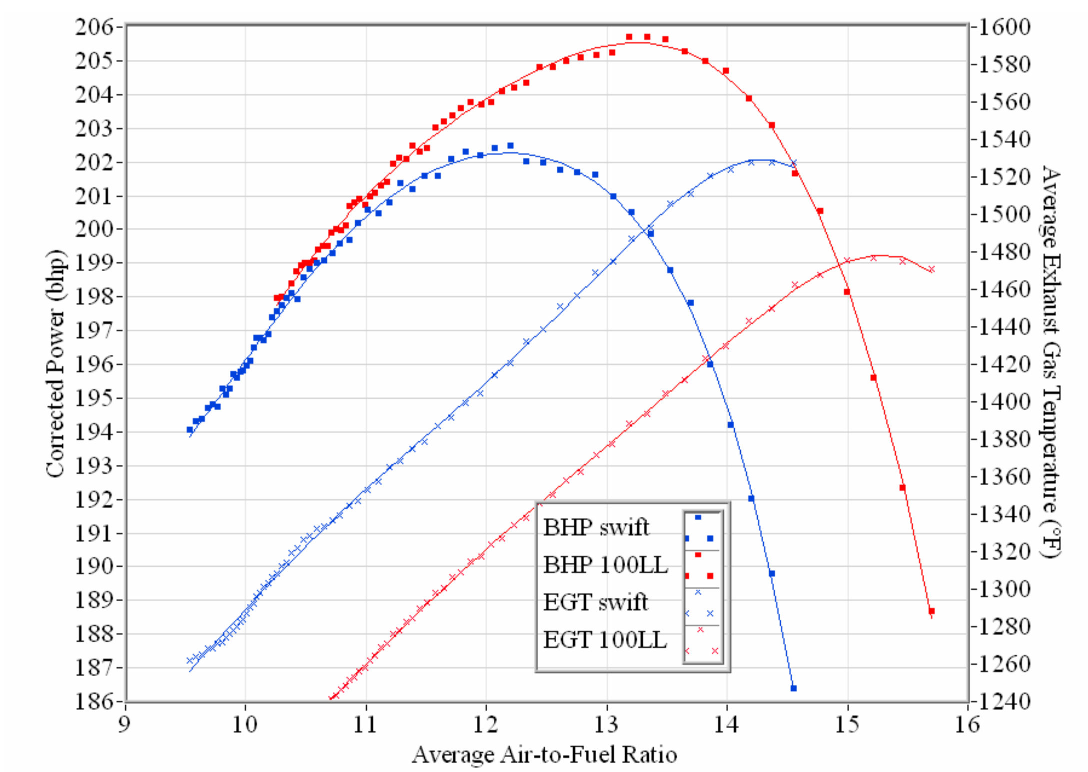


Figure A-27. Swift 702 Fuel Compared to 100LL; 2200 rpm, 26 inHg MAP

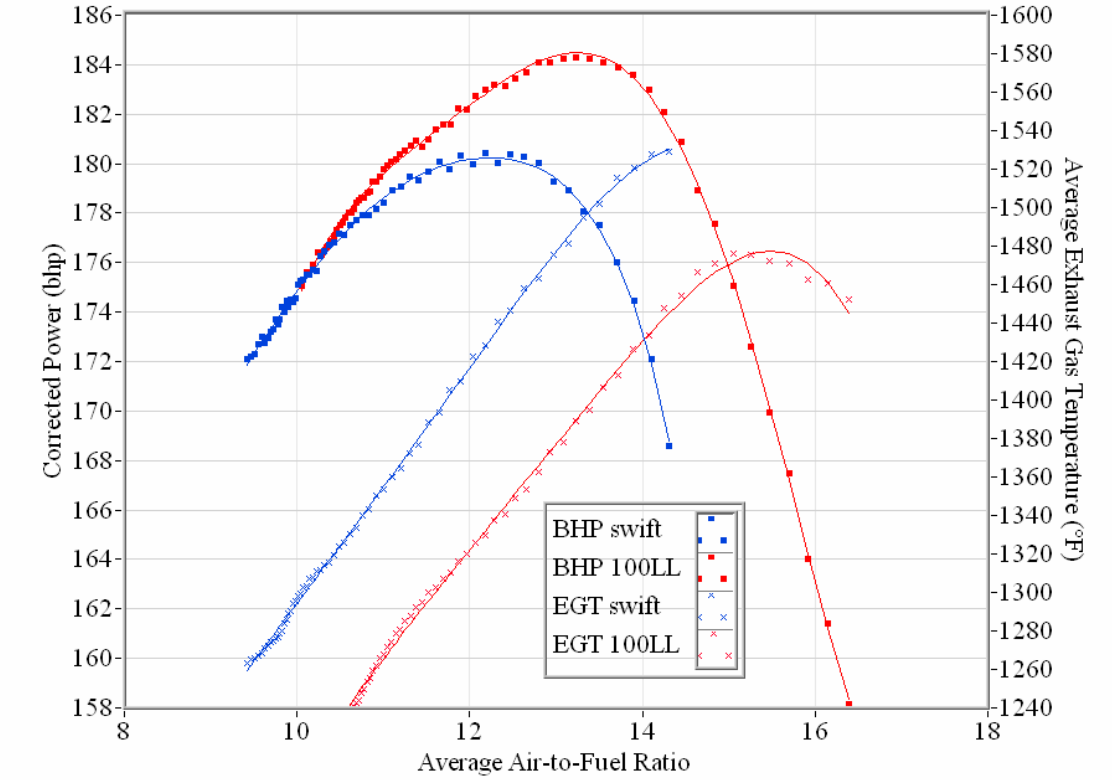


Figure A-28. Swift 702 Fuel Compared to 100LL; 2200 rpm, 24 inHg MAP

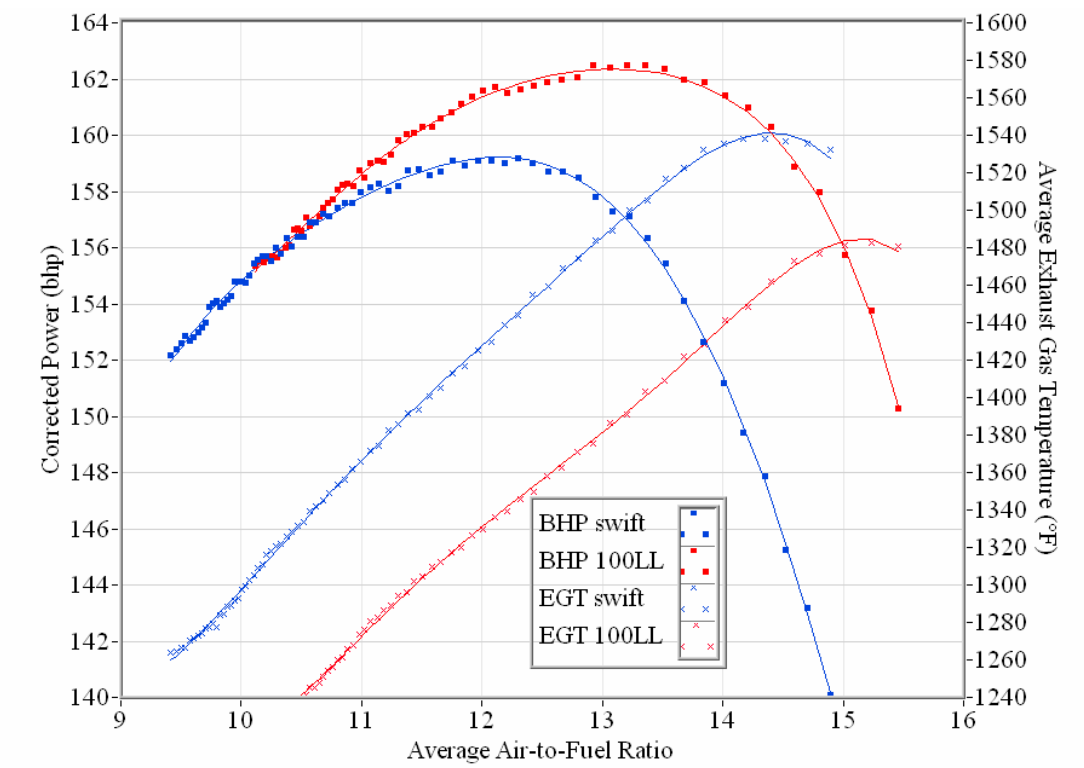


Figure A-29. Swift 702 Fuel Compared to 100LL; 2200 rpm, 22 inHg MAP

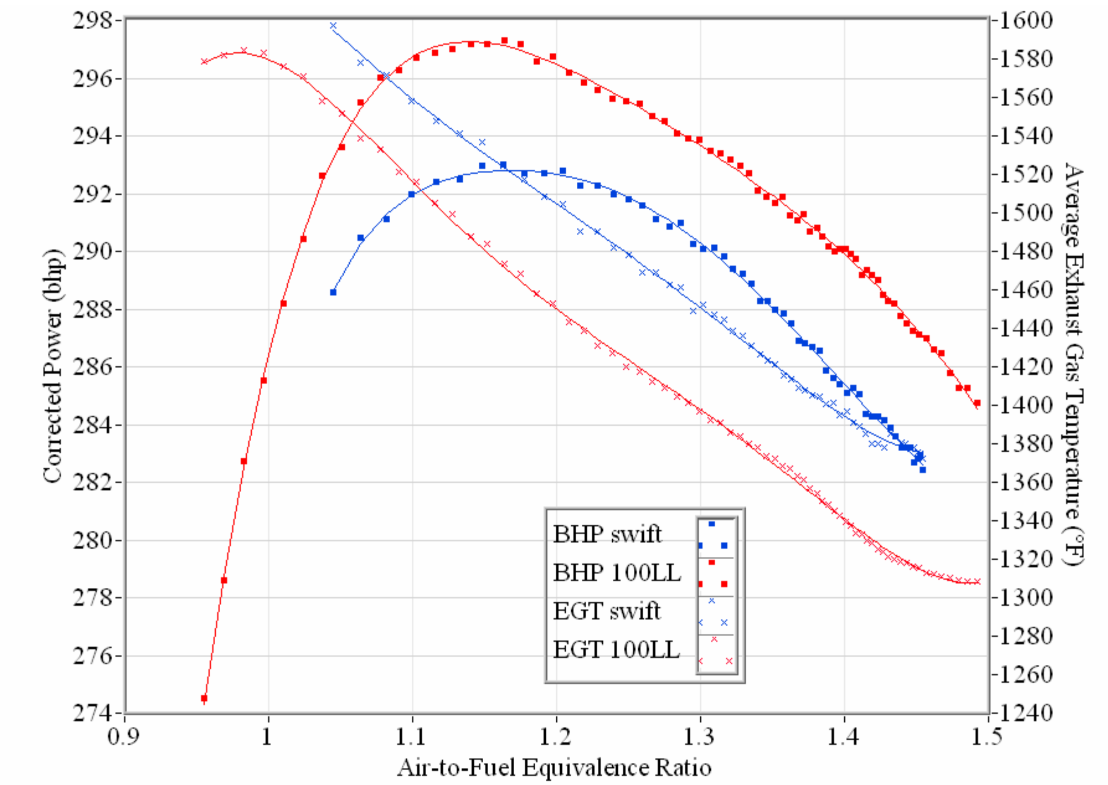


Figure A-30. Swift 702 Fuel Compared to 100LL; 2700 rpm, FT

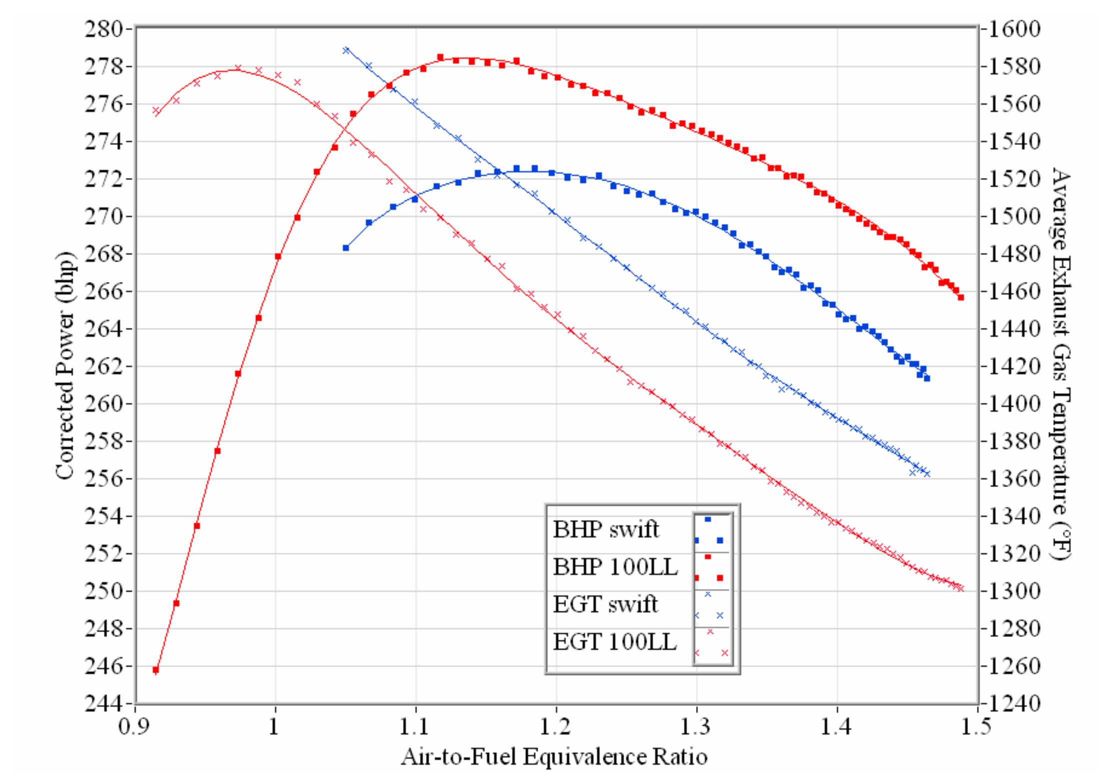


Figure A-31. Swift 702 Fuel Compared to 100LL; 2700 rpm, 28 inHg MAP

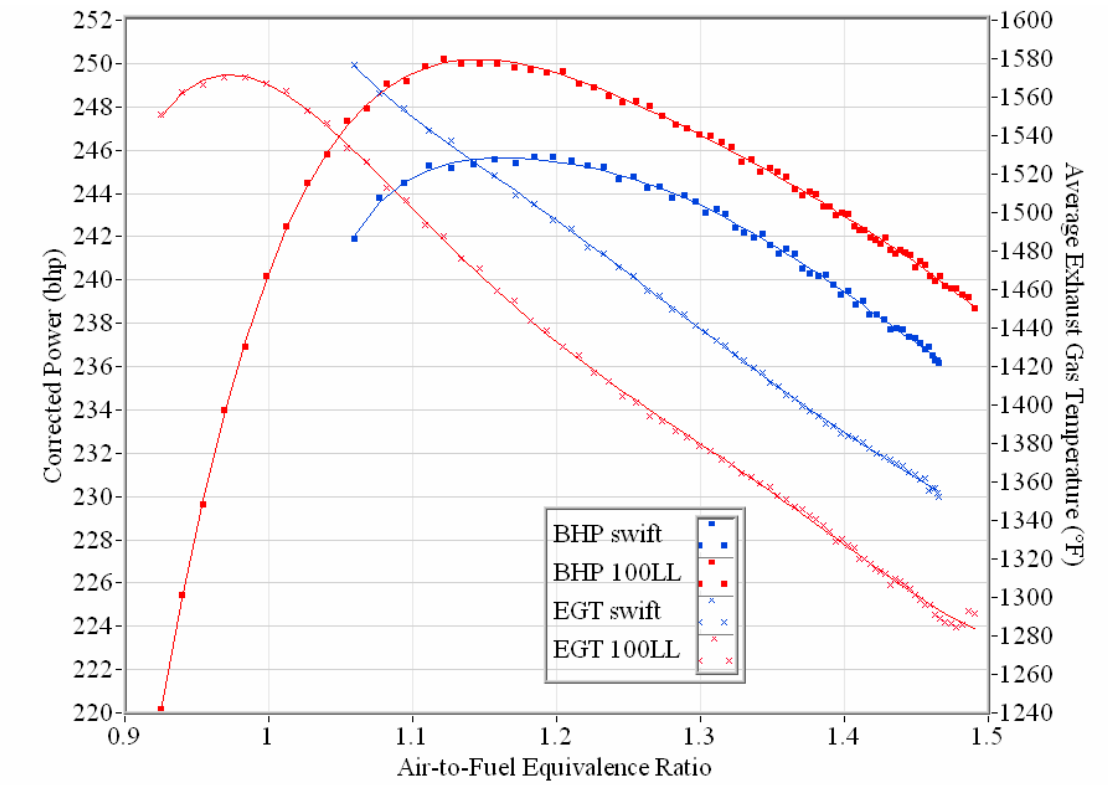


Figure A-32. Swift 702 Fuel Compared to 100LL; 2700 rpm, 26 inHg MAP

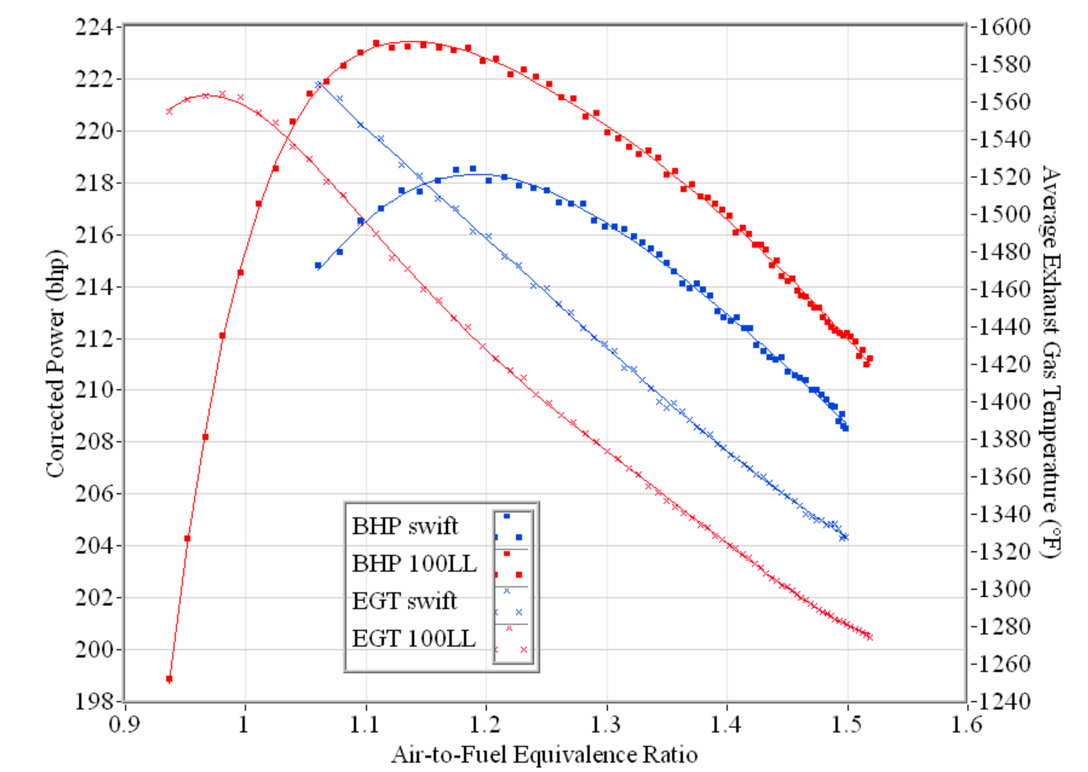


Figure A-33. Swift 702 Fuel Compared to 100LL; 2700 rpm, 24 inHg MAP

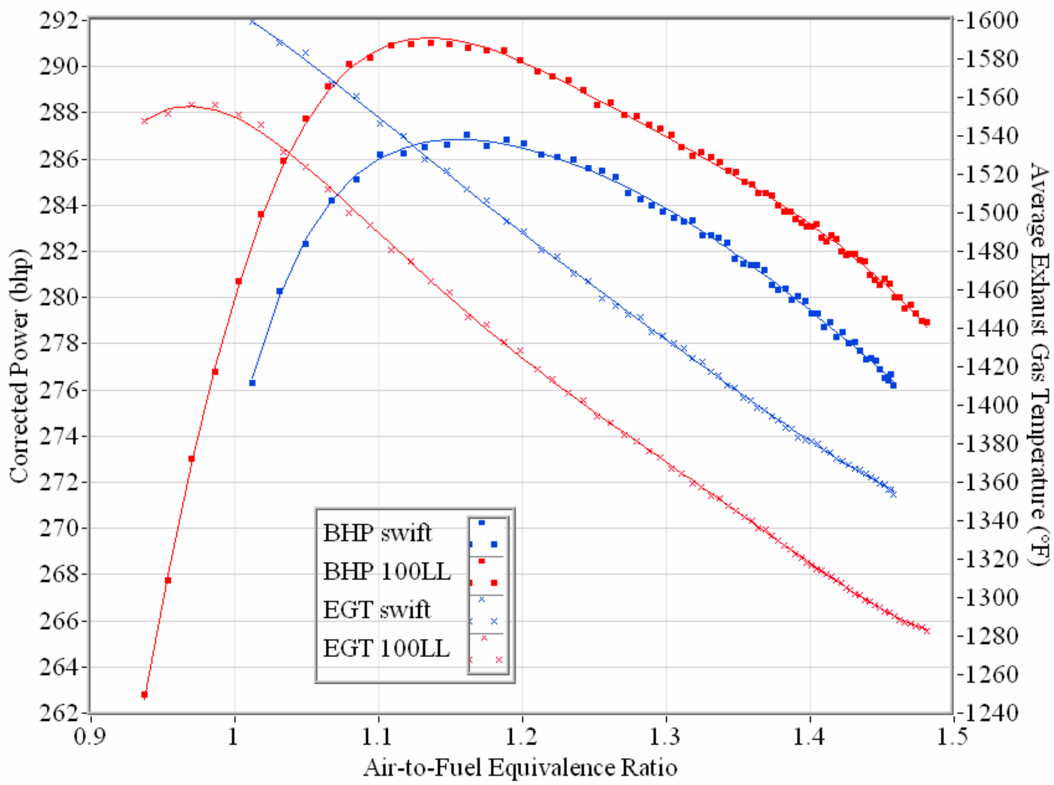


Figure A-34. Swift 702 Fuel Compared to 100LL; 2600 rpm, FT

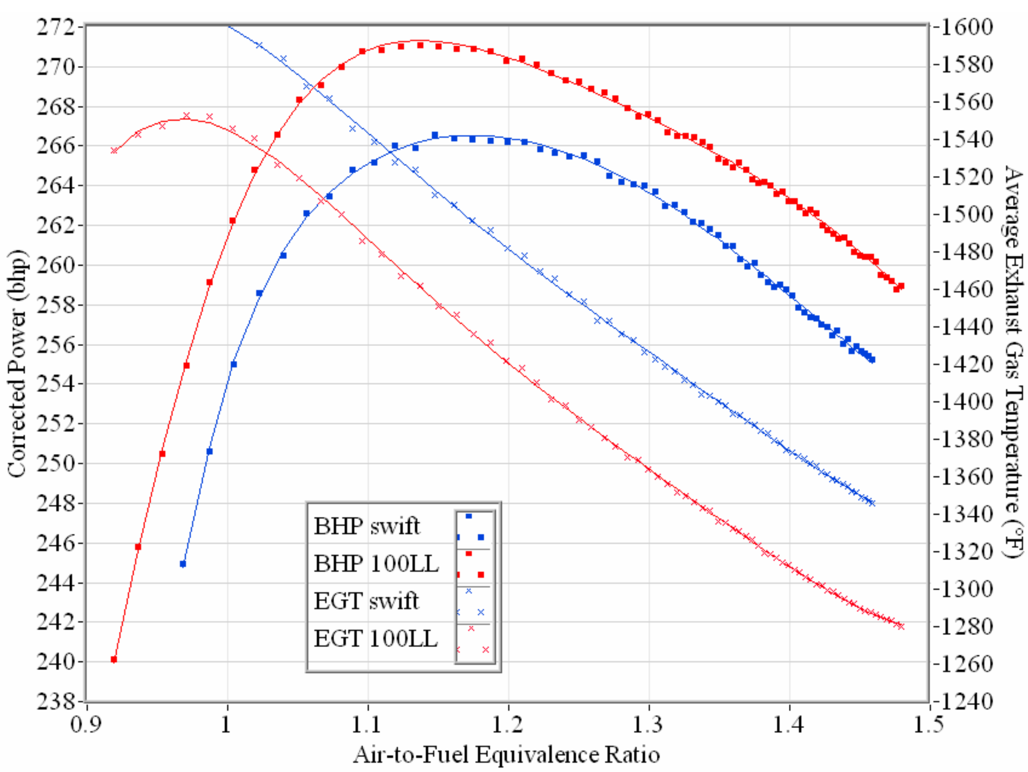


Figure A-35. Swift 702 Fuel Compared to 100LL; 2600 rpm, 28 inHg MAP

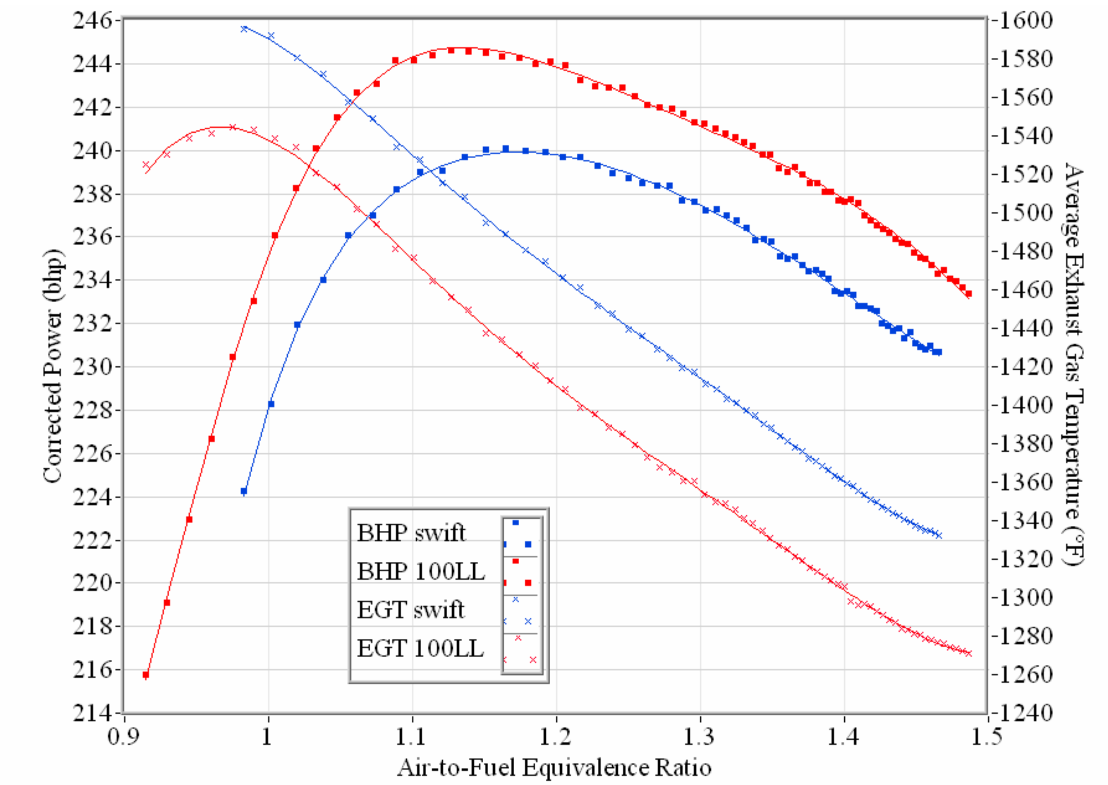


Figure A-36. Swift 702 Fuel Compared to 100LL; 2600 rpm, 26 inHg MAP

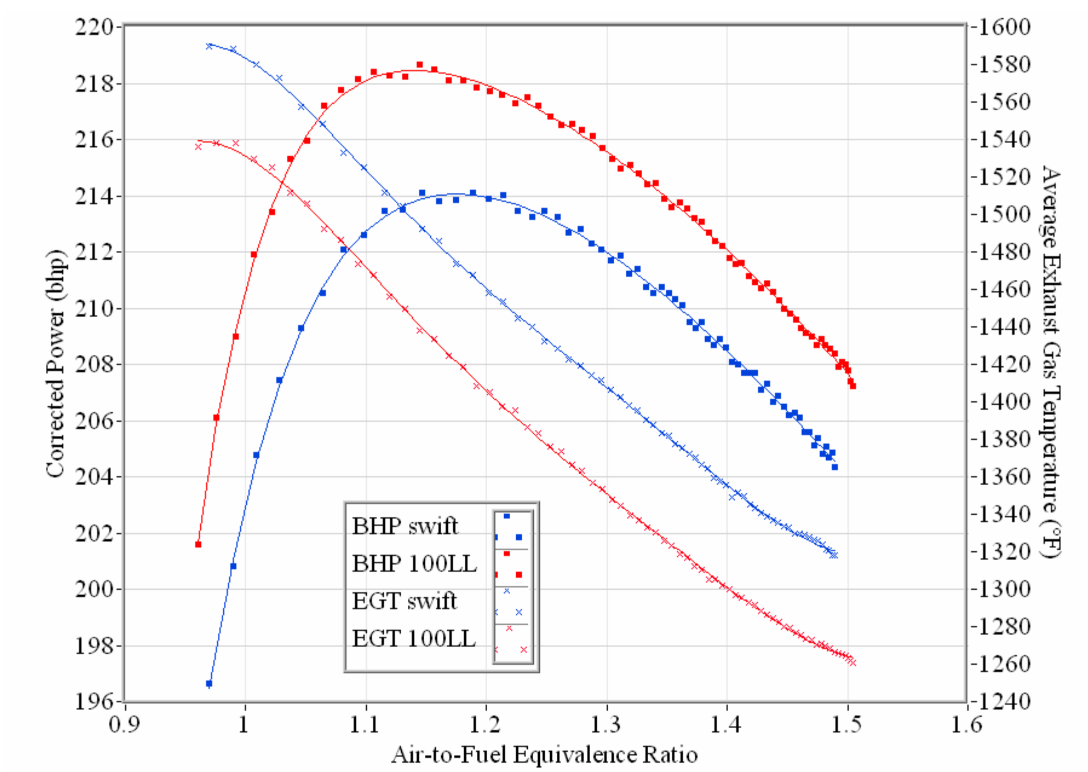


Figure A-37. Swift 702 Fuel Compared to 100LL; 2600 rpm, 24 inHg MAP

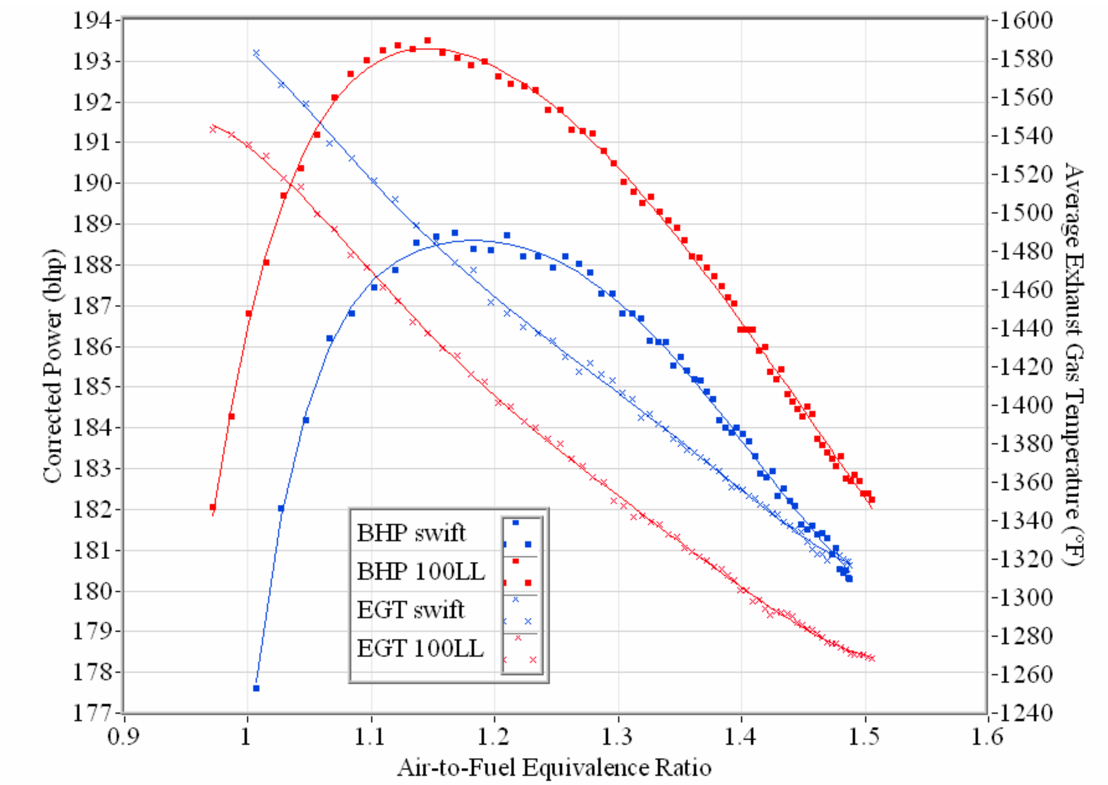


Figure A-38. Swift 702 Fuel Compared to 100LL; 2600 rpm, 22 inHg MAP

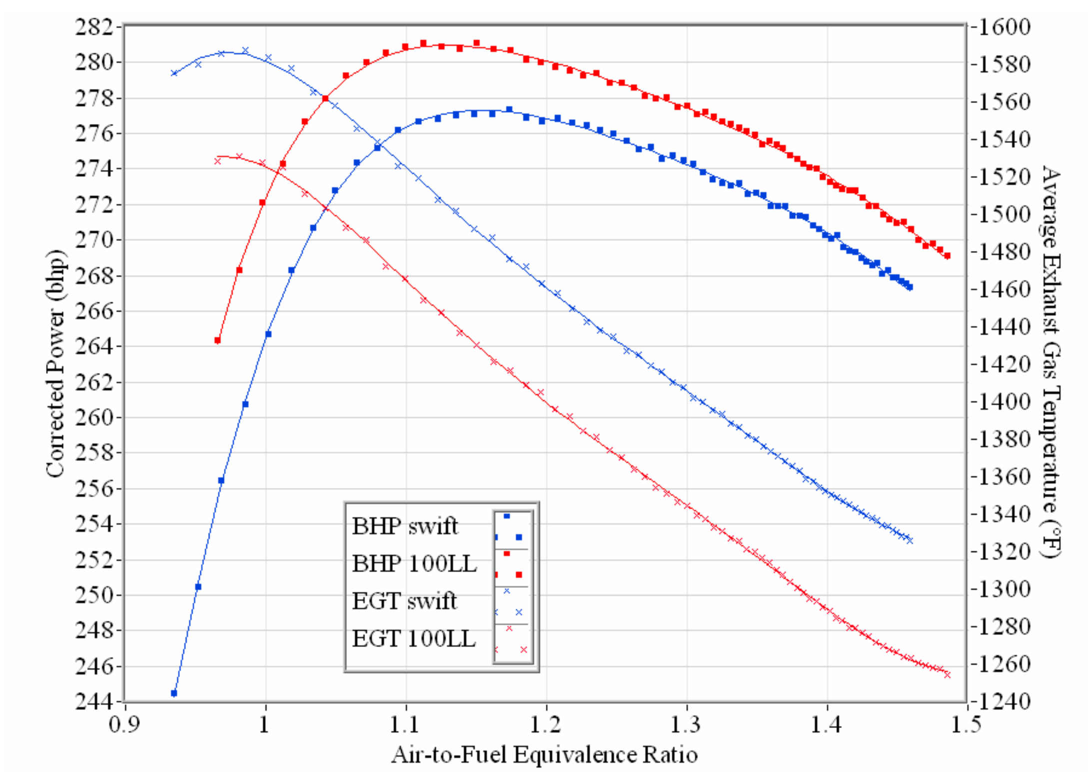


Figure A-39. Swift 702 Fuel Compared to 100LL; 2500 rpm, FT

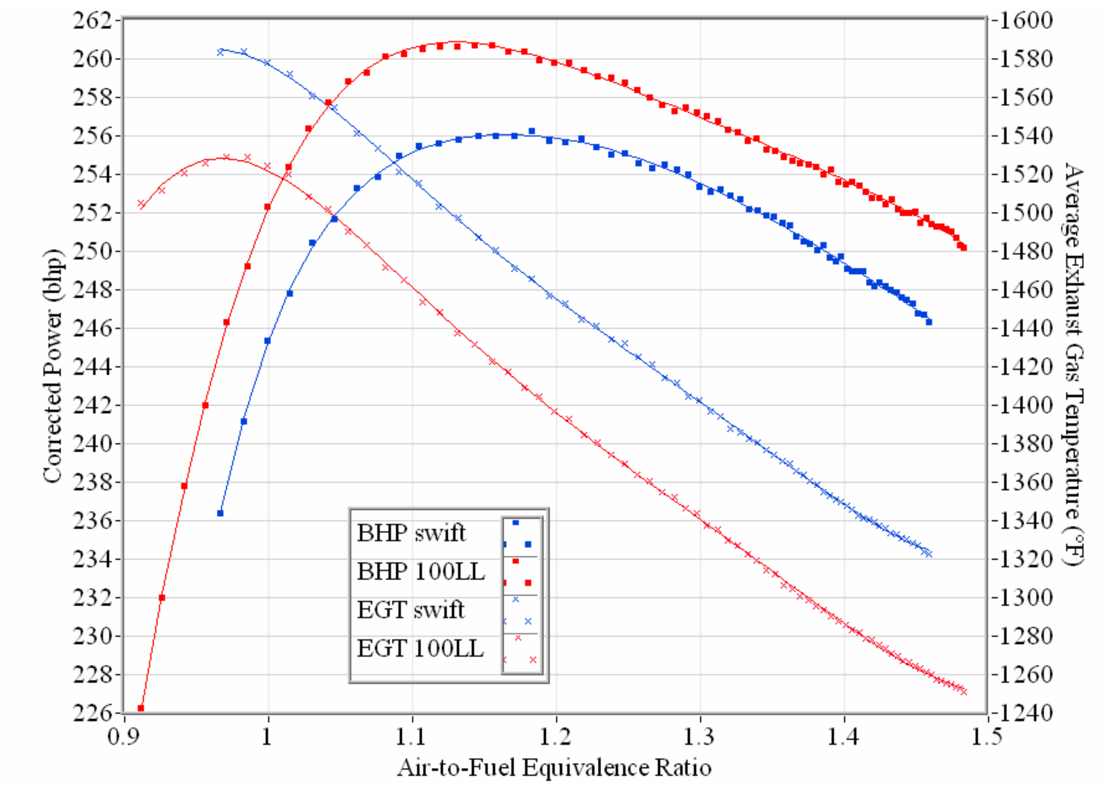


Figure A-40. Swift 702 Fuel Compared to 100LL; 2500 rpm, 28 inHg MAP

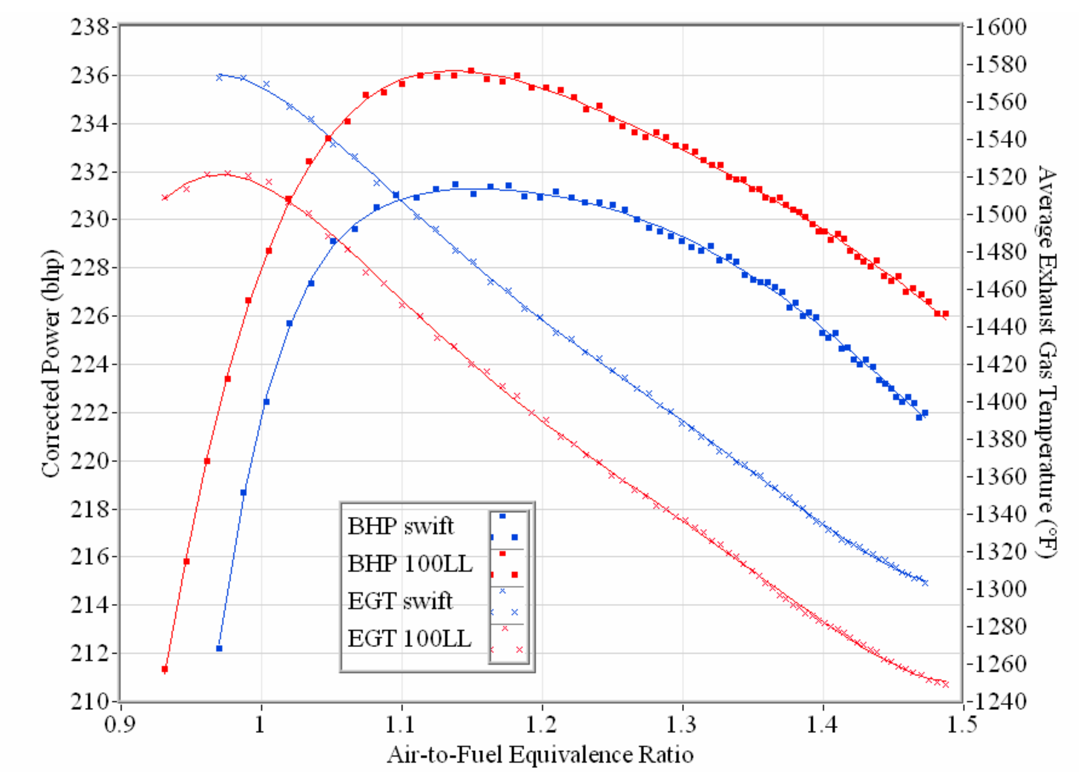
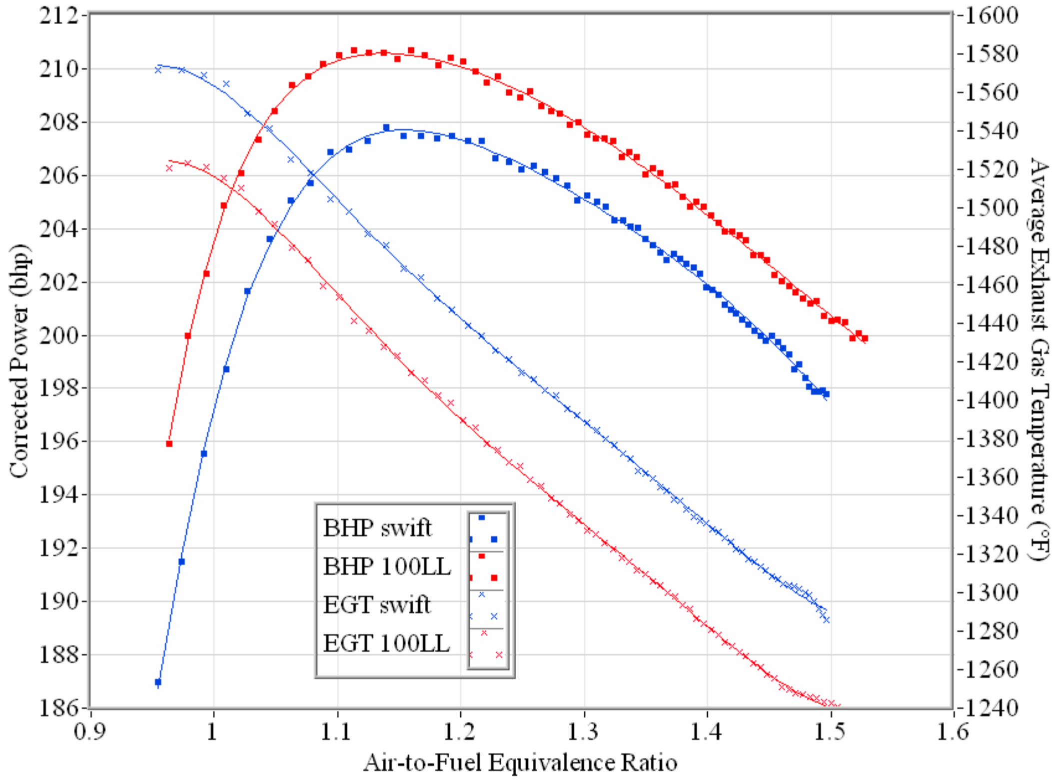


Figure A-41. Swift 702 Fuel Compared to 100LL; 2500 rpm, 26 inHg MAP



FIigure A-42. Swift 702 Fuel Compared to 100LL; 2500 rpm, 24 inHg MAP

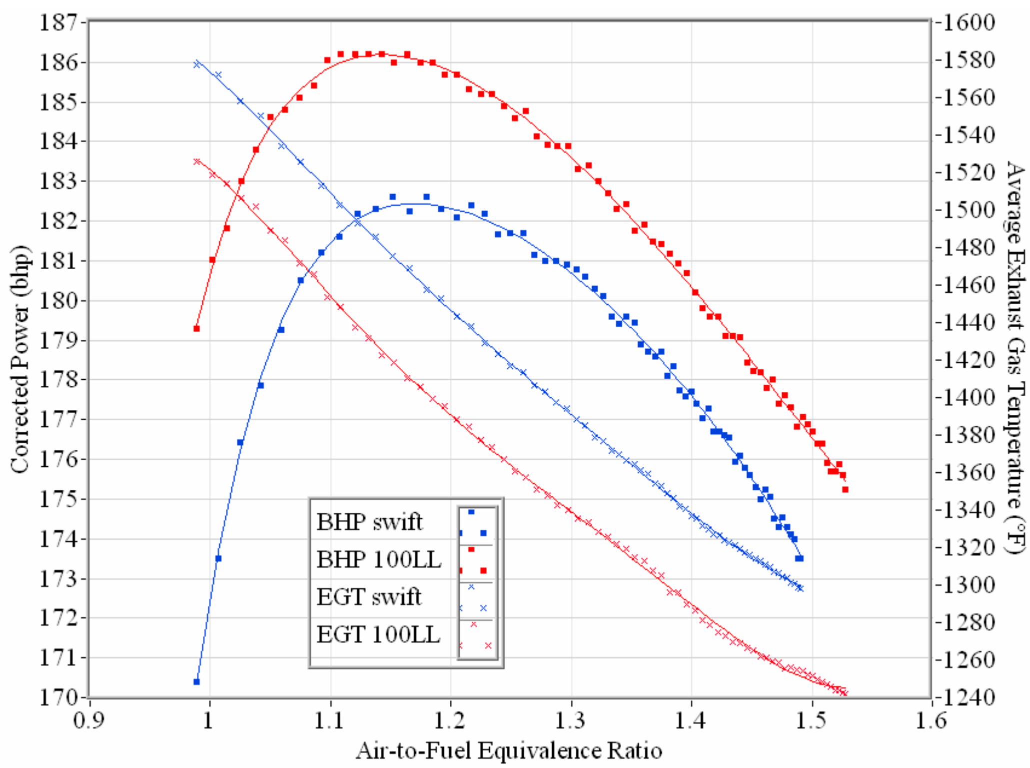


Figure A-43. Swift 702 Fuel Compared to 100LL; 2500 rpm, 22 inHg MAP

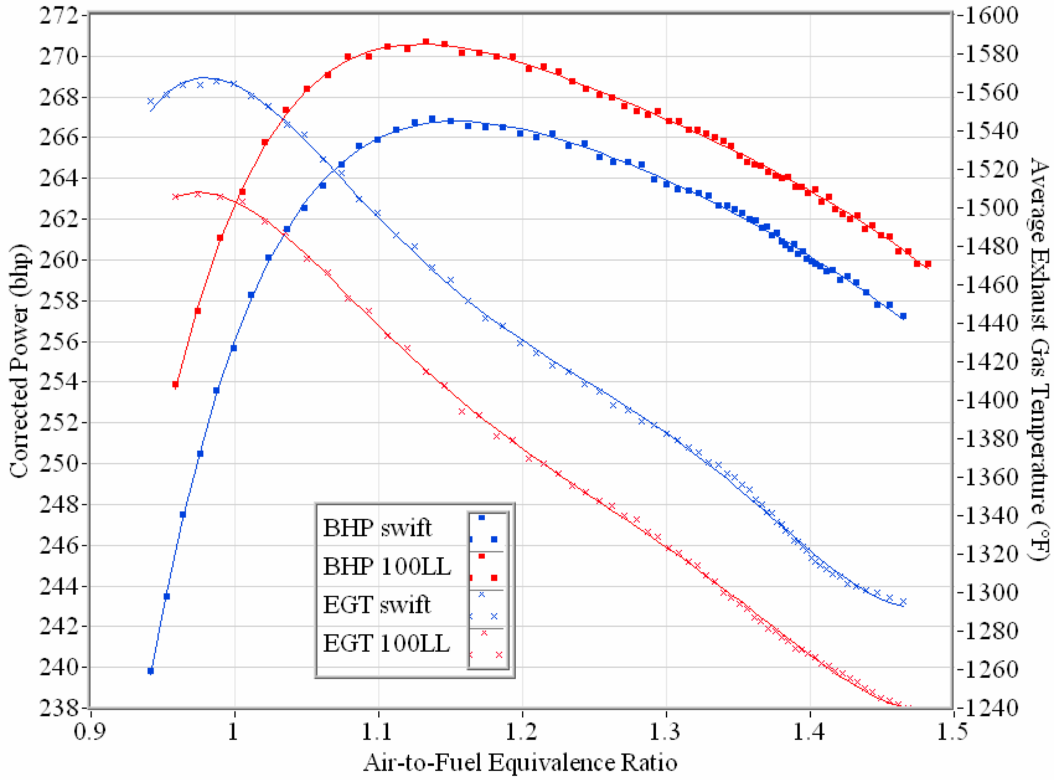


Figure A-44. Swift 702 Fuel Compared to 100LL; 2400 rpm, FT

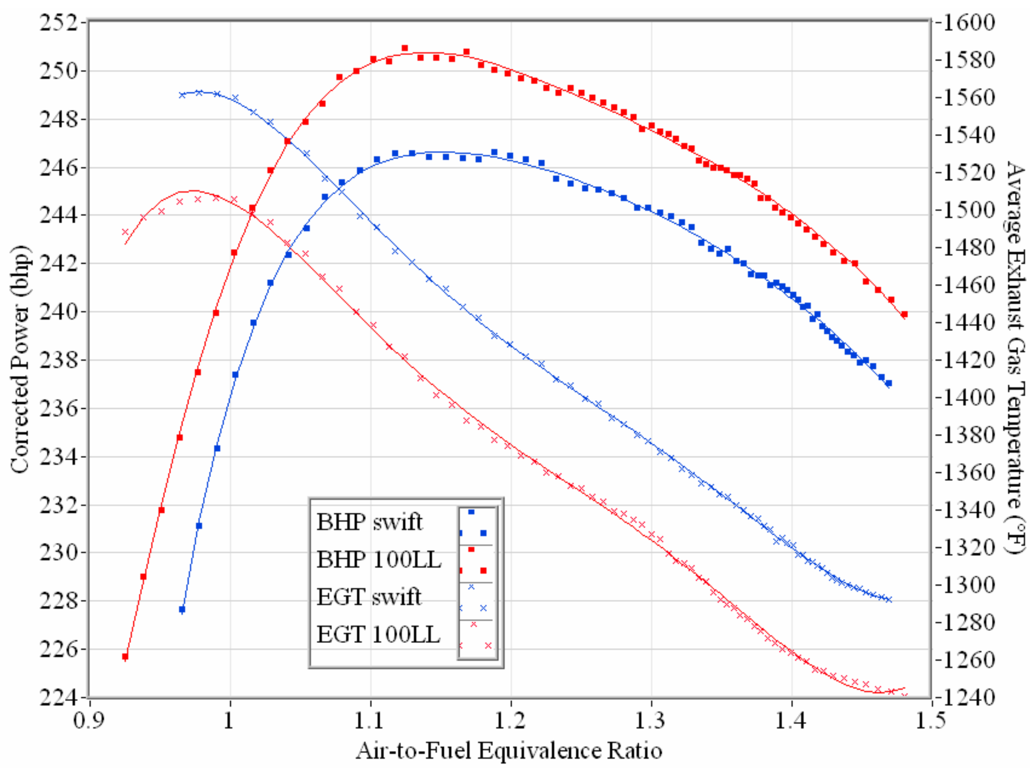


Figure A-45. Swift 702 Fuel Compared to 100LL; 2400 rpm, 28 inHg MAP

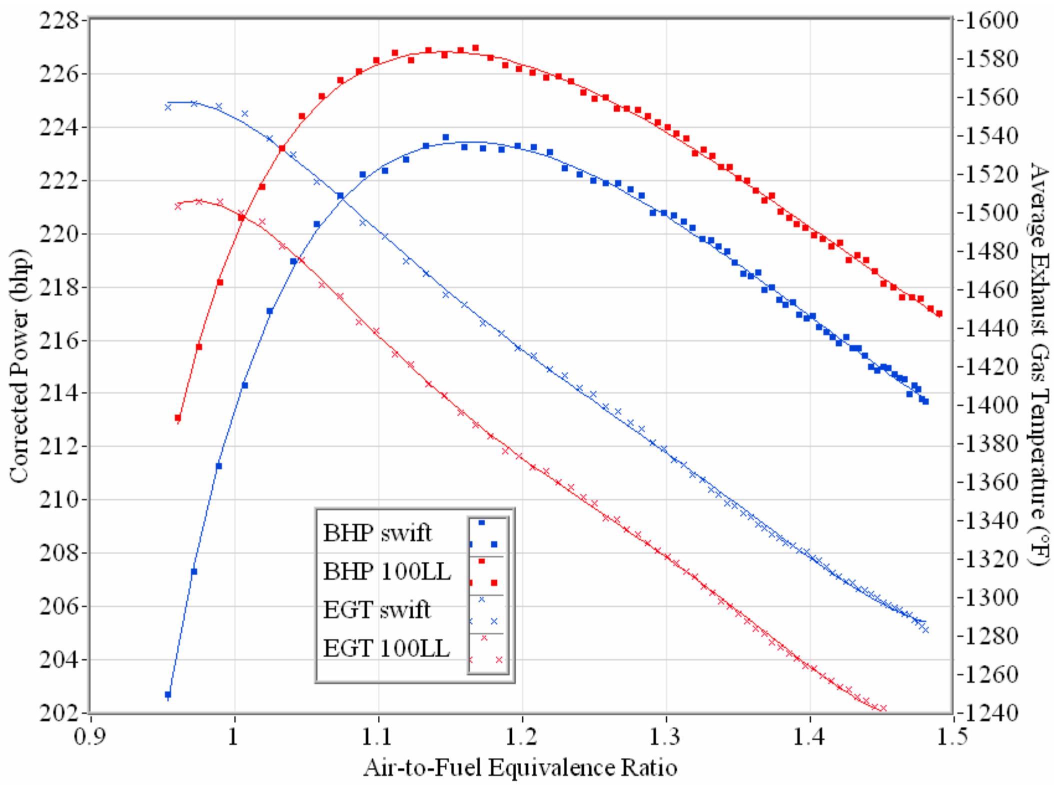


Figure A-46. Swift 702 Fuel Compared to 100LL; 2400 rpm, 26 inHg MAP

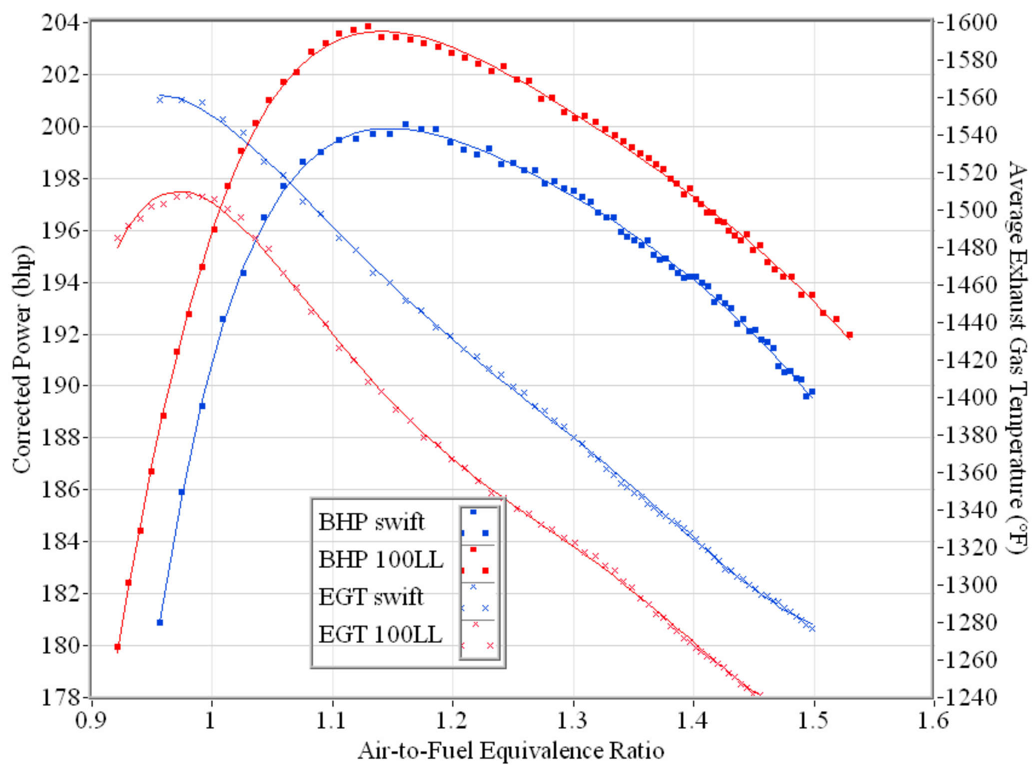


Figure A-47. Swift 702 Fuel Compared to 100LL; 2400 rpm, 24 inHg MAP

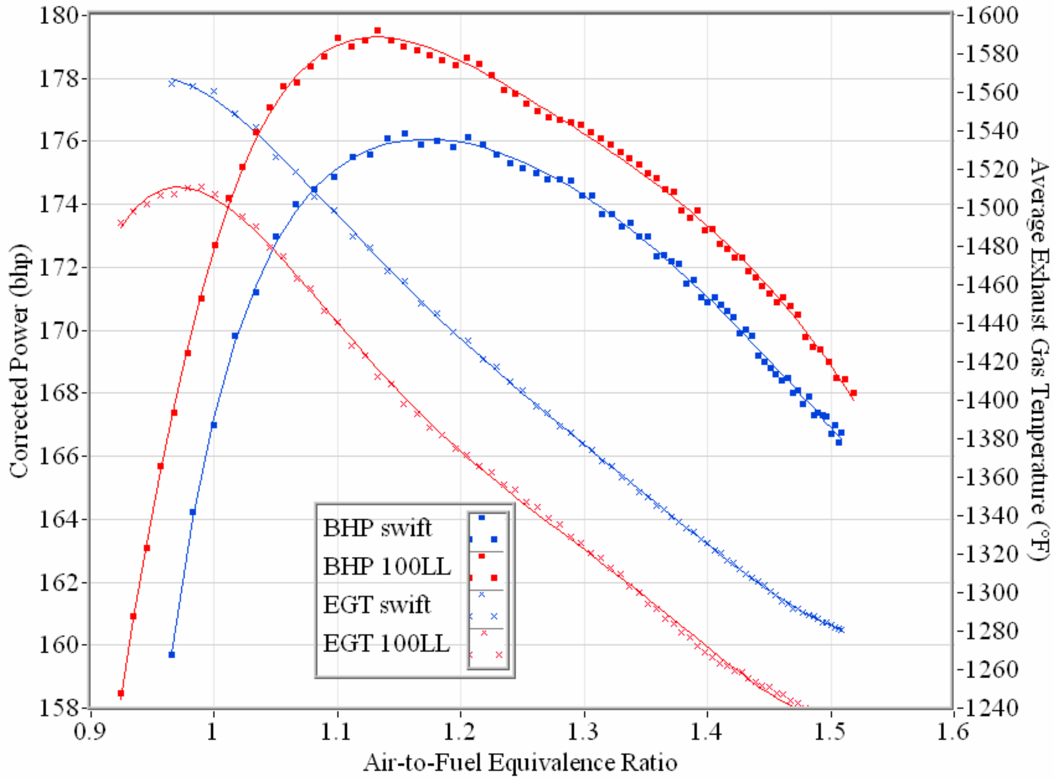


Figure A-48. Swift 702 Fuel Compared to 100LL; 2400 rpm, 22 inHg MAP

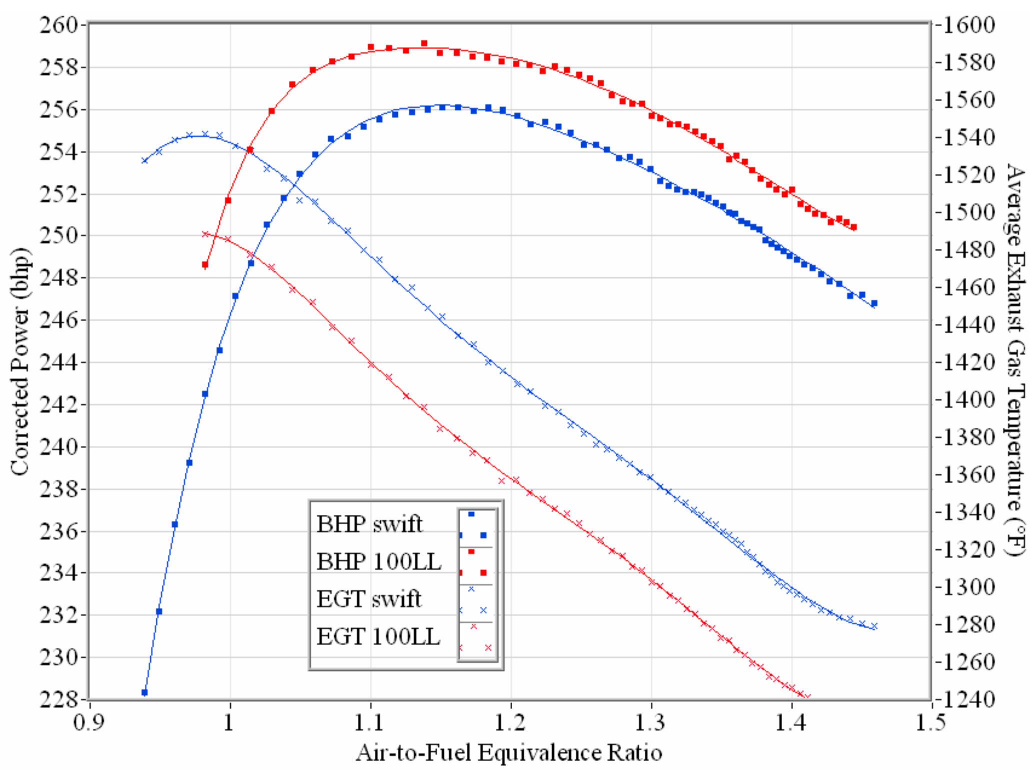


Figure A-49. Swift 702 Fuel Compared to 100LL; 2300 rpm, FT

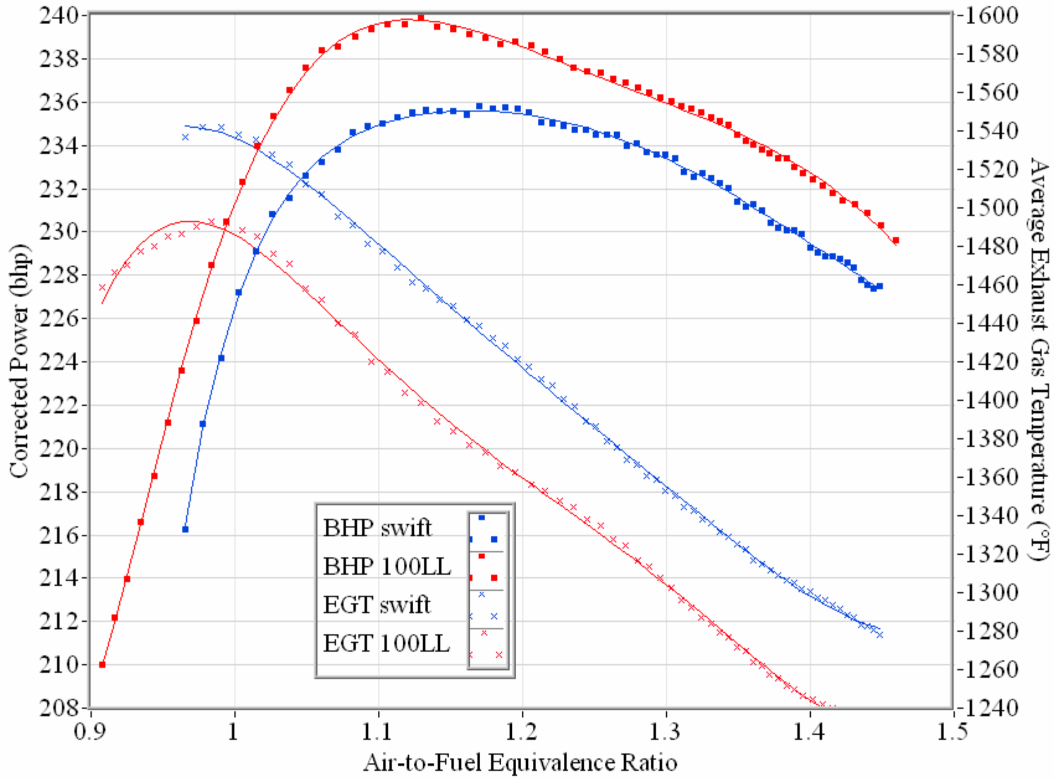


Figure A-50. Swift 702 Fuel Compared to 100LL; 2300 rpm, 28 inHg MAP

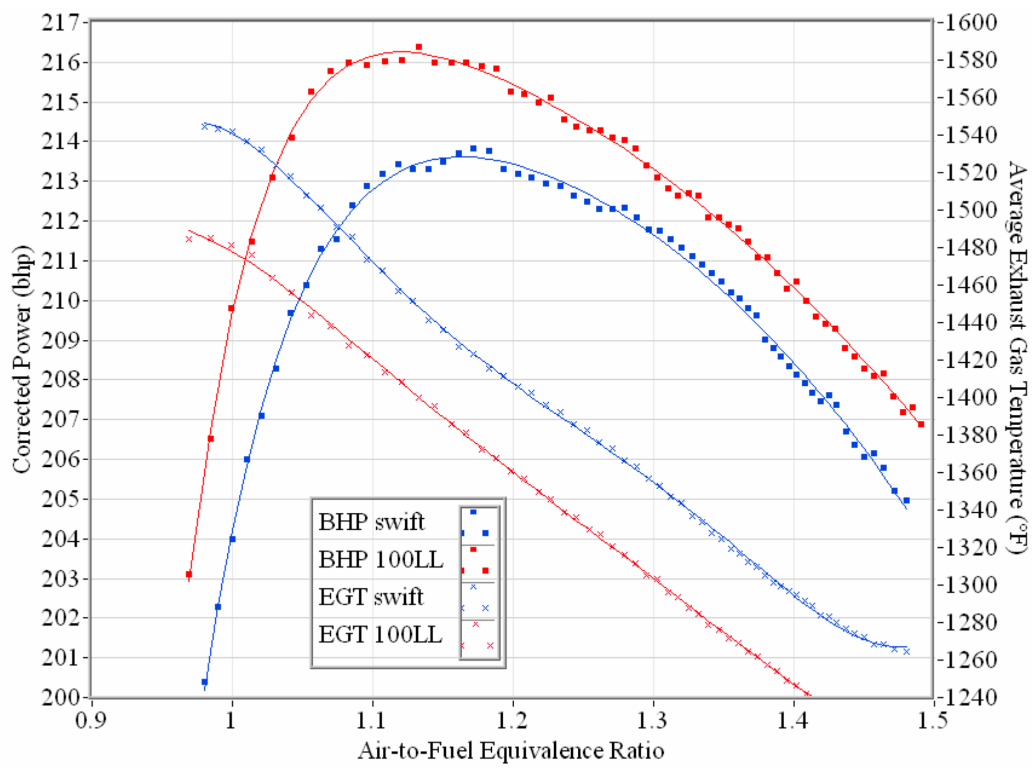


Figure A-51. Swift 702 Fuel Compared to 100LL; 2300 rpm, 26 inHg MAP

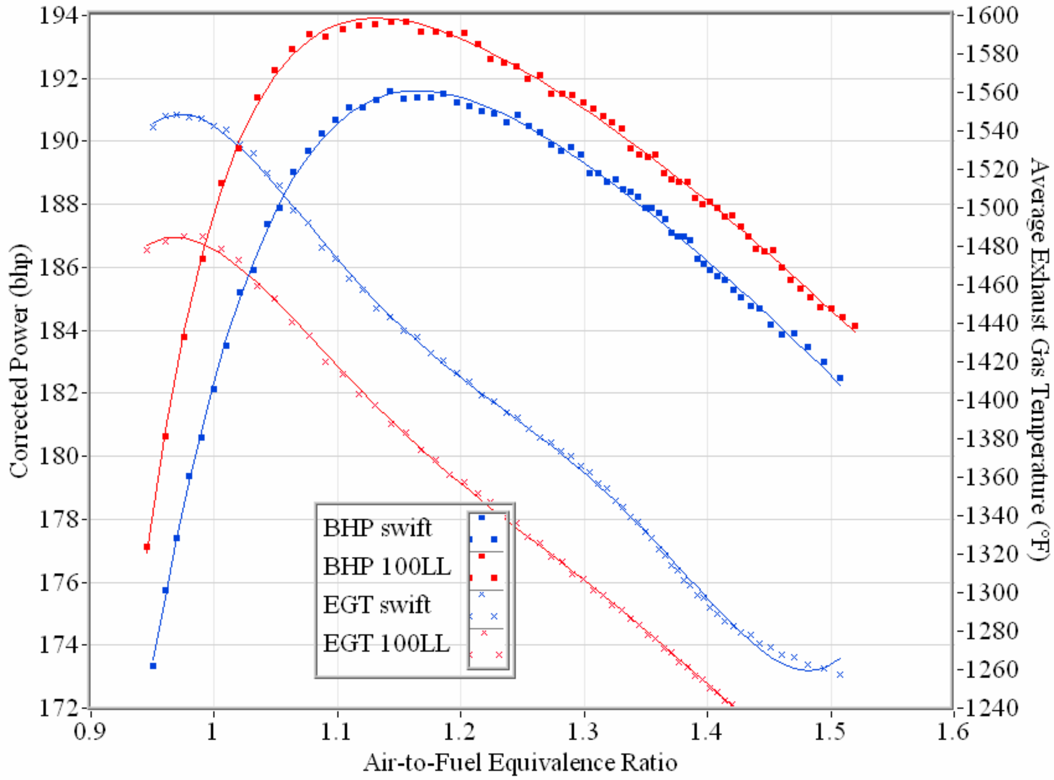


Figure A-52. Swift 702 Fuel Compared to 100LL; 2300 rpm, 24 inHg MAP

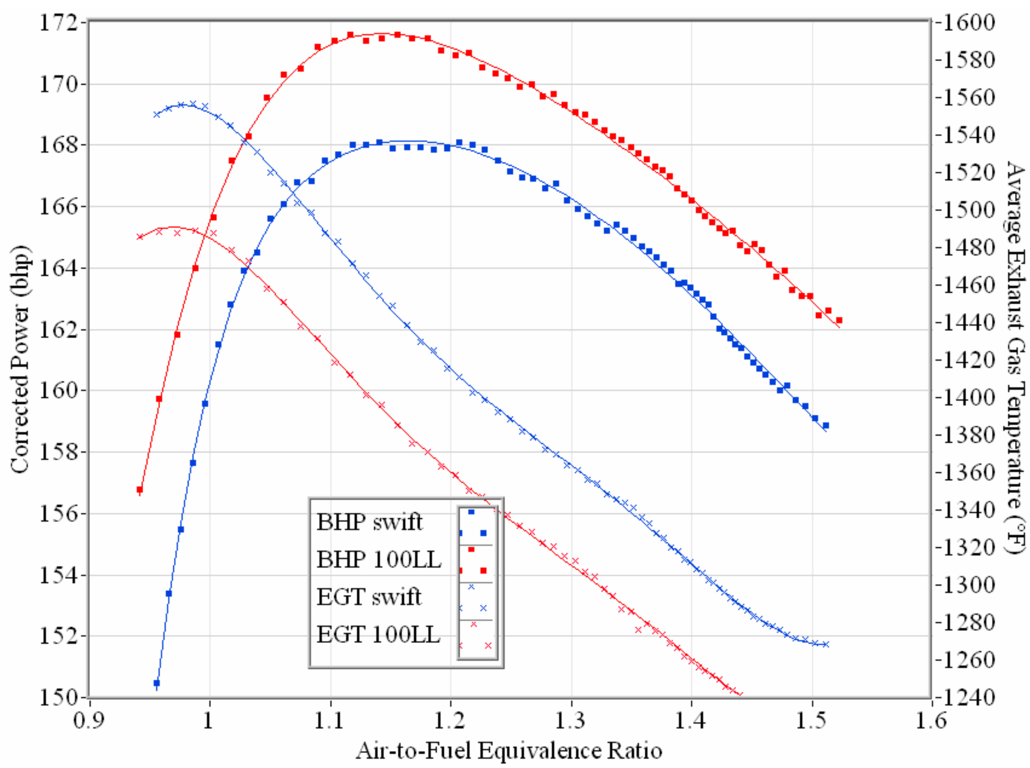


Figure A-53. Swift 702 Fuel Compared to 100LL; 2300 rpm, 22 inHg MAP

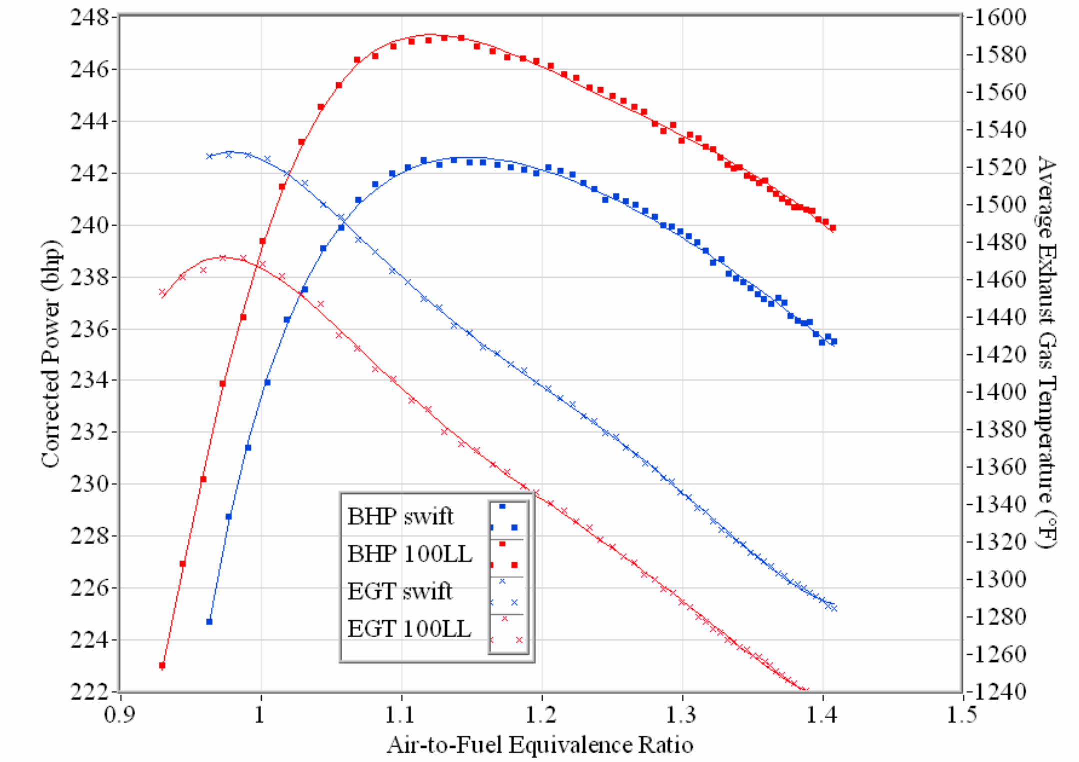


Figure A-54. Swift 702 Fuel Compared to 100LL; 2200 rpm, FT

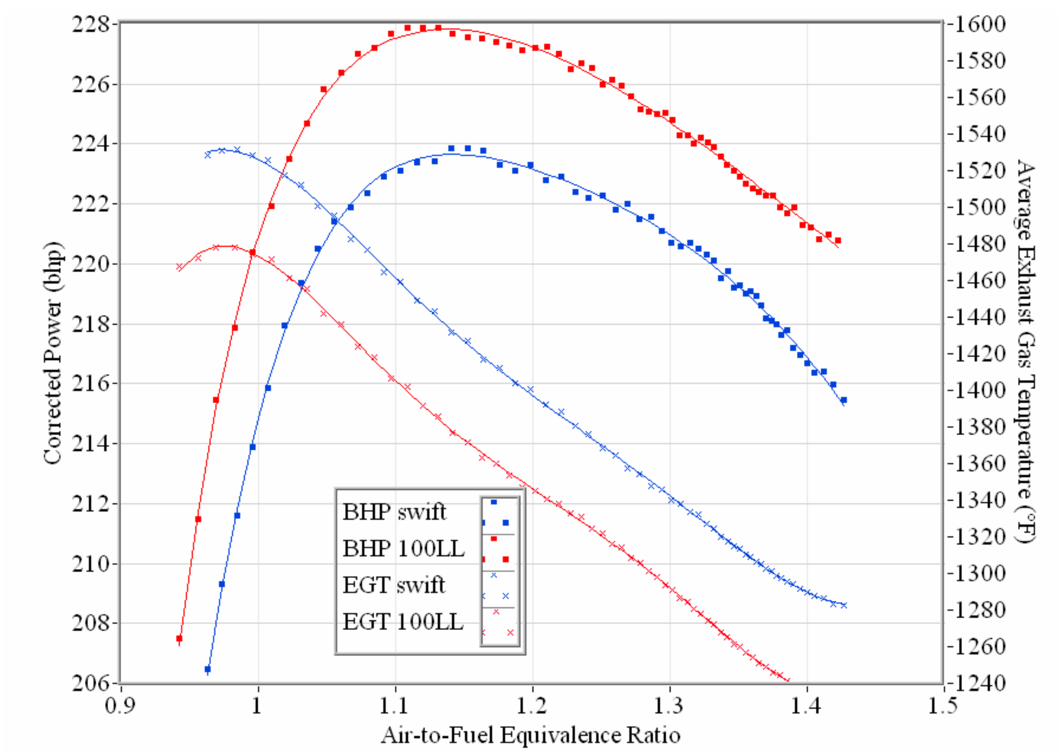


Figure A-55. Swift 702 Fuel Compared to 100LL; 2200 rpm, 28 inHg MAP

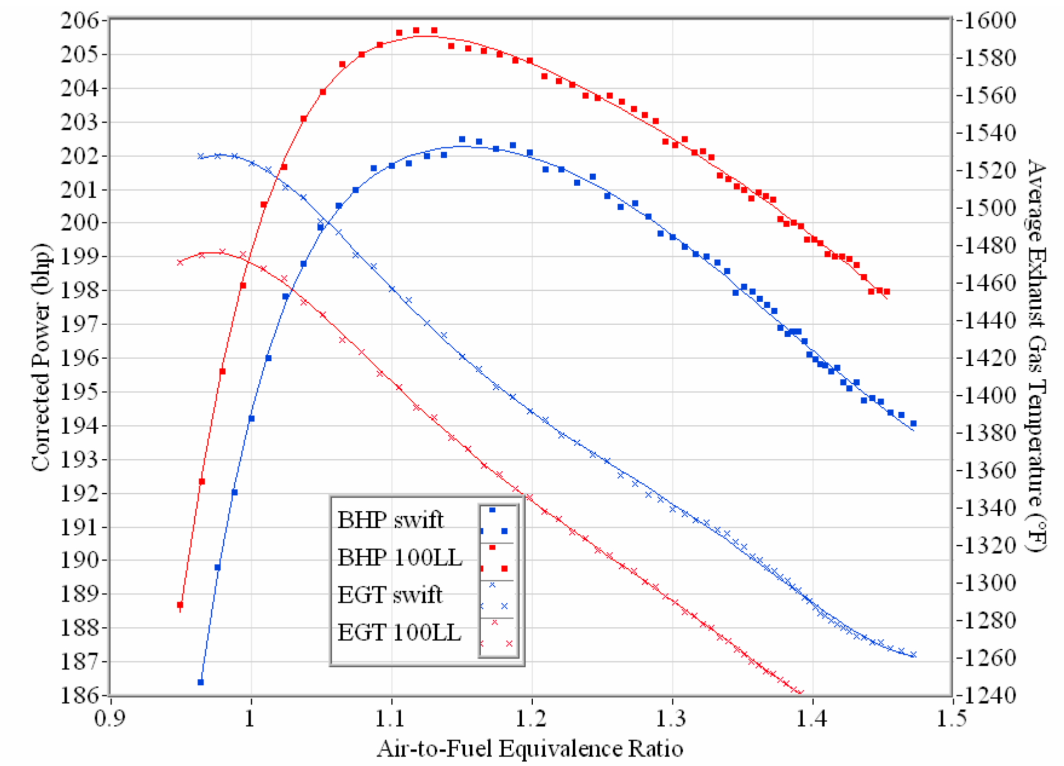


Figure A-56. Swift 702 Fuel Compared to 100LL; 2200 rpm, 26 inHg MAP

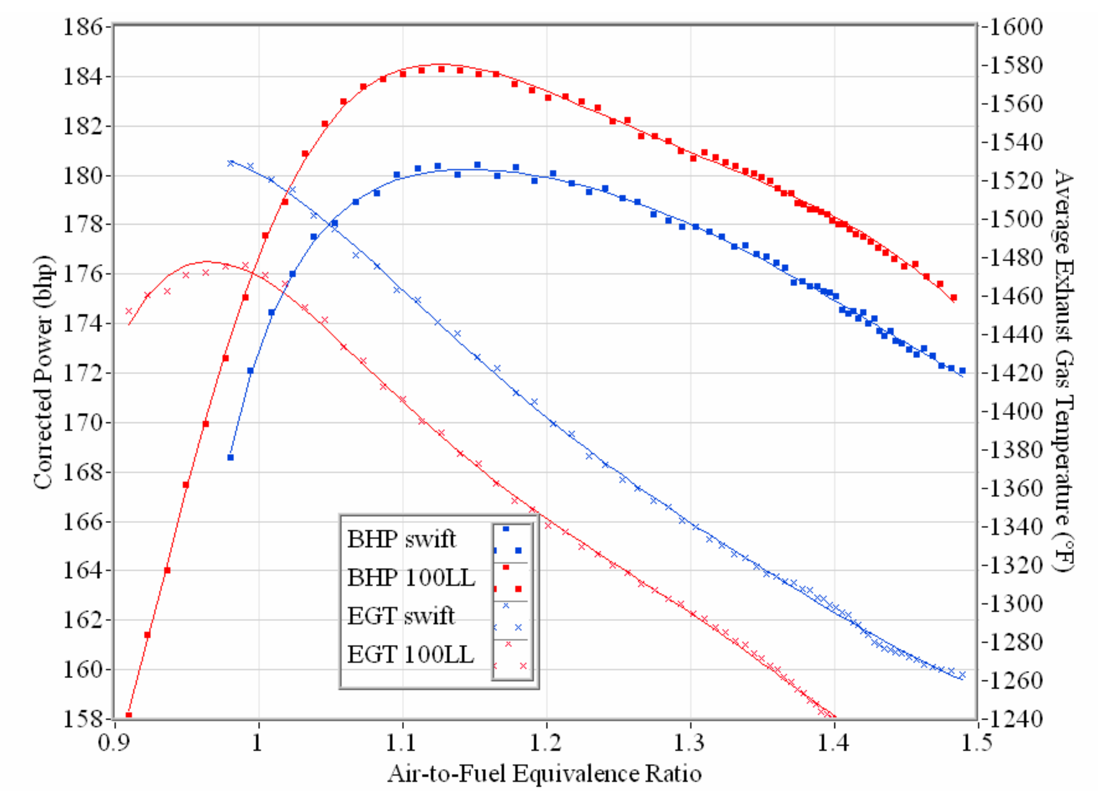


Figure A-57. Swift 702 Fuel Compared to 100LL; 2200 rpm, 24 inHg MAP

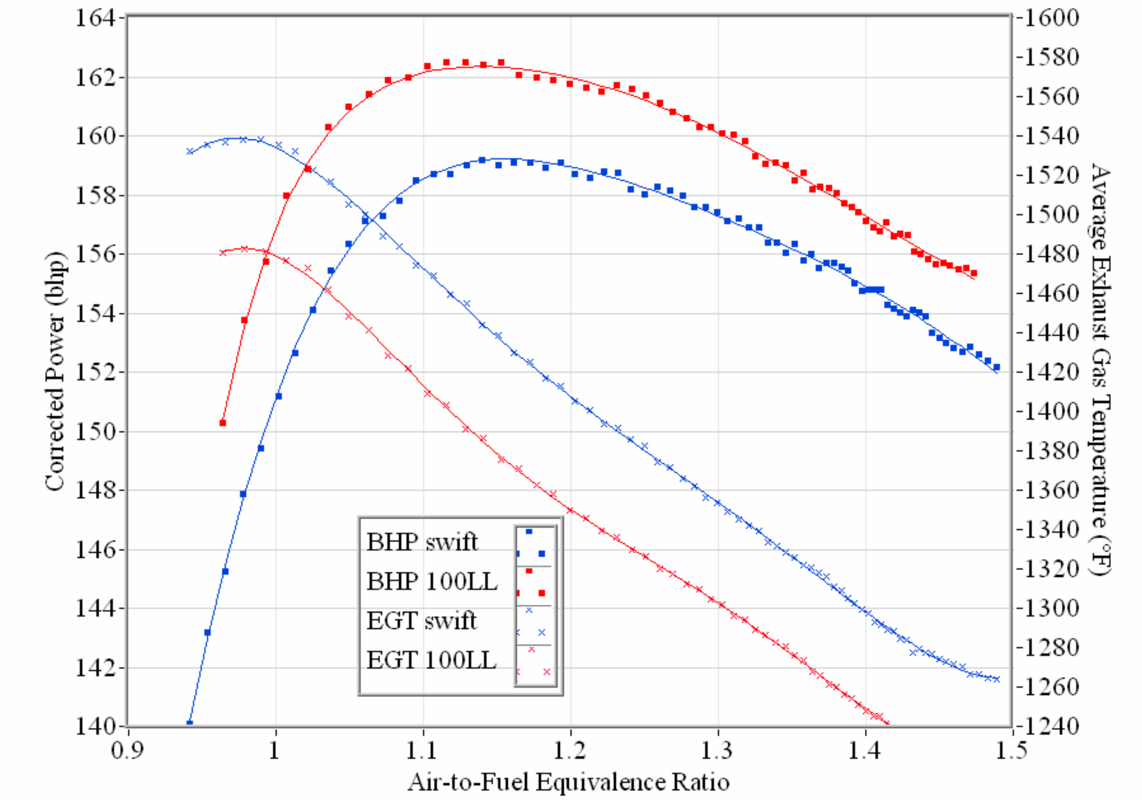


Figure A-58. Swift 702 Fuel Compared to 100LL; 2200 rpm, 22 inHg MAP

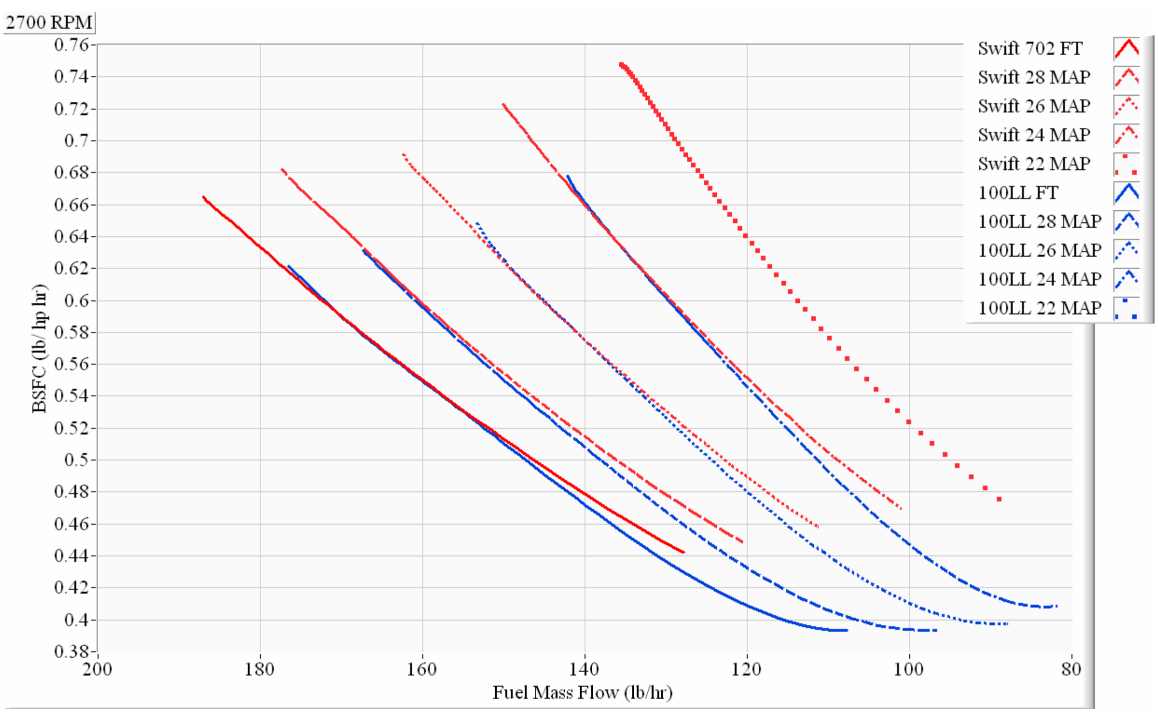


Figure A-59. Swift 702 Fuel Compared to 100LL; 2700 rpm, all MAP

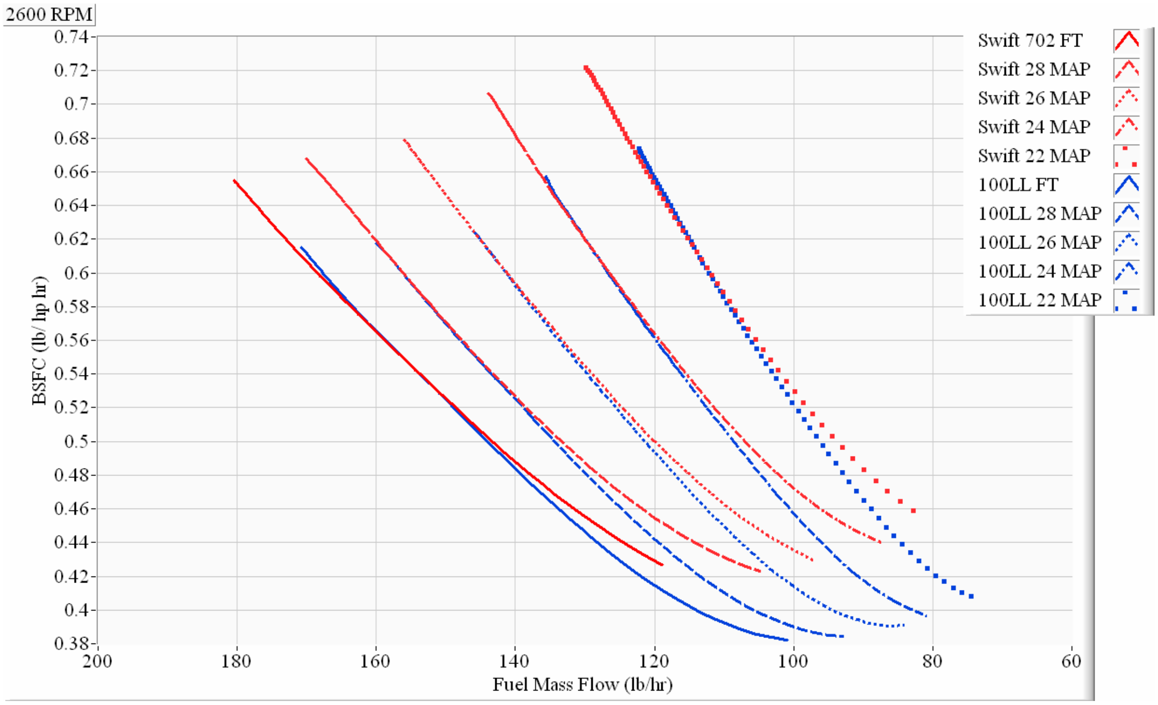


Figure A-60. Swift 702 Fuel Compared to 100LL; 2600 rpm, all MAP

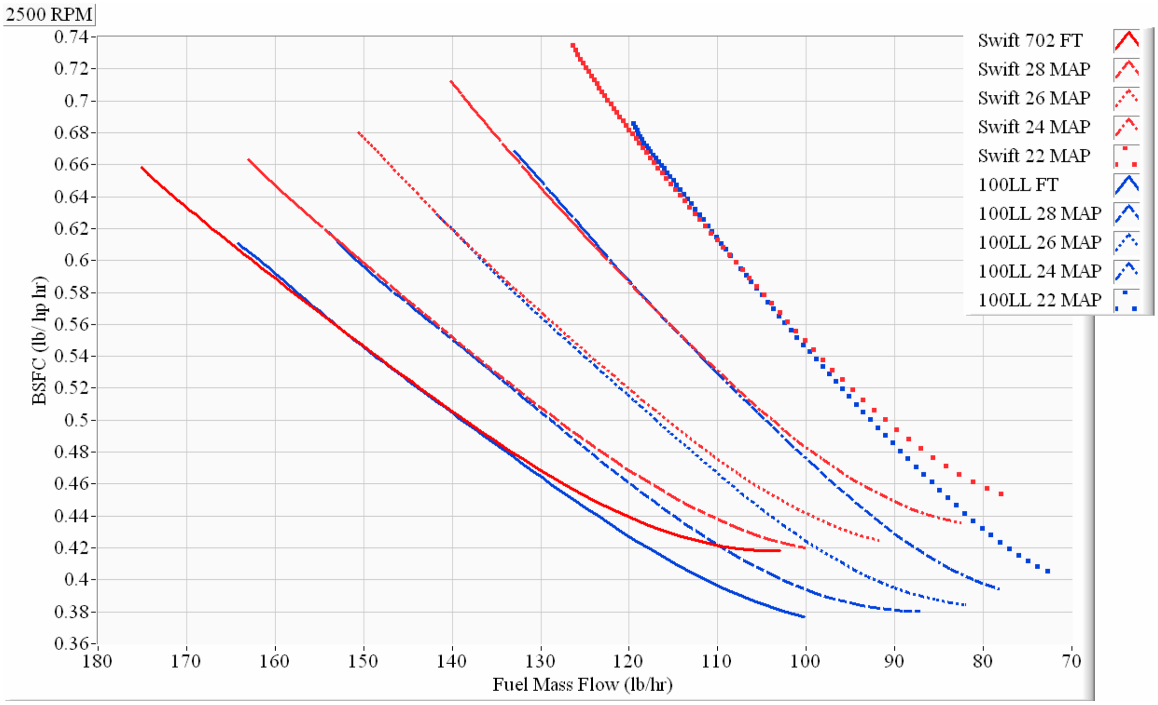


Figure A-61. Swift 702 Fuel Compared to 100LL; 2500 rpm, all MAP

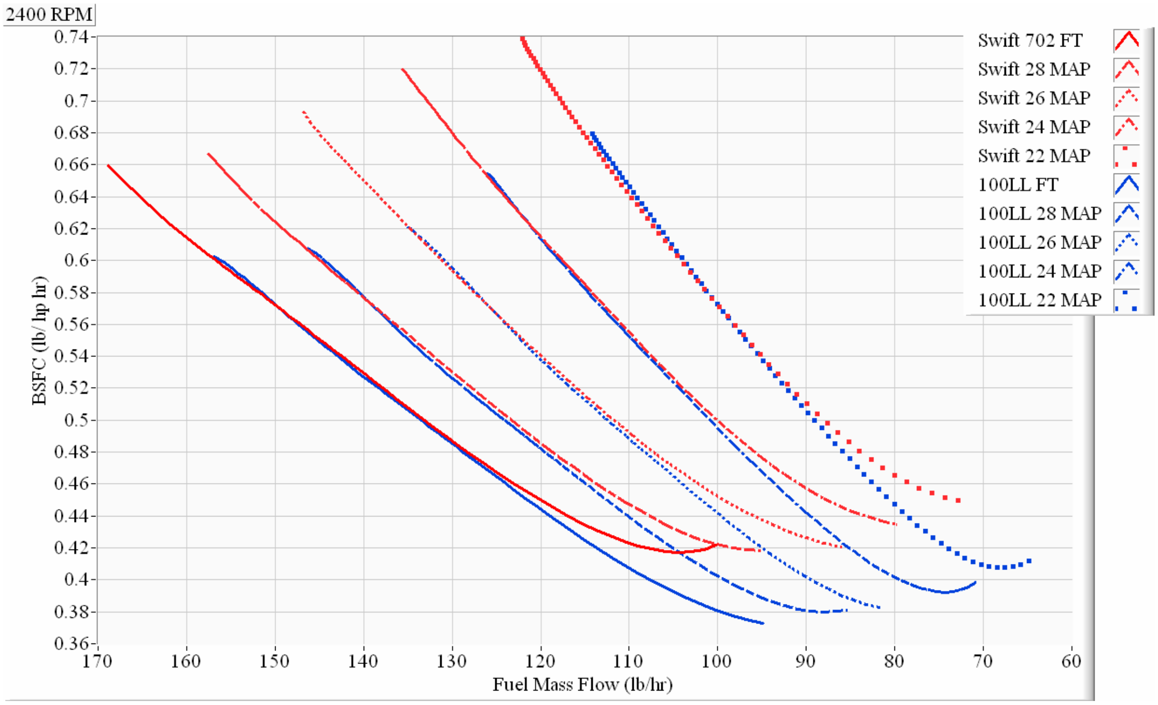


Figure A-62. Swift 702 Fuel Compared to 100LL; 2400 rpm, all MAP

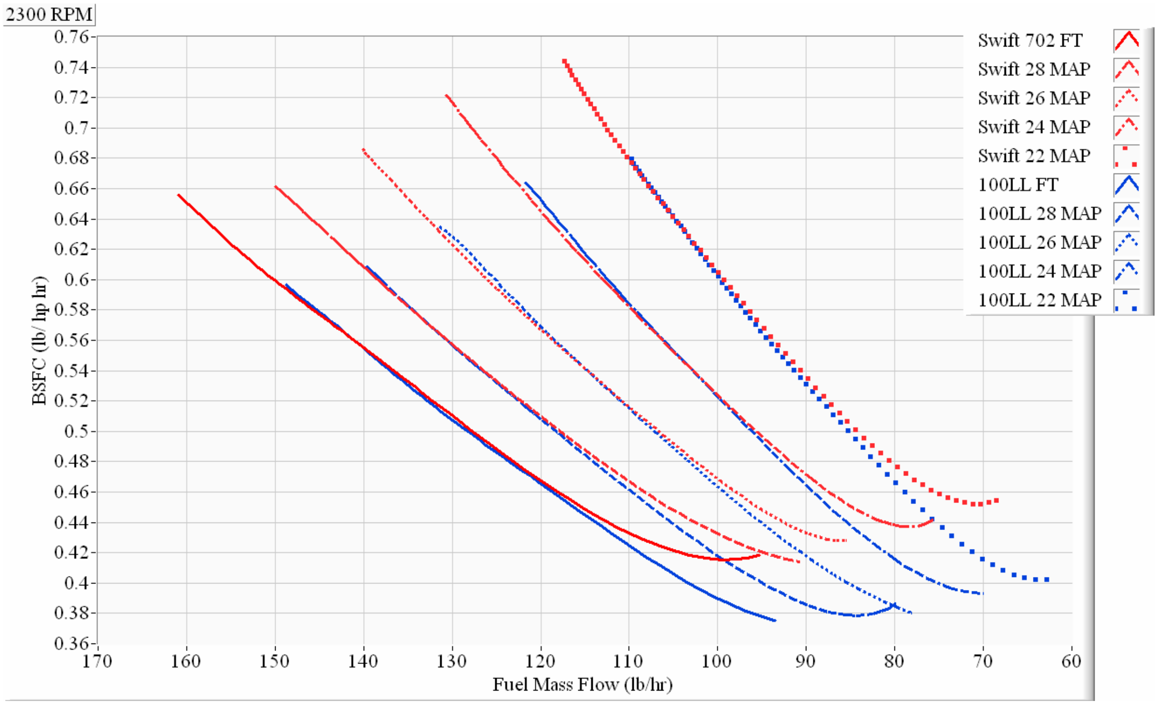


Figure A-63. Swift 702 Fuel Compared to 100LL; 2300 rpm, all MAP

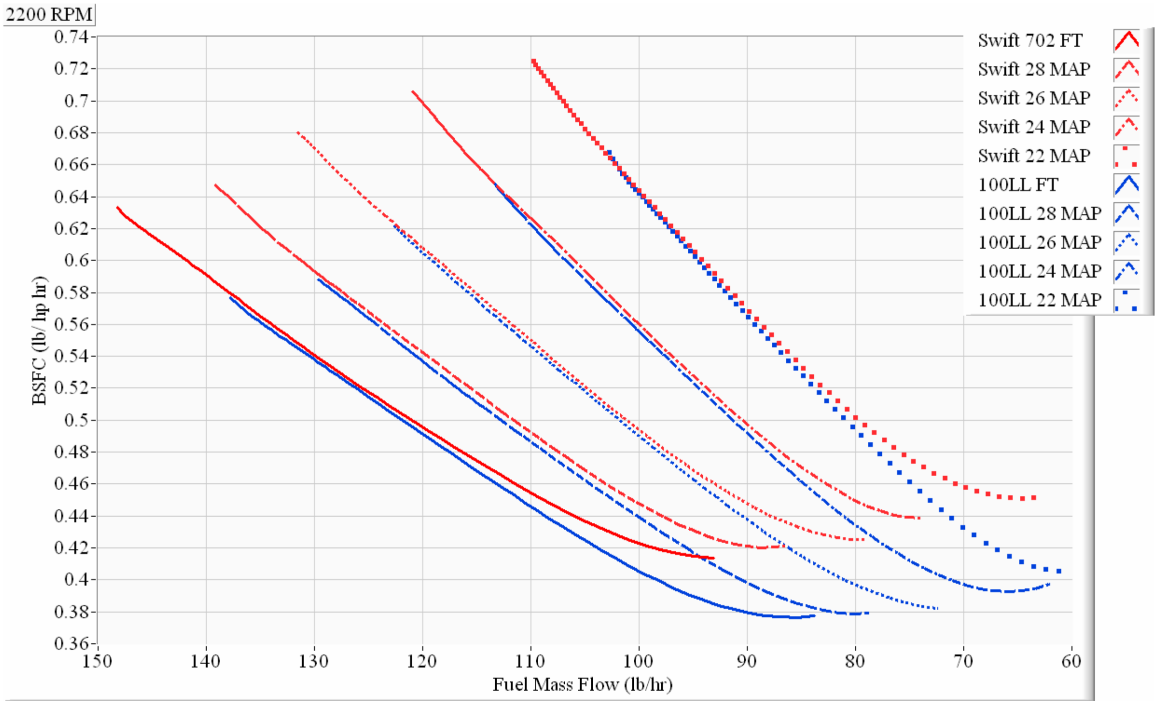


Figure A-64. Swift 702 Fuel Compared to 100LL; 2200 rpm, all MAP

APPENDIX B—LYCOMING IO-540-K DETONATION ONSET GRAPHS WITH AVERAGE EXHAUST GAS TEMPERATURE

The graphical data contained in this appendix show detonation onset for the fixed-base operator 100 low-lead (100LL), the minimum specification 100LL and the Swift 702 fuel. The square data points on the curves show the richest mixture where detonation onset occurred.

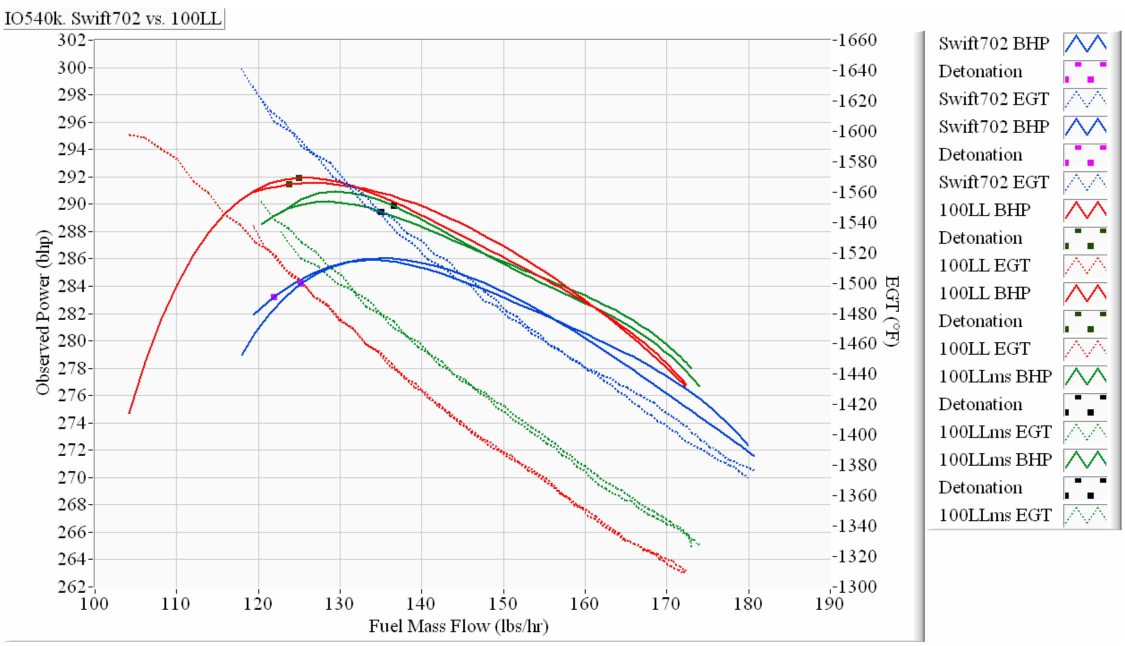


Figure B-1. Detonation Onset Comparison; 2700 rpm, FT

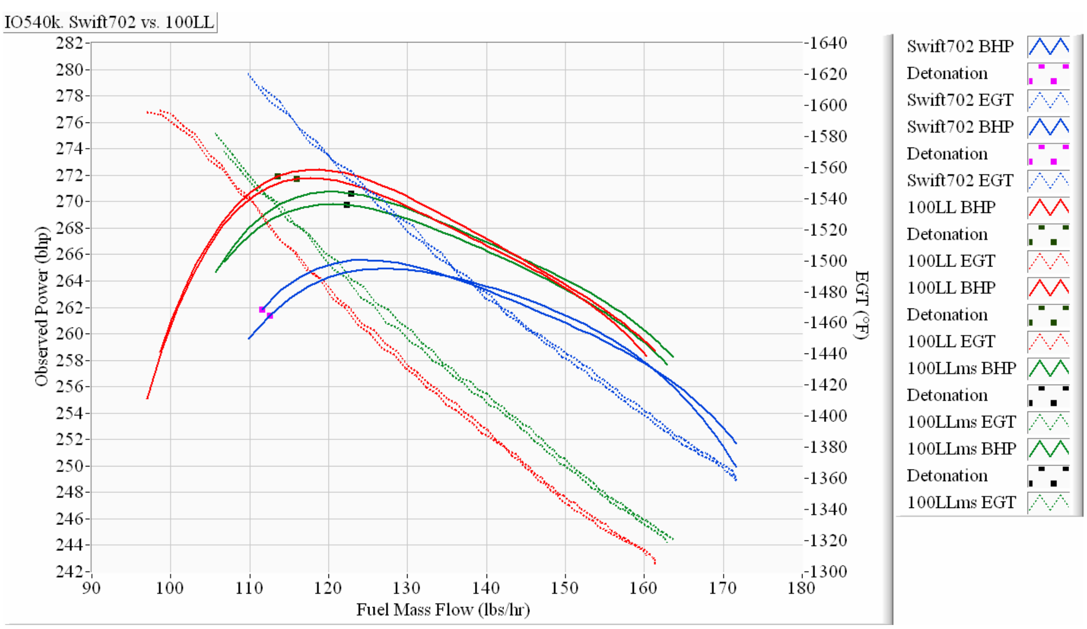


Figure B-2. Detonation Onset Comparison; 2700 rpm, 28 inHg MAP

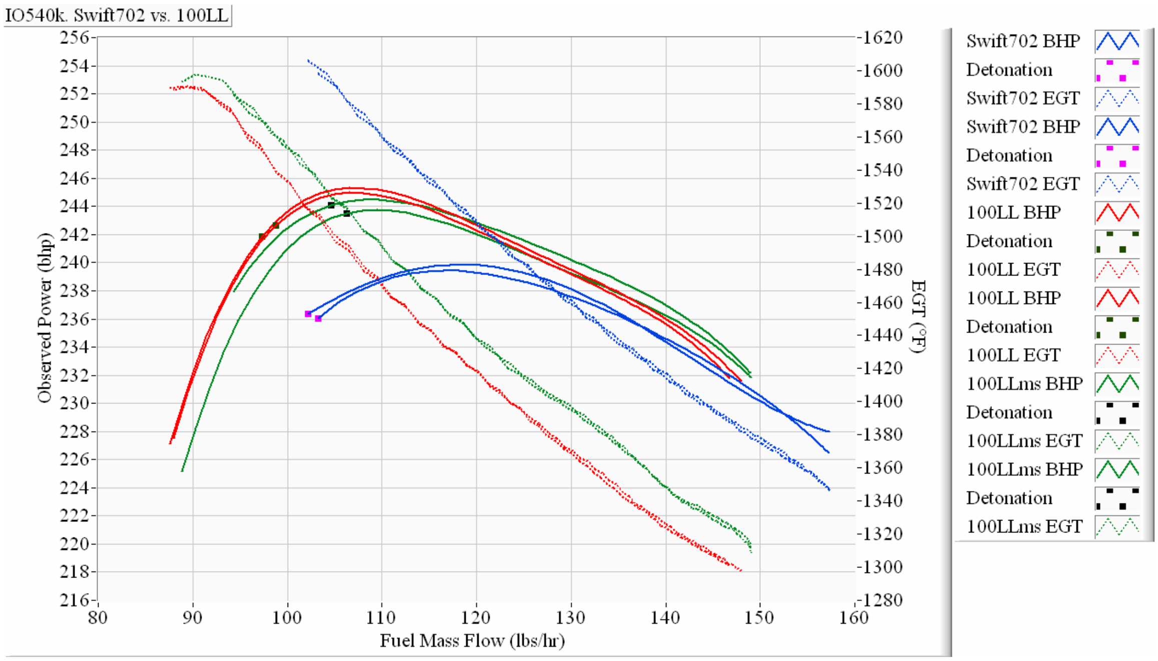


Figure B-3. Detonation Onset Comparison; 2700 rpm, 26 inHg MAP

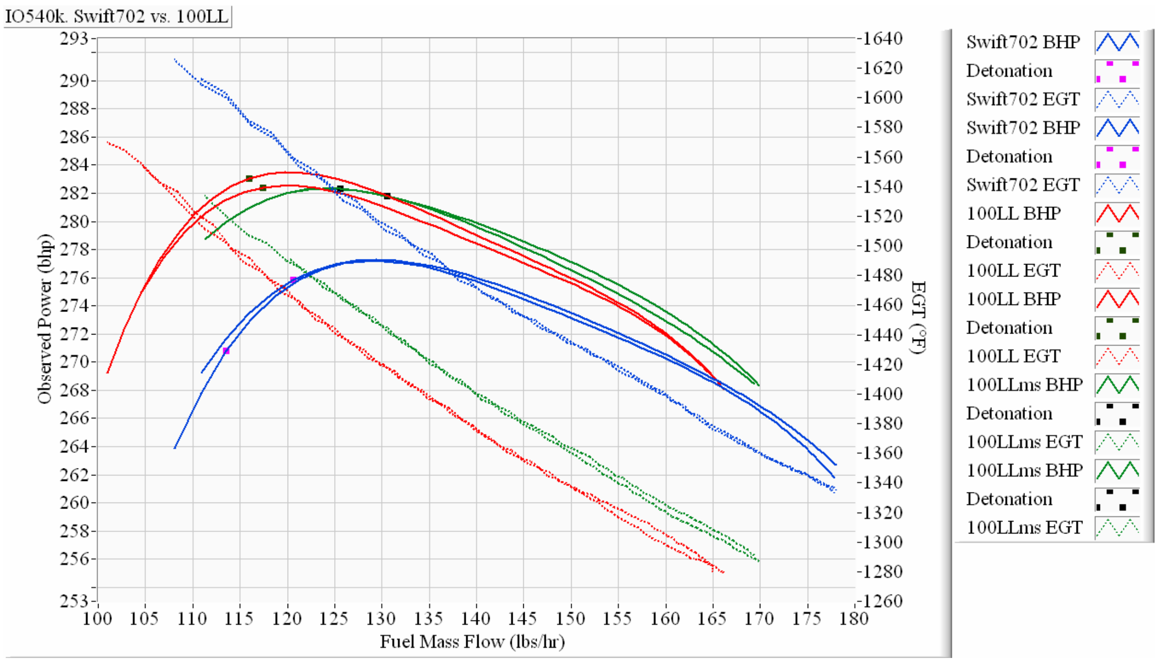


Figure B-4. Detonation Onset Comparison; 2600 rpm, FT

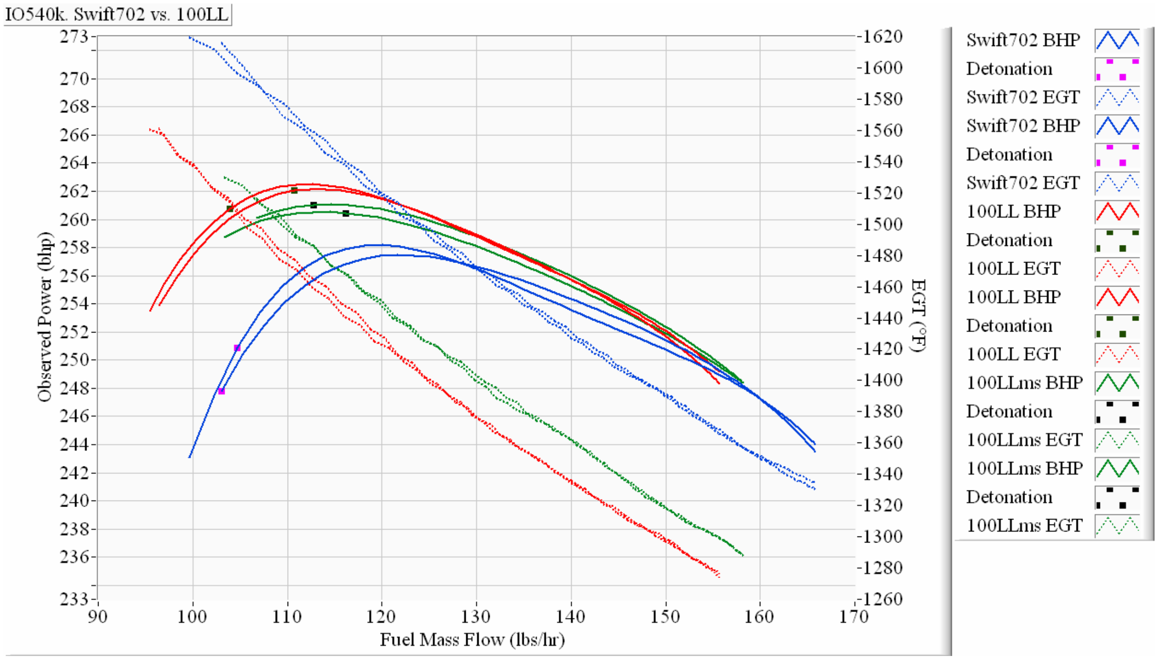


Figure B-5. Detonation Onset Comparison; 2600 rpm, 28 inHg MAP

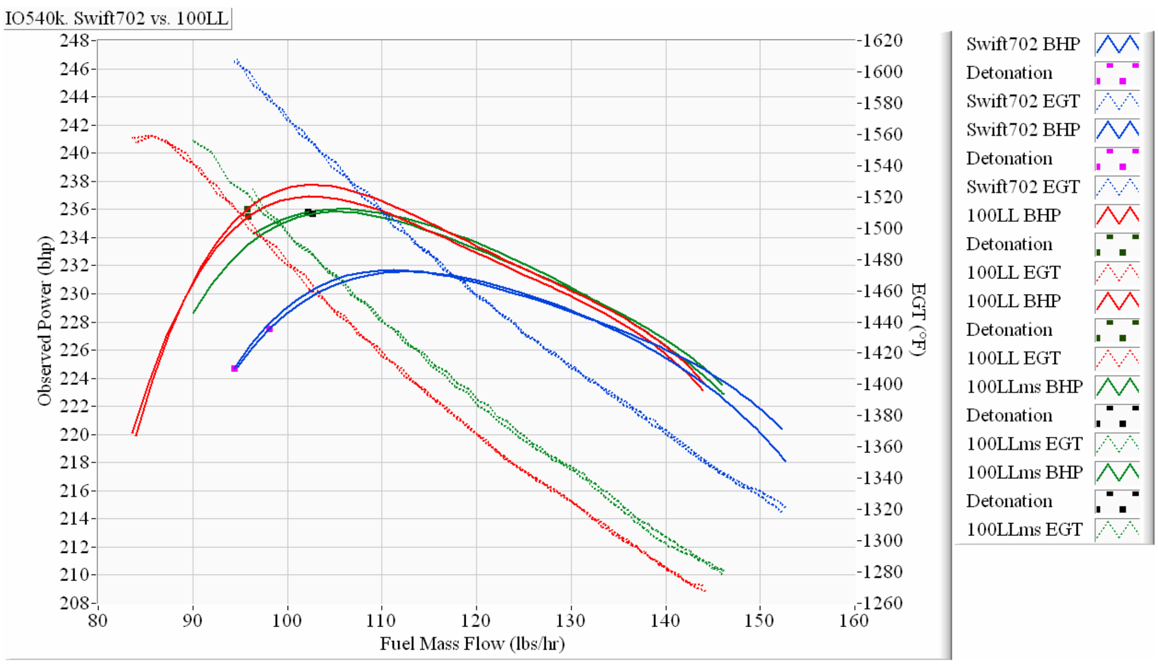


Figure B-6. Detonation Onset Comparison; 2600 rpm, 26 inHg MAP

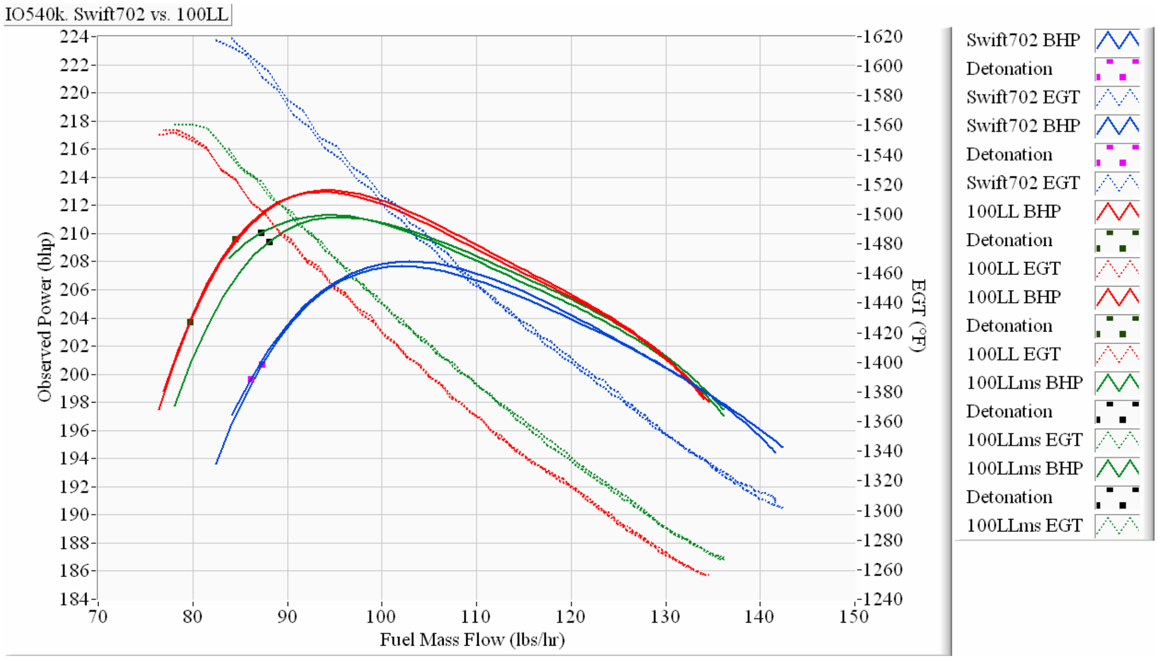


Figure B-7. Detonation Onset Comparison; 2600 rpm, 24 inHg MAP

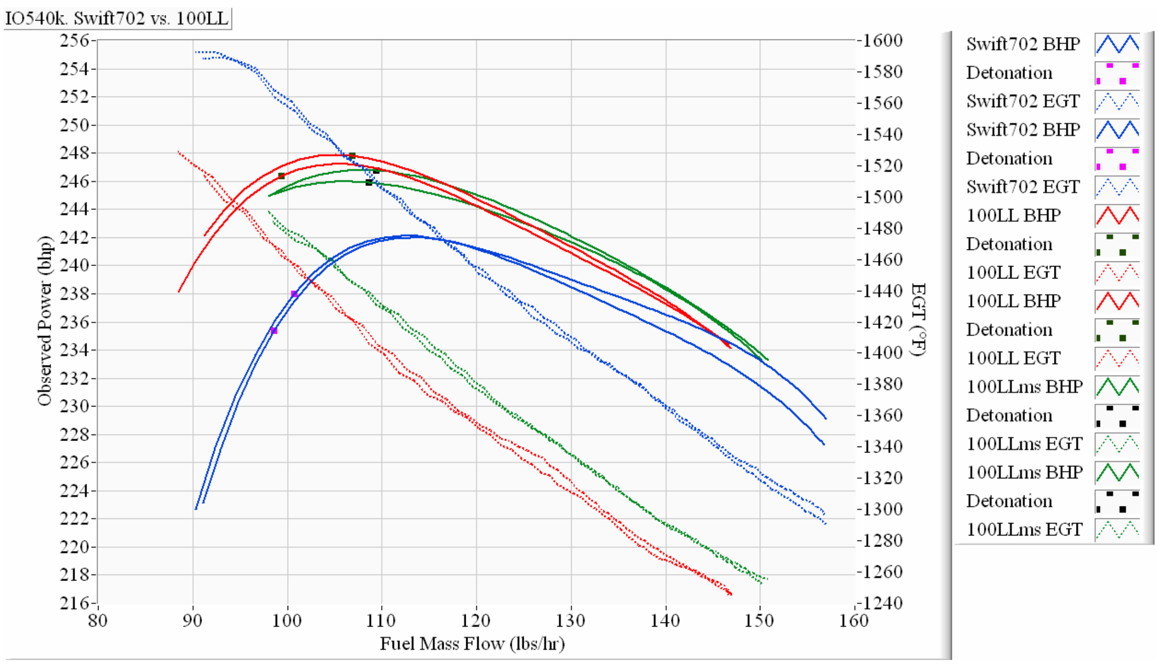


Figure B-8. Detonation Onset Comparison; 2450 rpm, 28 inHg MAP

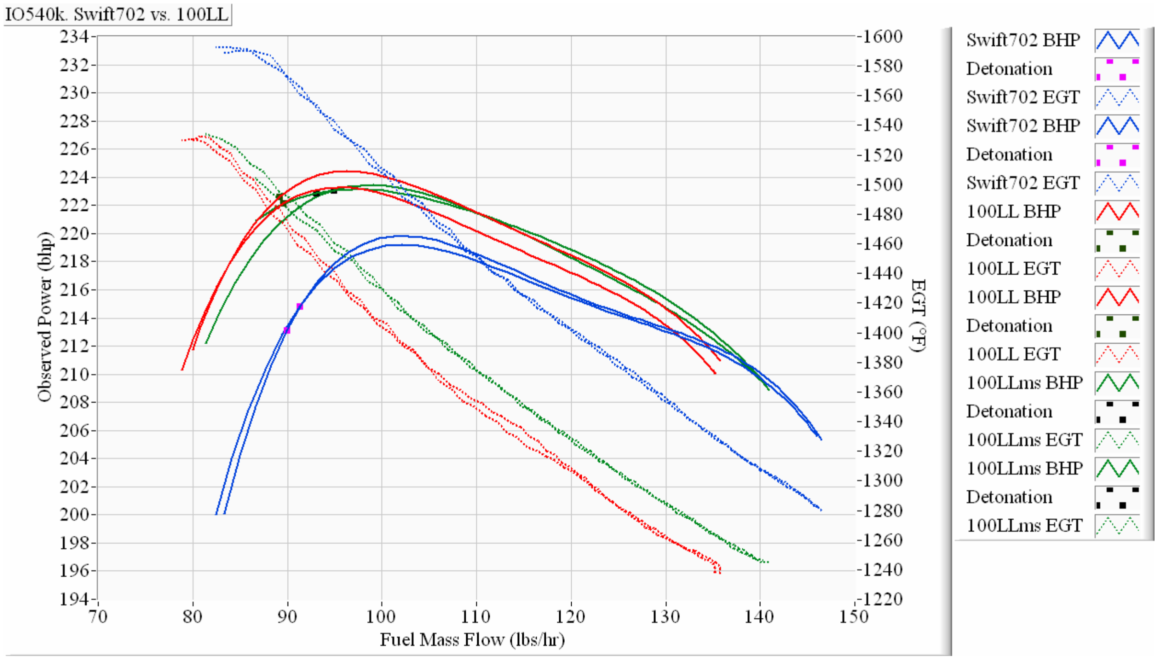


Figure B-9. Detonation Onset Comparison; 2450 rpm, 26 inHg MAP

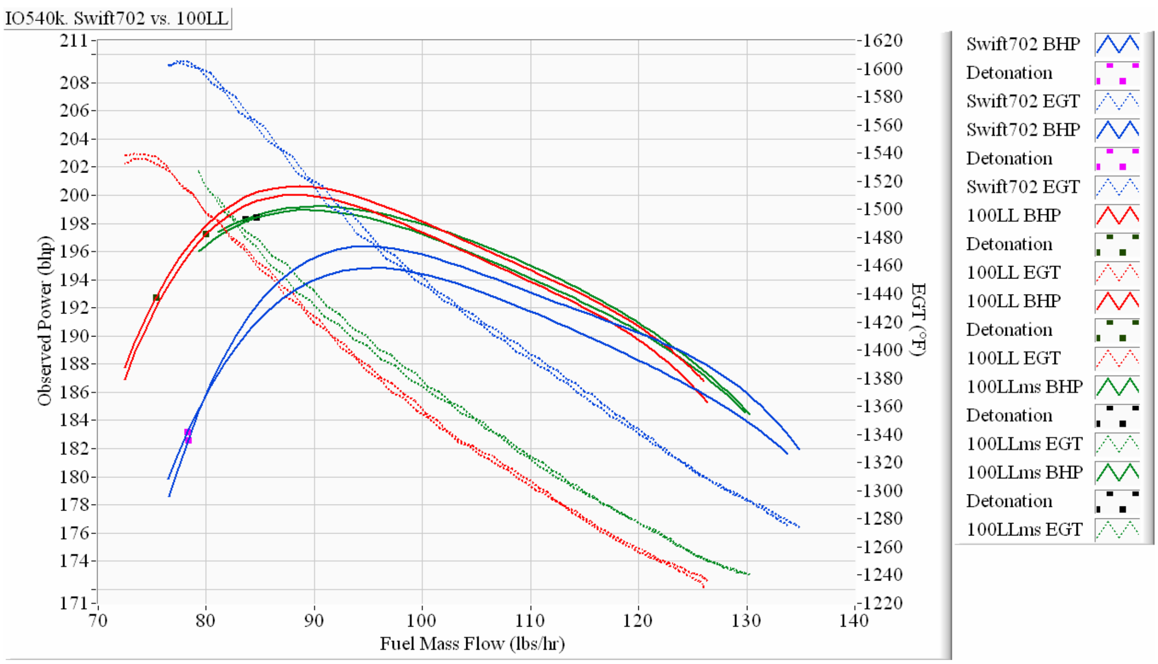


Figure B-10. Detonation Onset Comparison; 2450 rpm, 24 inHg MAP

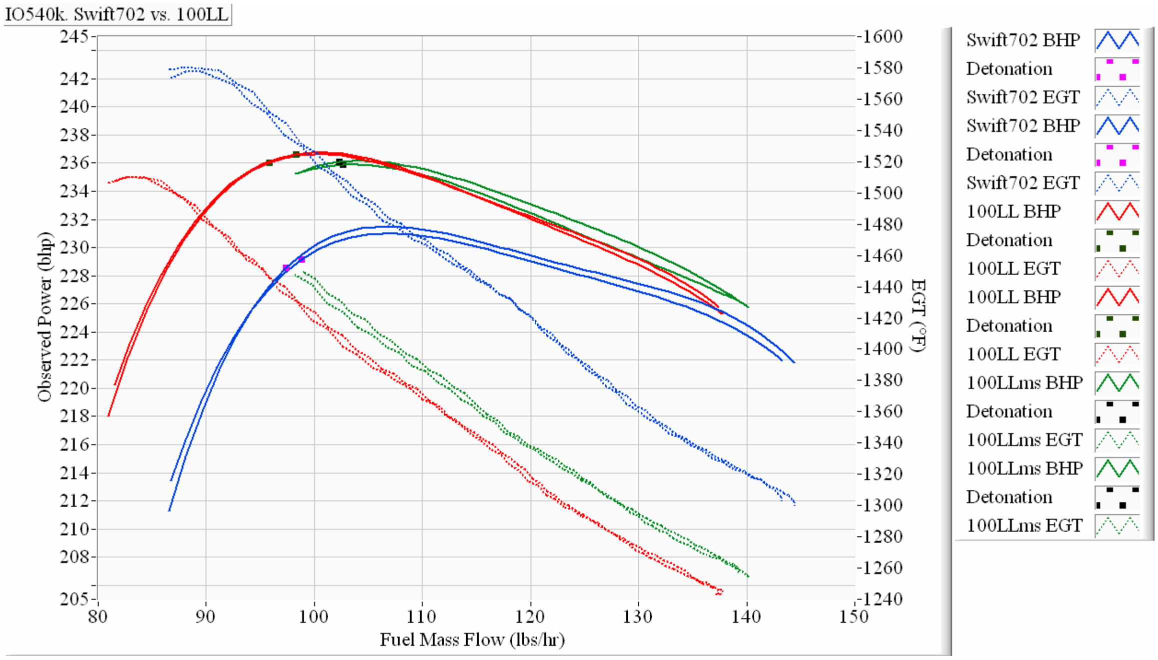


Figure B-11. Detonation Onset Comparison; 2350 rpm, 28 inHg MAP

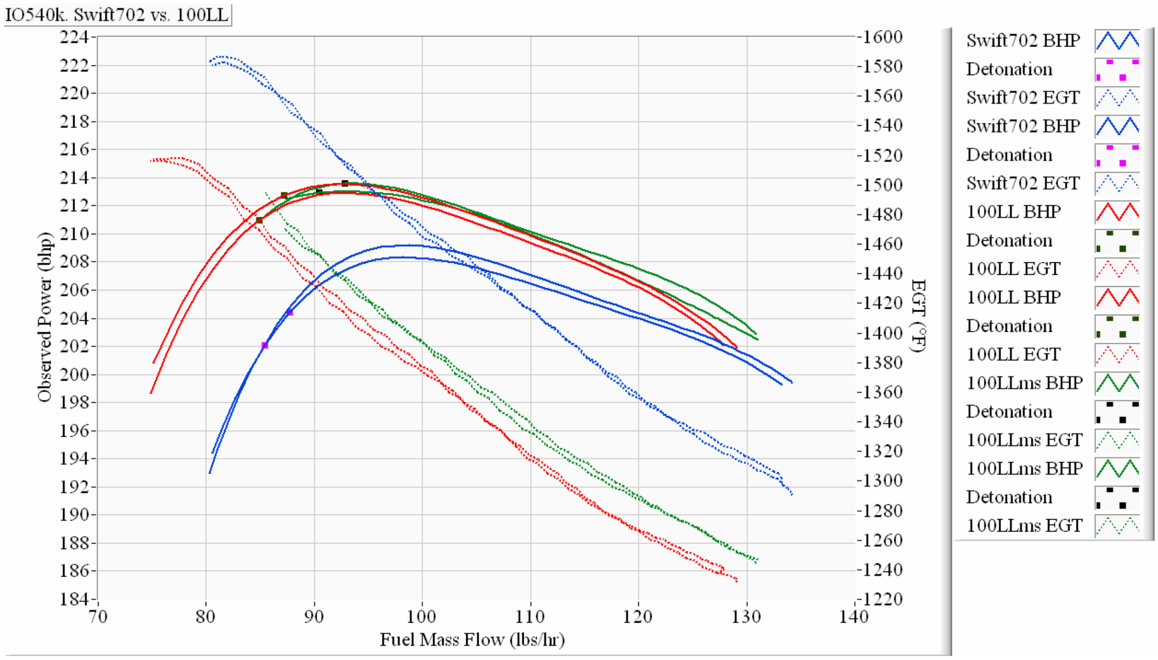


Figure B-12. Detonation Onset Comparison; 2350 rpm, 26 inHg MAP

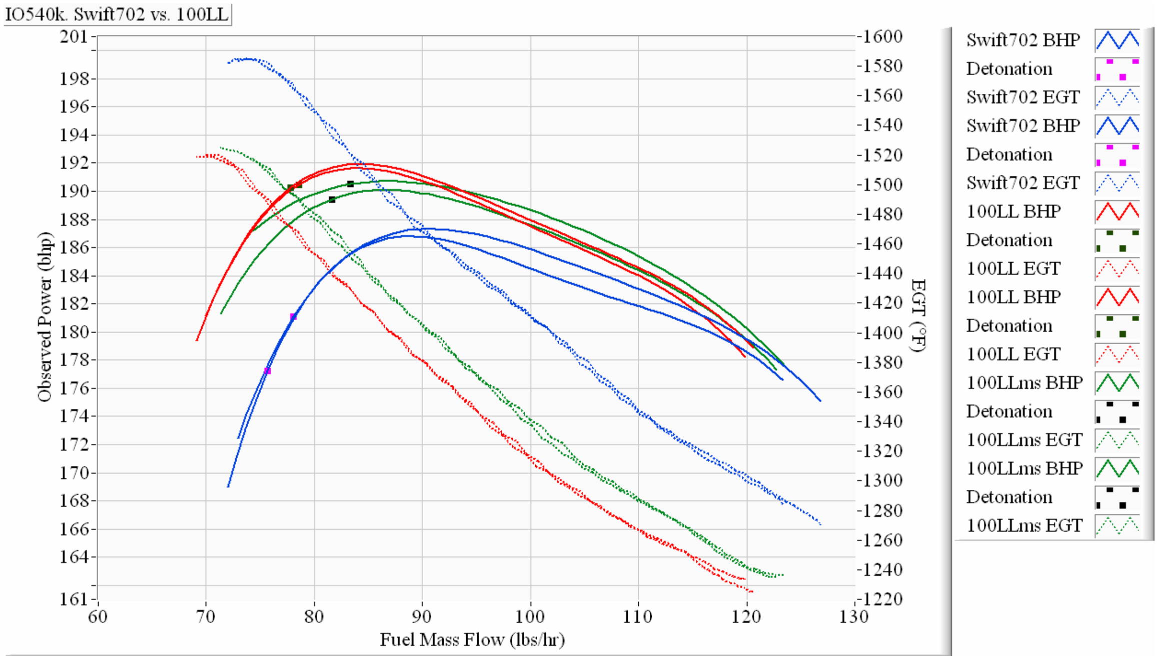


Figure B-13. Detonation Onset Comparison; 2350 rpm, 24 inHg MAP

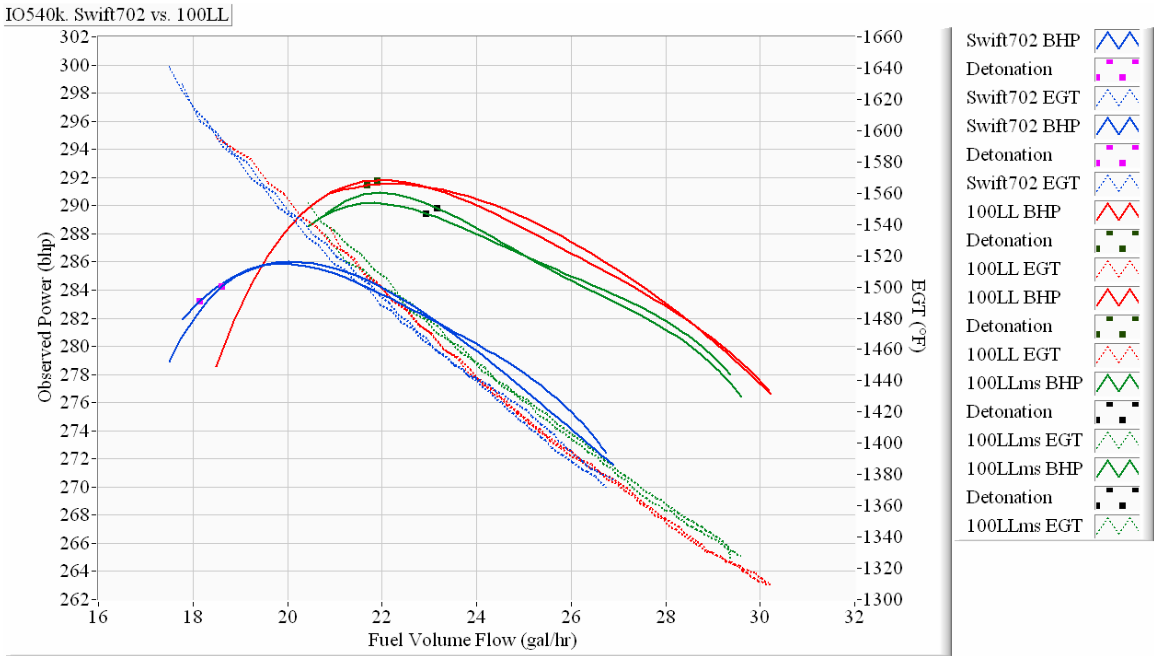


Figure B-14. Detonation Onset Comparison; 2700 rpm, FT

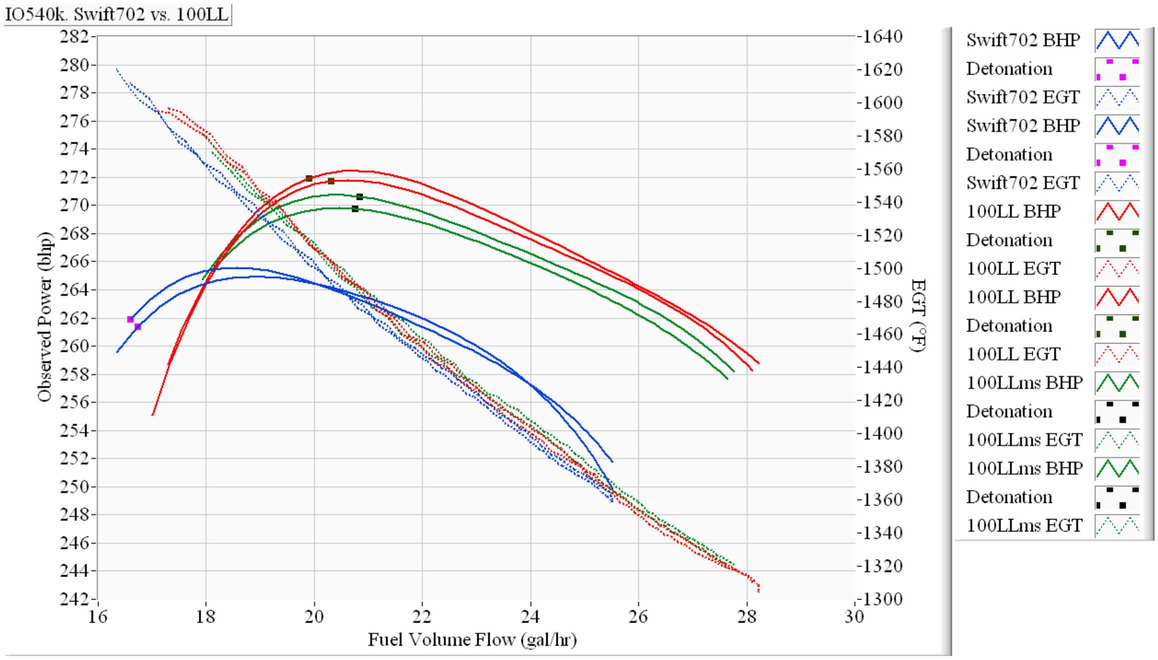


Figure B-15. Detonation Onset Comparison; 2700 rpm, 28 inHg MAP

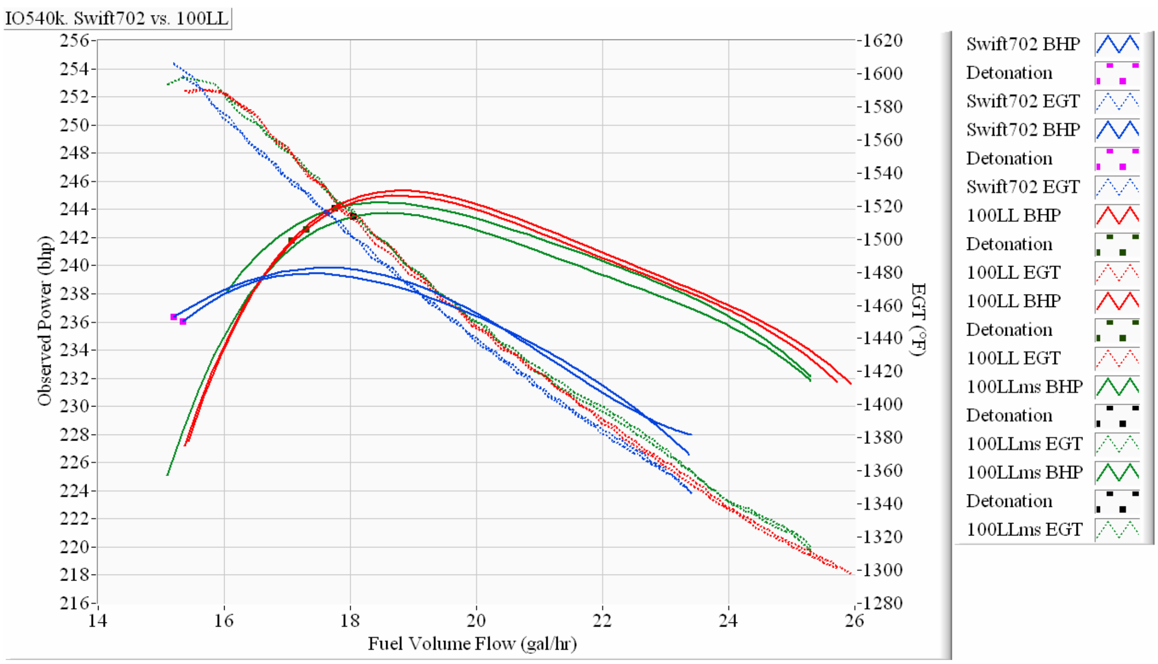


Figure B-16. Detonation Onset Comparison; 2700 rpm, 26 inHg MAP

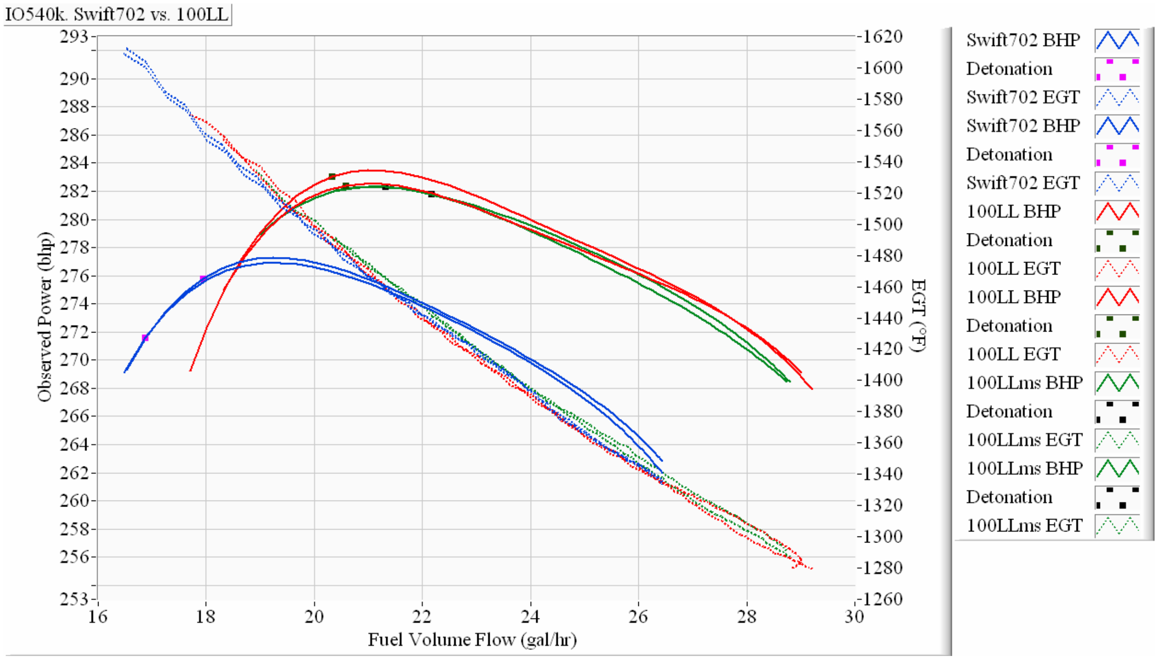


Figure B-17. Detonation Onset Comparison; 2600 rpm, FT

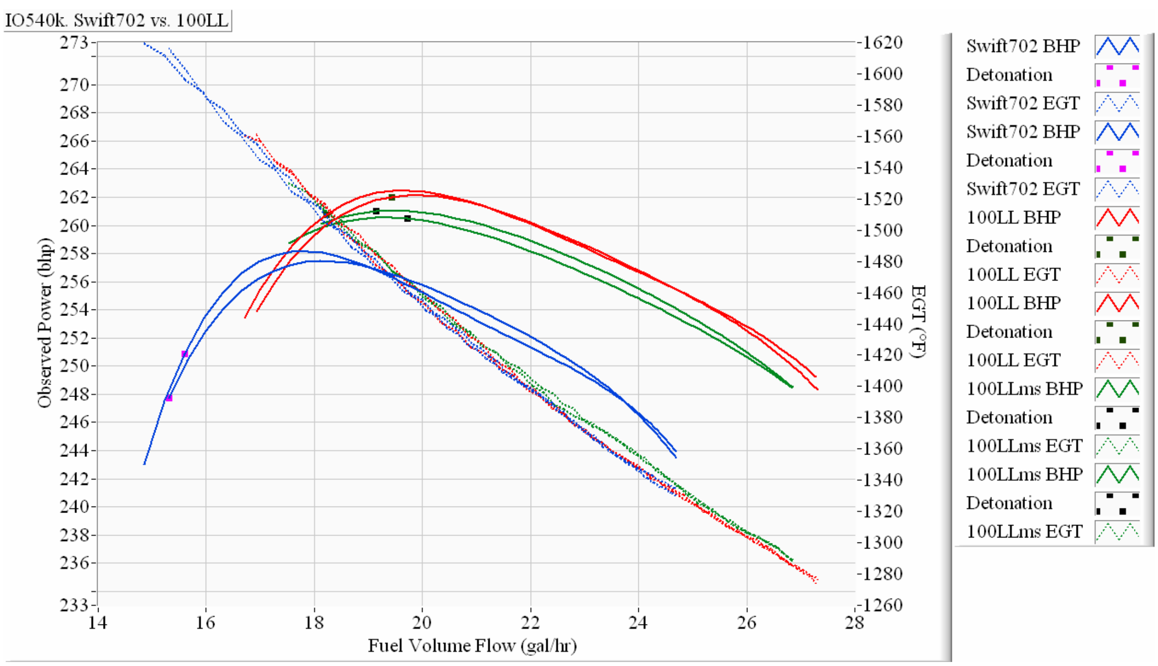


Figure B-18. Detonation Onset Comparison; 2600 rpm, 28 inHg MAP

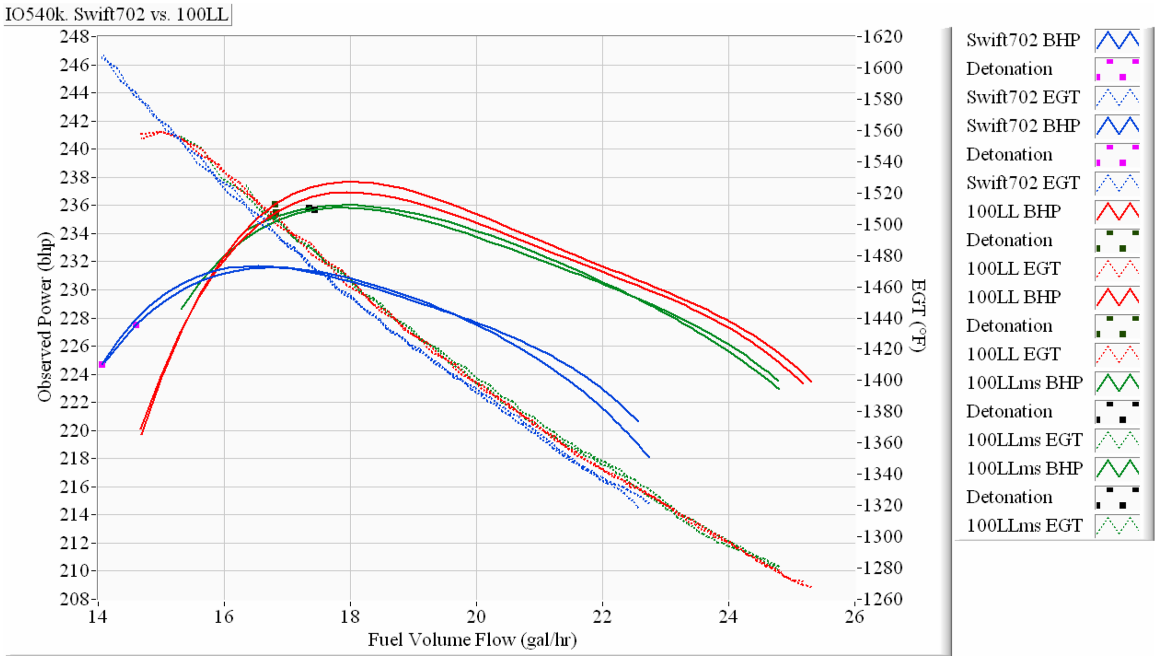


Figure B-19. Detonation Onset Comparison; 2600 rpm, 26 inHg MAP

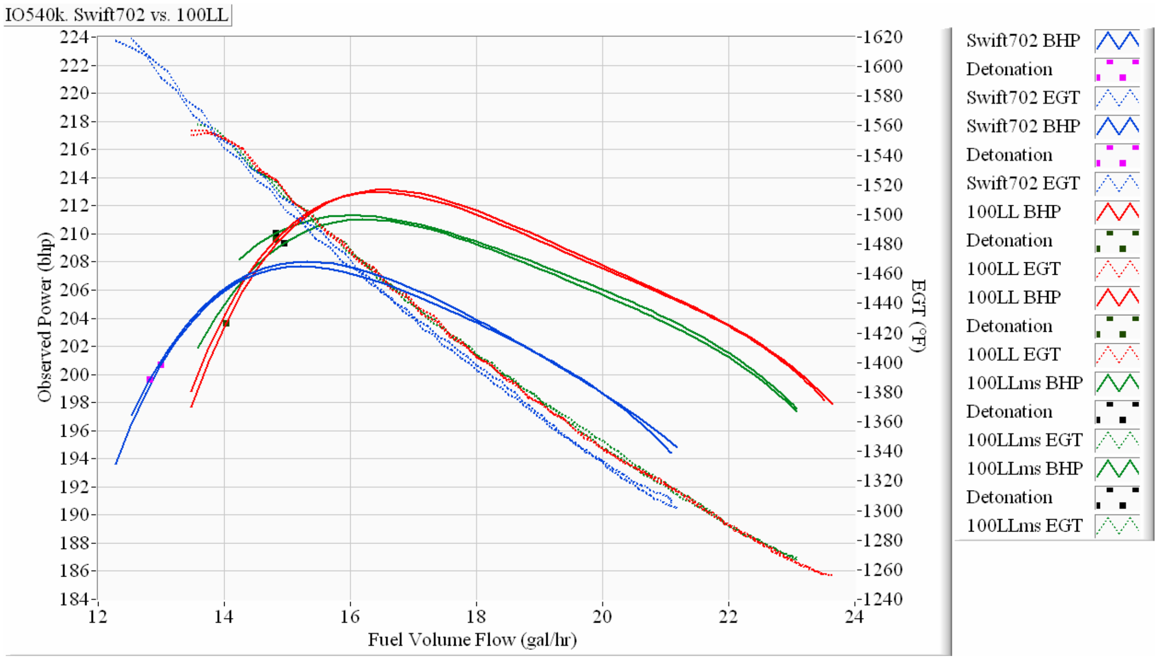


Figure B-20. Detonation Onset Comparison; 2600 rpm, 24 inHg MAP

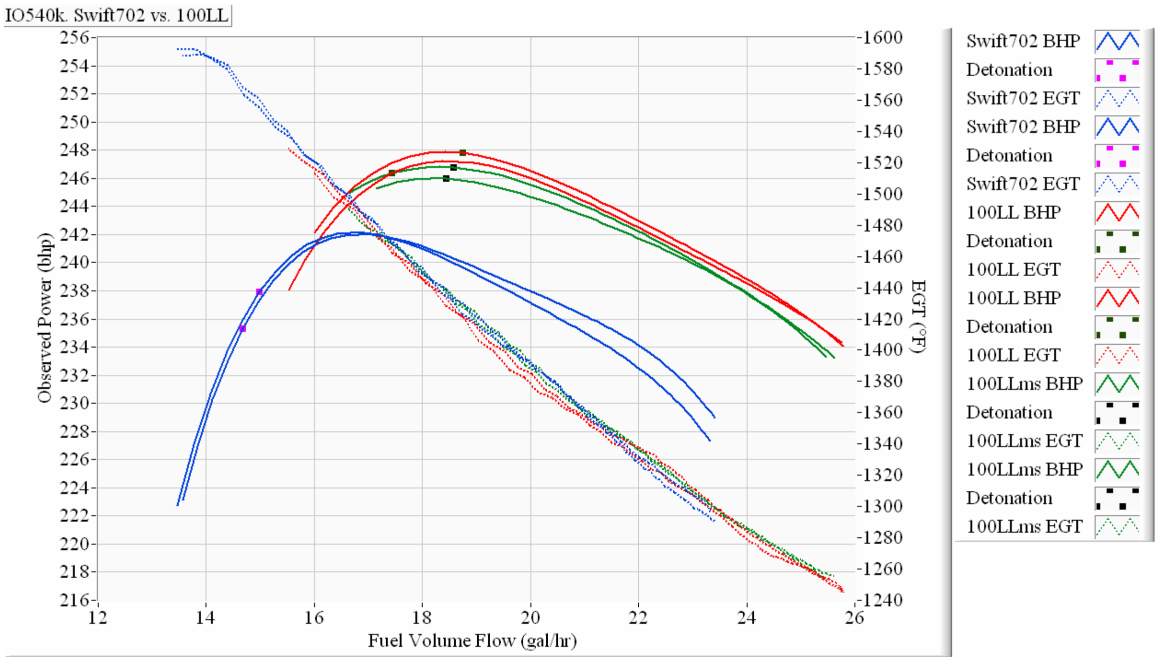


Figure B-21. Detonation Onset Comparison; 2450 rpm, 28 inHg MAP

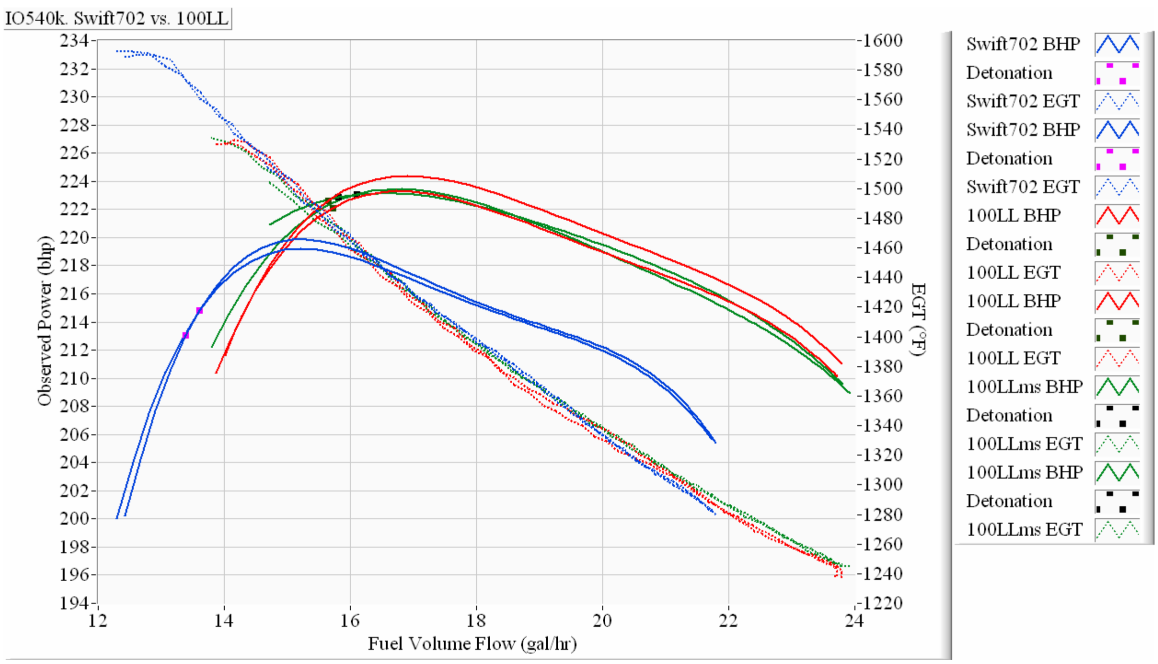


Figure B-22. Detonation Onset Comparison; 2450 rpm, 26 inHg MAP

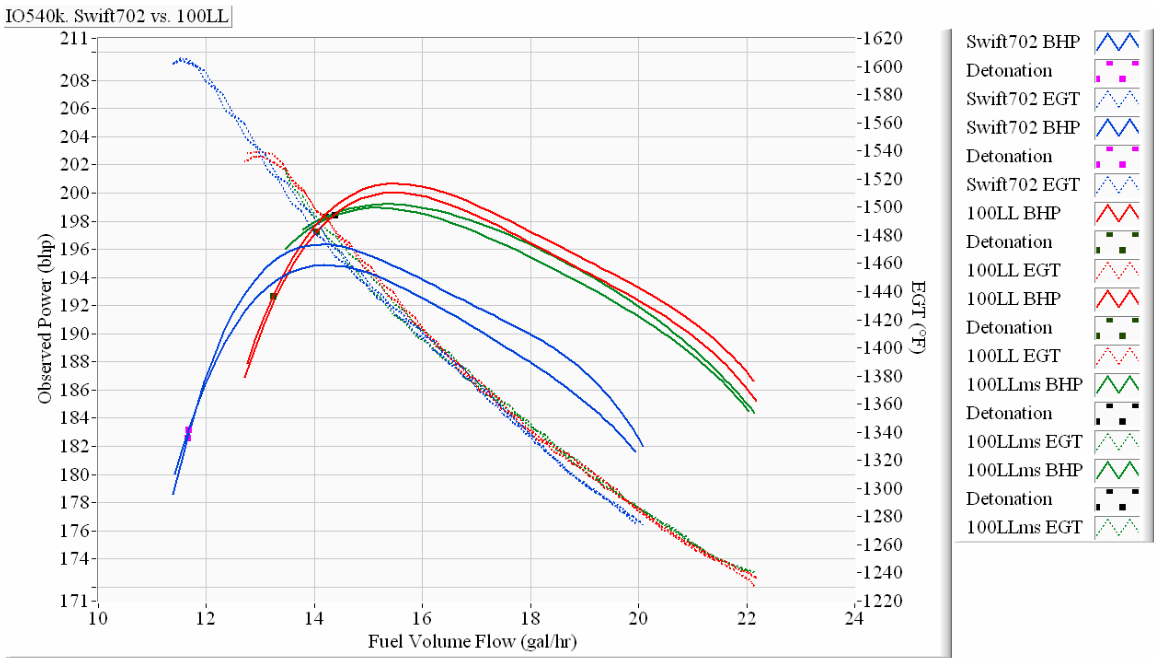


Figure B-23. Detonation Onset Comparison; 2450 rpm, 24 inHg MAP

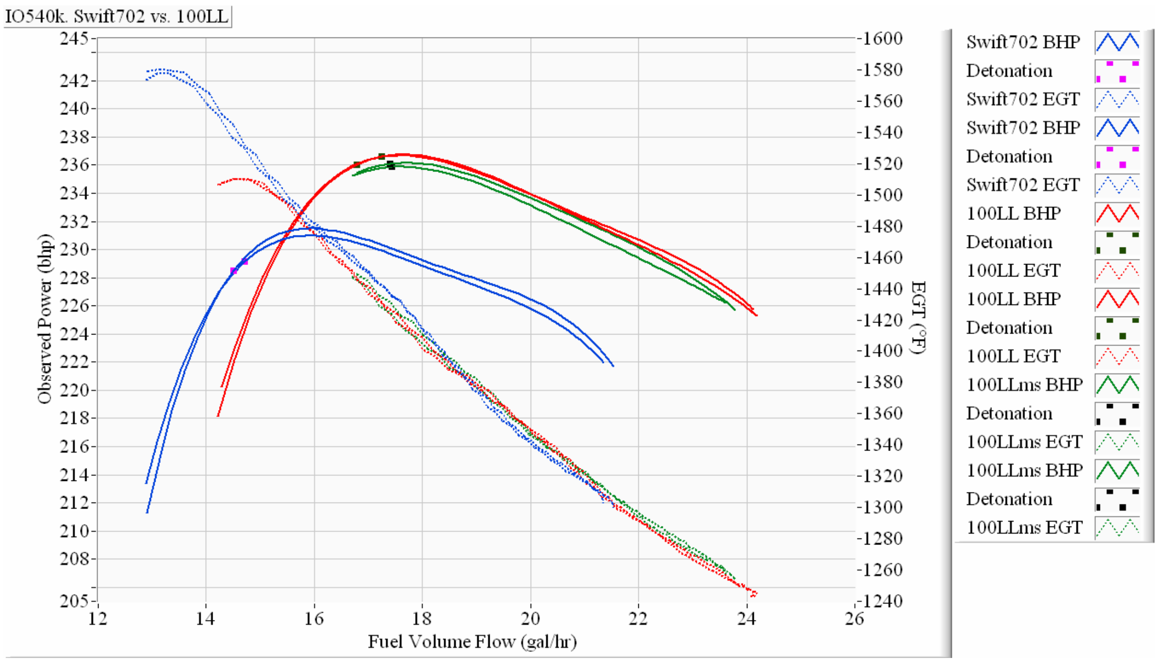


Figure B-24. Detonation Onset Comparison; 2350 rpm, 28 inHg MAP

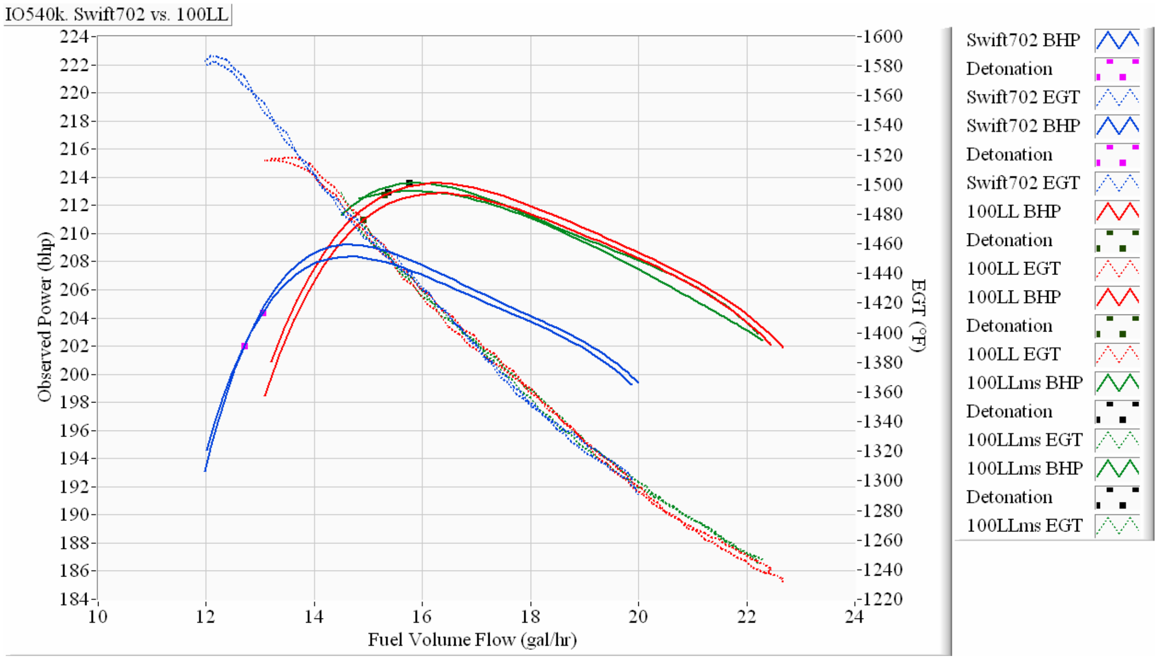


Figure B-25. Detonation Onset Comparison; 2350 rpm, 26 inHg MAP

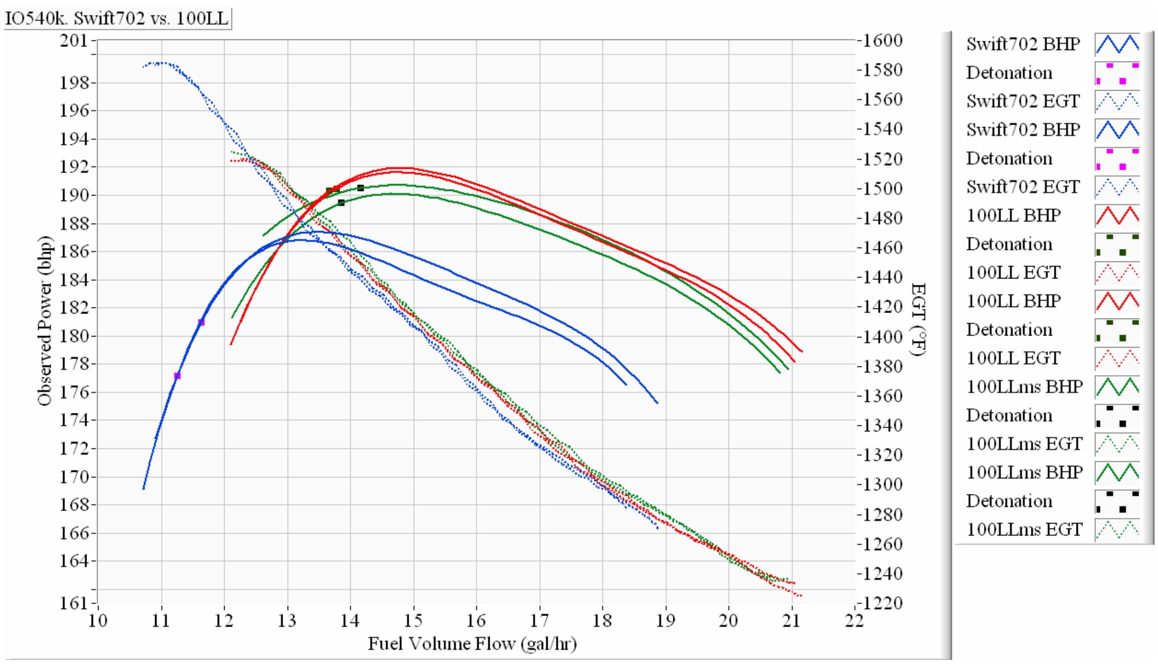


Figure B-26. Detonation Onset Comparison; 2350 rpm, 24 inHg MAP

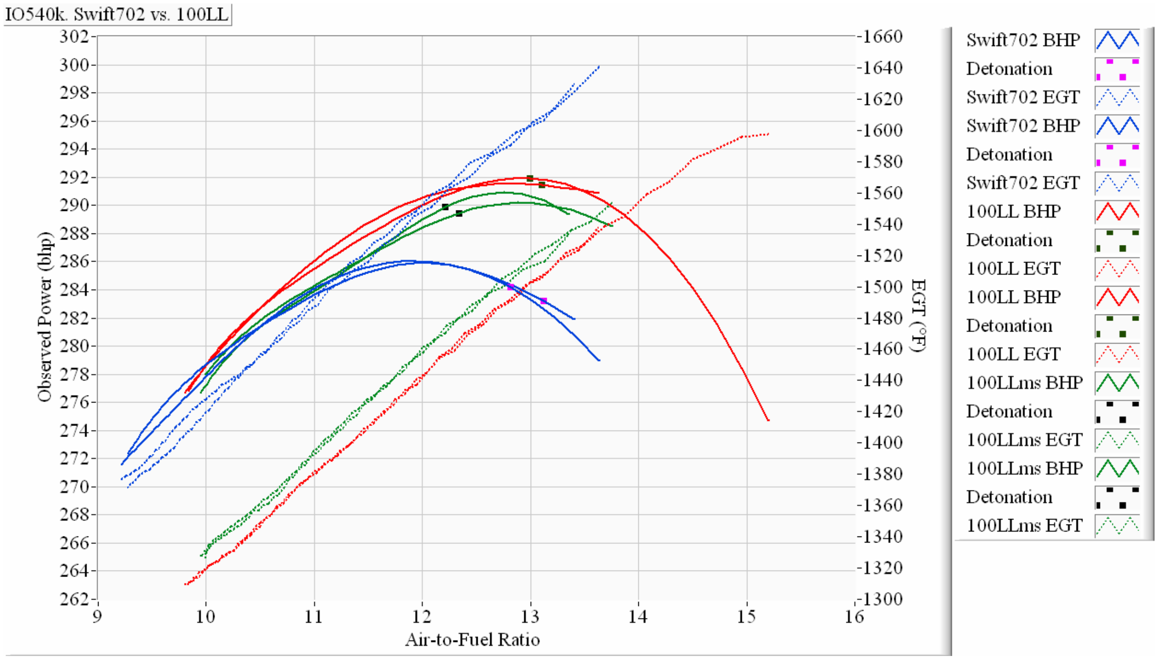


Figure B-27. Detonation Onset Comparison; 2700 rpm, FT

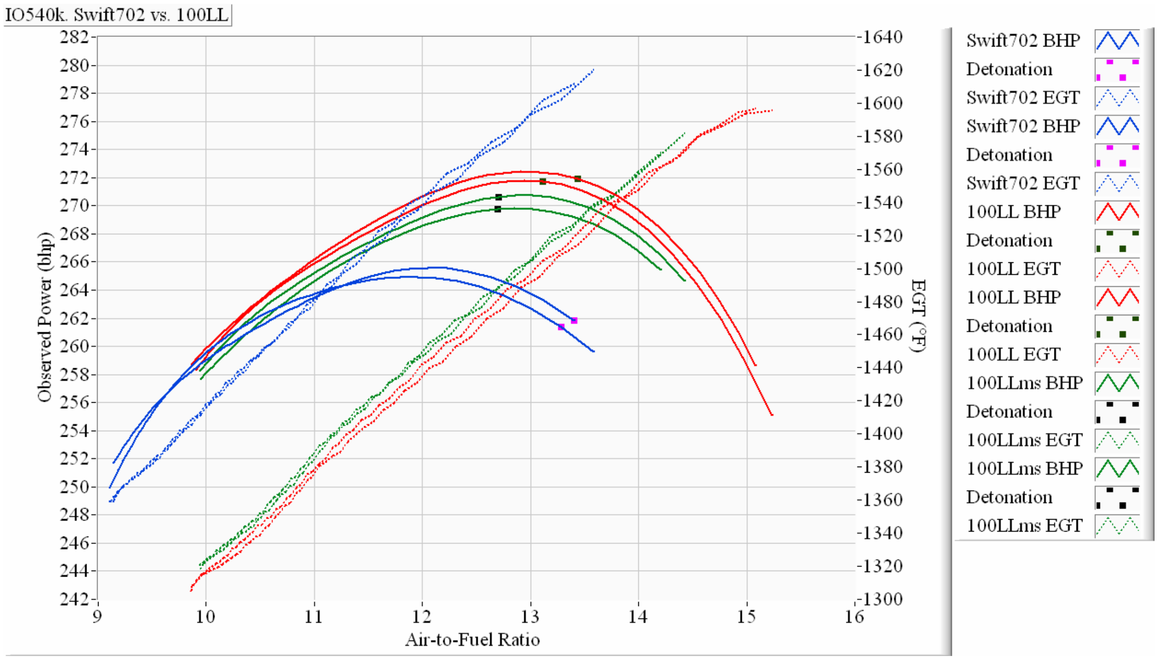


Figure B-28. Detonation Onset Comparison; 2700 rpm, 28 inHg MAP

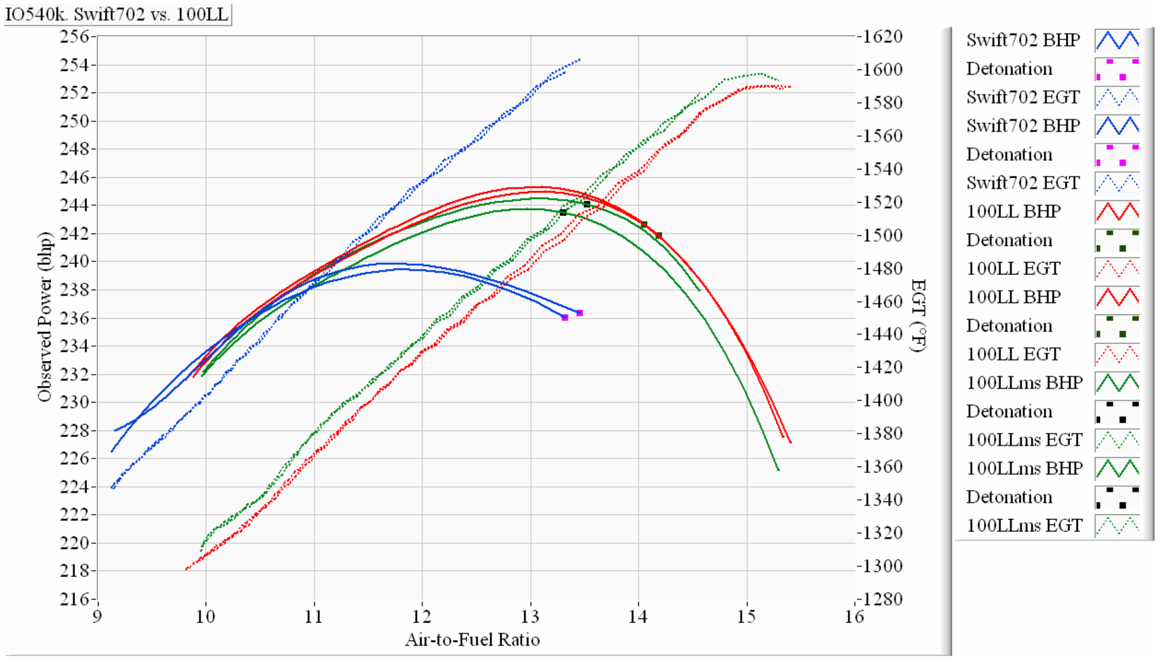


Figure B-29. Detonation Onset Comparison; 2700 rpm, 26 inHg MAP

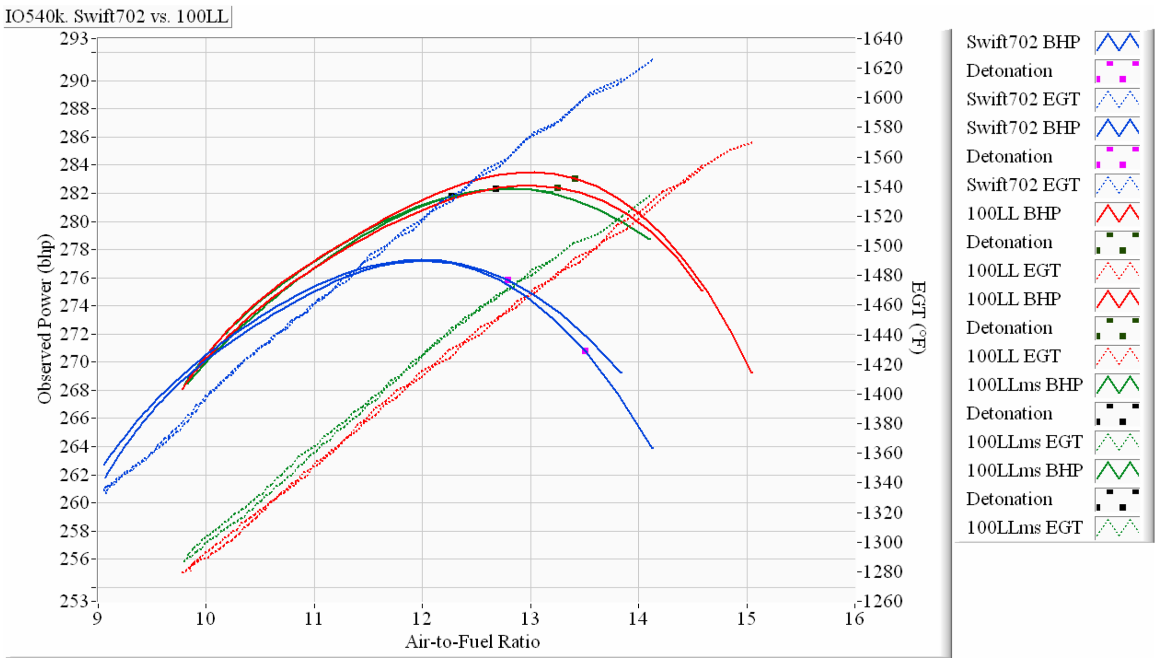


Figure B-30. Detonation Onset Comparison; 2600 rpm, FT

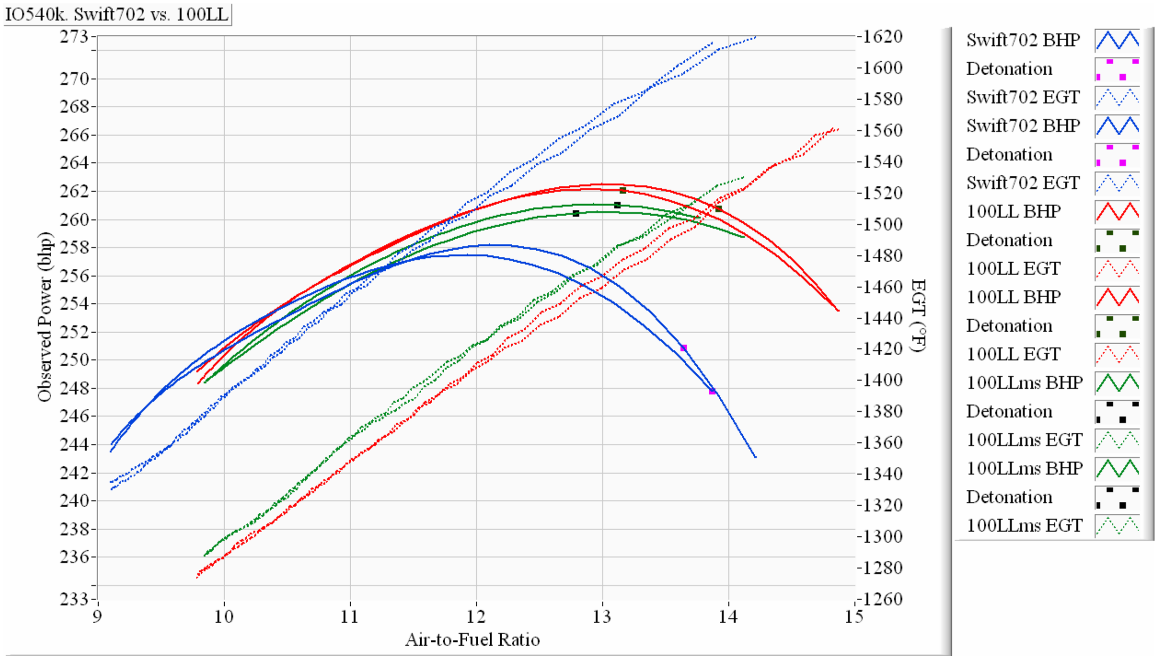


Figure B-31. Detonation Onset Comparison; 2600 rpm, 28 inHg MAP

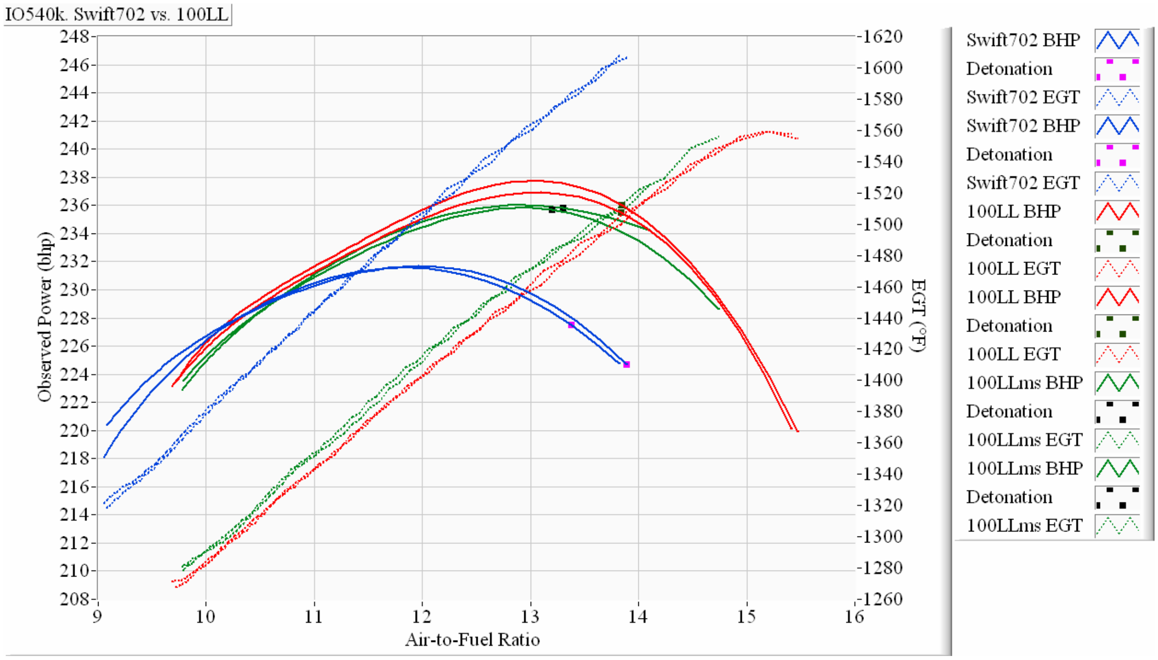


Figure B-32. Detonation Onset Comparison; 2600 rpm, 26 inHg MAP

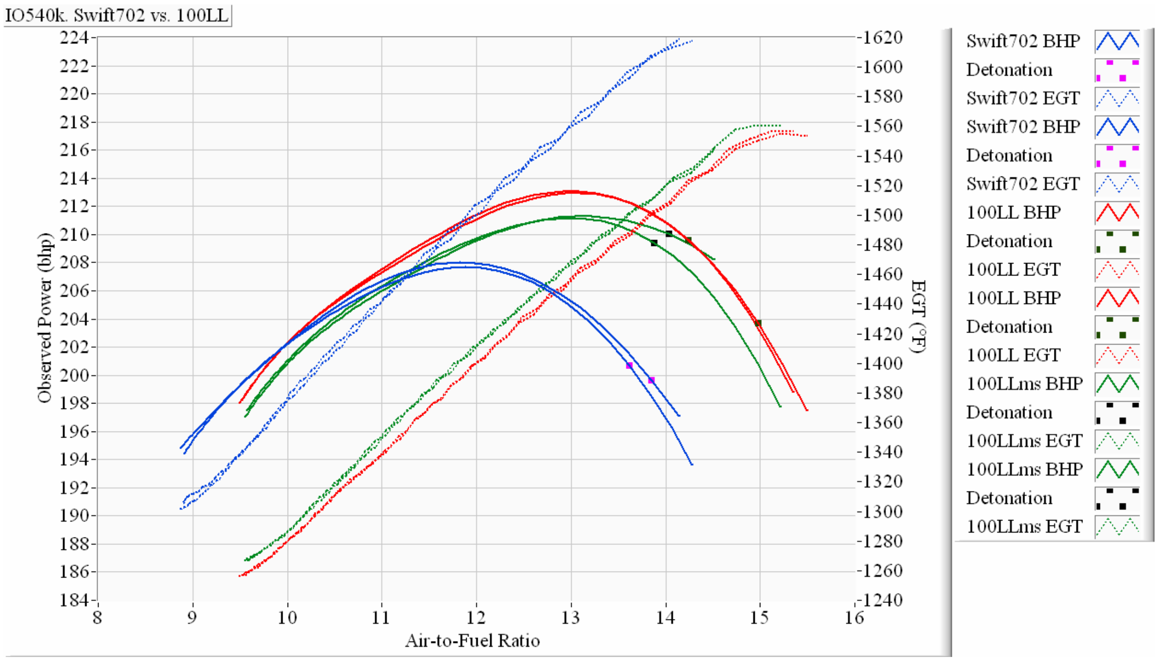


Figure B-33. Detonation Onset Comparison; 2600 rpm, 24 inHg MAP

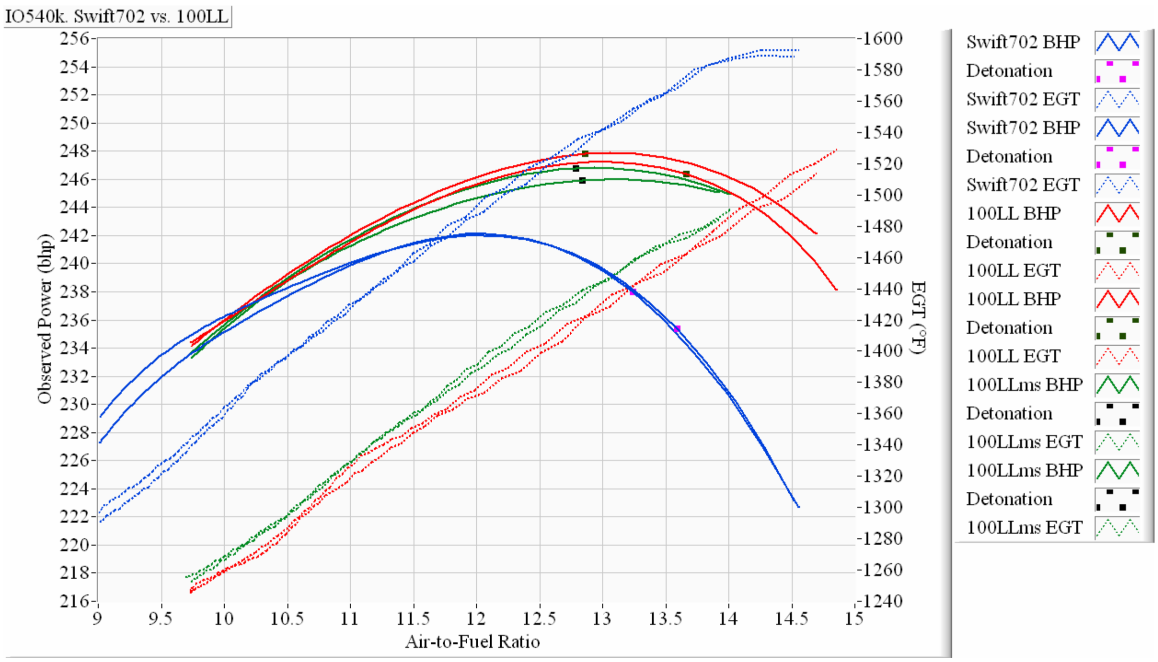


Figure B-34. Detonation Onset Comparison; 2450 rpm, 28 inHg MAP

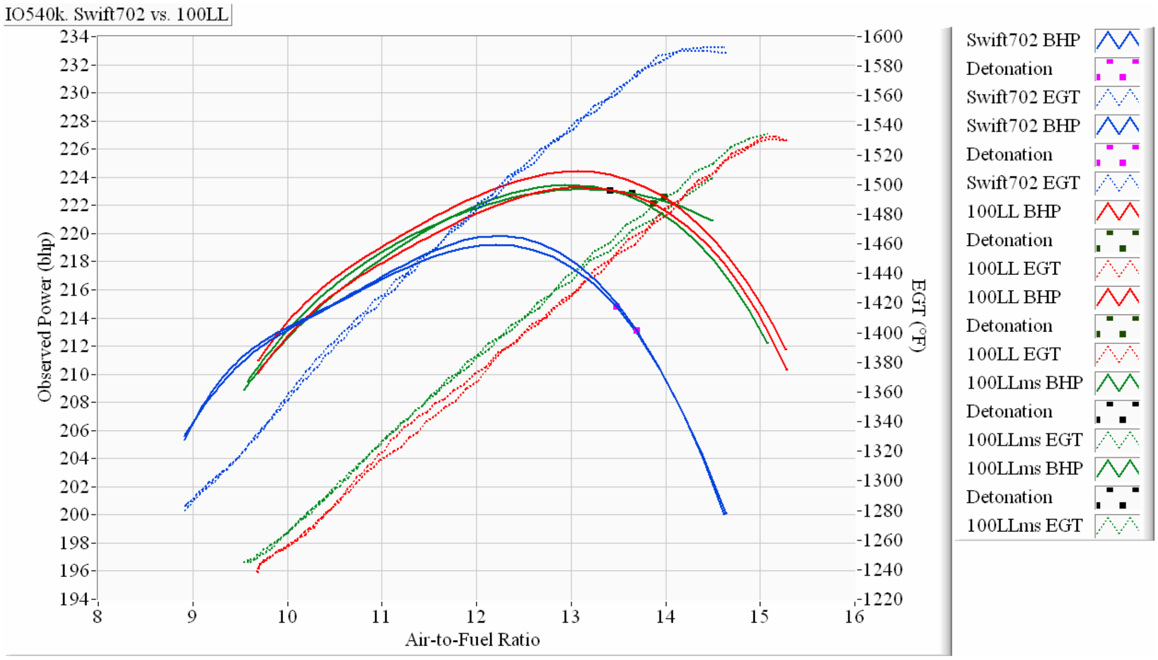


Figure B-35. Detonation Onset Comparison; 2450 rpm, 26 inHg MAP

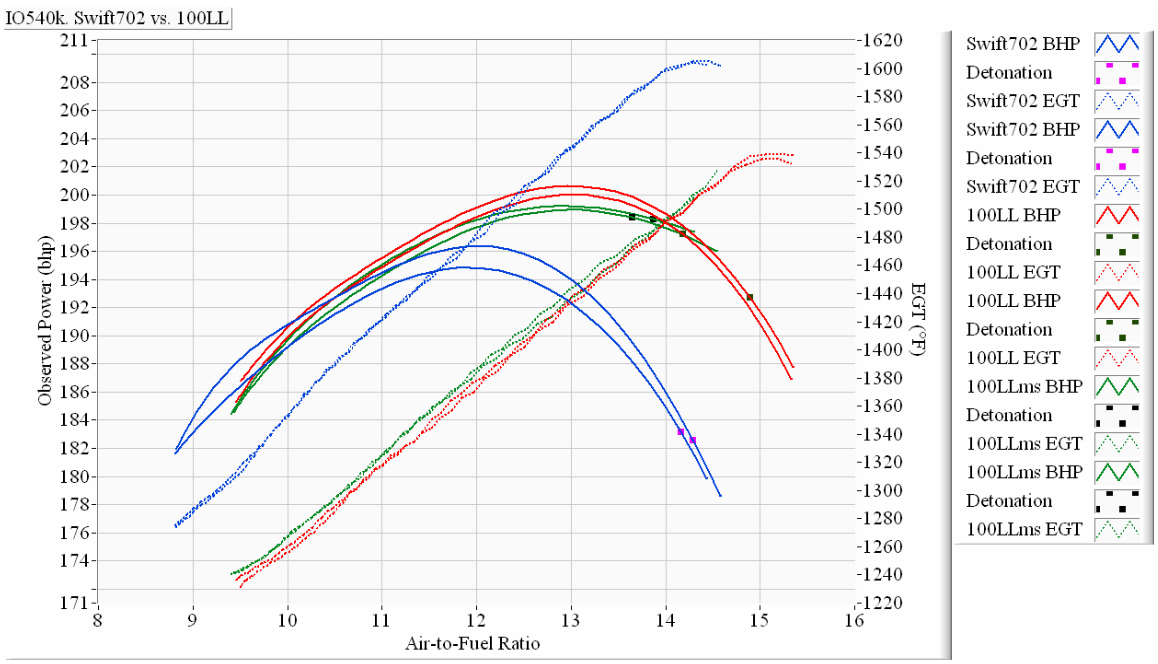


Figure B-36. Detonation Onset Comparison; 2450 rpm, 24 inHg MAP

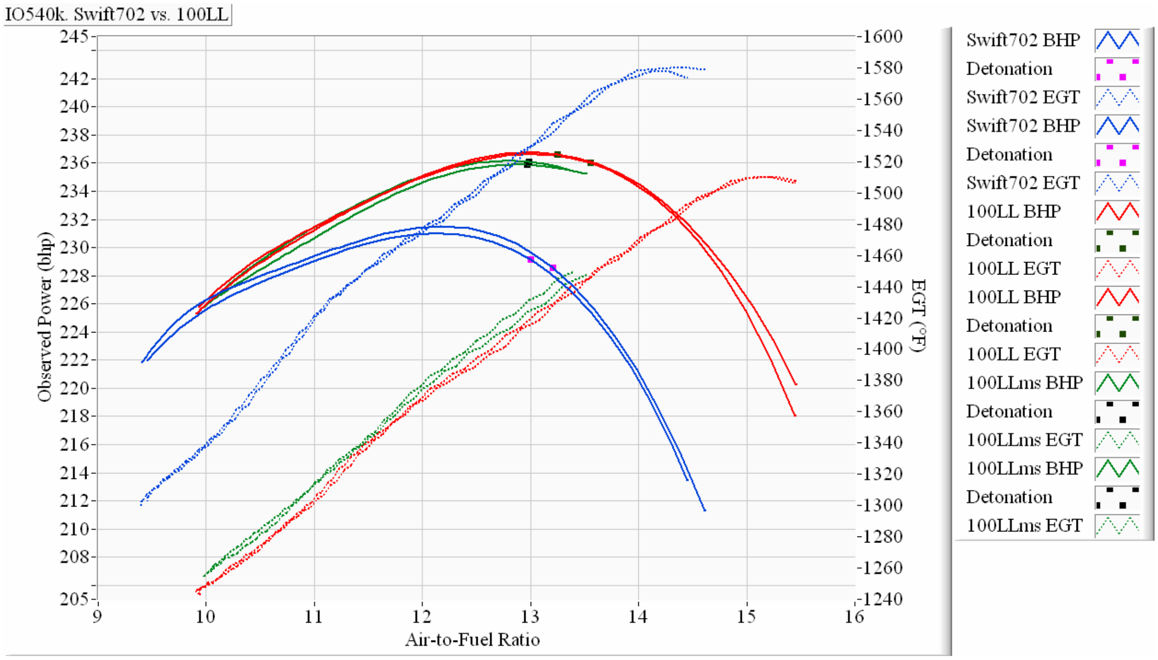


Figure B-37. Detonation Onset Comparison; 2350 rpm, 28 inHg MAP

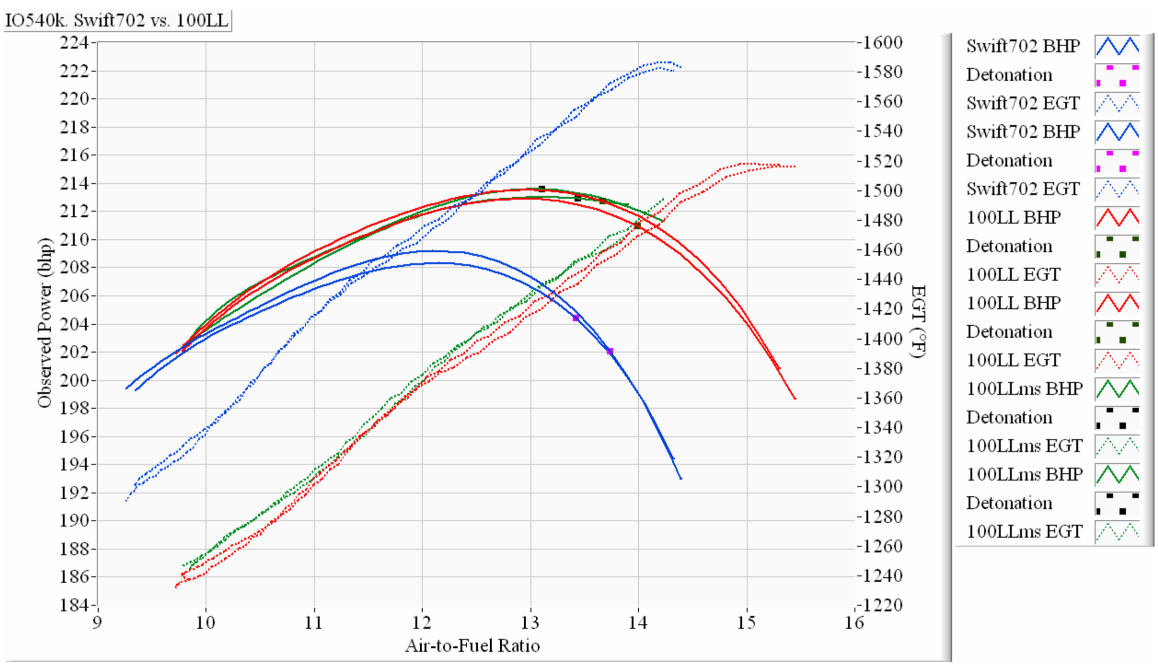


Figure B-38. Detonation Onset Comparison; 2350 rpm, 26 inHg MAP

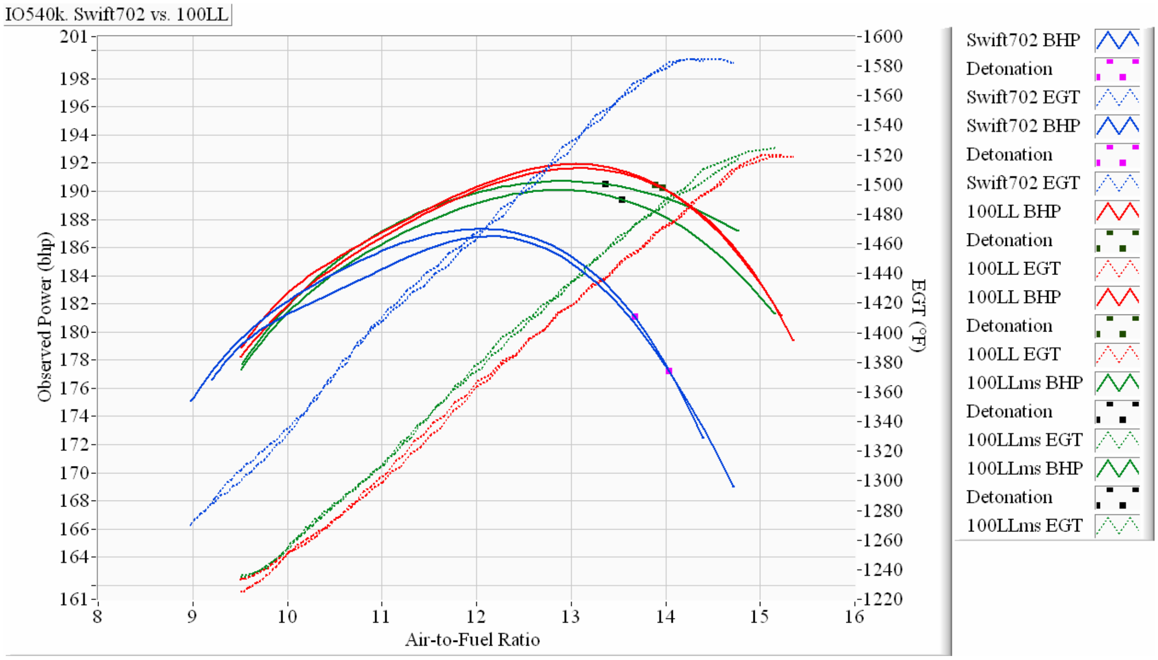


Figure B-39. Detonation Onset Comparison; 2350 rpm, 24 inHg MAP

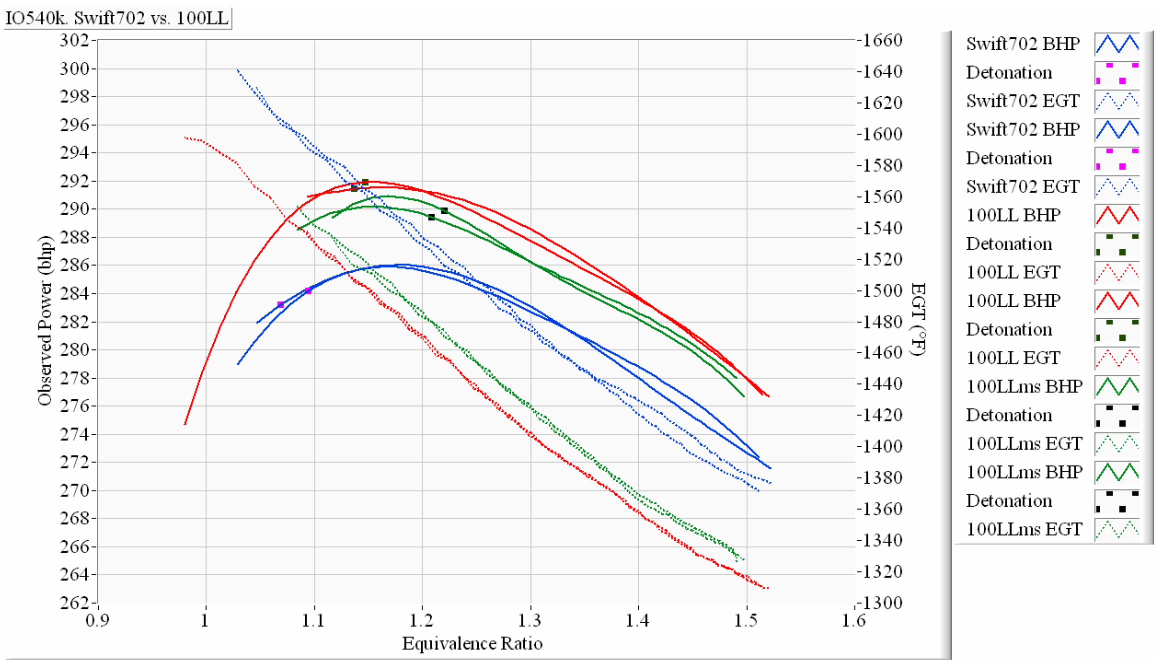


Figure B-40. Detonation Onset Comparison; 2700 rpm, FT

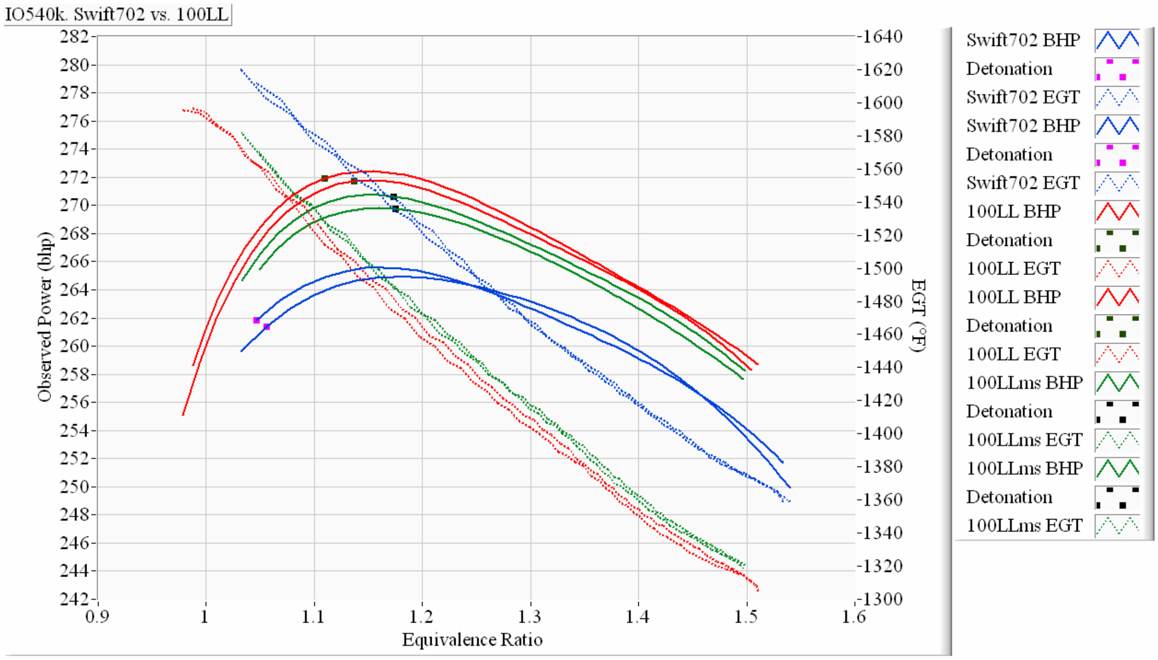


Figure B-41. Detonation Onset Comparison; 2700 rpm, 28 inHg MAP

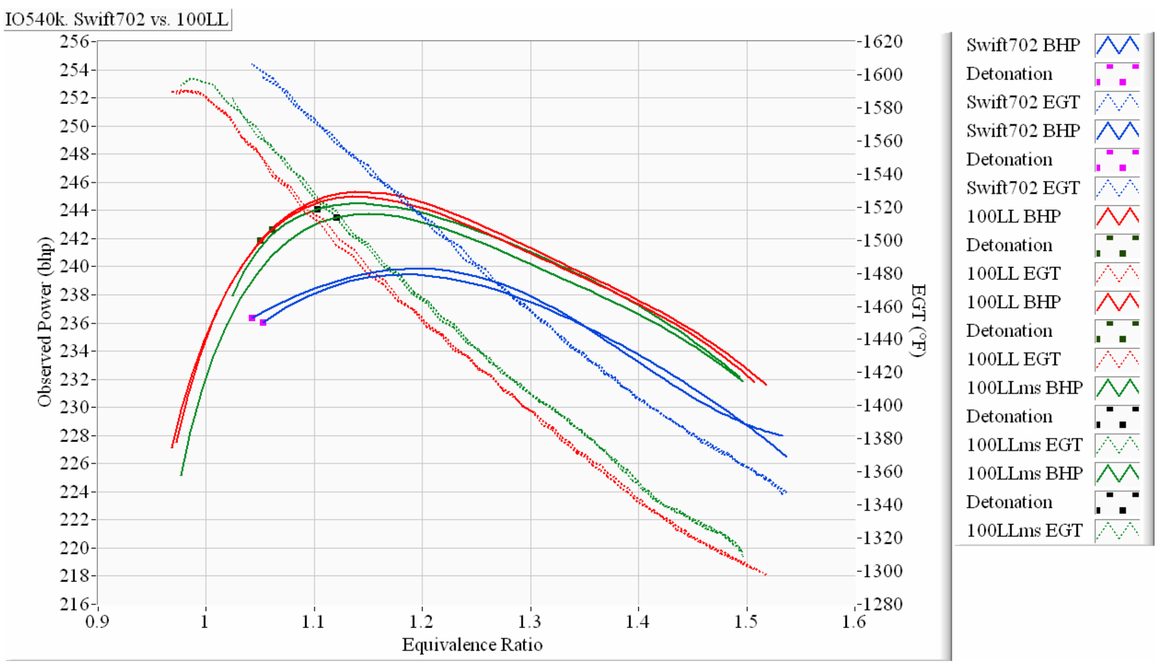


Figure B-42. Detonation Onset Comparison; 2700 rpm, 26 inHg MAP

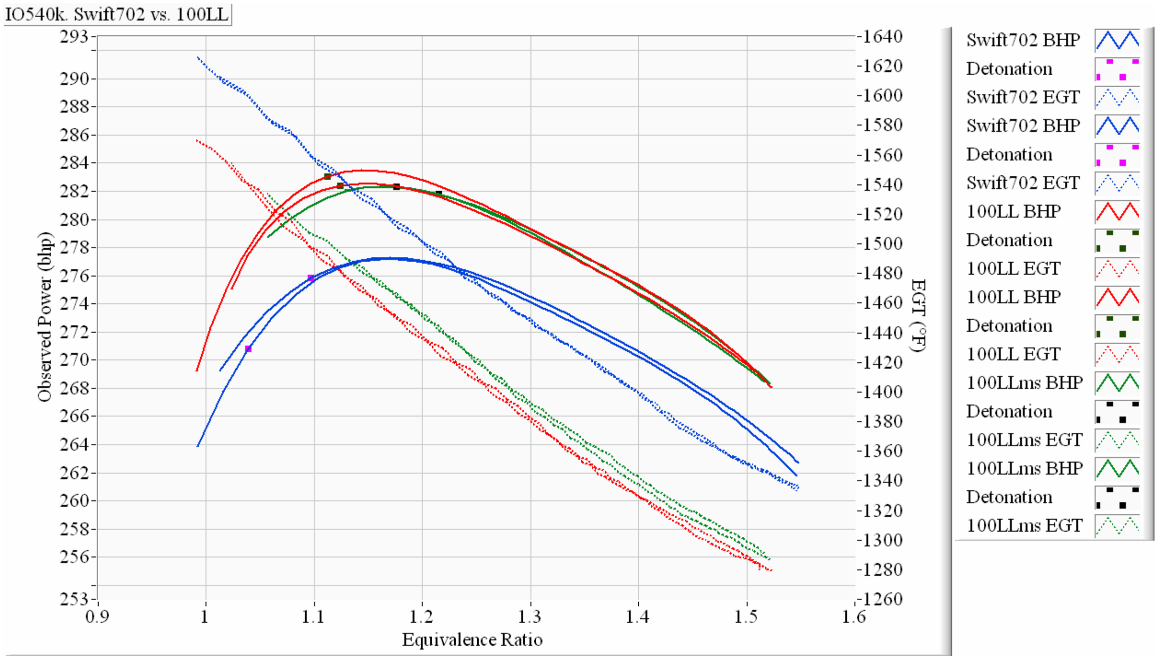


Figure B-43. Detonation Onset Comparison; 2600 rpm, FT

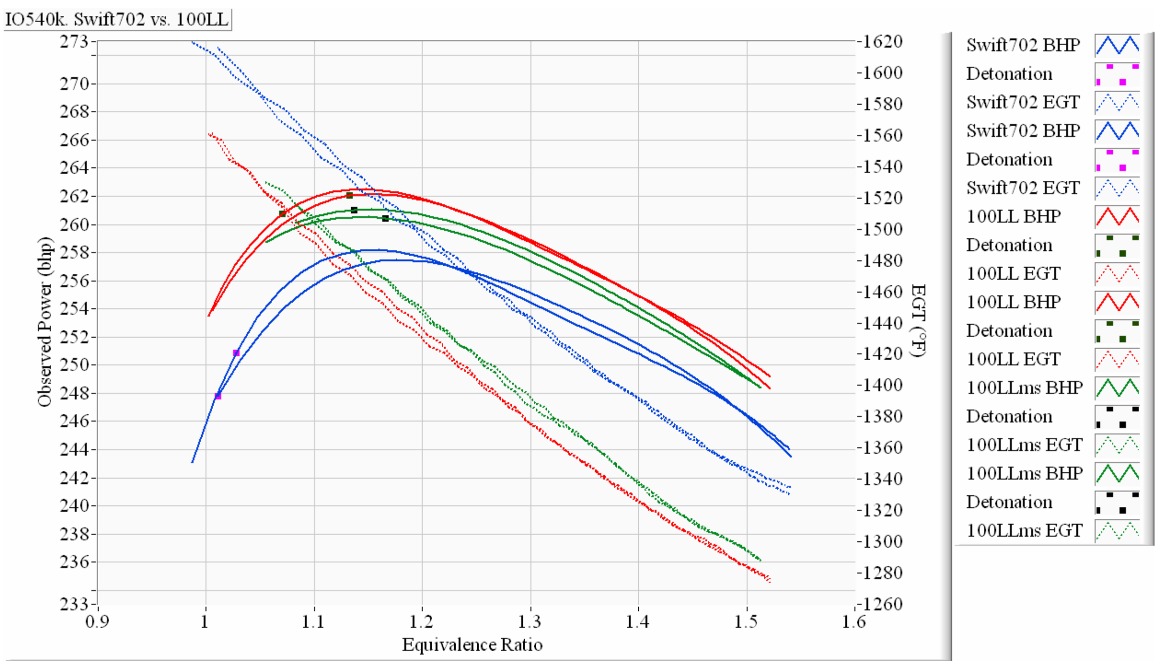


Figure B-44. Detonation Onset Comparison; 2600 rpm, 28 inHg MAP

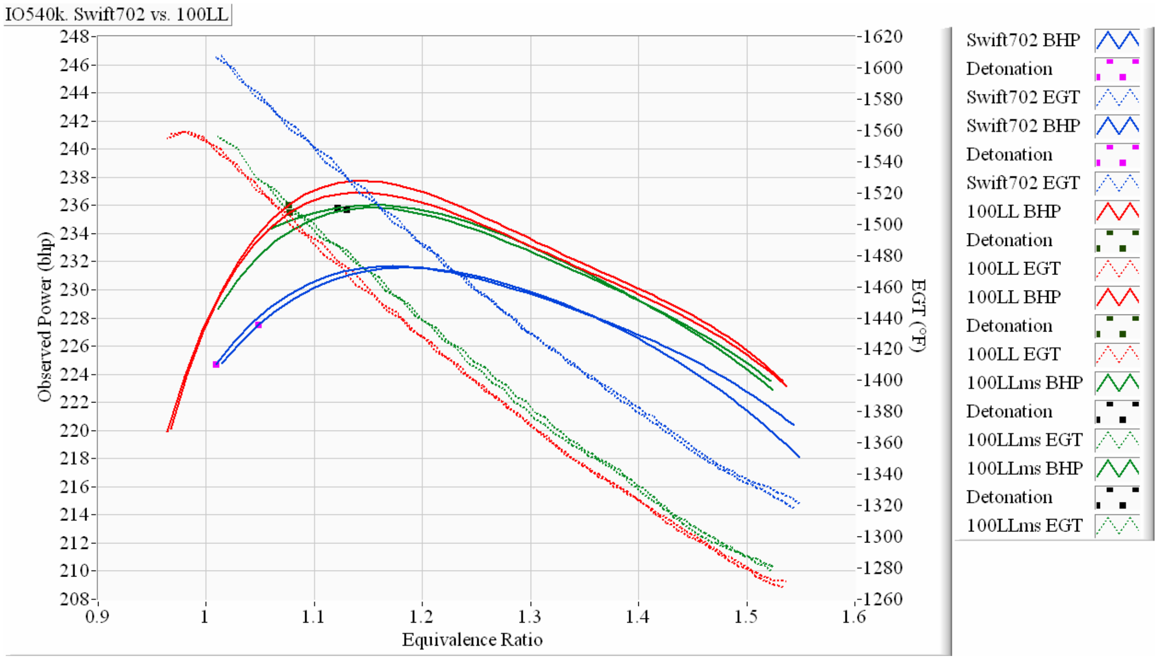


Figure B-45. Detonation Onset Comparison; 2600 rpm, 26 inHg MAP

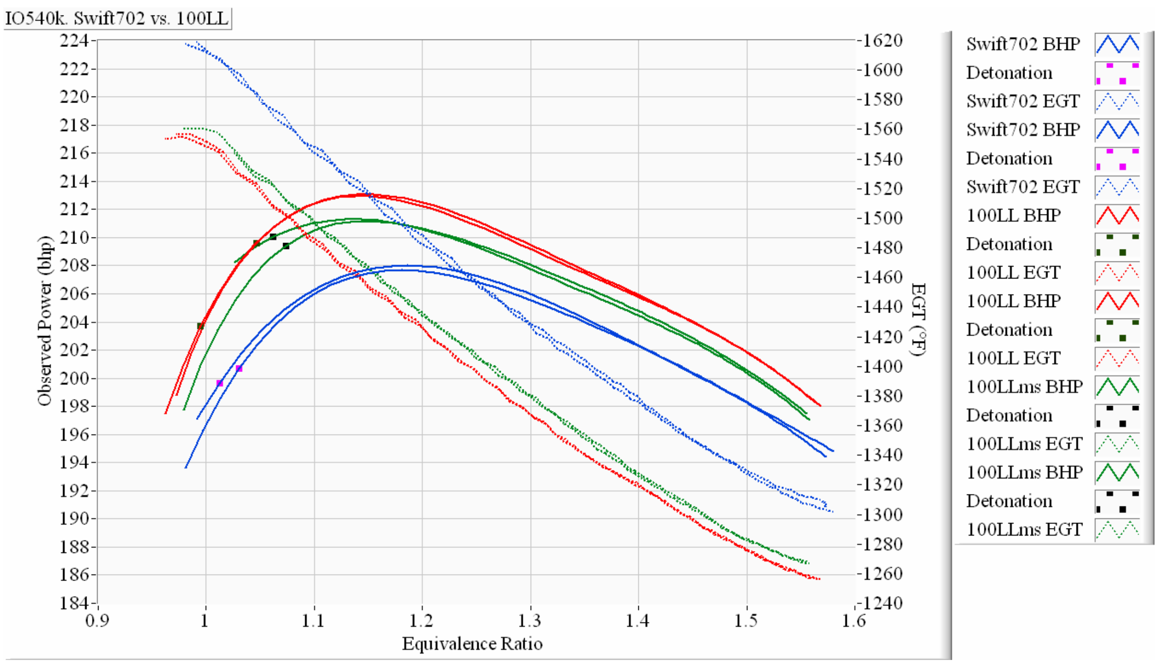


Figure B-46. Detonation Onset Comparison; 2600 rpm, 24 inHg MAP

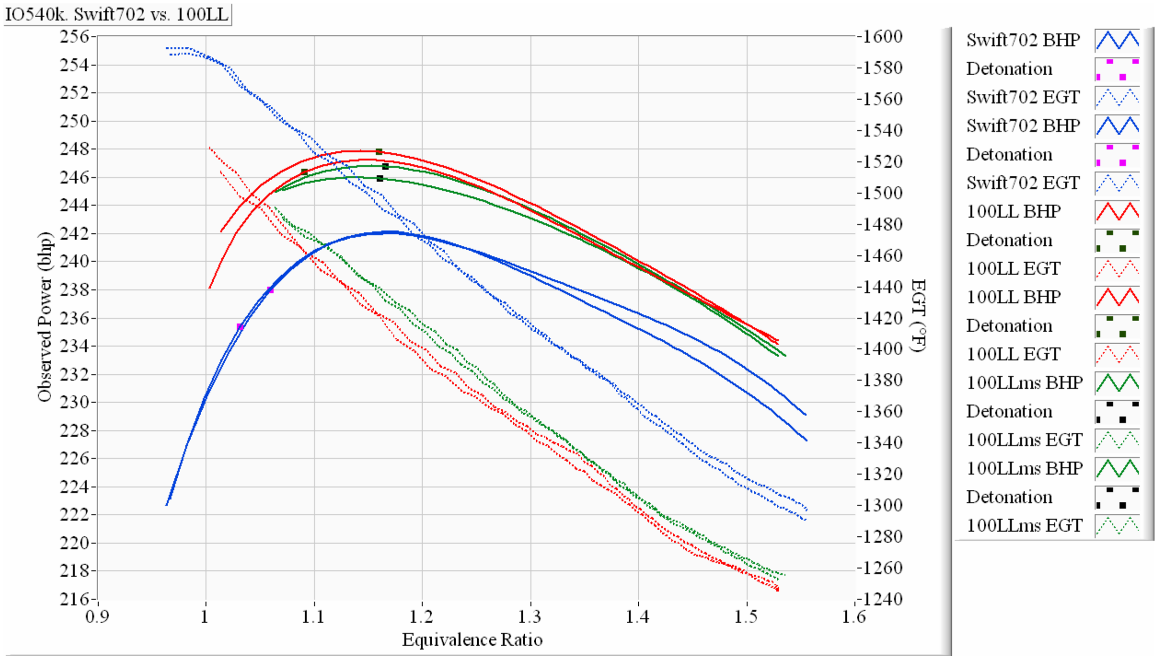
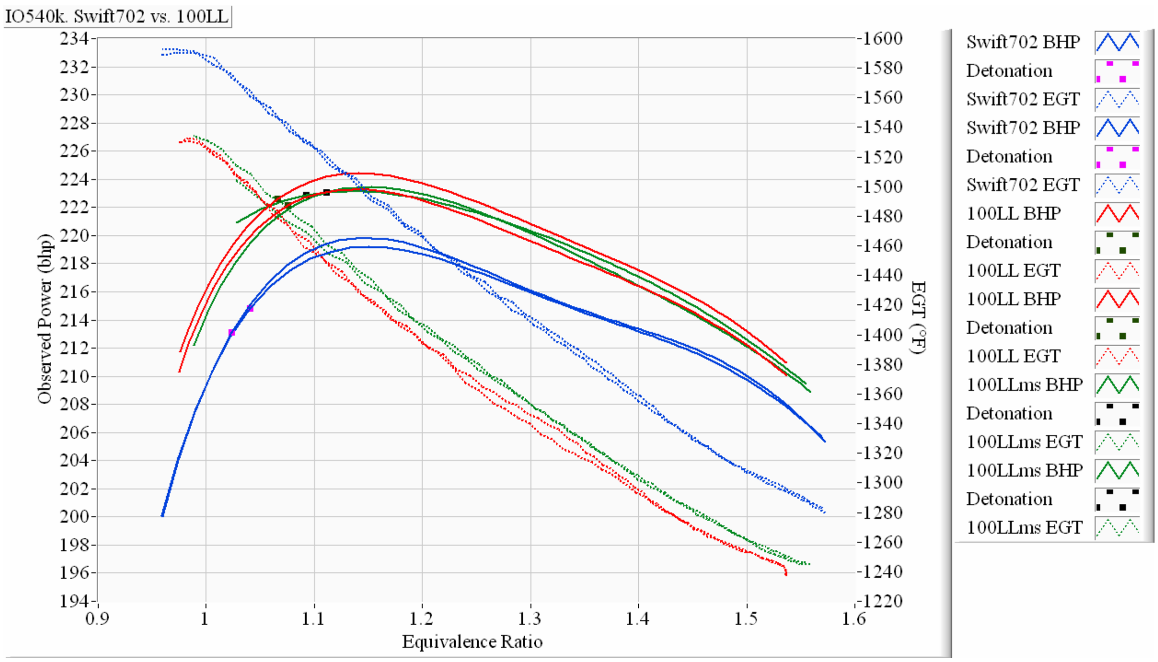


Figure B-47. Detonation Onset Comparison; 2450 rpm, 28 inHg MAP



FIigure B-48. Detonation Onset Comparison; 2450 rpm, 26 inHg MAP

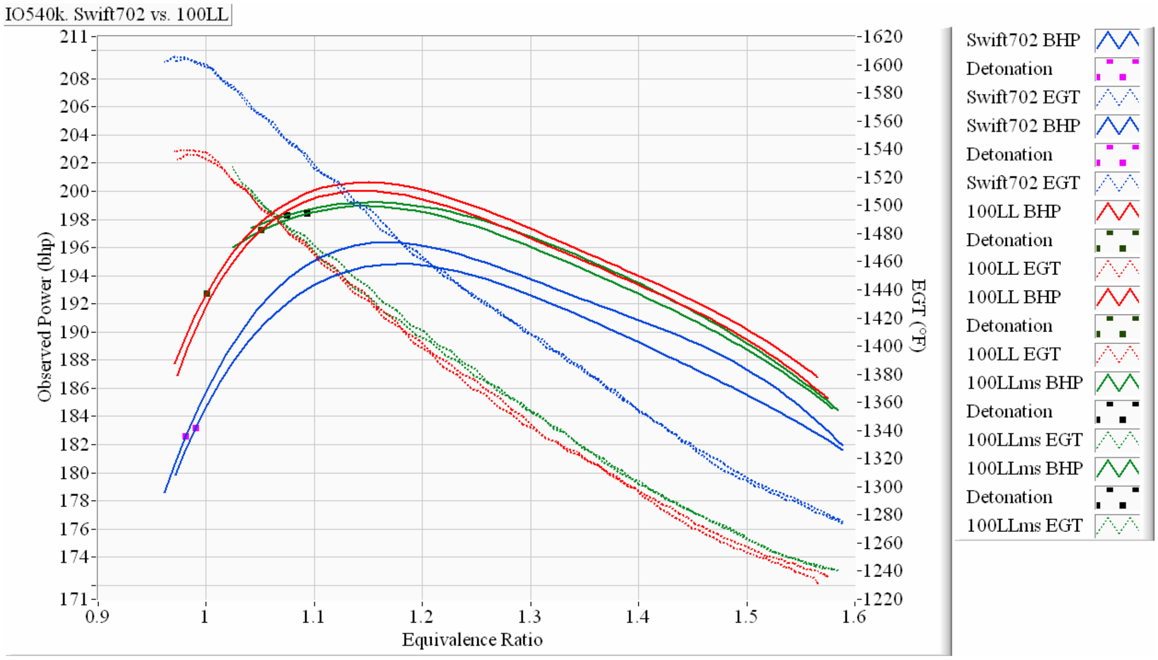


Figure B-49. Detonation Onset Comparison; 2450 rpm, 24 inHg MAP

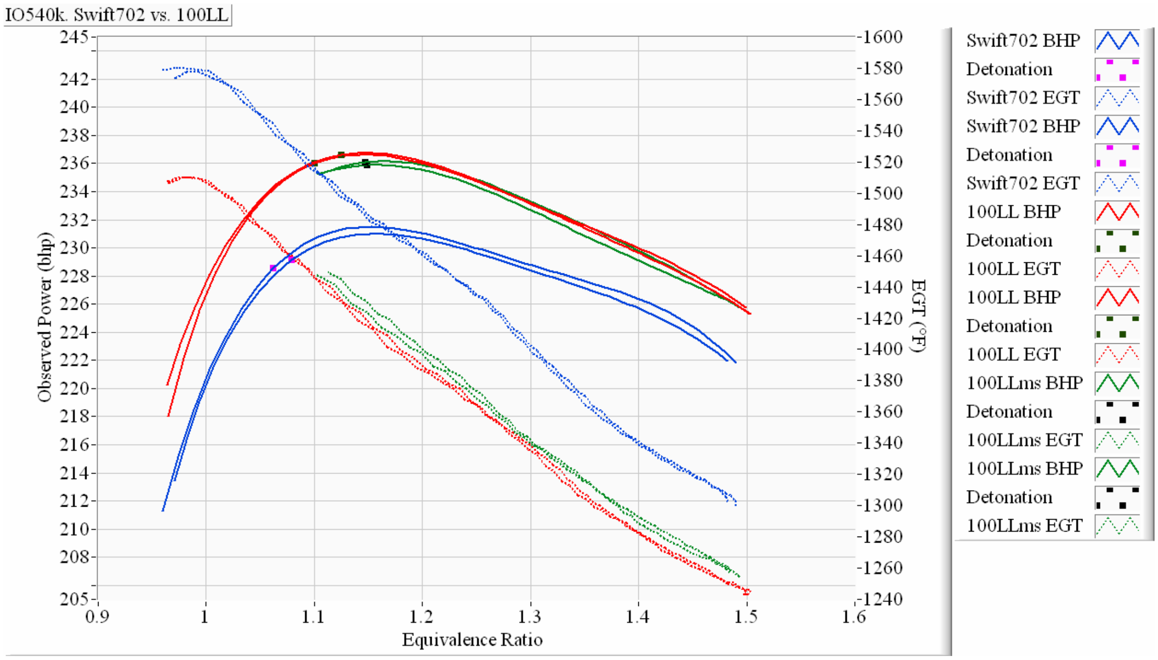


Figure B-50. Detonation Onset Comparison; 2350 rpm, 28 inHg MAP

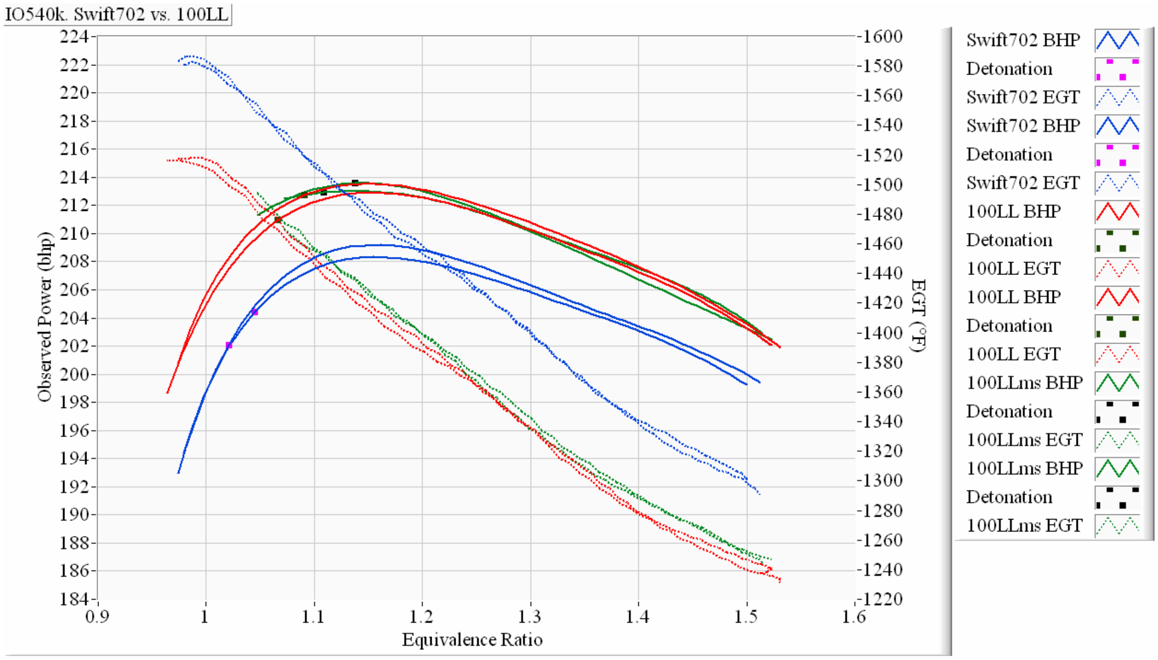


Figure B-51. Detonation Onset Comparison; 2350 rpm, 26 inHg MAP

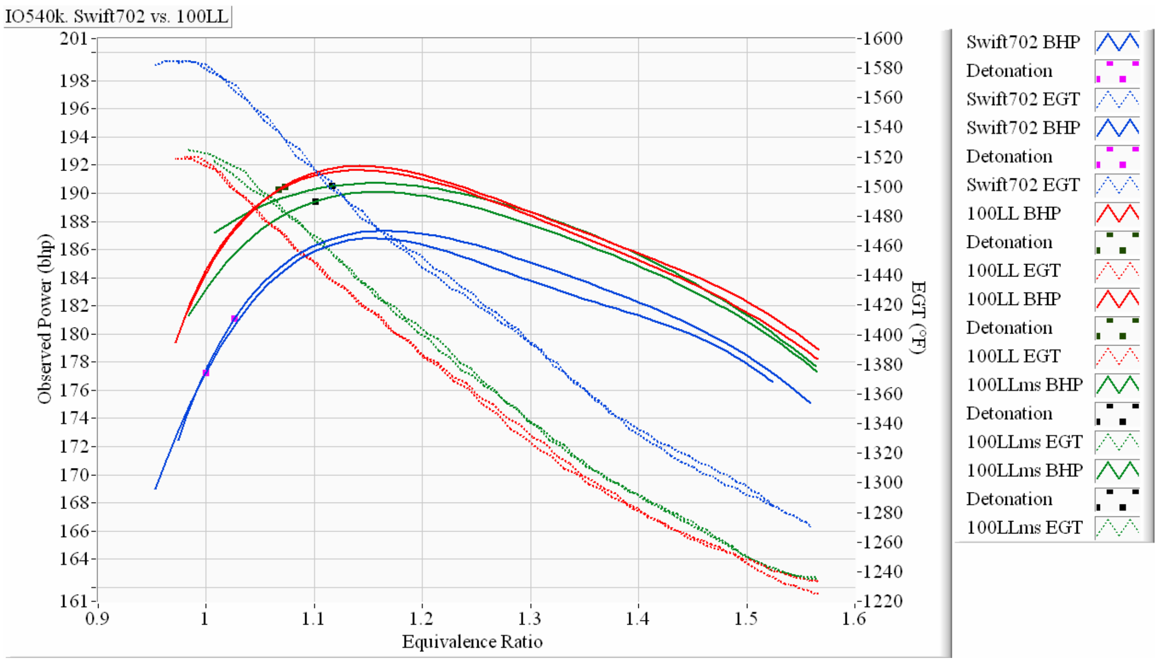


Figure B-52. Detonation Onset Comparison; 2350 rpm, 24 inHg MAP

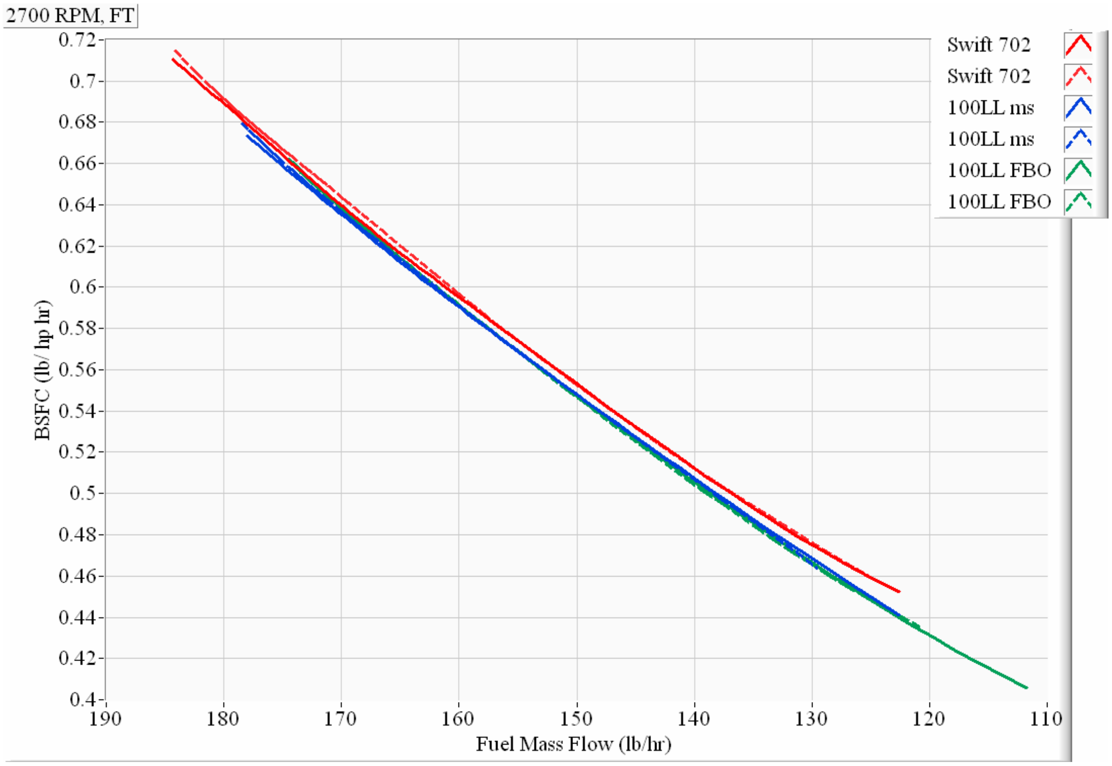


Figure B-53. Detonation Onset Comparison; 2700 rpm, FT

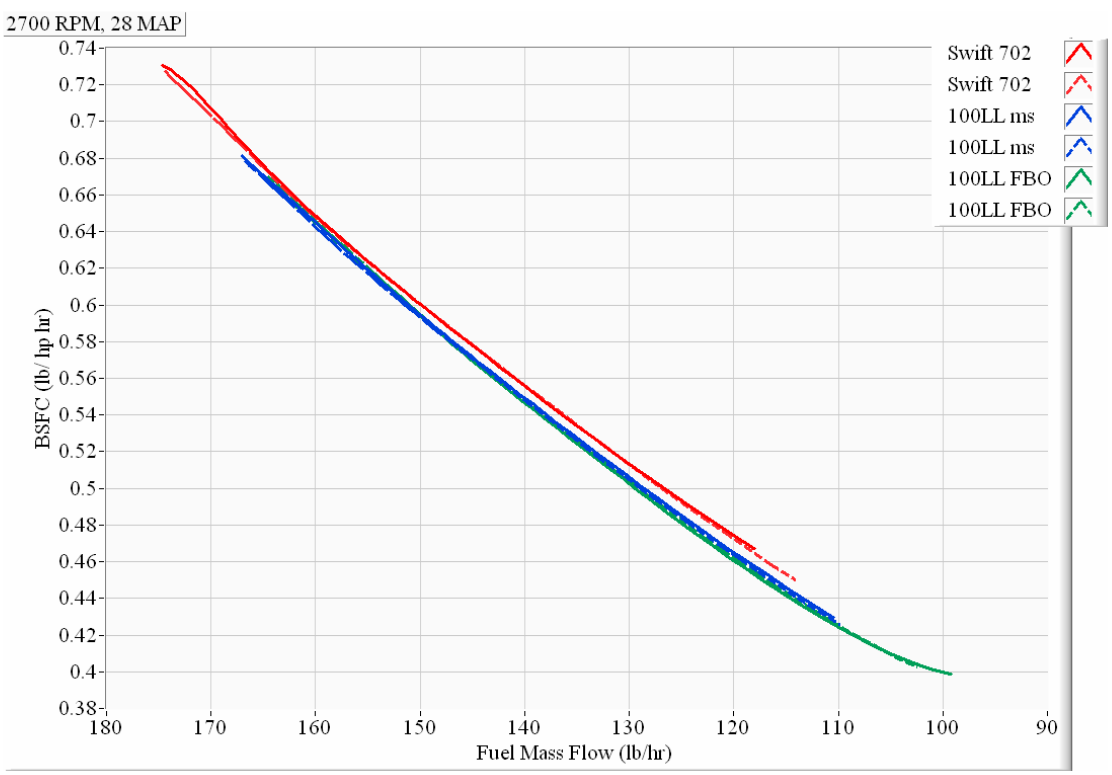


Figure B-54. Detonation Onset Comparison; 2700 rpm, 28 inHg MAP

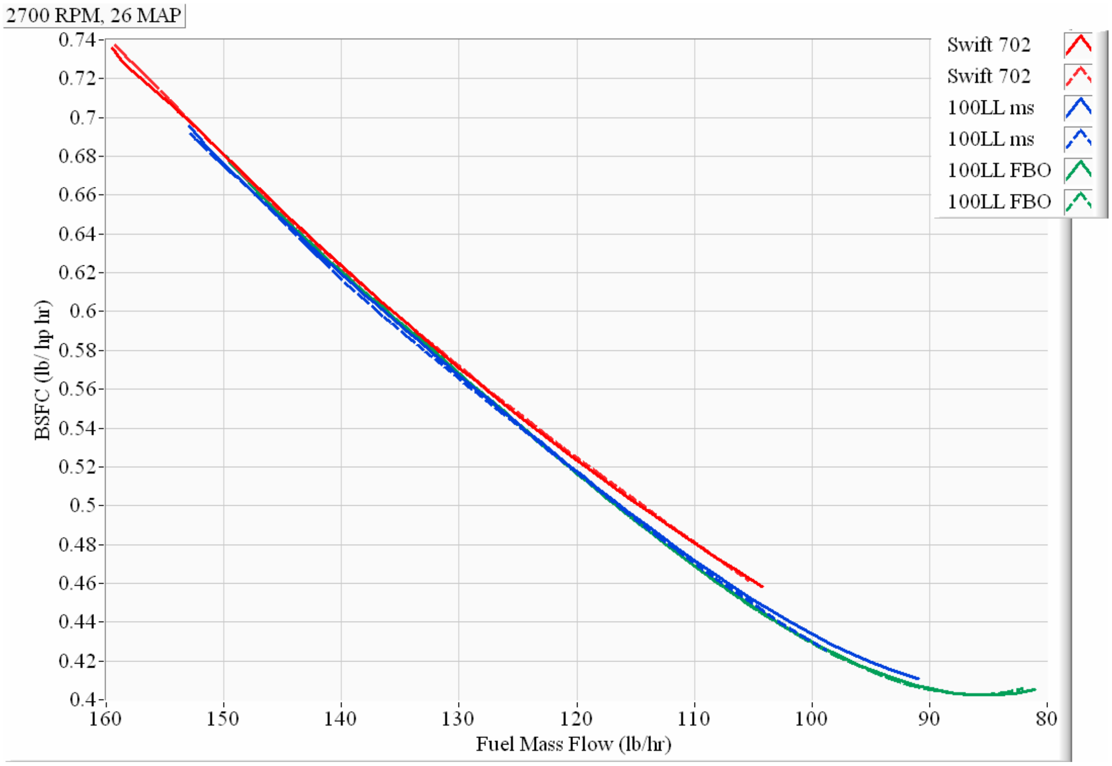


Figure B-55. Detonation Onset Comparison; 2700 rpm, 26 inHg MAP

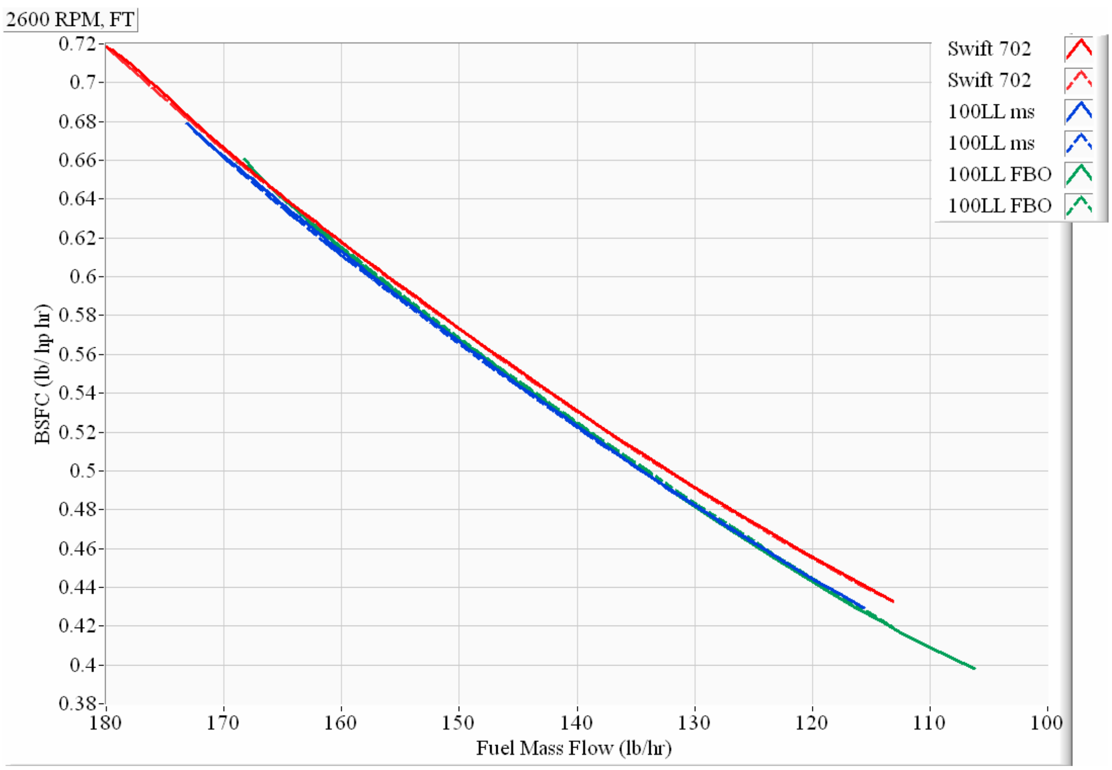


Figure B-56. Detonation Onset Comparison; 2600 rpm, FT

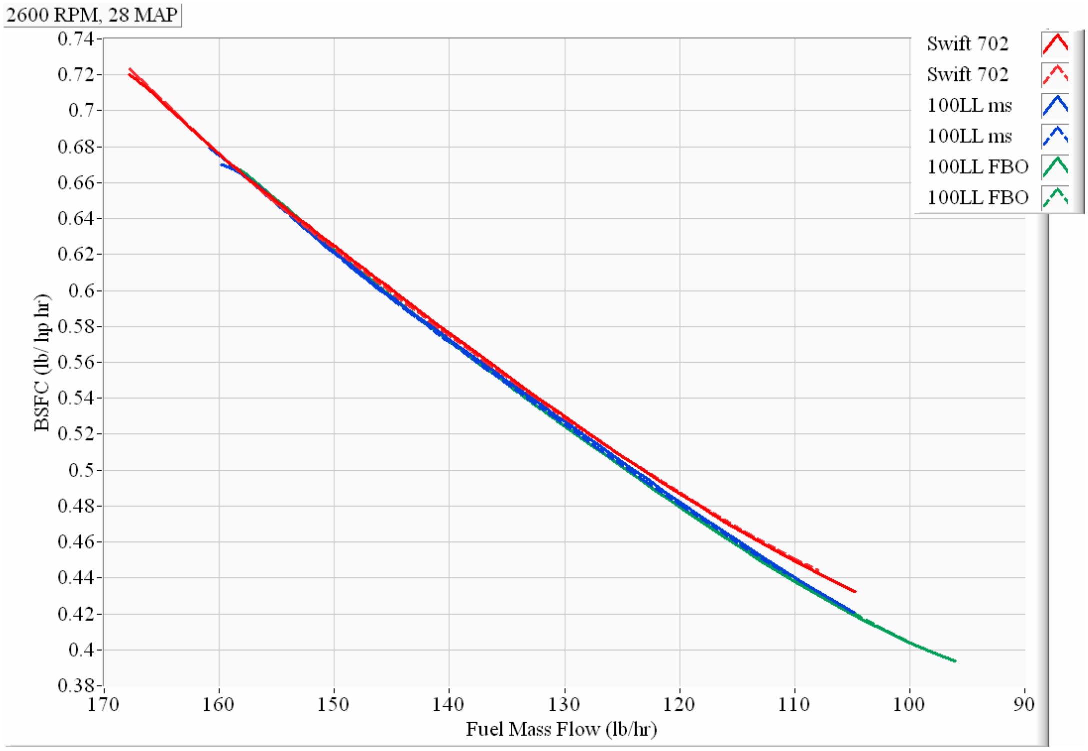


Figure B-57. Detonation Onset Comparison; 2600 rpm, 28 inHg MAP

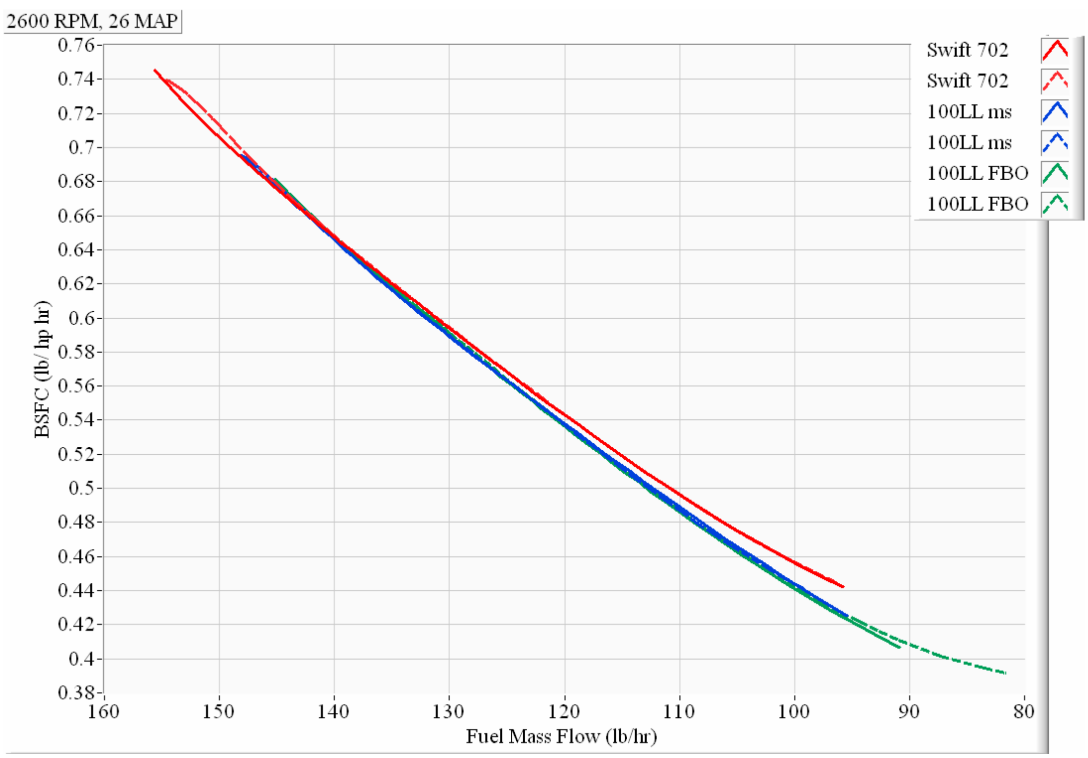


Figure B-58. Detonation Onset Comparison; 2600 rpm, 26 inHg MAP

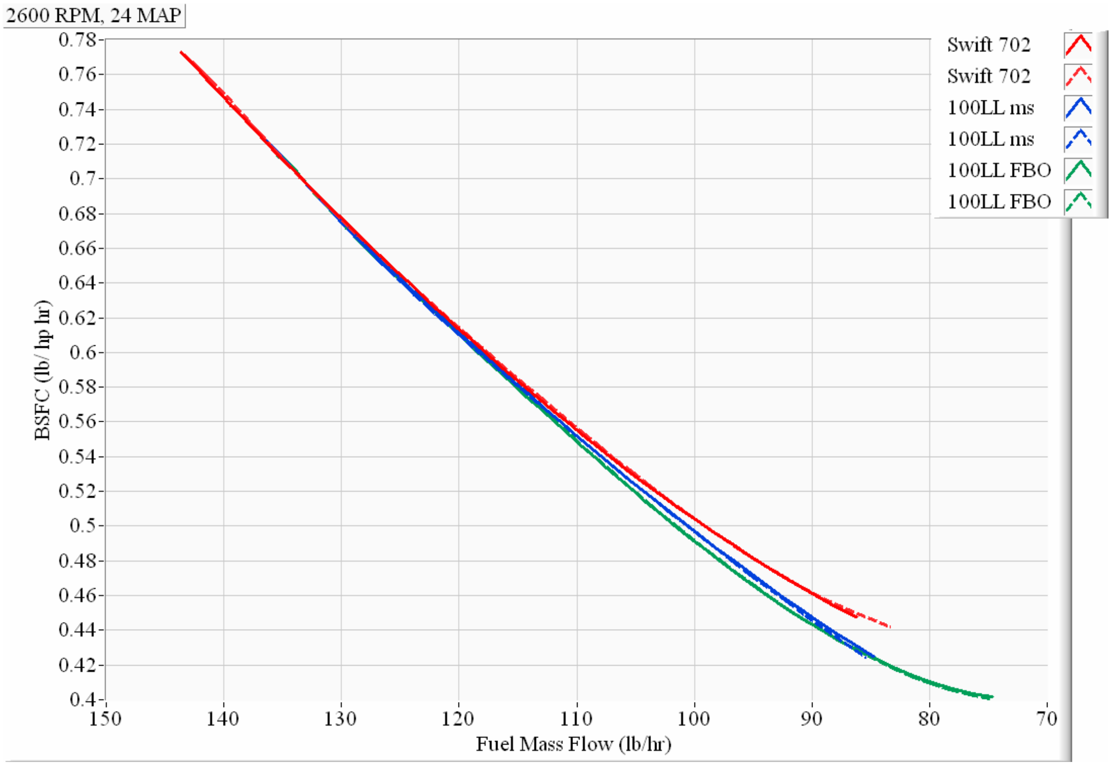


Figure B-59. Detonation Onset Comparison; 2600 rpm, 24 inHg MAP

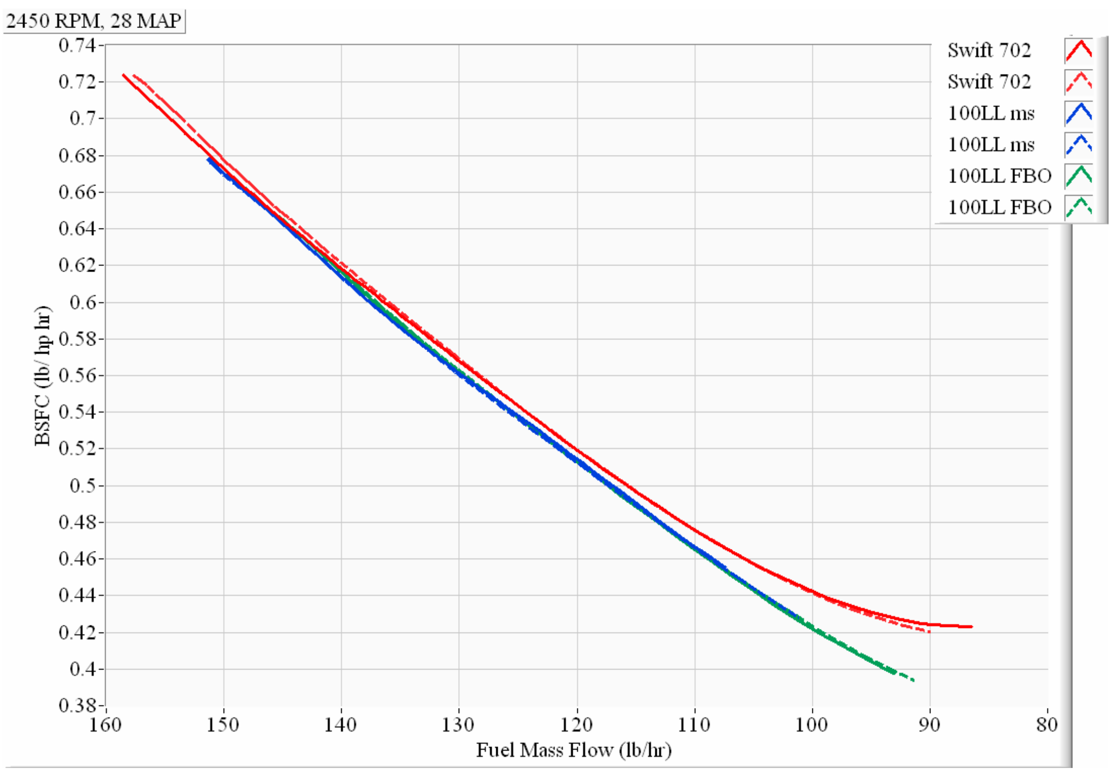


Figure B-60. Detonation Onset Comparison; 2450 rpm, 28 inHg MAP

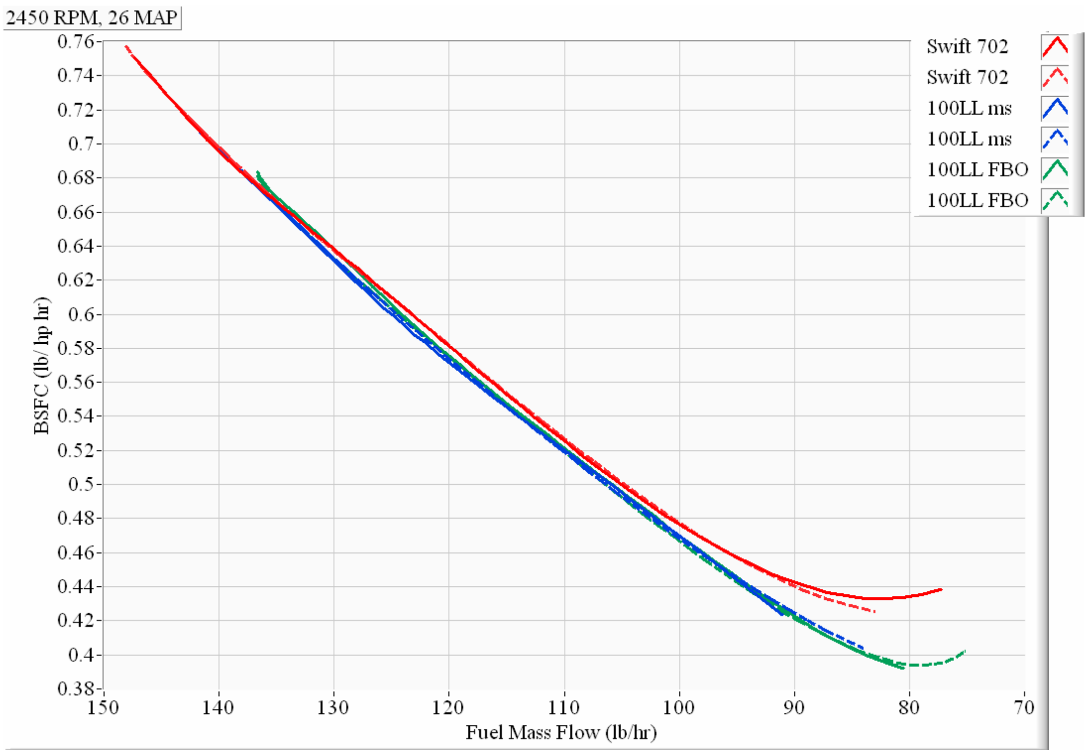


Figure B-61. Detonation Onset Comparison; 2450 rpm, 26 inHg MAP

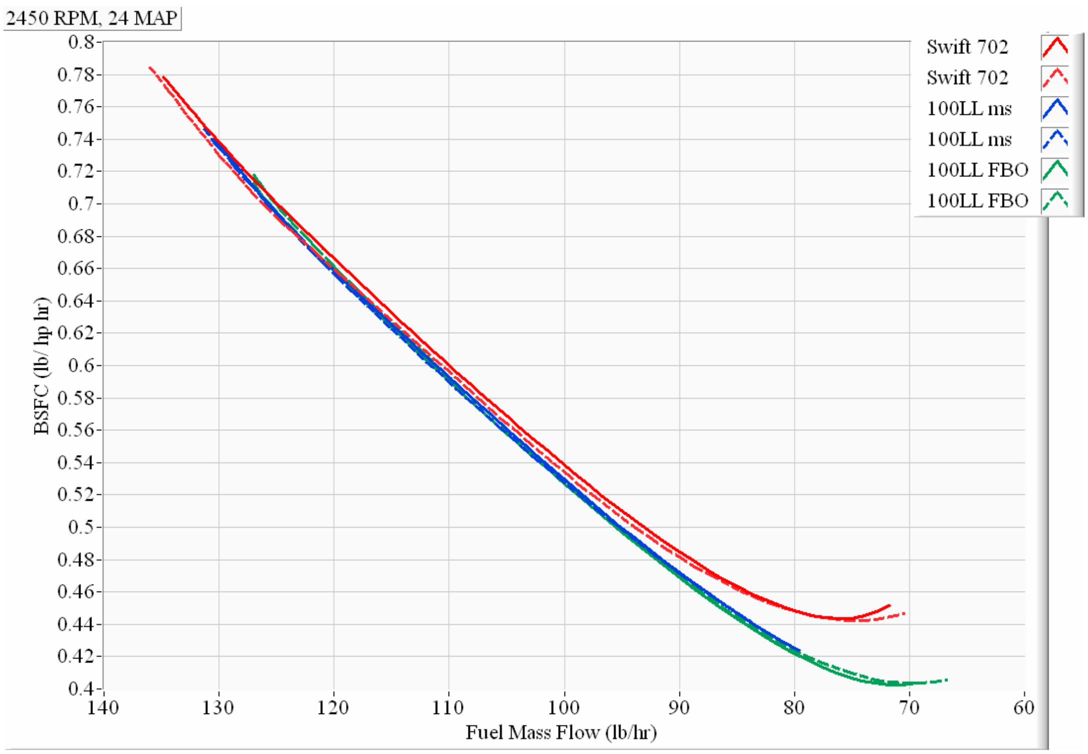


Figure B-62. Detonation Onset Comparison; 2450 rpm, 24 inHg MAP

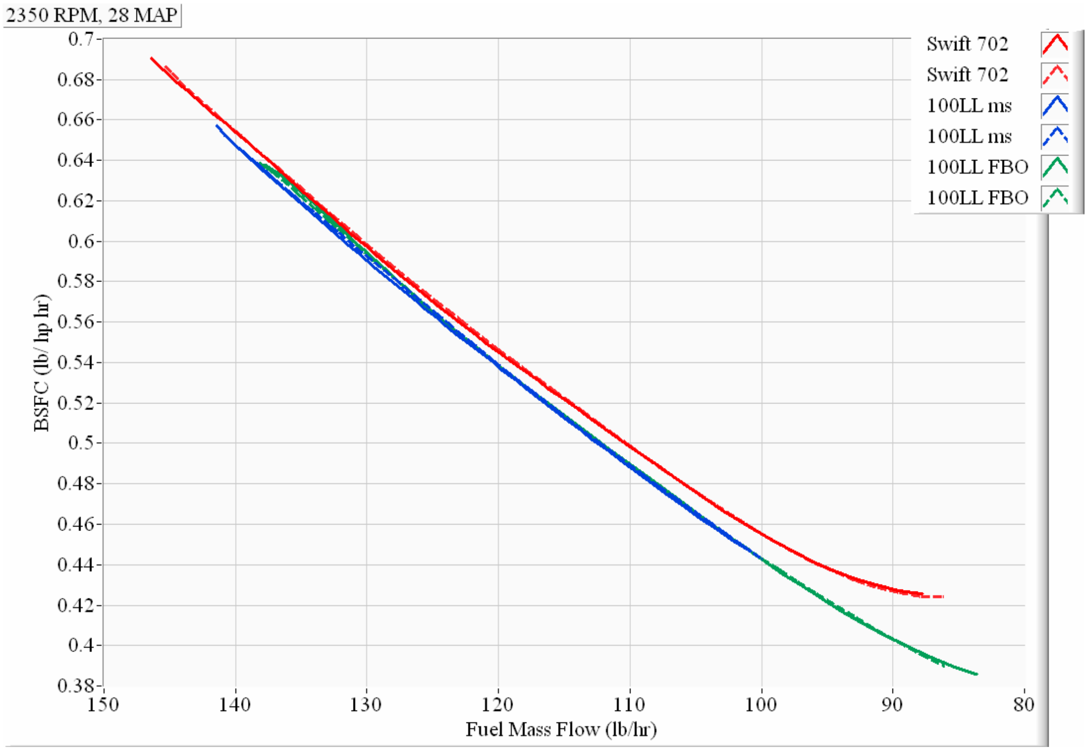


Figure B-63. Detonation Onset Comparison; 2350 rpm, 28 inHg MAP

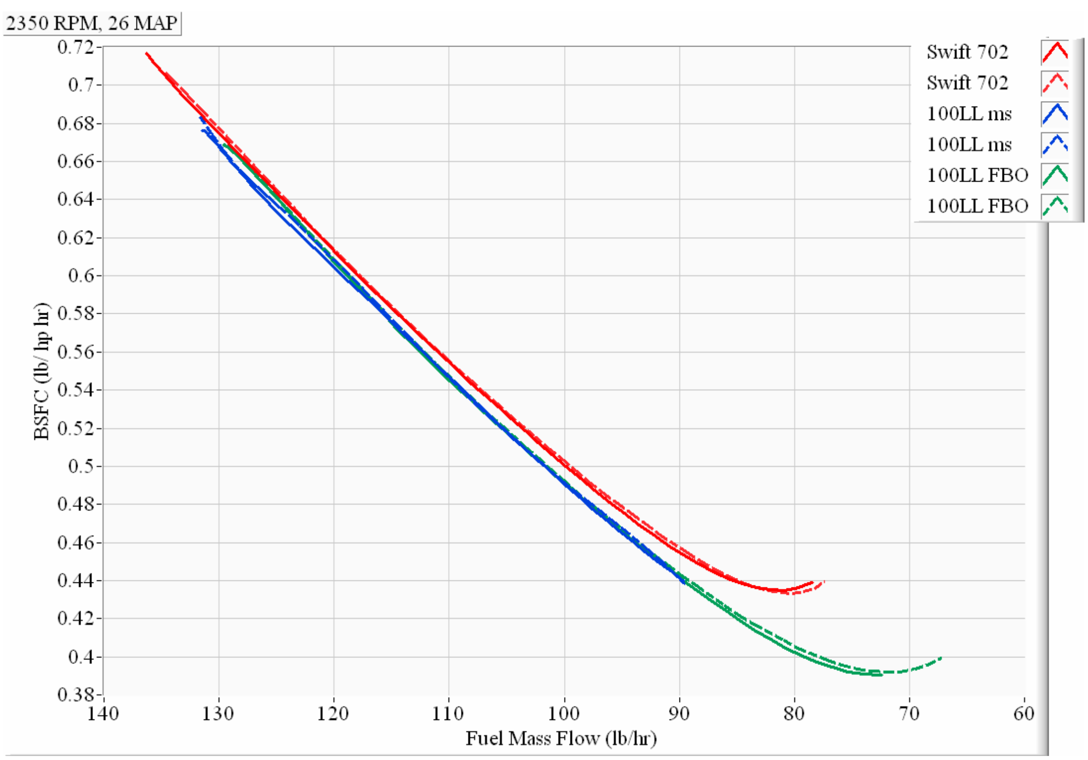


Figure B-64. Detonation Onset Comparison; 2350 rpm, 26 inHg MAP

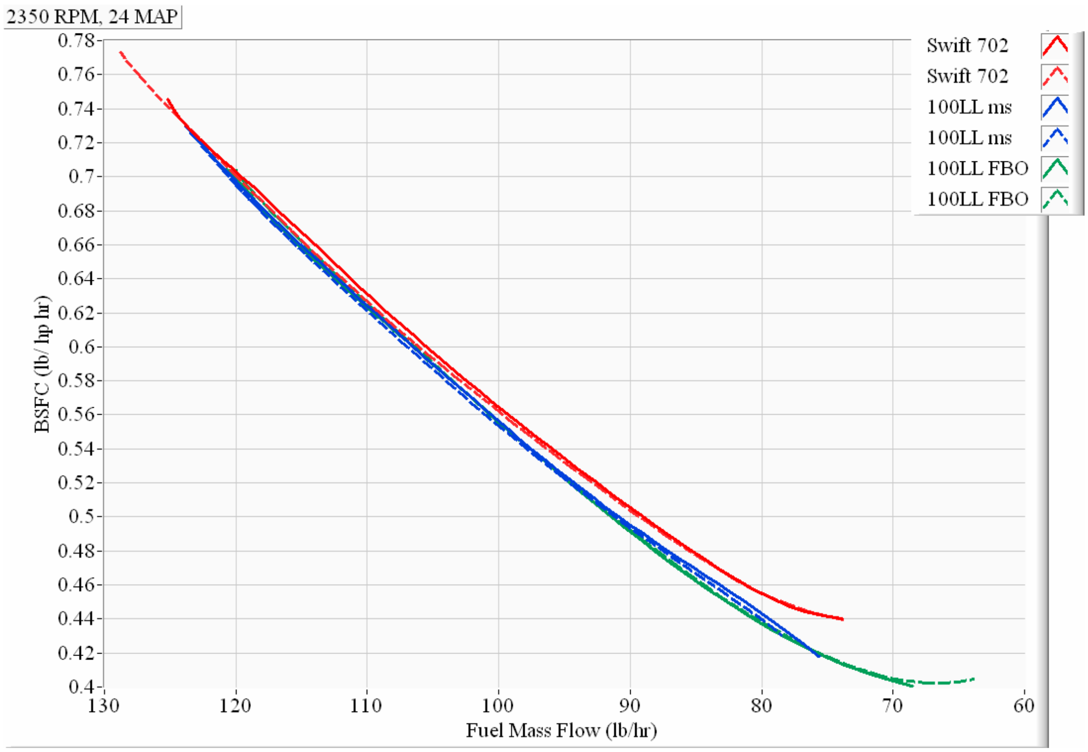


Figure B-65. Detonation Onset Comparison; 2350 rpm, 24 inHg MAP

APPENDIX C—LYCOMING IO-540-K BEST POWER AND DETONATION ONSET DATA FROM DETONATION TESTS

C.1 SWIFT 702 FUEL.

This section contains peak power and detonation onset data from detonation testing with the Lycoming IO-540-K engine for the Swift 702 fuel.

Table C-1. Swift 702 Fuel Detonation Onset and Peak Power Data From Detonation Tests

Power Setting	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)
2700 rpm, FT	Detonation Onset	124.7	18.5	284.5	12.82	1.094	0.458	1591
	Best Power	133.1	19.8	285.5	12.06	1.163	0.487	1551
	Detonation Onset	122.3	18.2	284.3	13.03	1.077	0.450	1606
	Best Power	134.7	20.0	285.3	11.91	1.178	0.494	1548
2700 rpm, 28 inHg MAP	Detonation Onset	113.5	16.9	262.1	13.25	1.059	0.453	1602
	Best Power	127.2	18.9	264.3	11.93	1.176	0.503	1535
	Detonation Onset	111.1	16.5	260.9	13.38	1.048	0.445	1612
	Best Power	124.8	18.6	265.1	12.04	1.165	0.492	1545
2700 rpm, 26 inHg MAP	Detonation Onset	102.3	15.2	236.2	13.40	1.047	0.453	1606
	Best Power	118.5	17.6	239.9	11.72	1.197	0.516	1516
	Detonation Onset	103.7	15.4	235.7	13.26	1.058	0.460	1598
	Best Power	116.7	17.4	239.9	11.87	1.181	0.508	1528
2600 rpm, FT	Detonation Onset	113.5	16.9	271.5	13.50	1.039	0.437	1601
	Best Power	127.3	19.4	277.0	11.88	1.181	0.492	1511
	Detonation Onset	121.1	18.0	276.3	12.82	1.094	0.458	1559
	Best Power	129.5	19.3	276.9	11.97	1.172	0.489	1517
2600 rpm, 28 inHg MAP	Detonation Onset	105.1	15.7	251.7	13.63	1.029	0.436	1597
	Best Power	119.5	17.8	257.9	12.17	1.153	0.484	1518
	Detonation Onset	101.6	15.1	246.7	13.89	1.010	0.430	1616
	Best Power	121.2	18.0	257.3	11.95	1.174	0.492	1514
2600 rpm, 26 inHg MAP	Detonation Onset	94.0	14.0	224.2	13.84	1.013	0.438	1607
	Best Power	111.5	16.6	231.1	11.93	1.176	0.504	1501
	Detonation Onset	98.9	14.7	228.5	13.42	1.045	0.452	1584
	Best Power	113.4	16.9	231.8	11.75	1.194	0.511	1491
2600 rpm, 24 inHg MAP	Detonation Onset	85.9	12.8	199.0	13.84	1.014	0.451	1606
	Best Power	102.9	15.3	208.0	11.82	1.186	0.517	1494
	Detonation Onset	87.4	13.0	201.6	13.64	1.029	0.453	1593
	Best Power	102.2	15.2	207.3	11.86	1.183	0.515	1496
2450 rpm, 28 inHg MAP	Detonation Onset	99.4	14.8	237.6	13.56	1.034	0.437	1568
	Best Power	112.8	16.8	241.9	12.08	1.161	0.487	1489
	Detonation Onset	102.2	15.2	239.0	13.24	1.060	0.447	1556
	Best Power	111.7	16.6	241.7	12.06	1.163	0.483	1499
2450 rpm, 26 inHg MAP	Detonation Onset	90.9	13.5	214.5	13.64	1.029	0.443	1573
	Best Power	102.3	15.2	219.5	12.19	1.151	0.487	1493
	Detonation Onset	92.4	13.8	216.0	13.46	1.042	0.447	1561

Table C-1. Swift 702 Fuel Detonation Onset and Peak Power Data From Detonation Tests (Continued)

Power Setting	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)
	Best Power	102.4	15.3	218.2	12.15	1.154	0.490	1492
2450 rpm, 24 inHg MAP	Detonation Onset	78.7	11.7	184.2	14.01	1.001	0.447	1602
	Best Power	95.7	14.2	194.6	11.89	1.179	0.514	1477
	Detonation Onset	78.4	11.7	181.9	14.34	0.978	0.450	1605
	Best Power	93.8	14.0	196.1	12.08	1.161	0.500	1485
2350 rpm, 28 inHg MAP	Detonation Onset	96.1	14.3	228.3	13.31	1.054	0.440	1545
	Best Power	107.5	16.0	230.7	12.05	1.164	0.487	1484
	Detonation Onset	97.5	14.5	228.9	13.11	1.070	0.445	1530
	Best Power	107.4	16.0	230.5	12.10	1.159	0.487	1482
2350 rpm, 26 inHg MAP	Detonation Onset	85.0	12.7	202.2	13.75	1.020	0.439	1573
	Best Power	99.0	14.7	208.2	12.00	1.169	0.496	1475
	Detonation Onset	87.2	13.0	205.7	13.41	1.046	0.443	1549
	Best Power	99.0	14.7	207.3	12.03	1.166	0.499	1481
2350 rpm, 24 inHg MAP	Detonation Onset	75.5	11.2	177.8	13.96	1.005	0.443	1583
	Best Power	90.4	13.5	186.5	12.07	1.162	0.507	1472
	Detonation Onset	78.5	11.7	181.9	13.65	1.028	0.451	1565
	Best Power	91.3	13.5	187.0	12.12	1.158	0.507	1473

FF = Fuel mass flow rate
BHP = Brake horsepower
BSFC = Brake-specific fuel consumption
EGT = Exhaust gas temperature

FT = Full throttle
MAP = Manifold absolute pressure
rpm = Revolutions per minute

C.2 100 LOW-LEAD AVIATION GASOLINE FIXED-BASE OPERATOR FUEL.

This section contains peak power and detonation onset data from detonation testing with the Lycoming IO-540-K engine for the 100LL fixed-base operator (FBO) fuel.

Table C-2. 100LL FBO Fuel Detonation Onset and Peak Power Data From Detonation Tests

Power Setting	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)
2700 rpm, FT	Detonation Onset	135.1	22.9	289.8	12.33	1.209	0.487	1480
	Best Power	127.6	21.7	290.4	12.91	1.155	0.459	1511
	Detonation Onset	136.2	23.1	289.6	12.19	1.222	0.491	1470
	Best Power	129.1	21.9	290.6	12.68	1.176	0.464	1500
2700 rpm, 28 inHg MAP	Detonation Onset	121.9	20.7	269.9	12.69	1.175	0.472	1489
	Best Power	119.9	20.4	269.6	12.80	1.165	0.465	1495
	Detonation Onset	123.3	20.9	270.0	12.67	1.176	0.477	1488
	Best Power	120.8	20.5	271.1	12.96	1.150	0.466	1499
2700 rpm, 26 inHg MAP	Detonation Onset	106.2	18.0	243.0	13.40	1.112	0.457	1517
	Best Power	108.3	18.4	243.1	13.03	1.144	0.466	1498
	Detonation Onset	104.6	17.7	244.2	13.50	1.104	0.447	1523
	Best Power	109.1	18.5	243.9	13.06	1.141	0.467	1497
2600 rpm, FT	Detonation Onset	125.8	21.4	282.3	12.64	1.179	0.466	1467
	Best Power	124.5	21.1	282.3	12.81	1.164	0.461	1472
	Detonation Onset	130.0	22.1	282.0	12.31	1.211	0.482	1445
	Best Power	123.8	21.0	282.5	12.89	1.157	0.458	1474
2600 rpm, 28 inHg MAP	Detonation Onset	115.8	19.6	259.9	12.77	1.167	0.465	1468
	Best Power	113.9	19.3	260.3	12.96	1.150	0.457	1474
	Detonation Onset	112.5	19.1	261.0	13.14	1.134	0.450	1486
	Best Power	115.4	19.6	261.0	12.86	1.159	0.462	1473
2600 rpm, 26 inHg MAP	Detonation Onset	102.4	17.4	235.7	13.25	1.125	0.454	1483
	Best Power	105.0	17.8	235.6	12.91	1.154	0.466	1466
	Detonation Onset	102.3	17.4	235.7	13.30	1.120	0.454	1486
	Best Power	104.0	17.7	235.7	13.04	1.143	0.461	1470
2600 rpm, 24 inHg MAP	Detonation Onset	87.4	14.8	209.6	13.85	1.076	0.436	1512
	Best Power	95.0	16.1	210.9	13.02	1.145	0.471	1469
	Detonation Onset	86.9	14.8	209.9	14.08	1.058	0.433	1522
	Best Power	95.2	15.8	211.6	13.31	1.120	0.459	1481
2450 rpm, 28 inHg MAP	Detonation Onset	108.2	18.4	246.0	12.89	1.157	0.460	1439
	Best Power	107.7	18.3	245.8	12.96	1.150	0.458	1445
	Detonation Onset	109.7	18.6	246.7	12.73	1.171	0.464	1431
	Best Power	106.5	18.1	246.7	13.03	1.144	0.451	1442
2450 rpm, 26 inHg MAP	Detonation Onset	92.3	15.7	223.3	13.72	1.086	0.432	1470
	Best Power	96.0	16.3	223.9	13.35	1.116	0.448	1449
	Detonation Onset	95.7	16.2	223.5	13.43	1.110	0.447	1461
	Best Power	98.7	16.7	223.4	12.99	1.147	0.461	1437
2450 rpm, 24 inHg MAP	Detonation Onset	84.5	14.4	198.7	13.75	1.084	0.445	1473
	Best Power	89.4	15.2	198.9	13.00	1.147	0.470	1435
2450 rpm, 28 inHg MAP	Detonation Onset	108.2	18.4	246.0	12.89	1.157	0.460	1439

Table C-2. 100LL FBO Fuel Detonation Onset and Peak Power Data From Detonation Tests (Continued)

Power Setting	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)
	Detonation Onset	84.3	14.3	198.6	13.76	1.083	0.443	1485
	Best Power	88.8	15.1	199.4	13.10	1.138	0.465	1443
2350 rpm, 28 inHg MAP	Detonation Onset	101.8	17.3	235.8	13.09	1.138	0.451	1432
	Best Power	105.1	17.6	236.0	12.82	1.162	0.458	1423
	Detonation Onset	102.7	17.4	235.4	12.95	1.151	0.456	1424
	Best Power	104.9	17.8	236.4	12.80	1.164	0.464	1414
2350 rpm, 26 inHg MAP	Detonation Onset	93.5	15.9	213.7	13.13	1.135	0.457	1436
	Best Power	93.7	15.9	213.5	12.93	1.153	0.459	1425
	Detonation Onset	90.0	15.3	212.7	13.46	1.107	0.442	1452
	Best Power	92.7	15.7	212.9	13.17	1.132	0.455	1437
2350 rpm, 24 inHg MAP	Detonation Onset	81.9	13.9	189.8	13.49	1.105	0.451	1463
	Best Power	86.4	14.7	189.5	12.94	1.152	0.476	1431
	Detonation Onset	83.0	14.1	190.7	13.51	1.103	0.455	1455
	Best Power	87.4	14.9	190.3	12.85	1.160	0.480	1426

FF = Fuel mass flow rate
BHP = Brake horsepower
BSFC = Brake-specific fuel consumption
EGT = Exhaust gas temperature

FT = Full throttle
MAP = Manifold absolute pressure
rpm = Revolutions per minute

C.3 100LL MINIMUM SPECIFICATON FUEL.

This section contains peak power and detonation onset data from detonation testing with the Lycoming IO-540-K engine for the minimum specification 100LL fuel.

Table C-3. 100LL Minimum Specification Fuel Detonation Onset and Peak Power Data From Detonation Tests

Power Setting	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)
2700 rpm, FT	Detonation Onset	124.4	21.8	291.6	13.04	1.143	0.446	1503
	Best Power	124.4	21.8	291.6	13.04	1.143	0.446	1503
	Detonation Onset	124.3	21.8	292.0	13.05	1.142	0.445	1506
	Best Power	127.7	22.4	291.4	12.81	1.164	0.458	1491
2700 rpm, 28 inHg MAP	Detonation Onset	113.9	19.9	271.9	13.42	1.110	0.437	1514
	Best Power	118.0	20.7	272.3	12.96	1.150	0.453	1489
	Detonation Onset	115.7	20.3	270.9	13.19	1.130	0.446	1505
	Best Power	118.3	20.7	271.7	12.87	1.158	0.455	1493
2700 rpm, 26 inHg MAP	Detonation Onset	98.4	17.2	243.5	14.09	1.058	0.422	1539
	Best Power	106.7	18.7	244.5	13.12	1.136	0.456	1491
	Detonation Onset	96.9	17.0	242.0	14.27	1.045	0.419	1552
	Best Power	105.2	18.4	244.4	13.19	1.130	0.450	1494
2600 rpm, FT	Detonation Onset	115.7	20.3	283.0	13.42	1.111	0.427	1492
	Best Power	119.4	20.9	282.7	13.05	1.142	0.441	1471
	Detonation Onset	116.8	20.5	282.0	13.31	1.120	0.433	1482
	Best Power	119.8	21.0	282.3	13.03	1.144	0.444	1469
2600 rpm, 28 inHg MAP	Detonation Onset	103.2	18.1	260.9	14.04	1.062	0.413	1514
	Best Power	112.9	19.8	262.4	12.99	1.147	0.449	1459
	Detonation Onset	110.4	19.4	261.4	13.18	1.131	0.441	1478
	Best Power	112.7	19.8	261.8	13.05	1.142	0.450	1466
2600 rpm, 26 inHg MAP	Detonation Onset	95.3	16.7	235.9	13.92	1.071	0.422	1507
	Best Power	103.5	18.2	237.0	12.98	1.148	0.456	1459
	Detonation Onset	95.9	16.8	235.8	13.83	1.078	0.425	1500
	Best Power	102.4	18.0	236.6	13.05	1.142	0.452	1461
2600 rpm, 24 inHg MAP	Detonation Onset	80.1	14.1	204.6	14.84	1.005	0.409	1550
	Best Power	93.4	16.5	213.2	12.90	1.155	0.464	1450
	Detonation Onset	84.5	14.8	210.6	14.24	1.046	0.419	1524
	Best Power	93.3	16.3	212.2	13.16	1.132	0.459	1464
2450 rpm, 28 inHg MAP	Detonation Onset	105.0	18.4	248.2	12.99	1.147	0.442	1422
	Best Power	104.8	18.4	247.7	13.08	1.140	0.442	1429
	Detonation Onset	99.6	17.5	246.3	13.66	1.091	0.423	1462
	Best Power	104.9	18.4	247.4	13.09	1.138	0.443	1436
2450 rpm, 26 inHg MAP	Detonation Onset	88.7	15.6	222.9	13.94	1.069	0.416	1474
	Best Power	95.0	16.7	222.6	13.20	1.129	0.446	1434
	Detonation Onset	88.3	15.5	222.6	14.13	1.055	0.414	1484
	Best Power	96.4	16.9	223.9	13.11	1.137	0.450	1428
2450 rpm, 24 inHg MAP	Detonation Onset	75.1	13.2	192.4	14.88	1.002	0.408	1537
	Best Power	87.9	15.4	200.1	12.98	1.148	0.459	1432

Table C-3. 100LL Minimum Specification Fuel Detonation Onset and Peak Power Data From Detonation Tests (Continued)

Power Setting	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)
	Detonation Onset	80.2	14.1	198.1	14.14	1.054	0.423	1497
	Best Power	87.3	15.3	199.5	13.13	1.135	0.457	1440
2350 rpm, 28 inHg MAP	Detonation Onset	97.6	17.1	235.9	13.29	1.121	0.432	1431
	Best Power	101.0	17.7	236.4	12.92	1.154	0.446	1413
	Detonation Onset	96.0	16.8	236.1	13.52	1.102	0.425	1446
	Best Power	100.2	17.6	236.5	13.07	1.140	0.443	1424
2350 rpm, 26 inHg MAP	Detonation Onset	86.6	15.2	212.7	13.75	1.084	0.425	1459
	Best Power	91.9	16.1	213.1	13.01	1.145	0.451	1425
	Detonation Onset	84.7	14.9	211.2	14.12	1.056	0.419	1470
	Best Power	92.4	16.2	212.8	12.98	1.149	0.454	1415
2350 rpm, 24 inHg MAP	Detonation Onset	78.3	13.7	190.7	13.88	1.074	0.429	1471
	Best Power	84.8	14.9	191.2	13.03	1.144	0.464	1420
	Detonation Onset	78.5	13.8	190.8	13.90	1.072	0.430	1468
	Best Power	85.4	15.0	191.5	12.93	1.153	0.466	1419

FF = Fuel mass flow rate
BHP = Brake horsepower
BSFC = Brake-specific fuel consumption
EGT = Exhaust gas temperature

FT = Full throttle
MAP = Manifold absolute pressure
rpm = Revolutions per minute

Figures D-1 through D-39 show the mixture lean-outs of the Swift 702 and 100 low-lead (100LL) aviation gasoline fuels at different power settings. Not all of the test points reviewed are represented, as the blends were tested 3 to 5 times each at each respective power setting. Furthermore, the dotted cursor does not necessarily represent a point of interest, but was merely the location of the cursor at the time the screen capture was taken. The data contained in the body of this report represented the average of the repeated tests, based on degree of repeatability, and the graphs following show some of the individual test runs. Only some of the data and test runs have been represented in graphical form in this appendix due to the large volume of data generated from these tests.

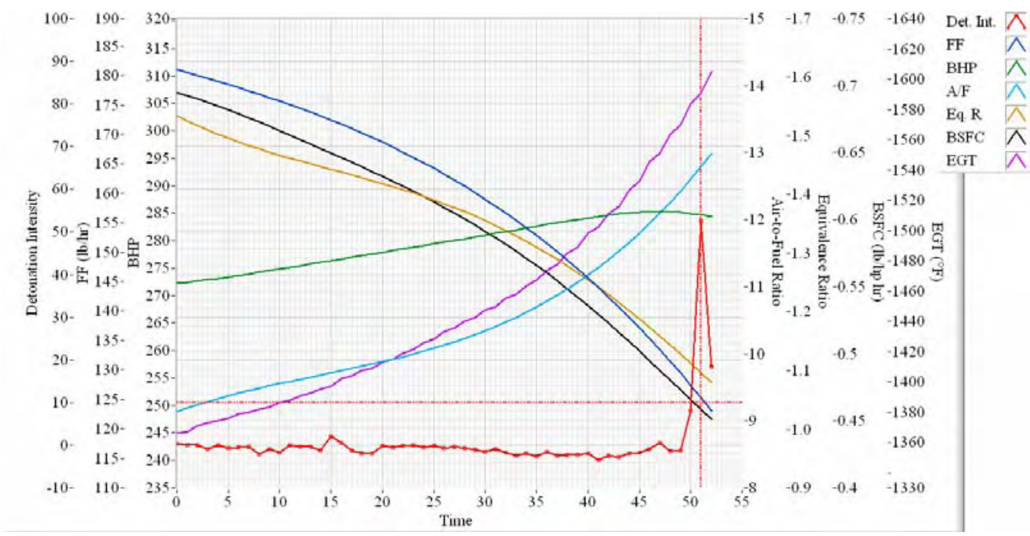


Figure D-1. Swift 702 Fuel, 2700 rpm, FT

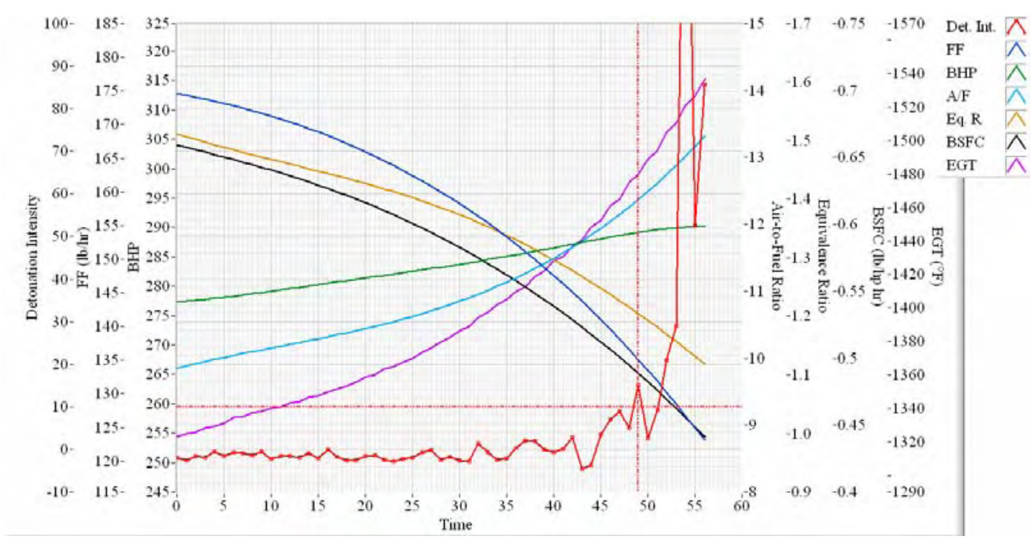


Figure D-2. Minimum Specification 100LL Fuel, 2700 rpm, FT

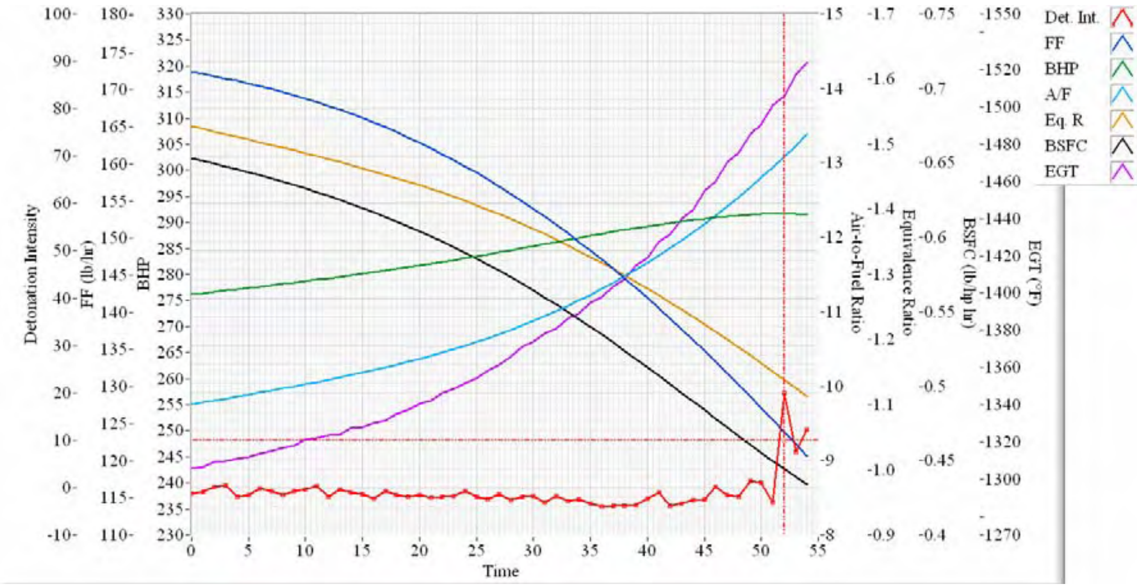


Figure D-3. Fixed-Base Operator 100LL Fuel, 2700 rpm, FT

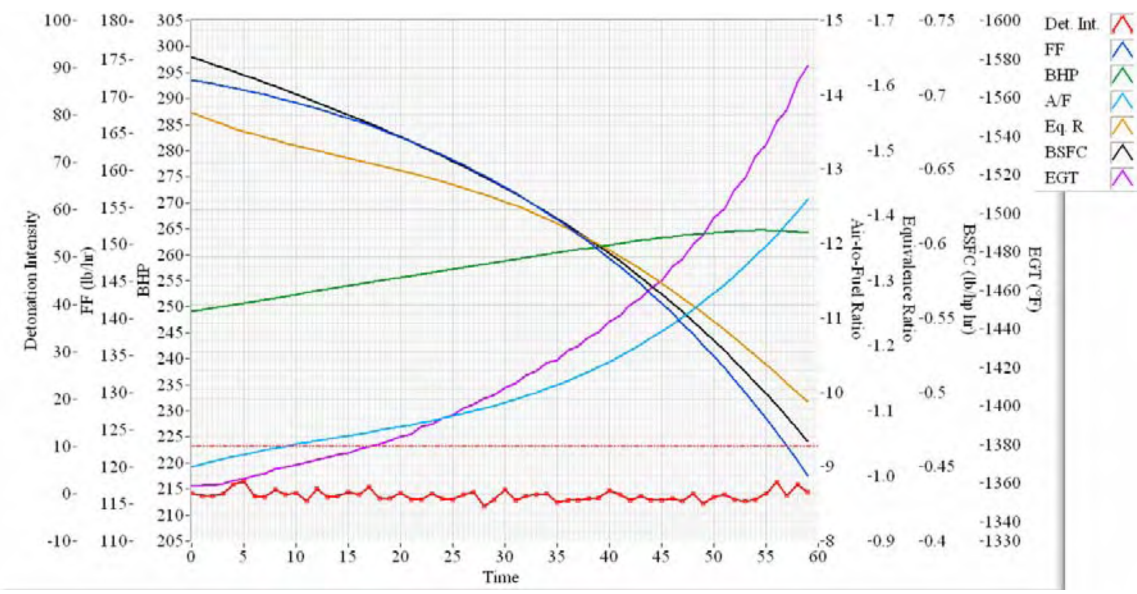


Figure D-4. Swift 702 Fuel, 2700 rpm, 28 inHg MAP

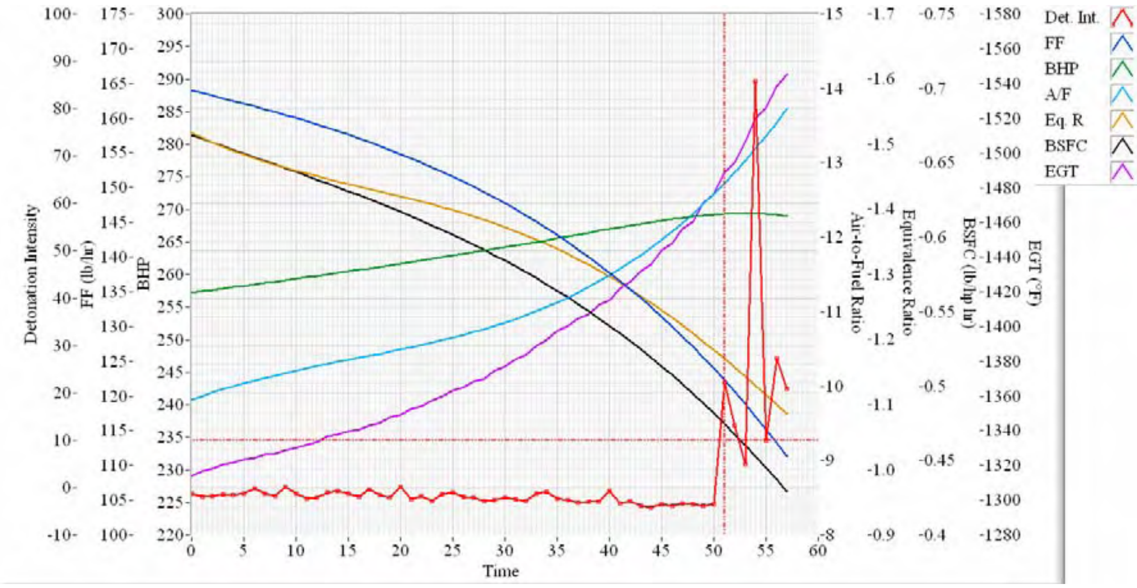


Figure D-5. Minimum Specification 100LL Fuel, 2700 rpm, 28 inHg MAP

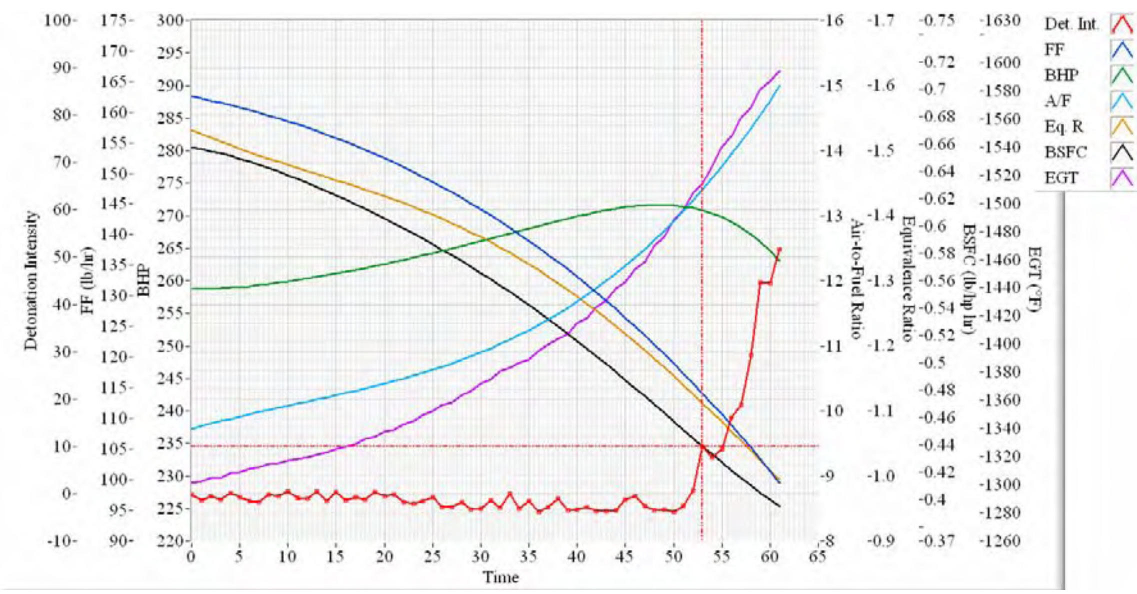


Figure D-6. Fixed-Base Operator 100LL Fuel, 2700 rpm, 28 inHg MAP

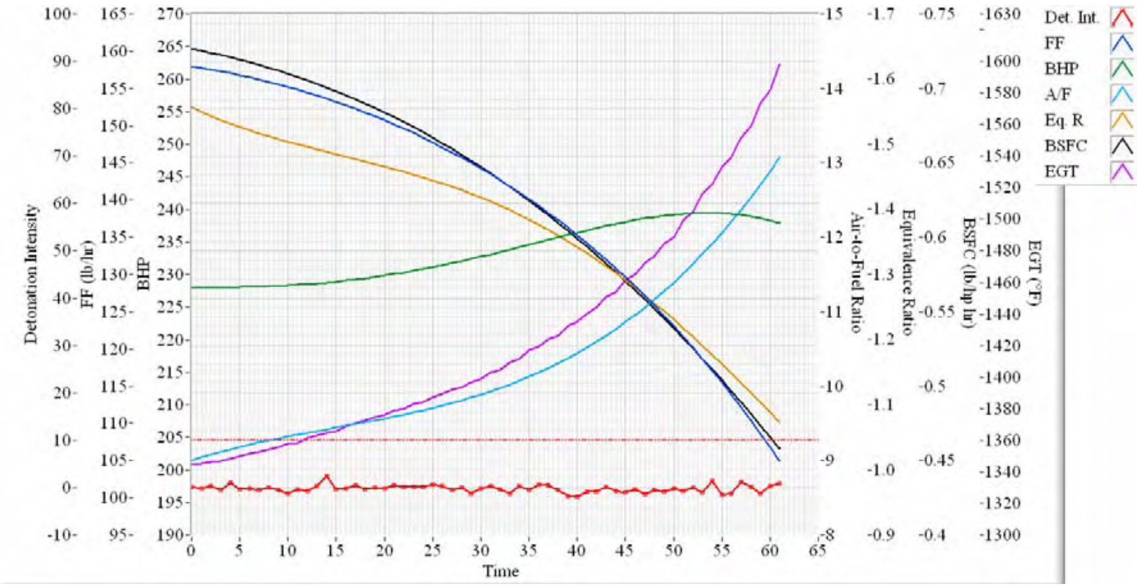


Figure D-7. Swift 702 Fuel, 2700 rpm, 26 inHg MAP

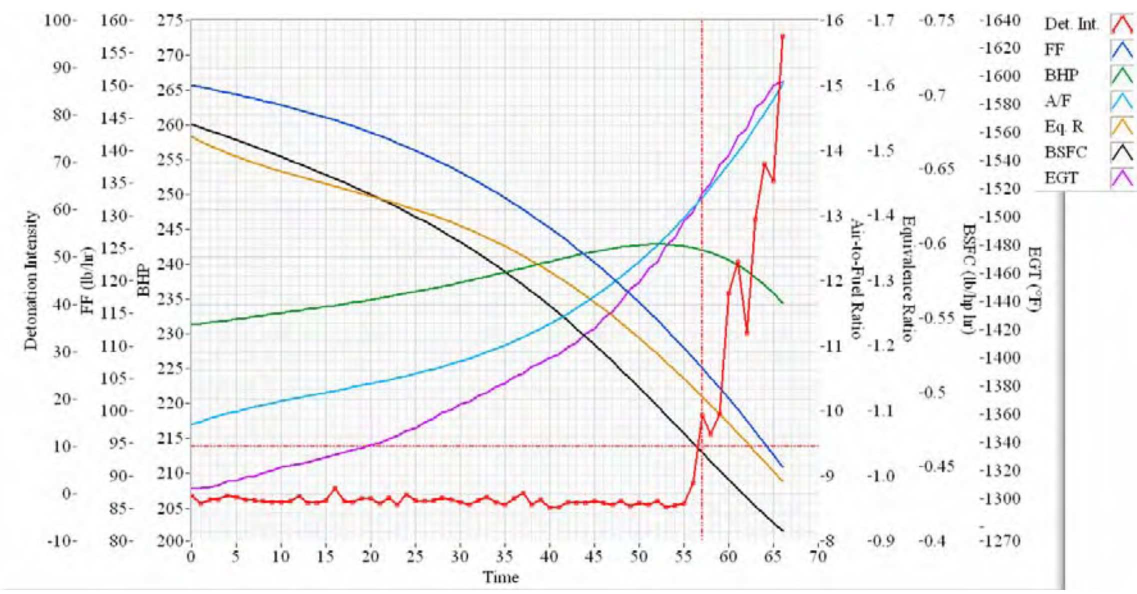


Figure D-8. Minimum Specification 100LL Fuel, 2700 rpm, 26 inHg MAP

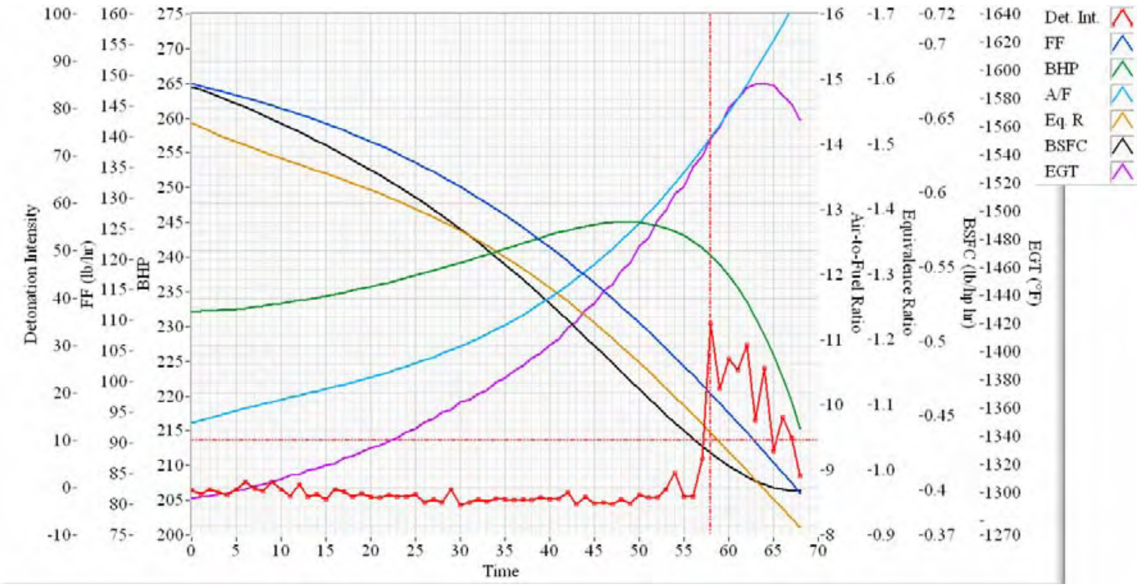


Figure D-9. Fixed-Base Operator 100LL Fuel, 2700 rpm, 26 inHg MAP

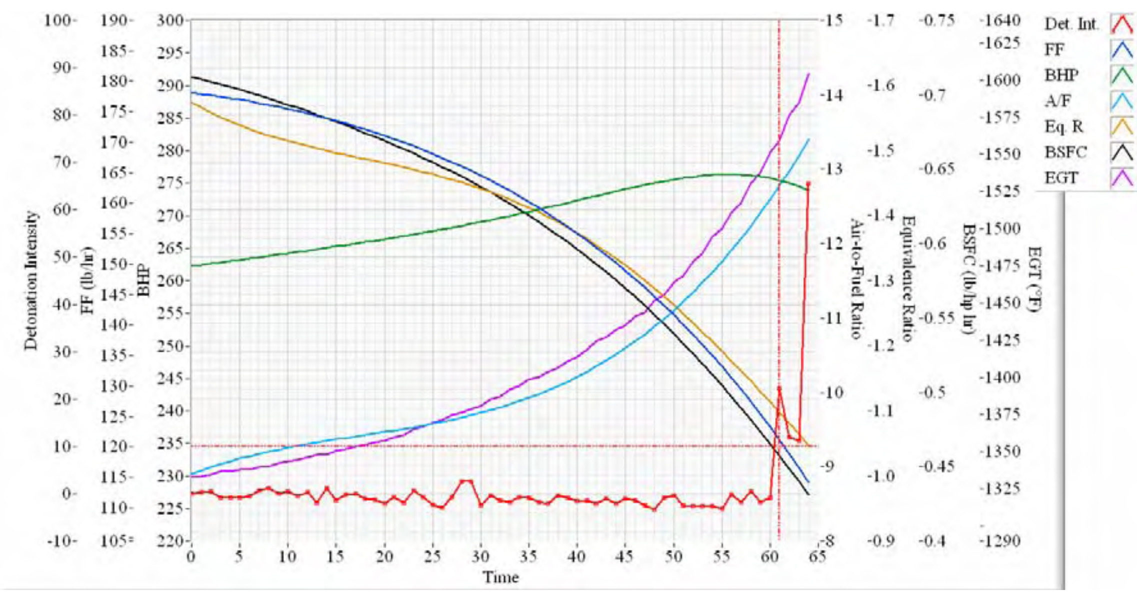


Figure D-10. Swift 702 Fuel, 2600 rpm, FT

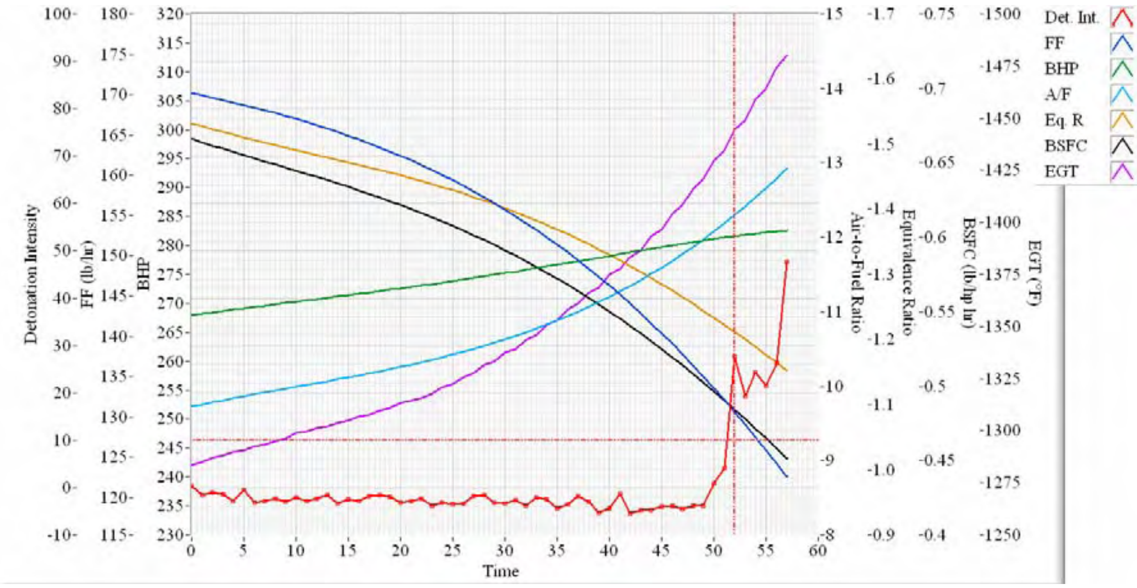


Figure D-11. Minimum Specification 100LL Fuel, 2600 rpm, FT

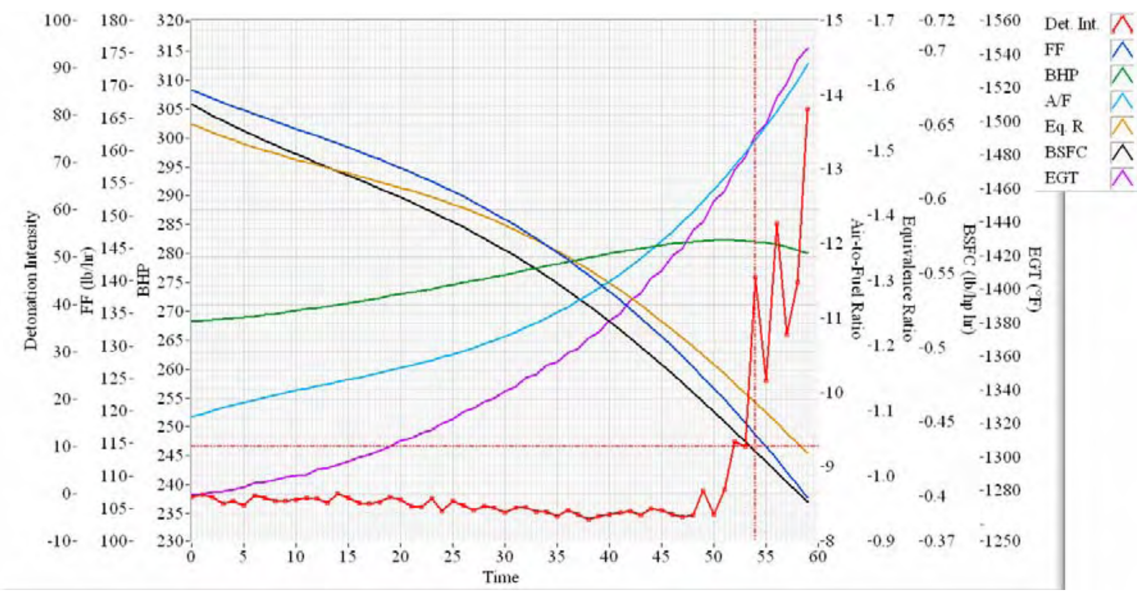


Figure D-12. Fixed-Base Operator 100LL Fuel, 2600 rpm, FT

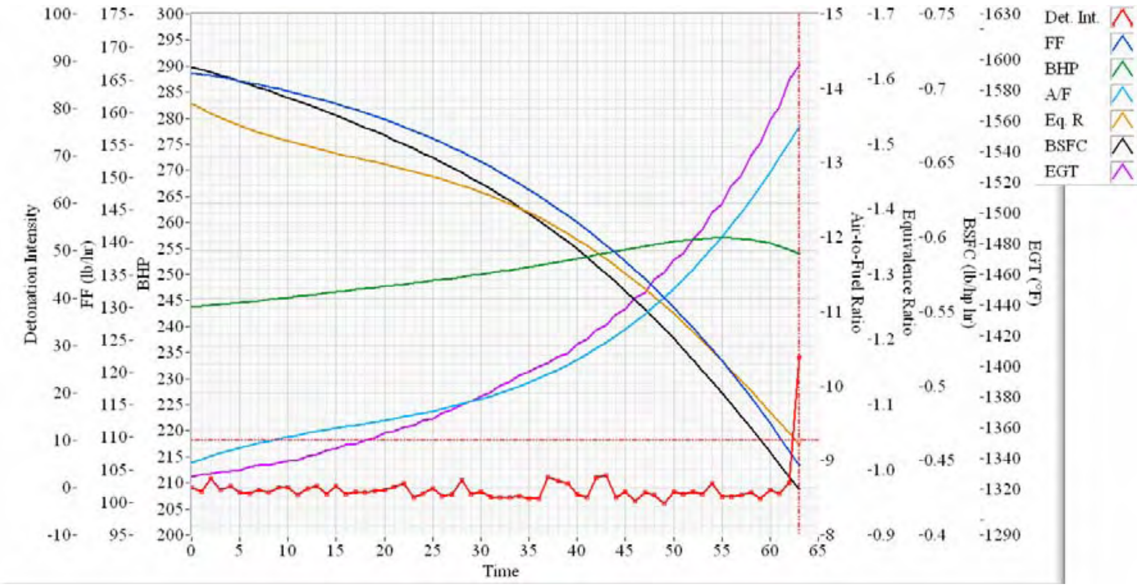


Figure D-13. Swift 702 Fuel, 2600 rpm, 28 inHg MAP

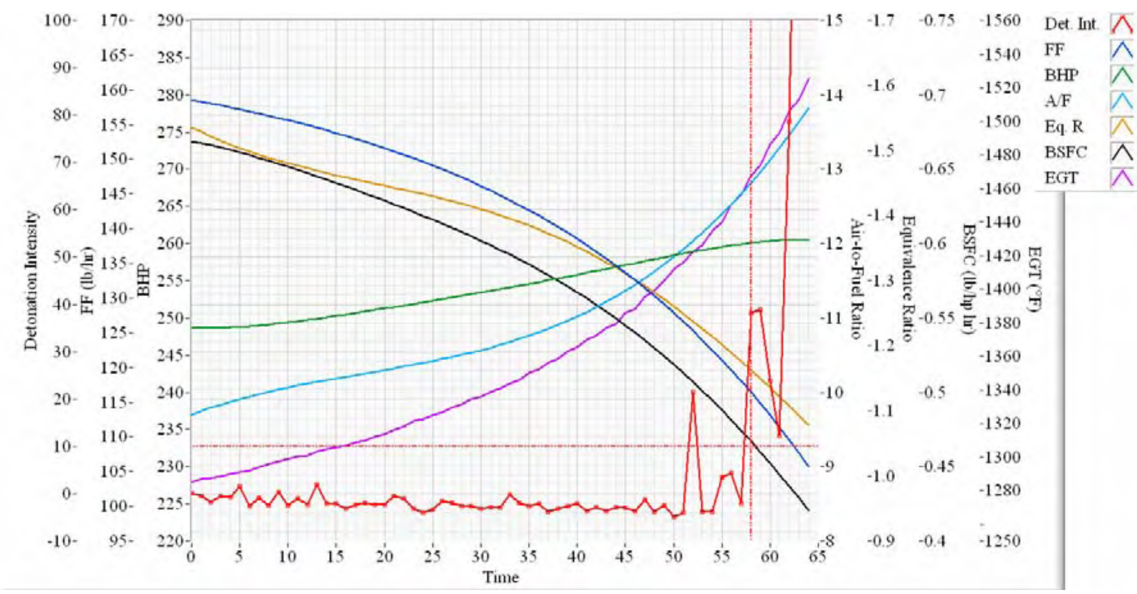


Figure D-14. Minimum Specification 100LL Fuel, 2600 rpm, 28 inHg MAP

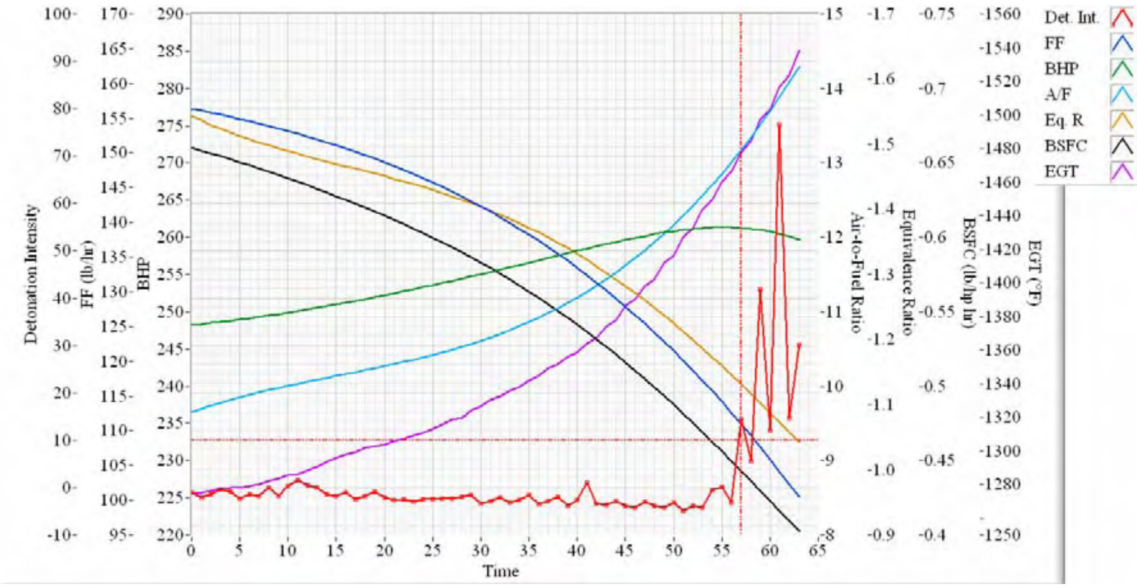


Figure D-15. Fixed-Base Operator 100LL Fuel, 2600 rpm, 28 inHg MAP

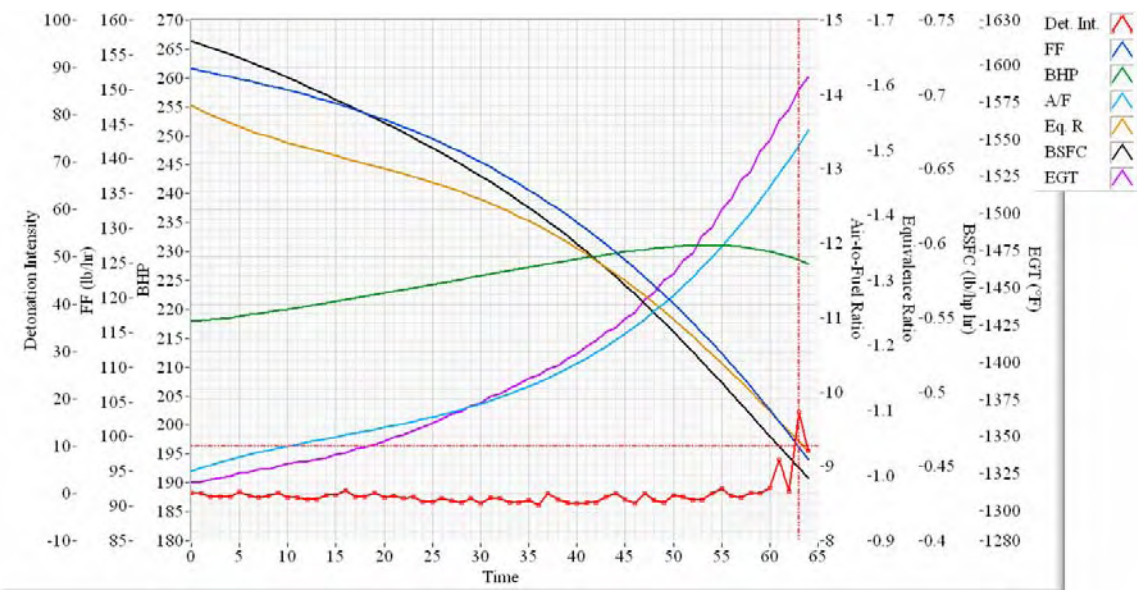


Figure D-16. Swift 702 Fuel, 2600 rpm, 26 inHg MAP

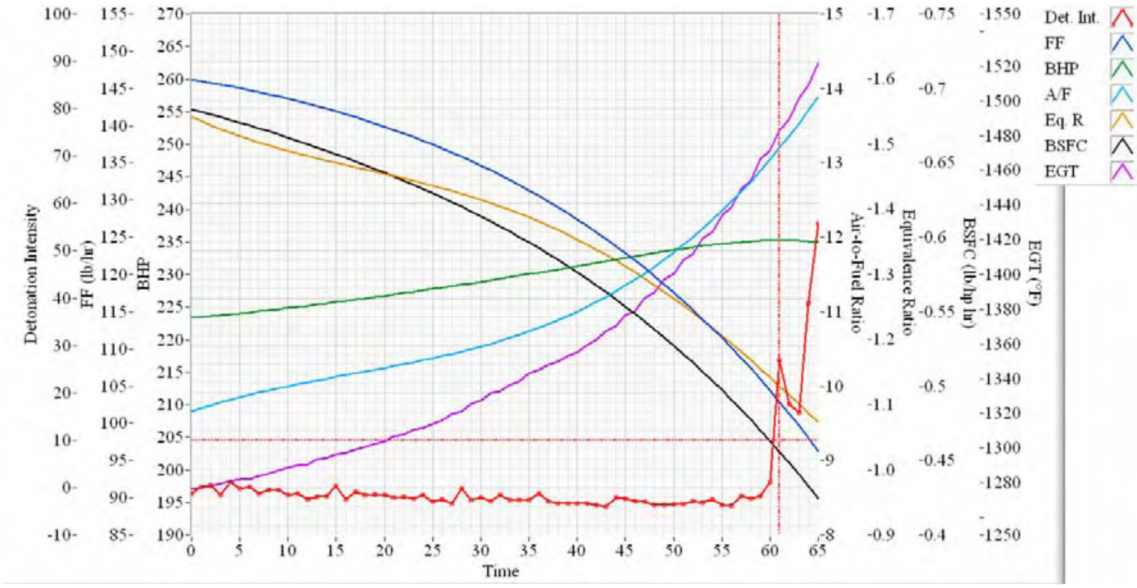


Figure D-17. Minimum Specification 100LL Fuel, 2600 rpm, 26 inHg MAP

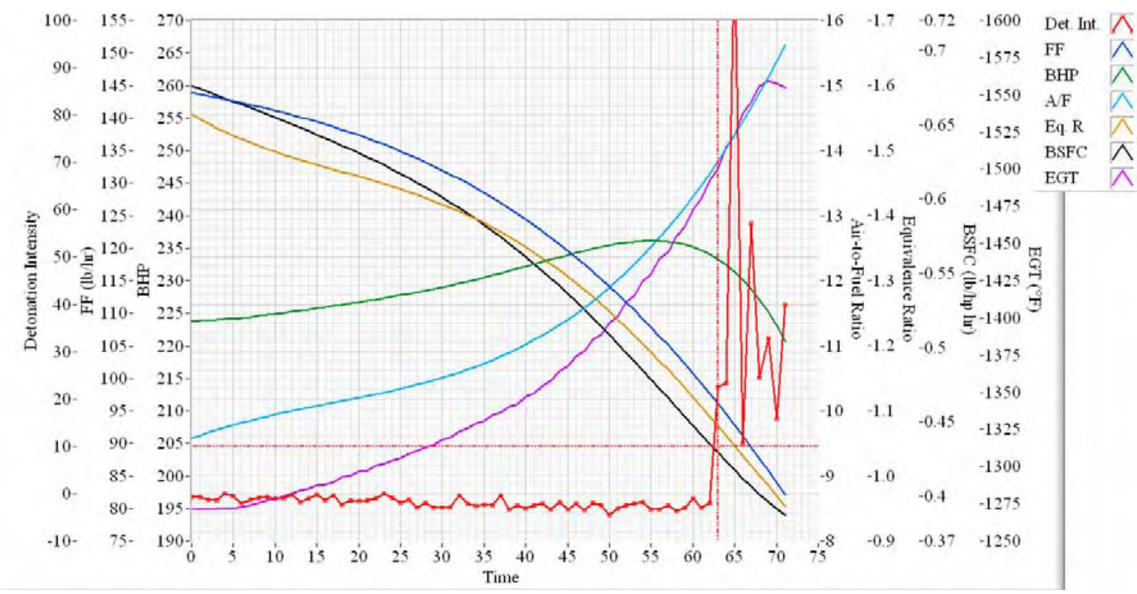


Figure D-18. Fixed-Base Operator 100LL Fuel, 2600 rpm, 26 inHg MAP

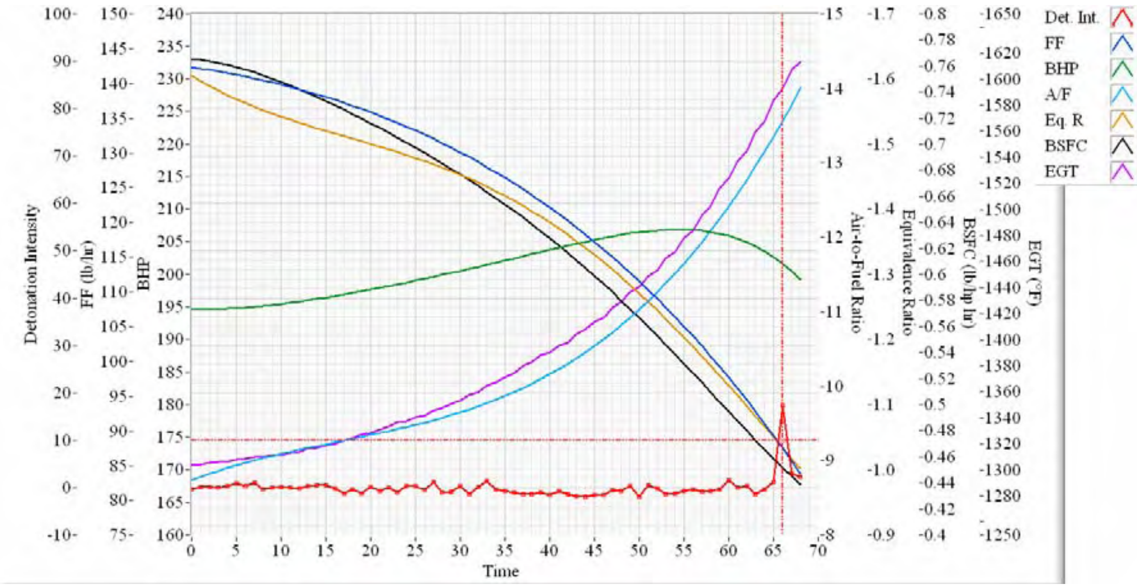


Figure D-19. Swift 702 Fuel, 2600 rpm, 24 inHg MAP

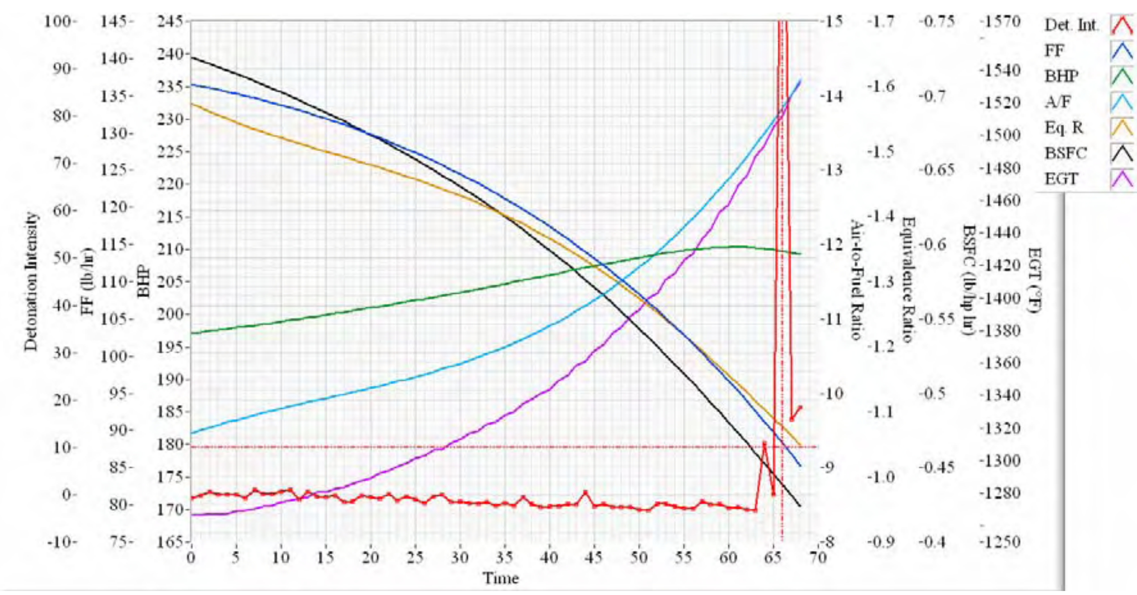


Figure D-20. Minimum Specification 100LL Fuel, 2600 rpm, 24 inHg MAP

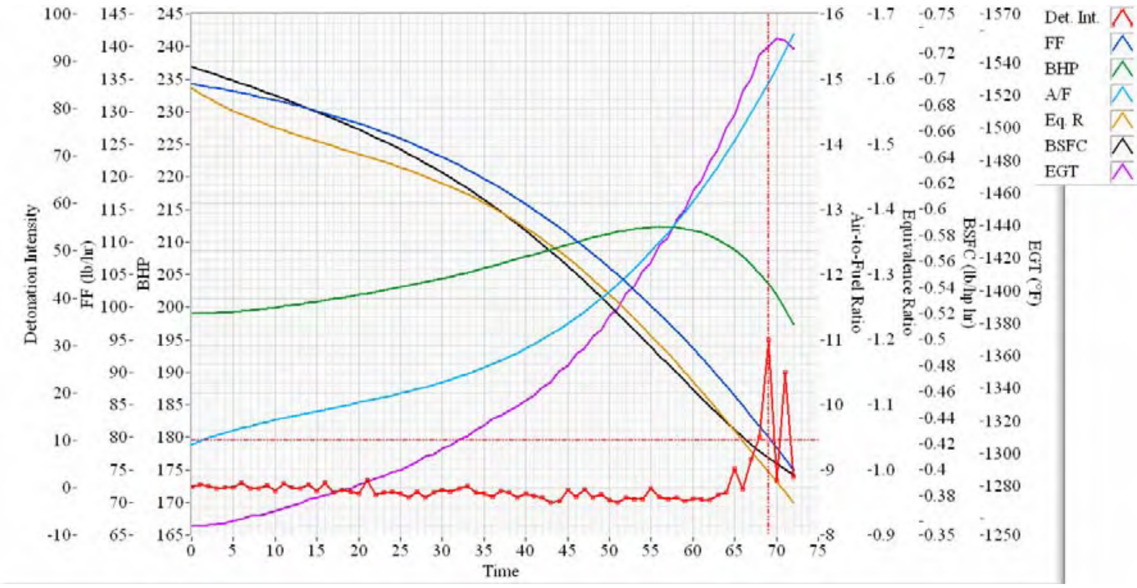


Figure D-21. Fuel-Based Operator 100LL Fuel, 2600 rpm, 24 inHg MAP

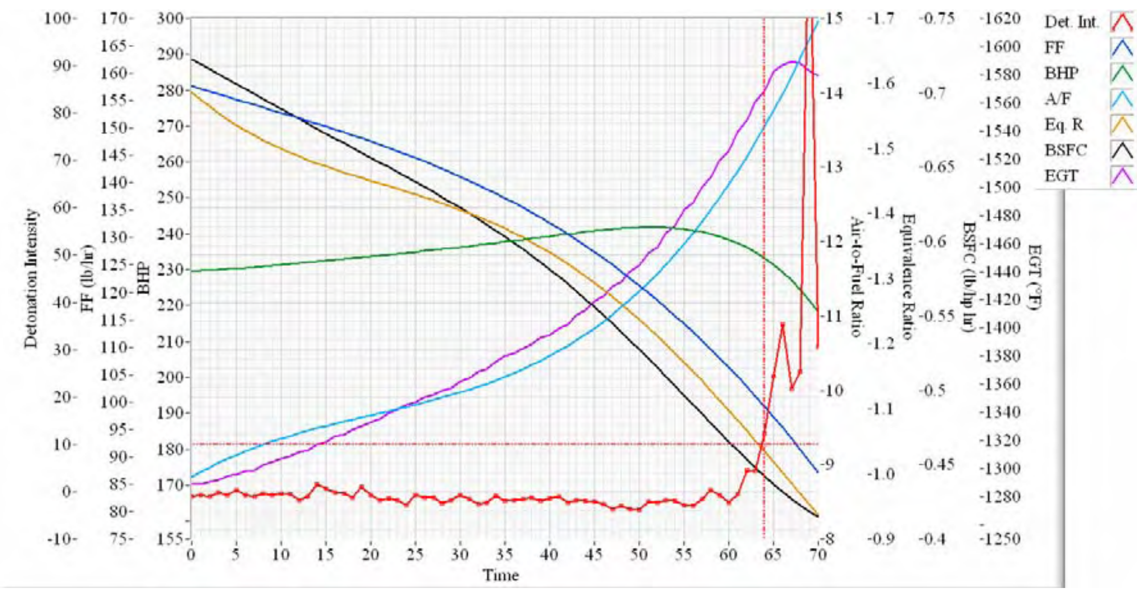


Figure D-22. Swift 702 Fuel, 2450 rpm, 28 inHg MAP

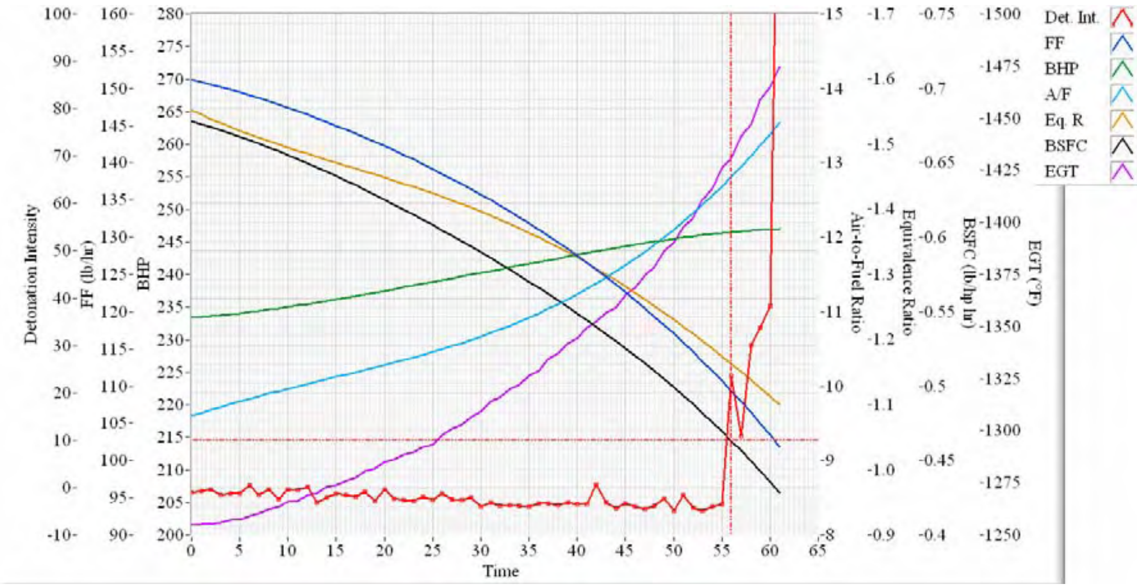


Figure D-23. Minimum Specification 100LL Fuel, 2450 rpm, 28 inHg MAP

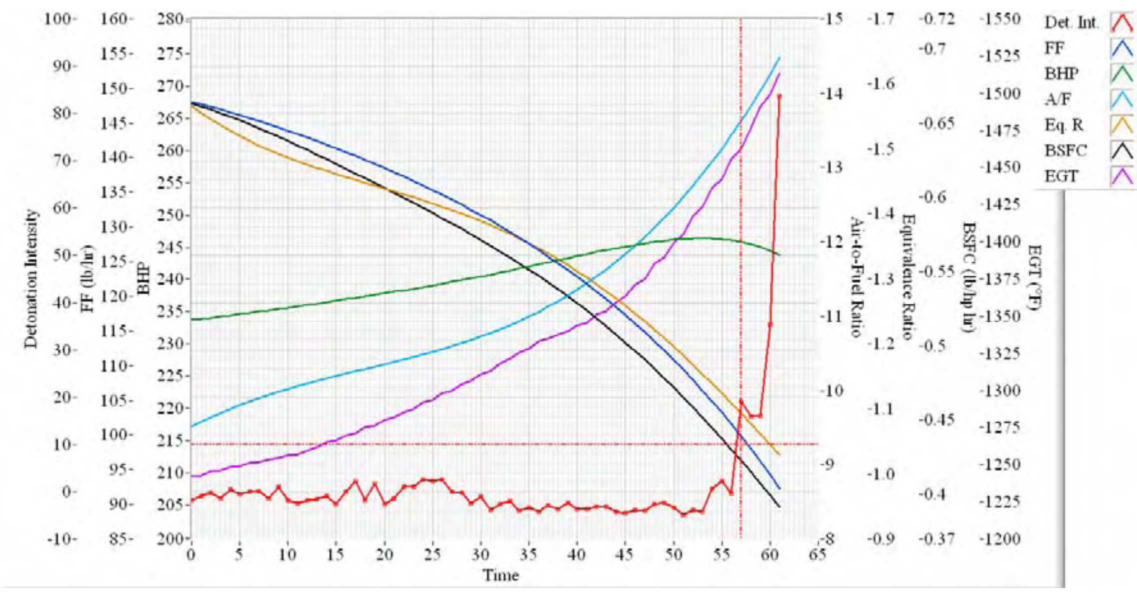


Figure D-24. Fixed-Base Operator 100LL Fuel, 2450 rpm, 28 inHg MAP

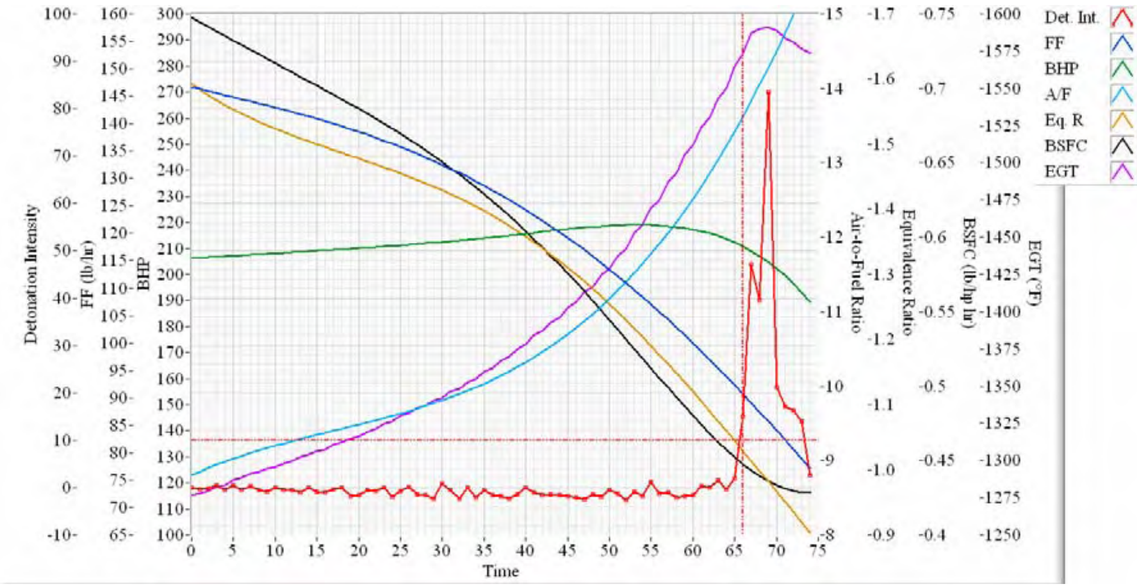


Figure D-25. Swift 702 Fuel, 2450 rpm, 26 inHg MAP

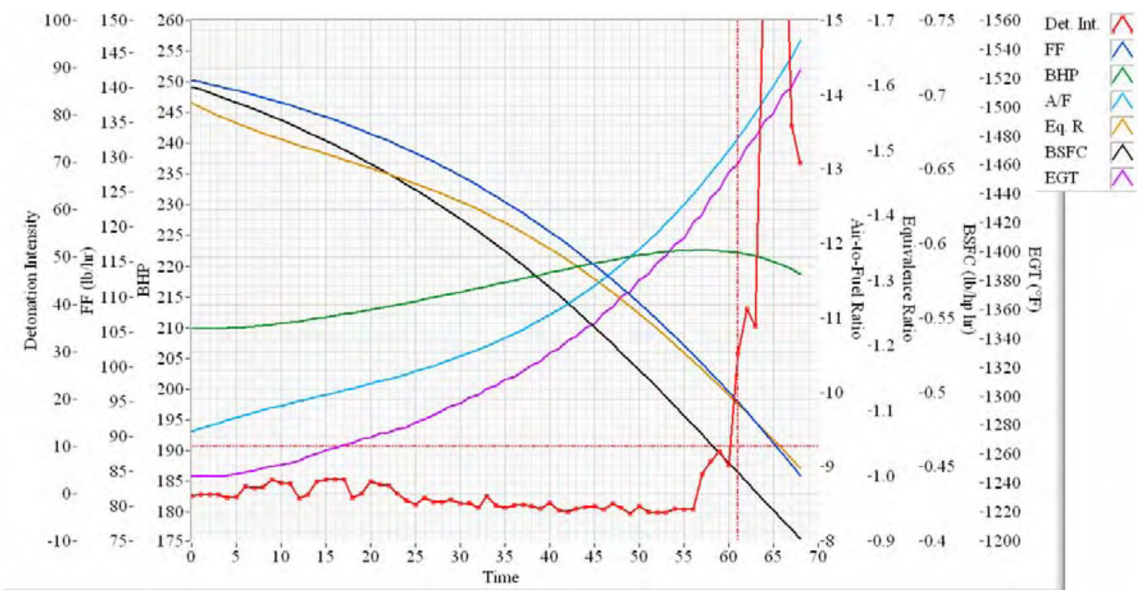


Figure D-26. Minimum Specification 100LL Fuel, 2450 rpm, 26 inHg MAP

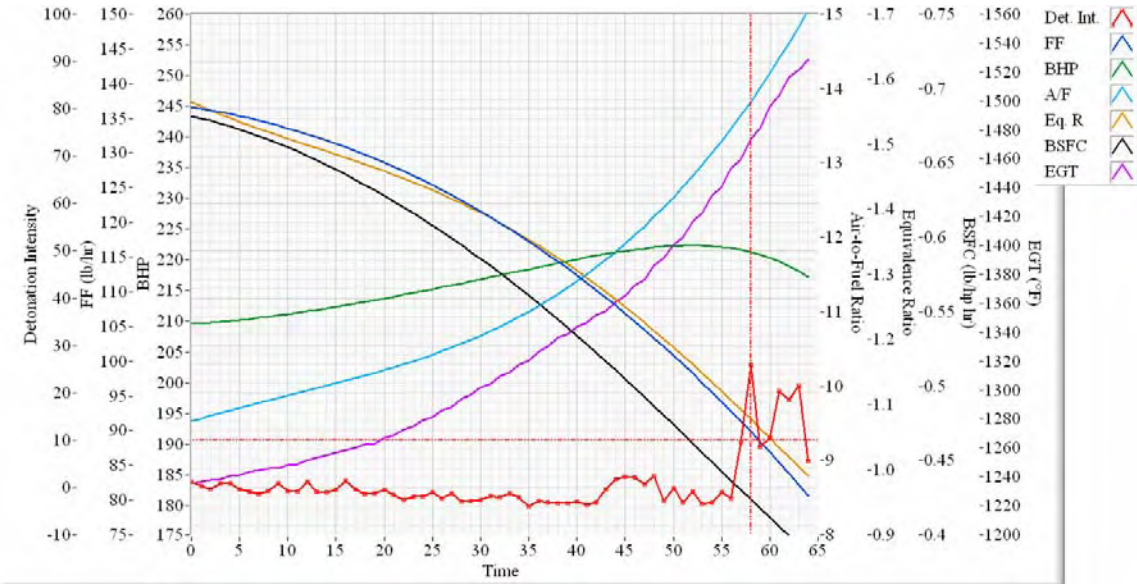


Figure D-27. Fixed-Base Operator 100LL Fuel, 2450 rpm, 26 inHg MAP

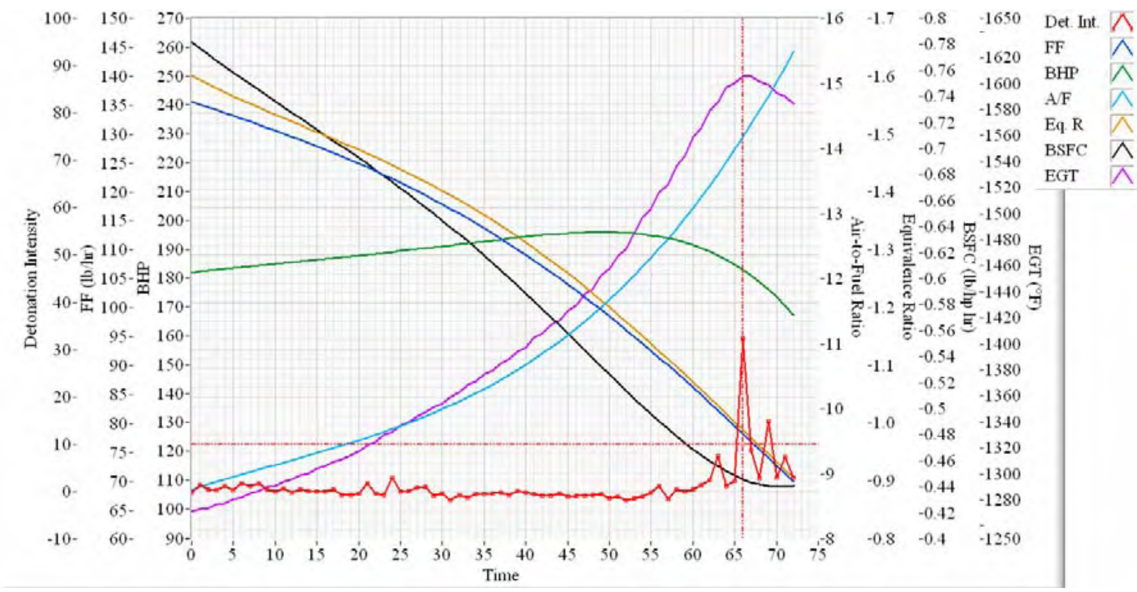


Figure D-28. Swift 702 Fuel, 2450 rpm, 24 inHg MAP

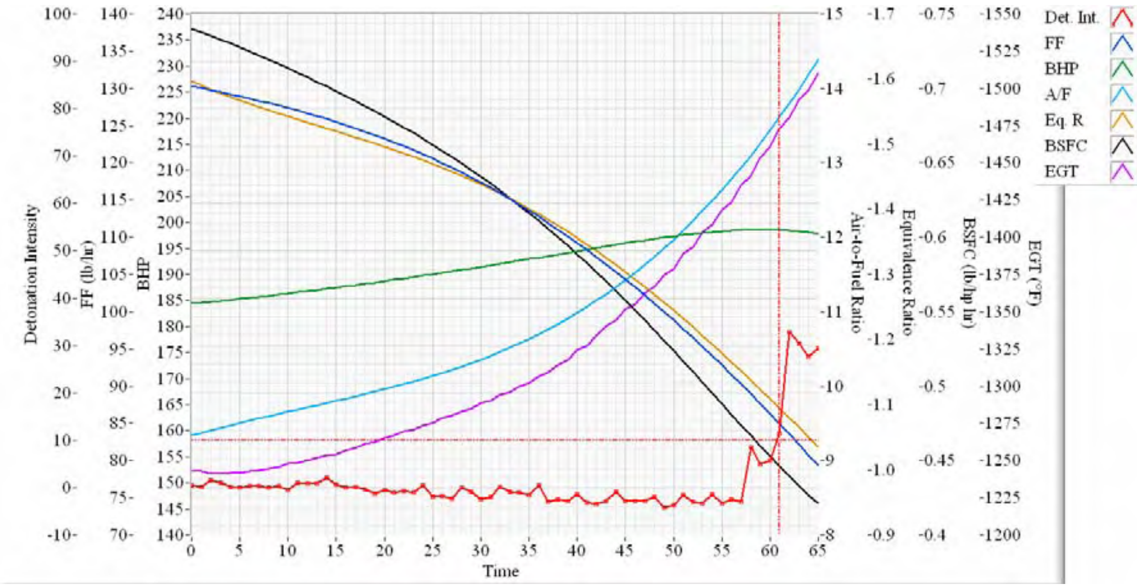


Figure D-29. Minimum Specification 100LL Fuel, 2450 rpm, 24 inHg MAP

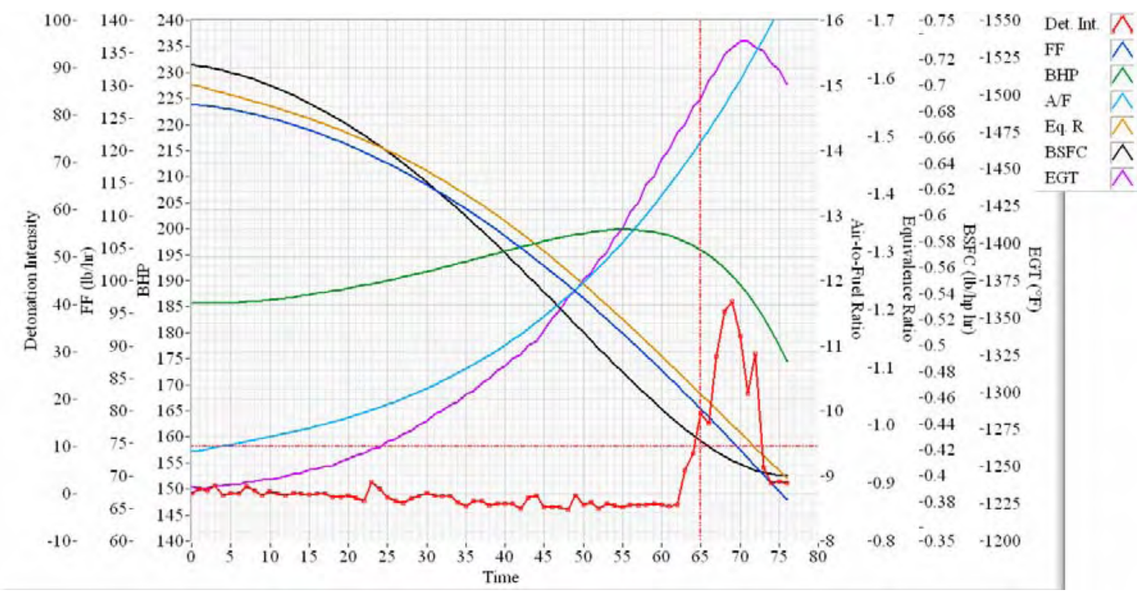


Figure D-30. Fixed-Base Operator 100LL Fuel, 2450 rpm, 24 inHg MAP

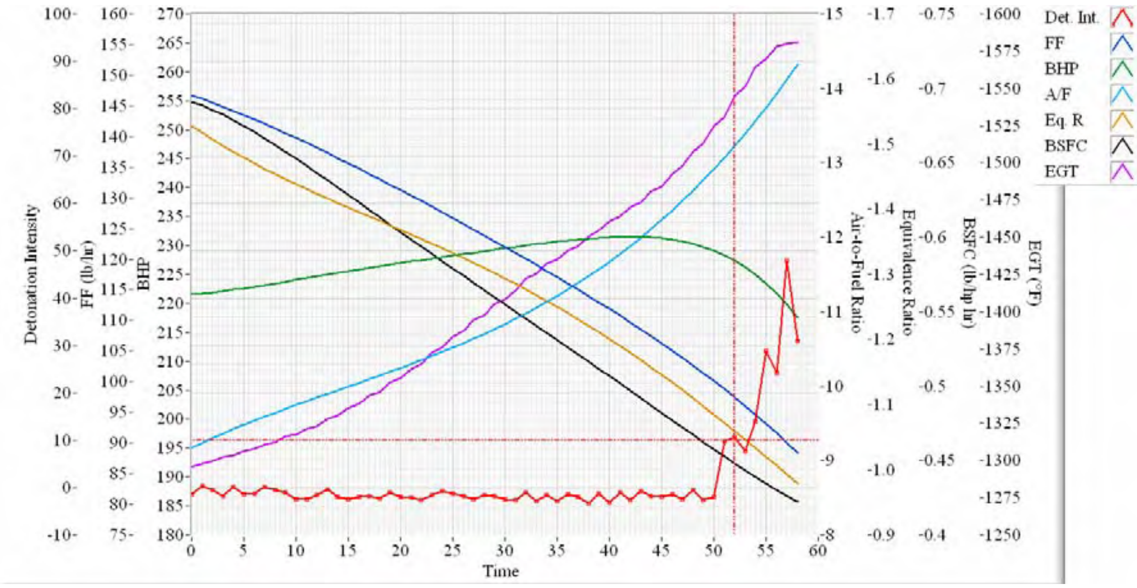


Figure D-31. Swift 702 Fuel, 2350 rpm, 28 inHg MAP

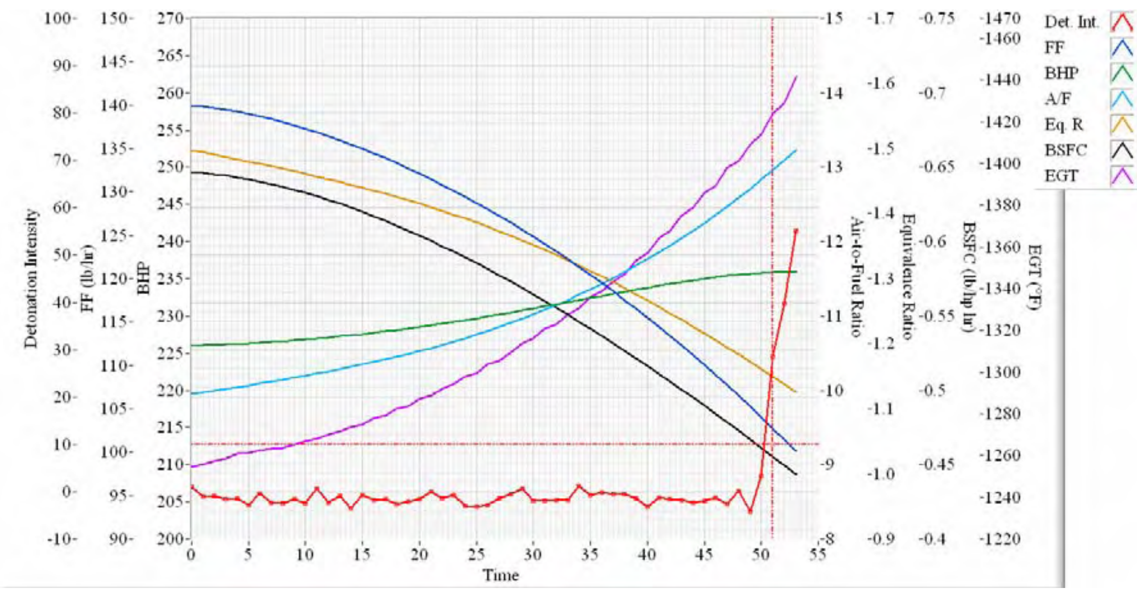


Figure D-32. Minimum Specification 100LL Fuel, 2350 rpm, 28 inHg MAP

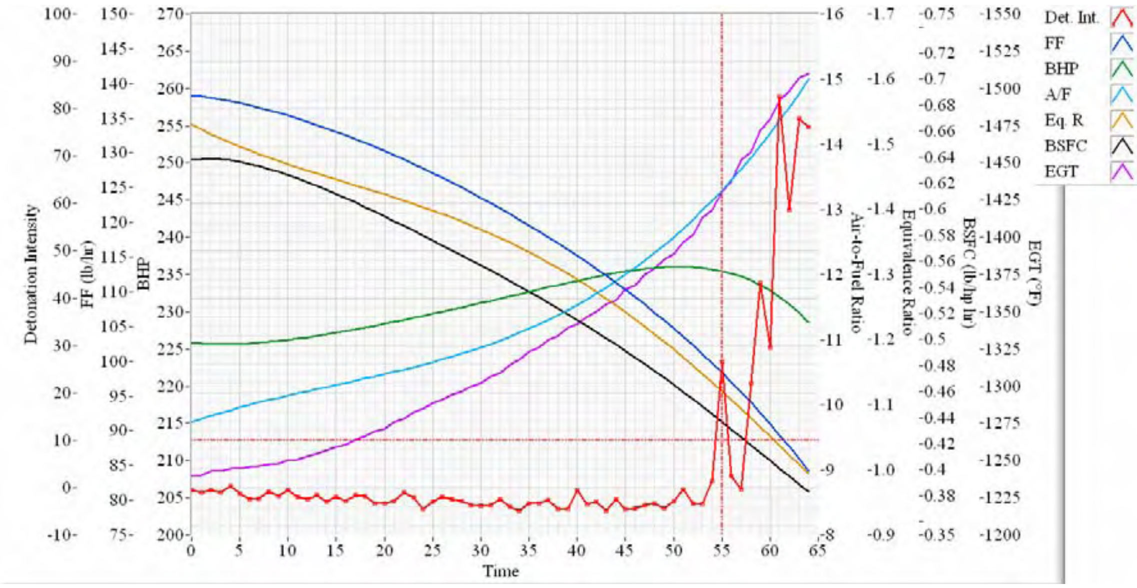


Figure D-33. Fixed-Base Operator 100LL Fuel, 2350 rpm, 28 inHg MAP

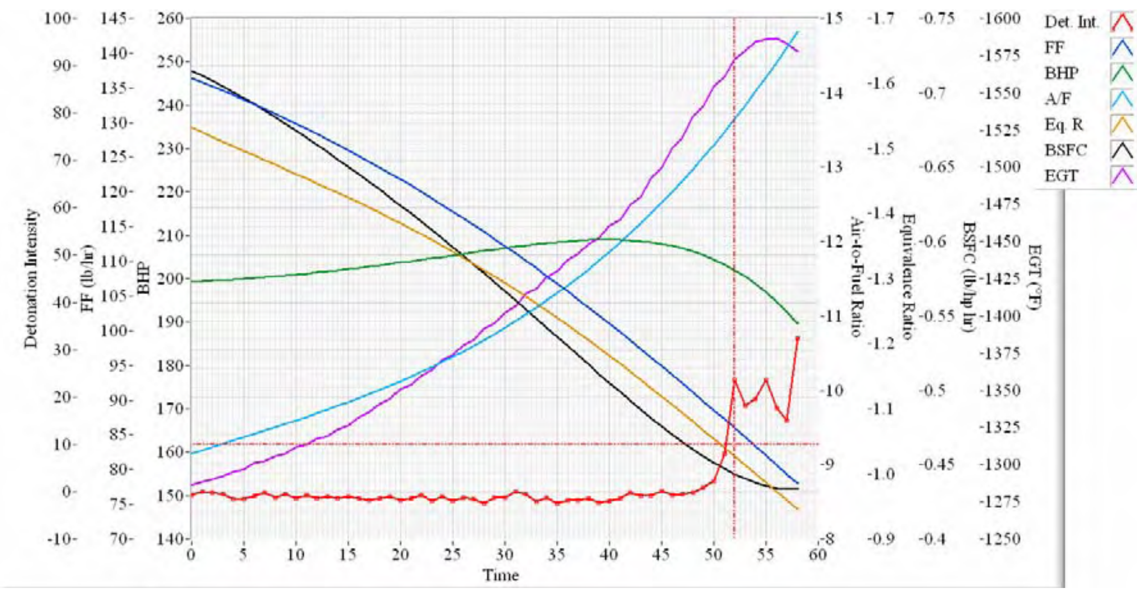


Figure D-34. Swift 702 Fuel, 2350 rpm, 26 inHg MAP

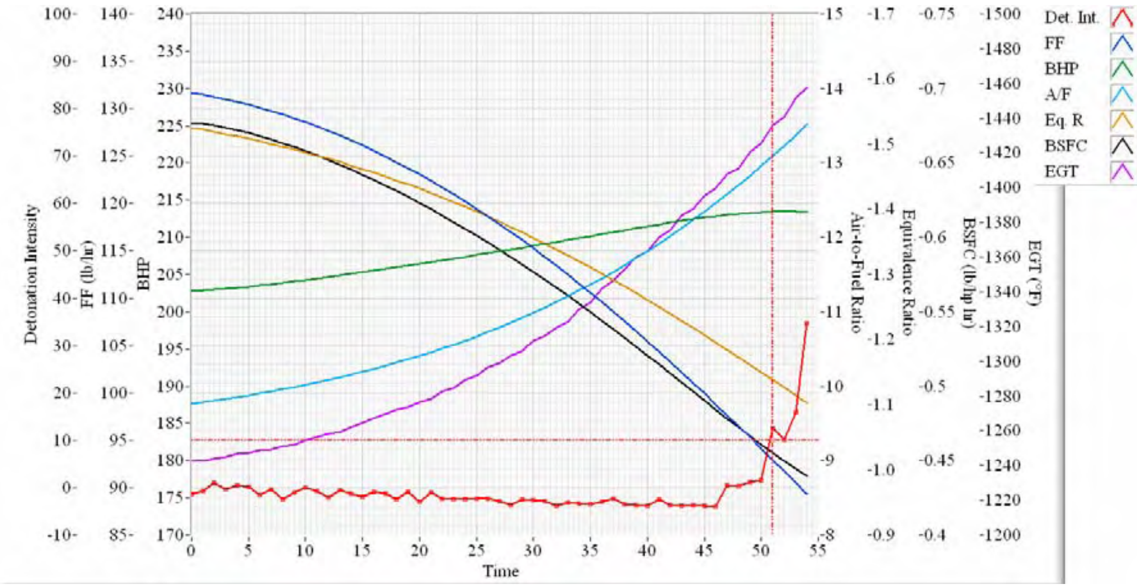


Figure D-35. Minimum Specification 100LL Fuel, 2350 rpm, 26 inHg MAP

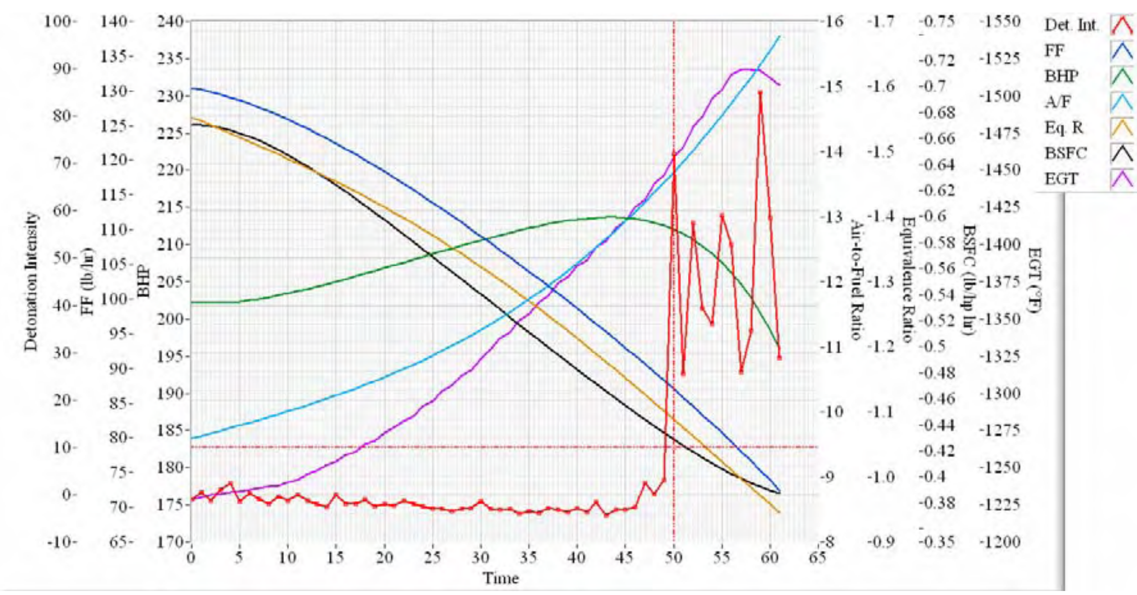


Figure D-36. Fixed-Base Operator 100LL Fuel, 2350 rpm, 26 inHg MAP

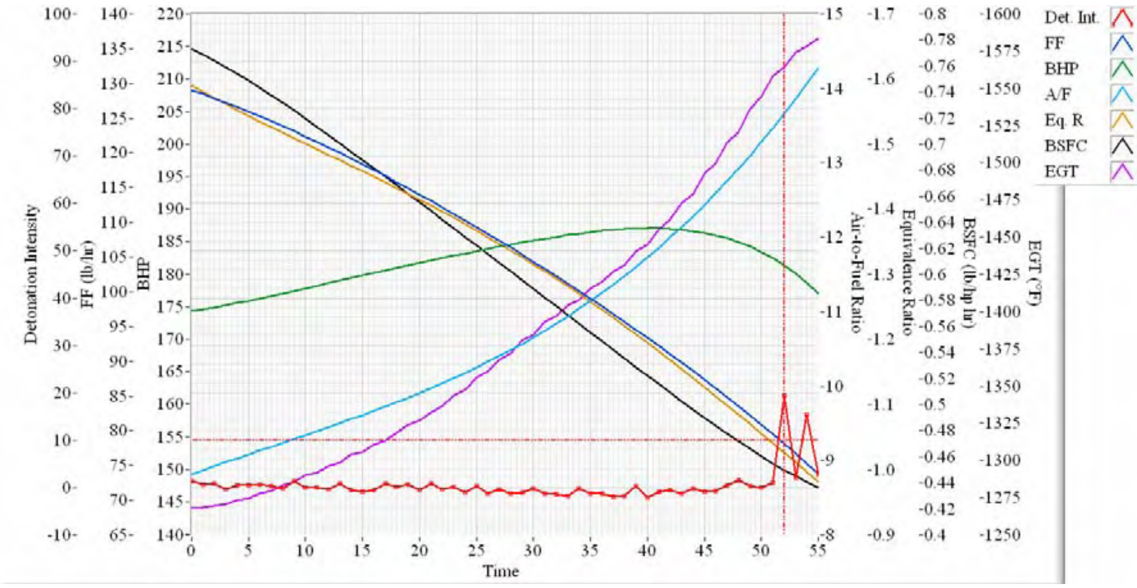


Figure D-37. Swift 702 Fuel, 2350 rpm, 24 inHg MAP

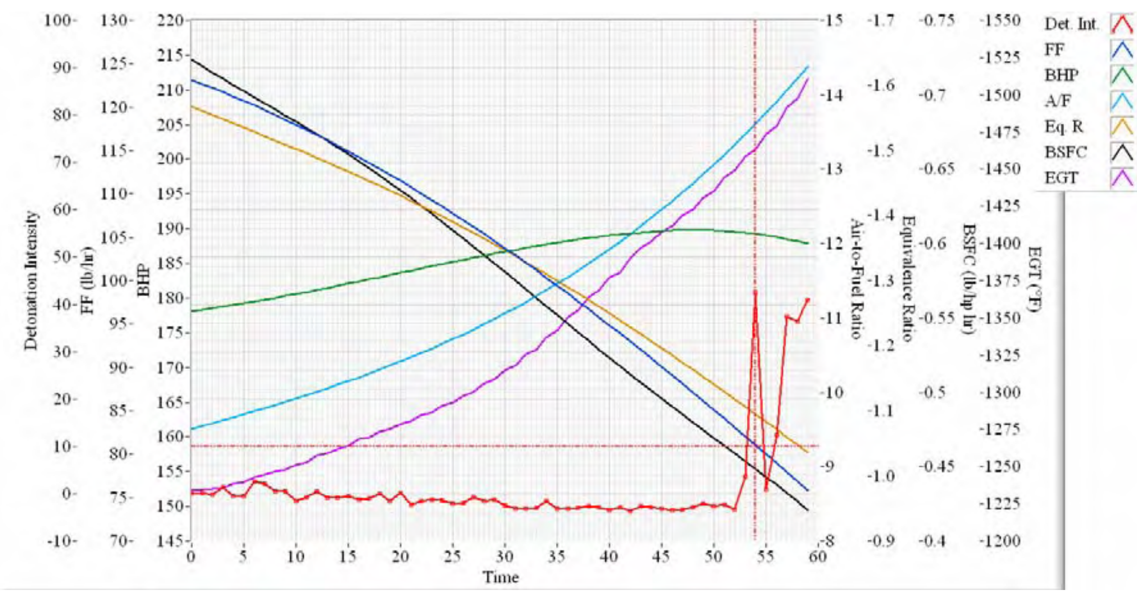


Figure D-38. Minimum Specification 100LL Fuel, 2350 rpm, 24 inHg MAP

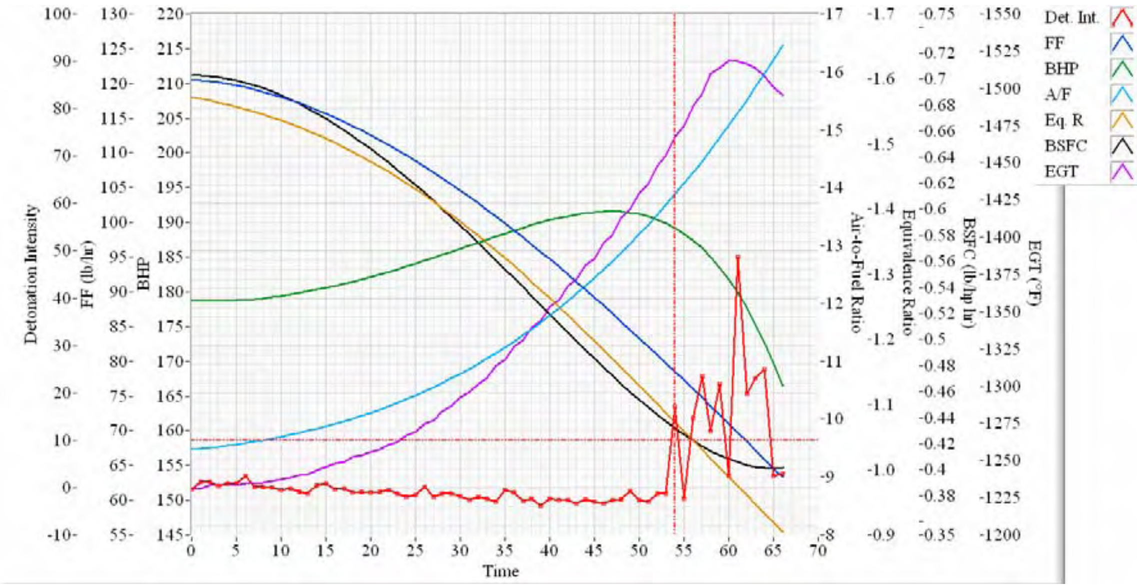


Figure D-39. Fixed-Base Operator 100LL Fuel, 2350 rpm, 24 inHg MAP

APPENDIX E —LYCOMING TIO-540-J2BD DETONATION ONSET GRAPHS WITH AVERAGE EXHAUST GAS TEMPERATURE

The graphical data in this section contains detonation onset data for the Swift 702 and 100 low-lead (100LL) fixed-base operator (FBO) fuels. The square data points on the curves represent the richest mixtures where detonation onset occurred.

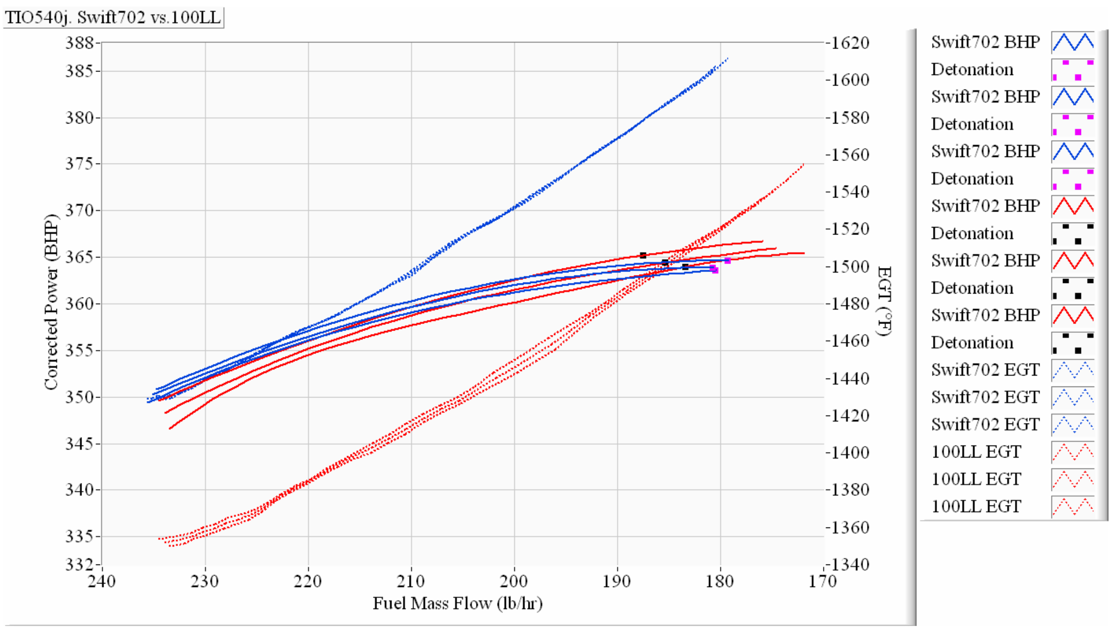


Figure E-1. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, TO

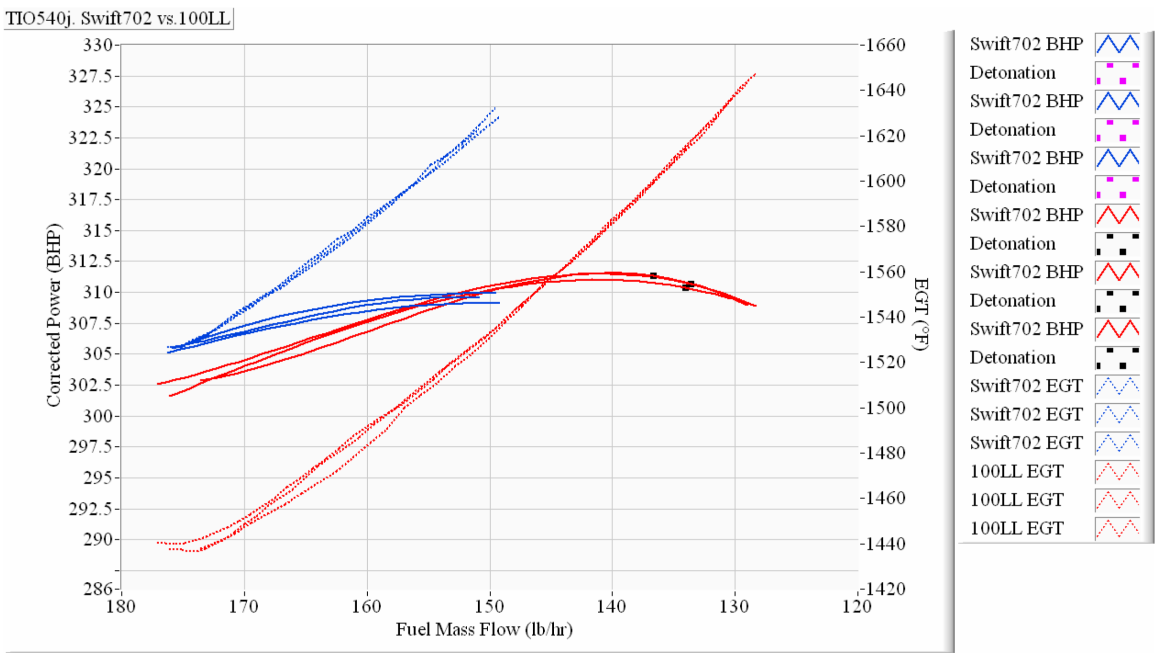


Figure E-2. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 85% Power

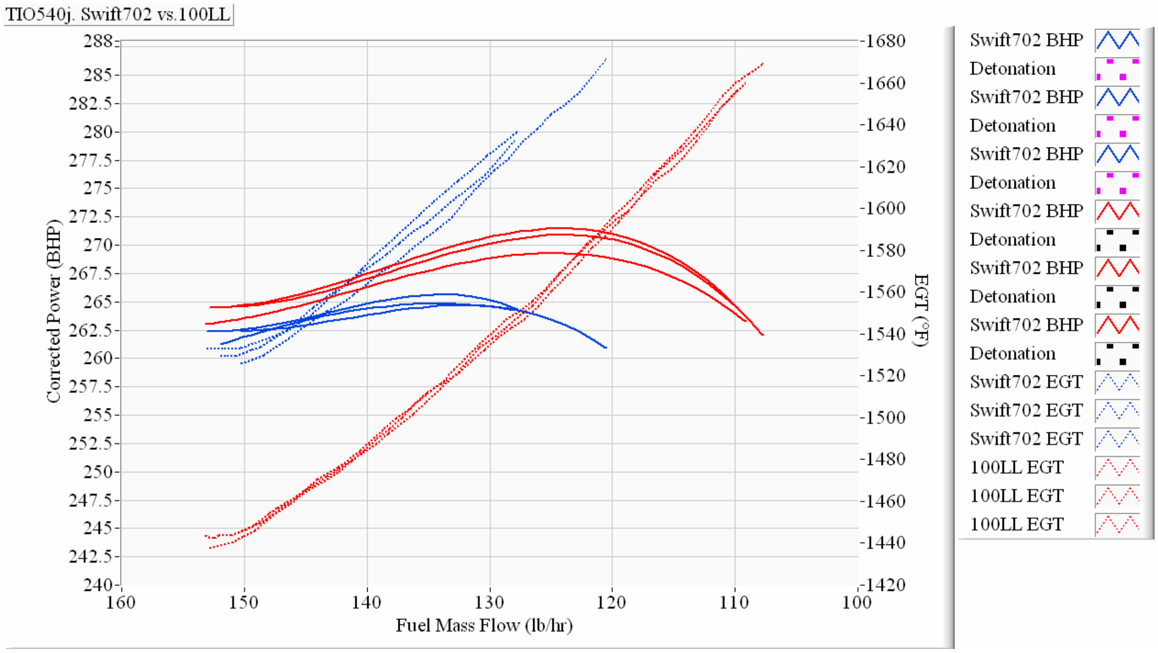


Figure E-3. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 75% Power

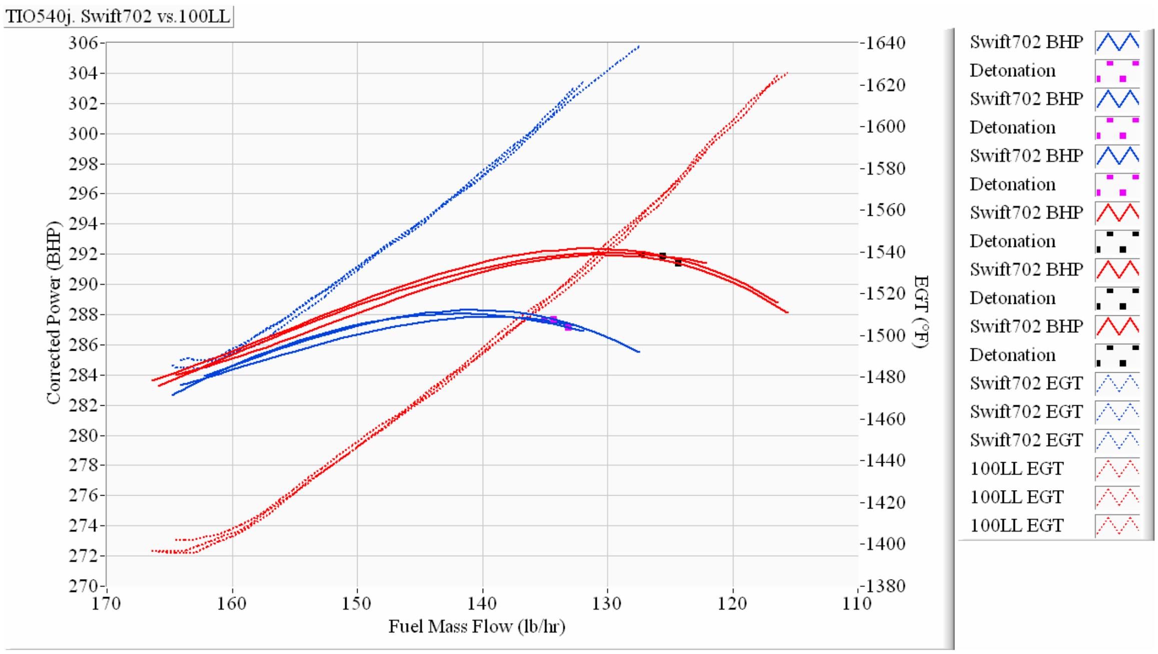


Figure E-4. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2400 rpm, 80% Power

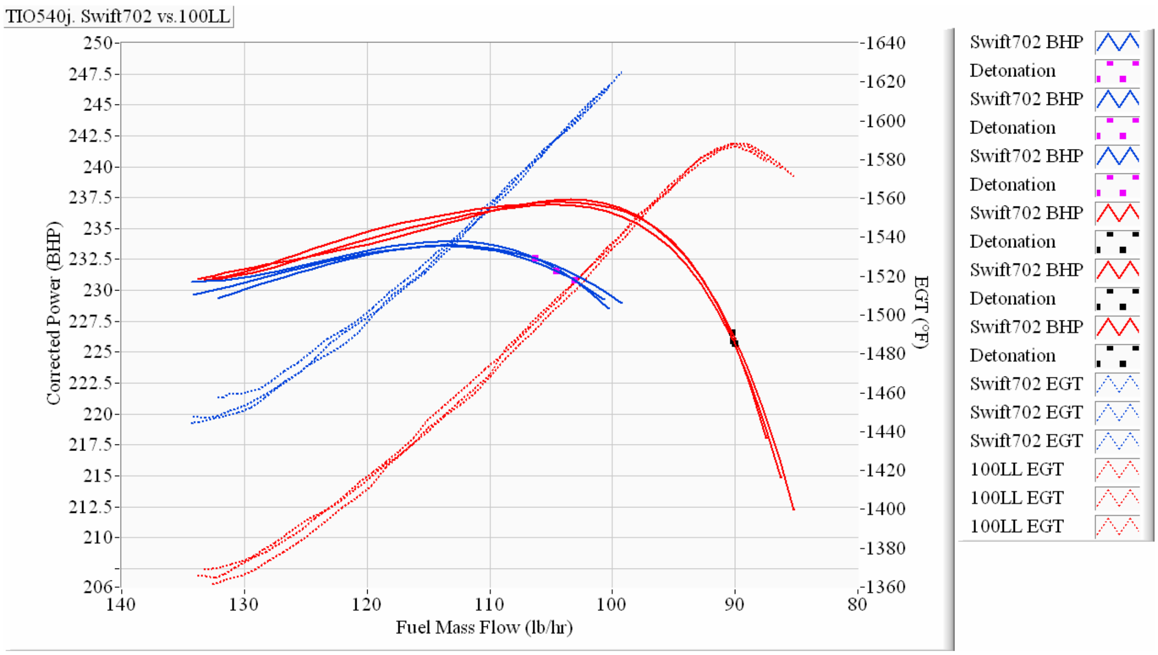


Figure E-5. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2200 rpm, 65% Power

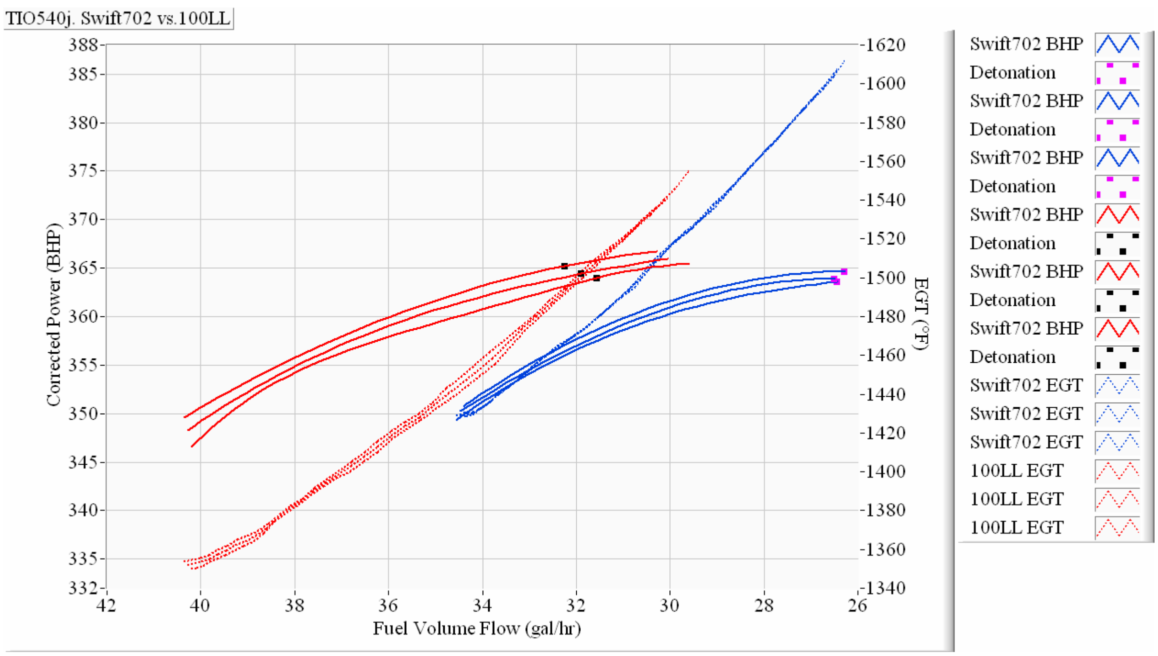


Figure E-6. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, TO

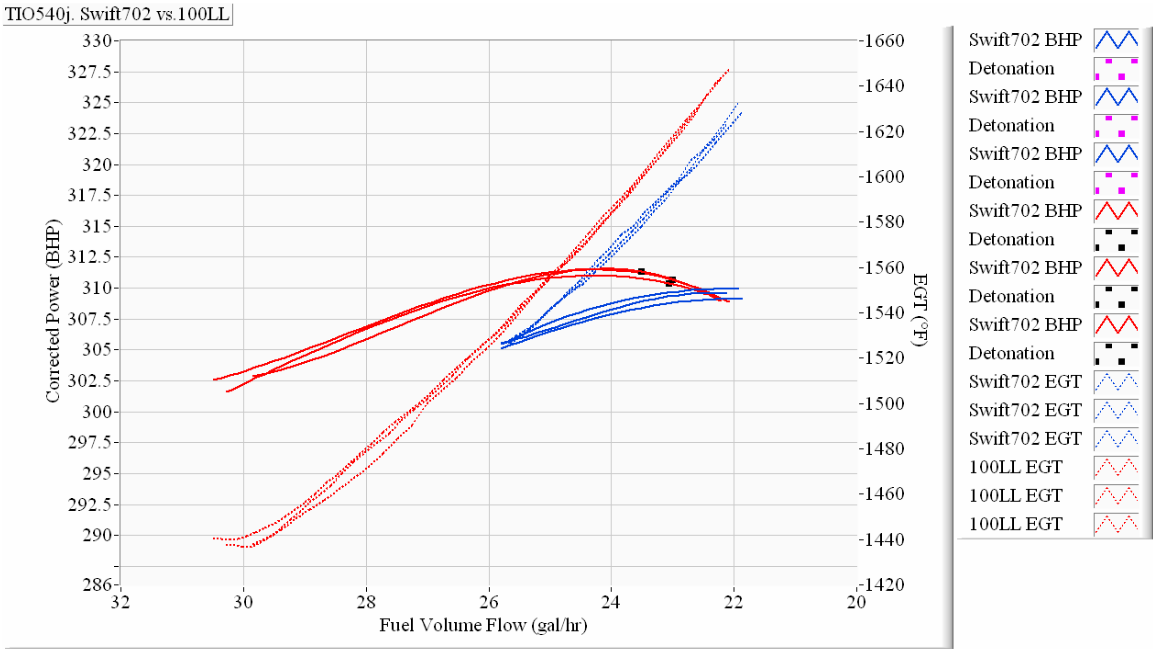


Figure E-7. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 85% Power

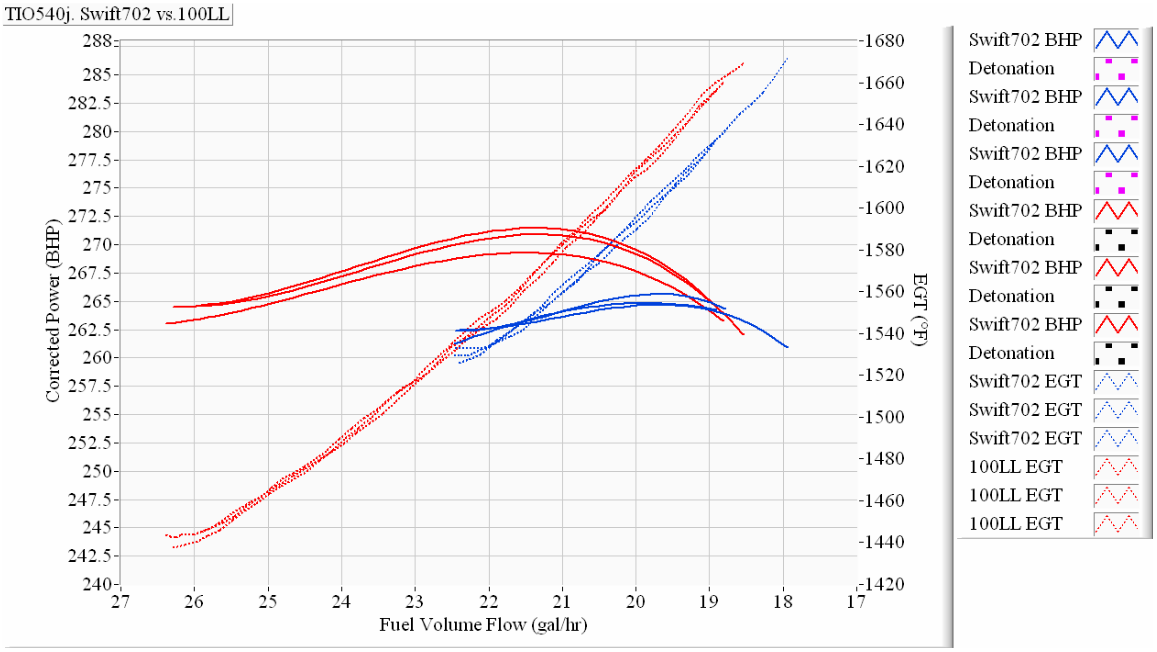


Figure E-8. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 75% Power

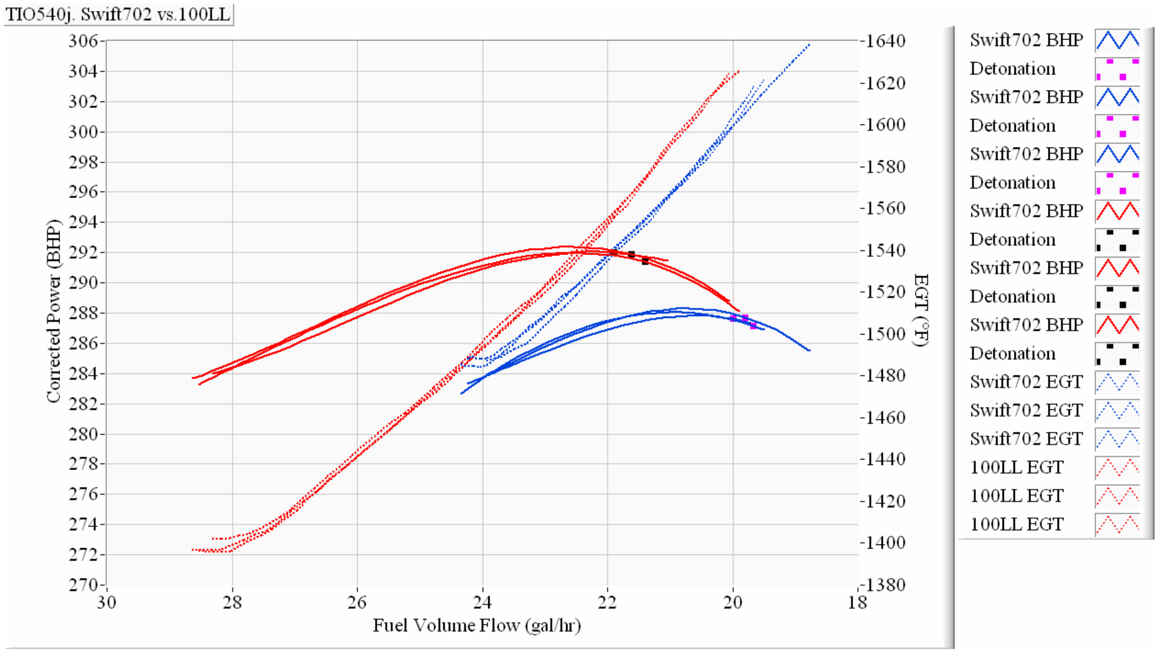


Figure E-9. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2400 rpm, 80% Power

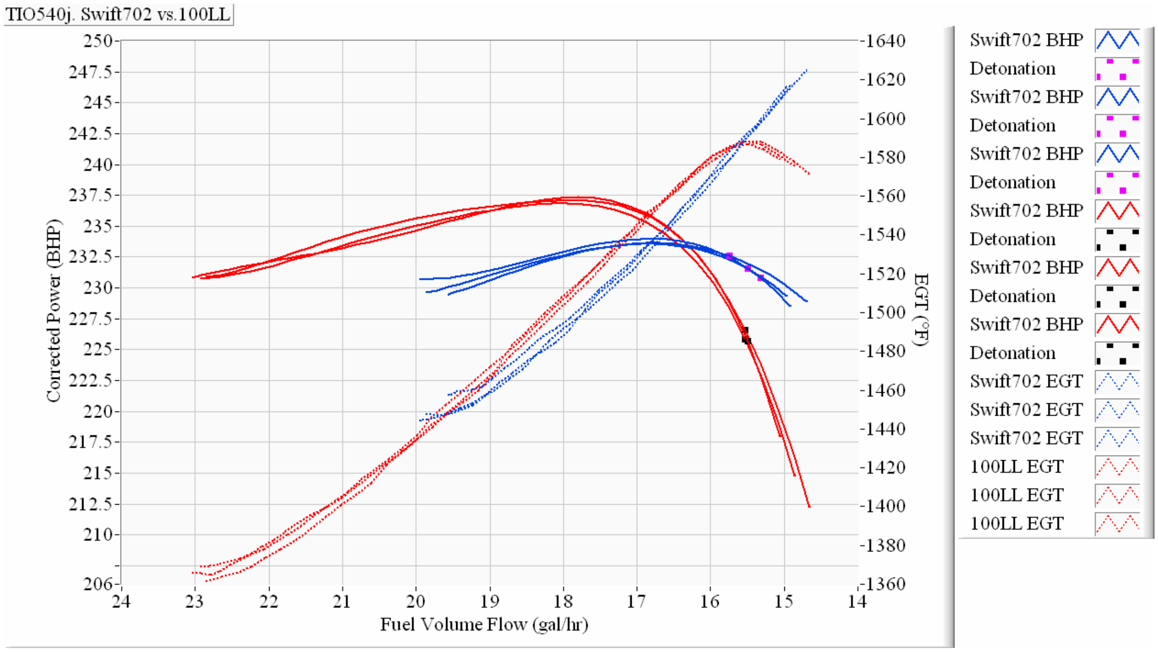


Figure E-10. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2200 rpm, 65% Power

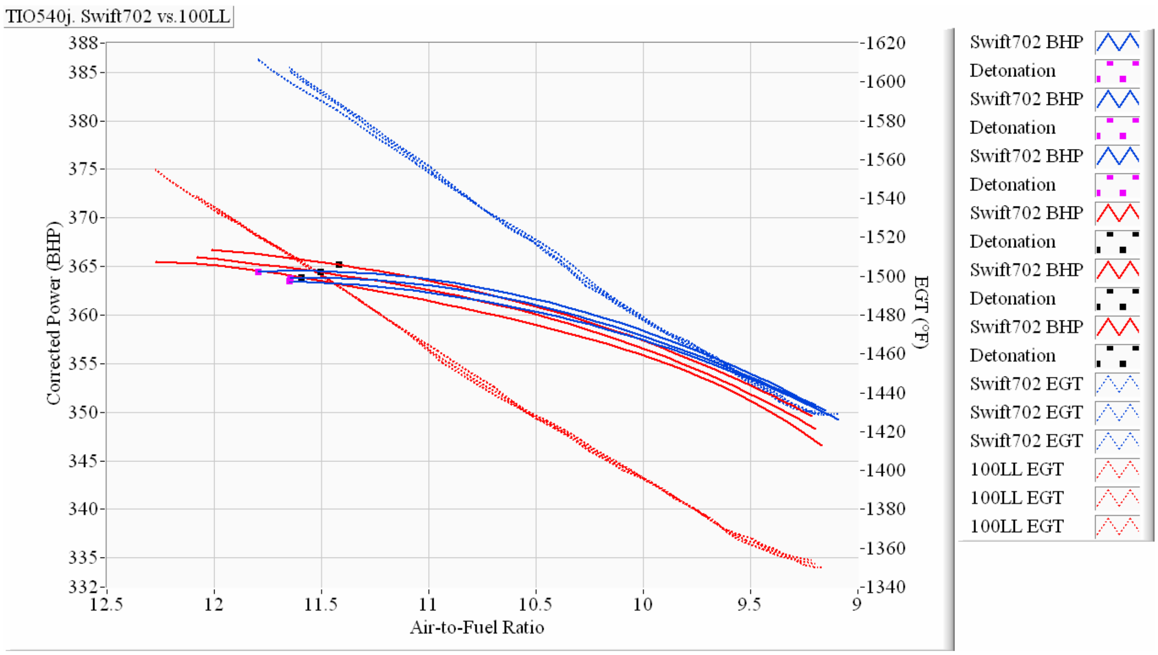


Figure E-11. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, TO

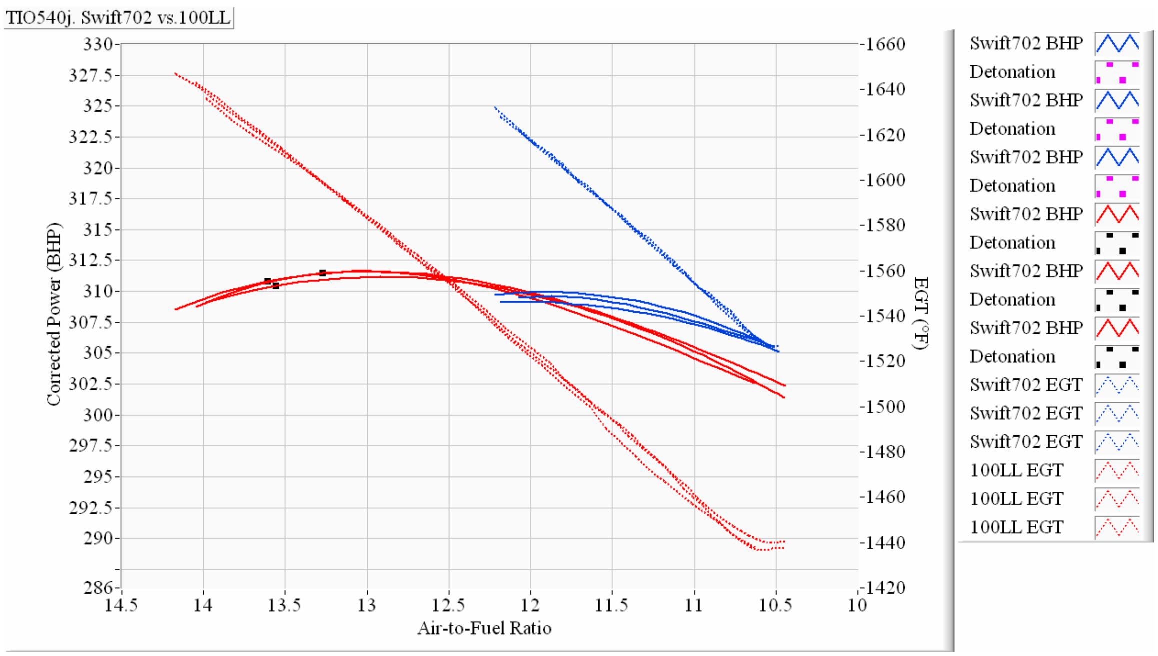


Figure E-12. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 85% Power

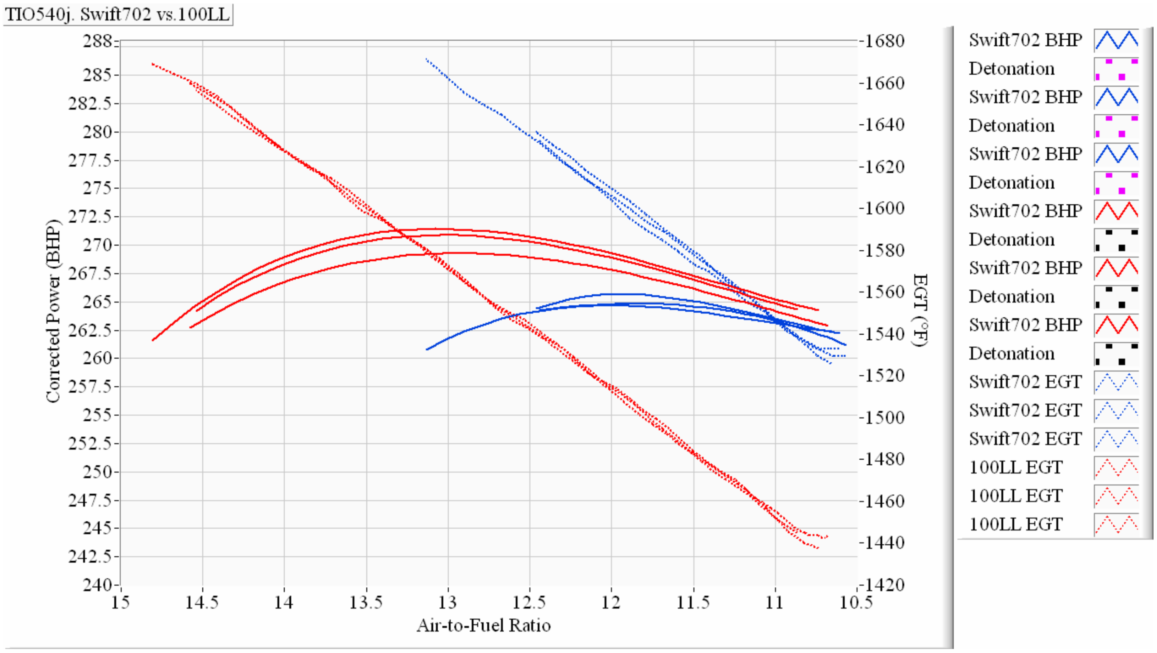


Figure E-13. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 75% Power

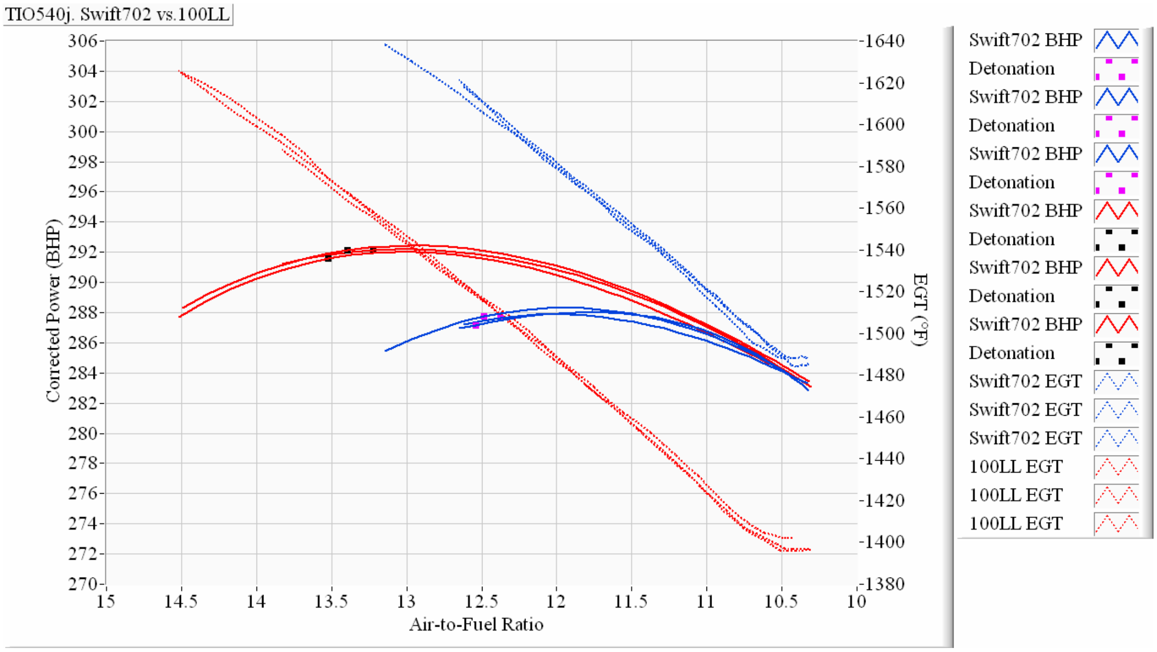


Figure E-14. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2400 rpm, 80% Power

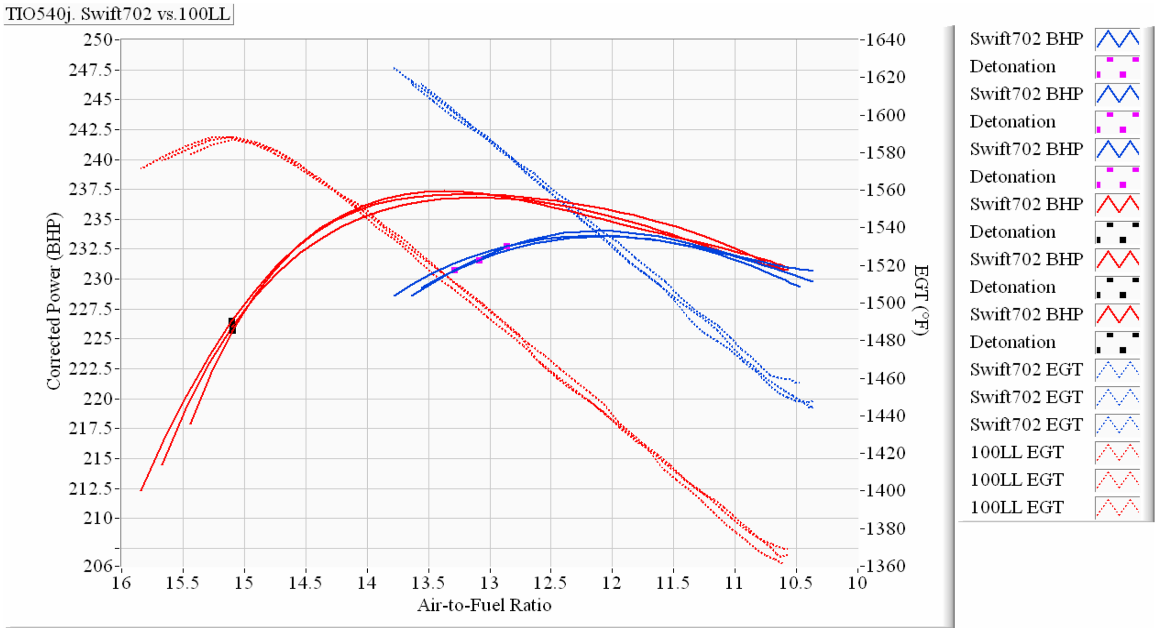


Figure E-15. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2200 rpm, 65% Power

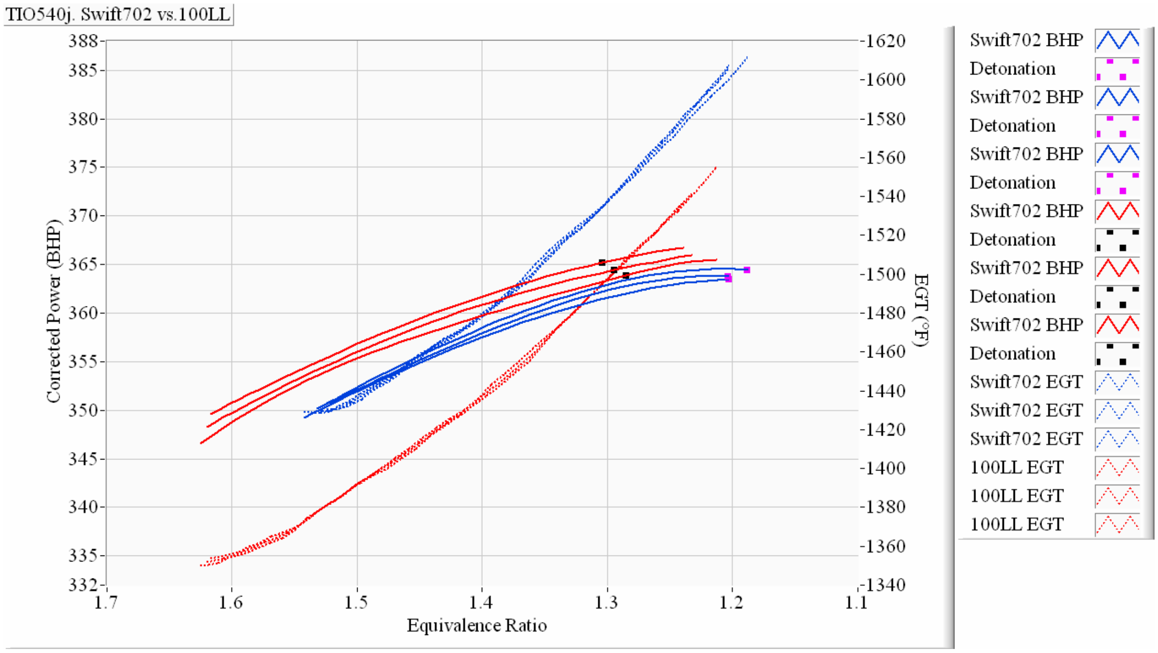


Figure E-16. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, TO

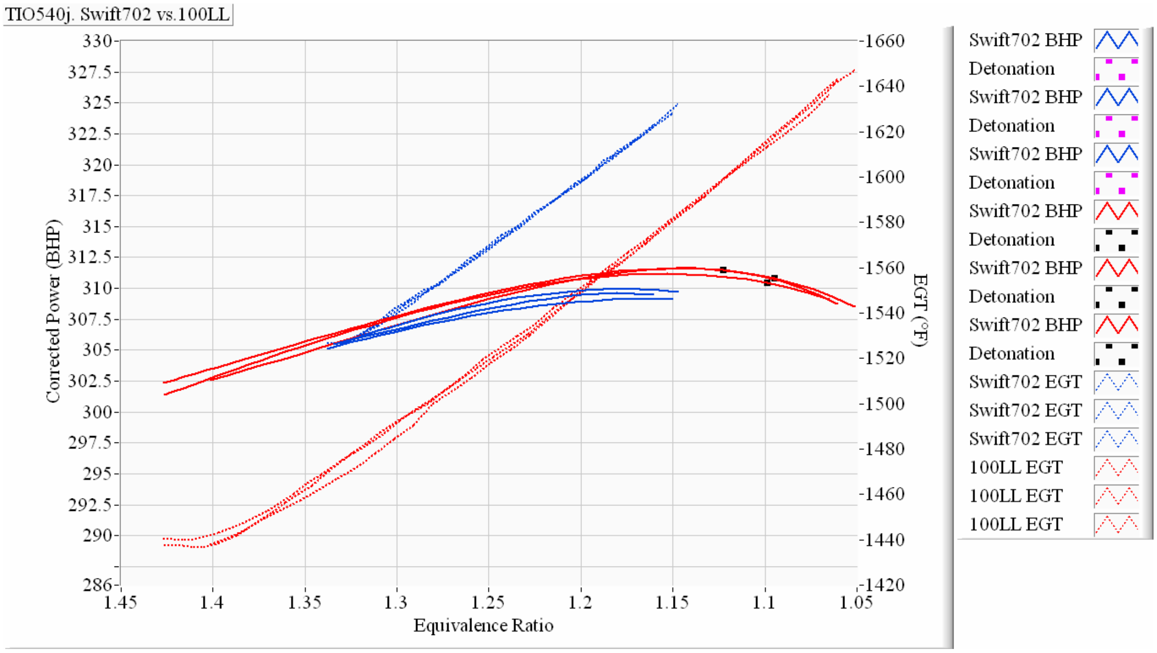


Figure E-17. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 85% Power

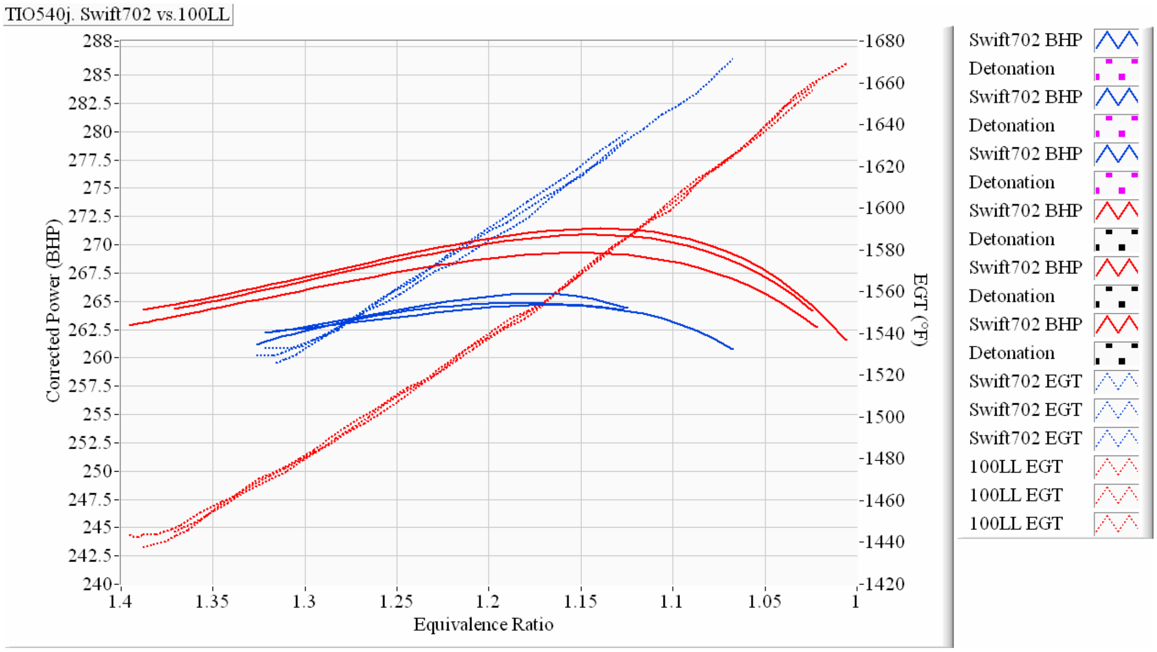


Figure E-18. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 75% Power

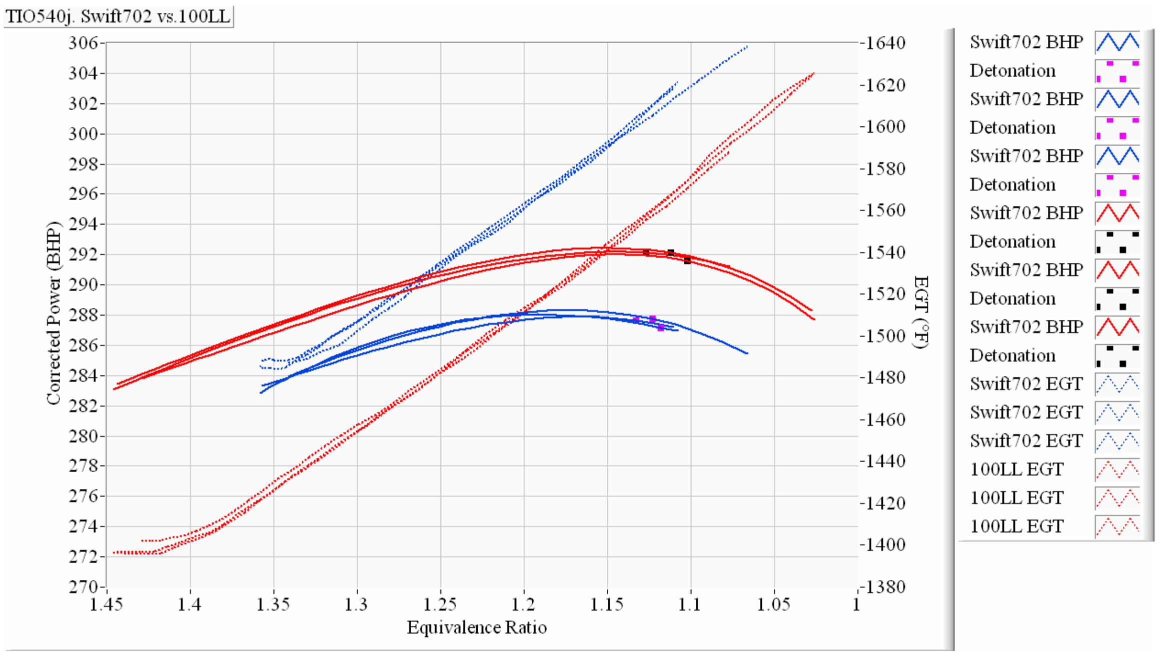


Figure E-19. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2400 rpm, 80% Power

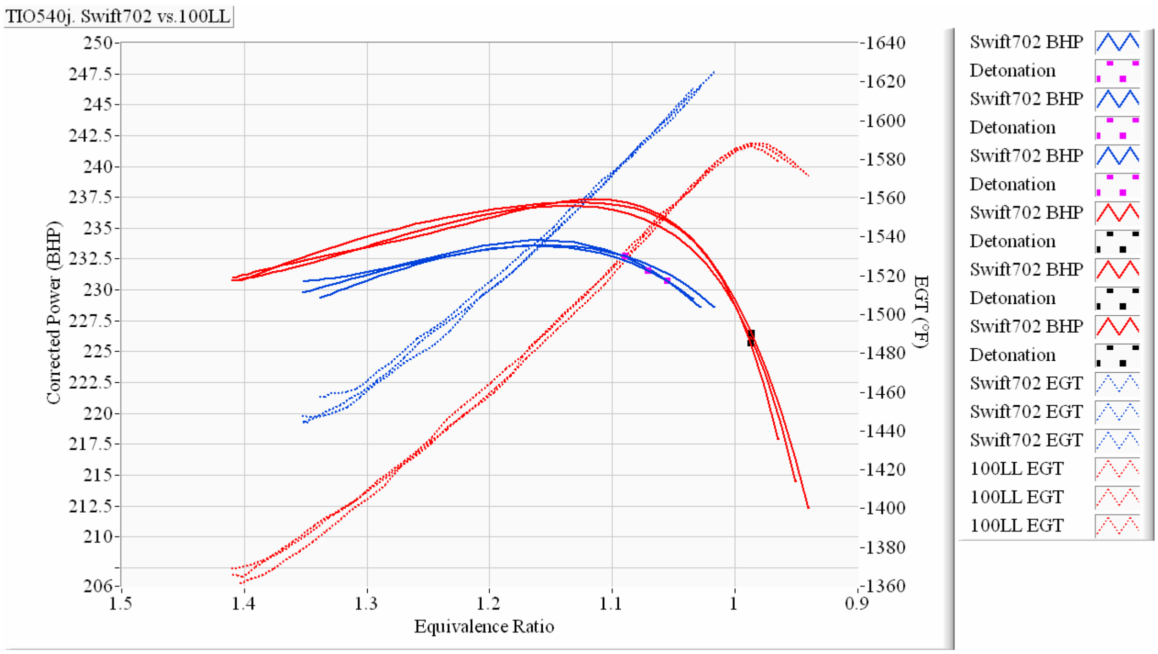


Figure E-20. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2200 rpm, 65% Power

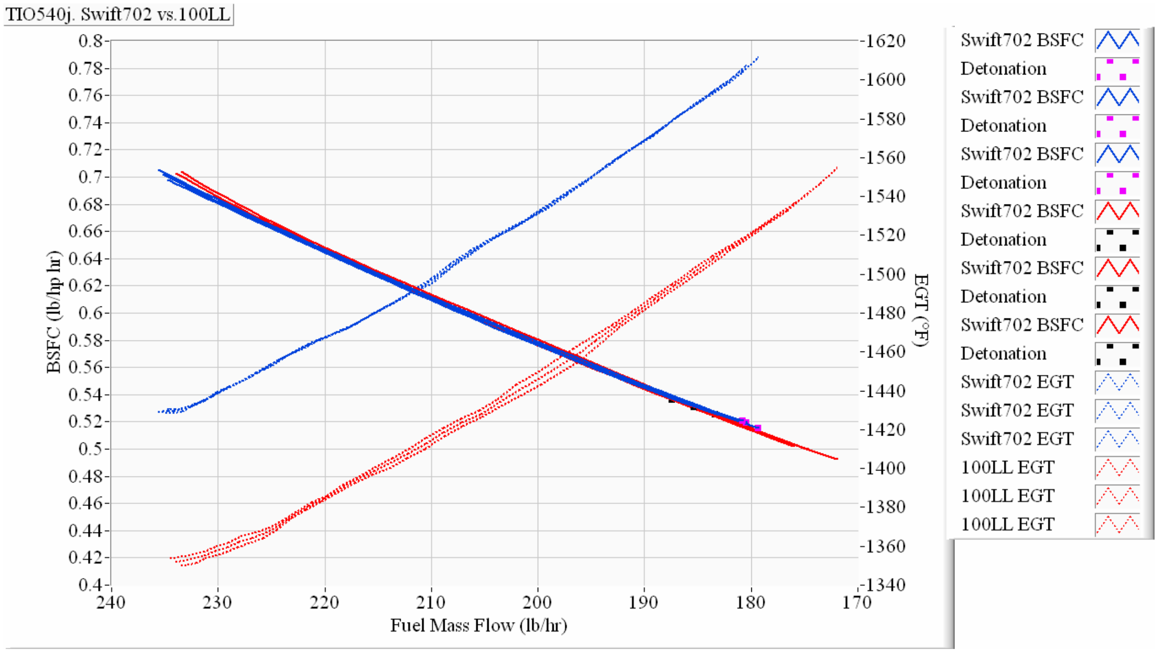


Figure E-21. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, TO

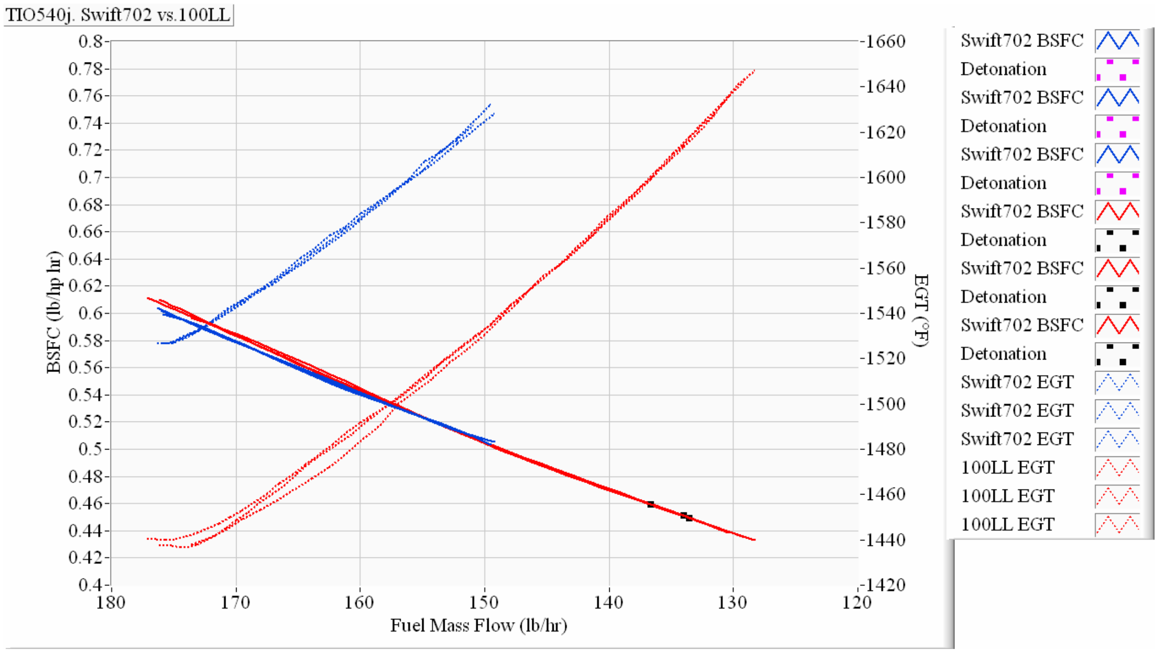


Figure E-22. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 85% Power

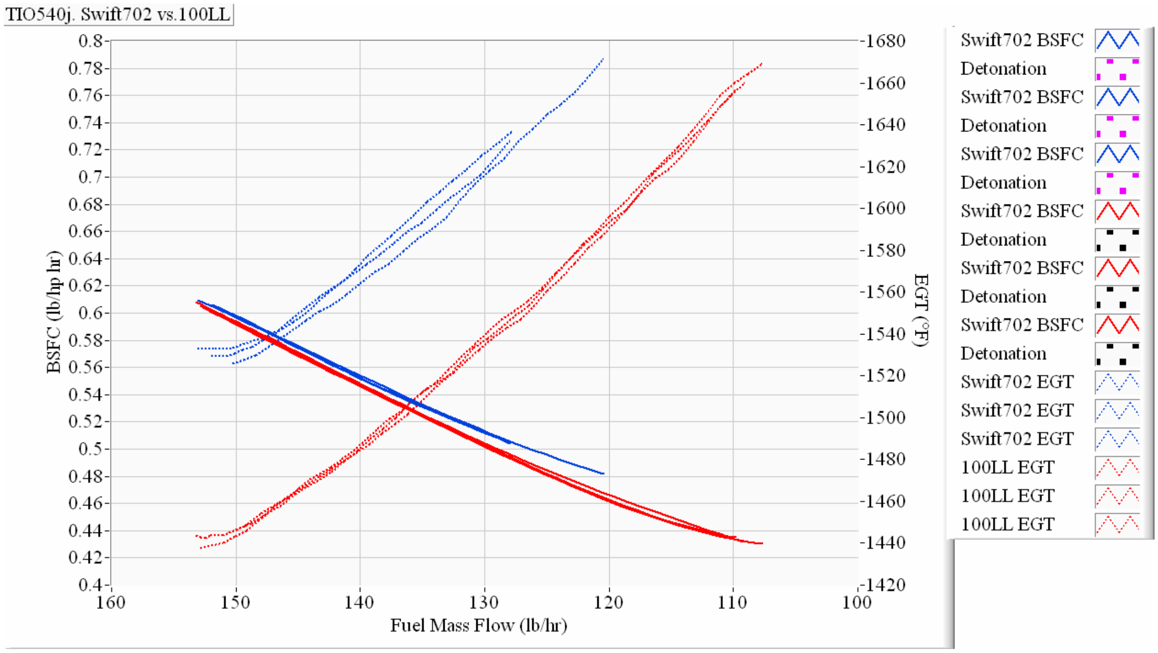


Figure E-23. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 75% Power

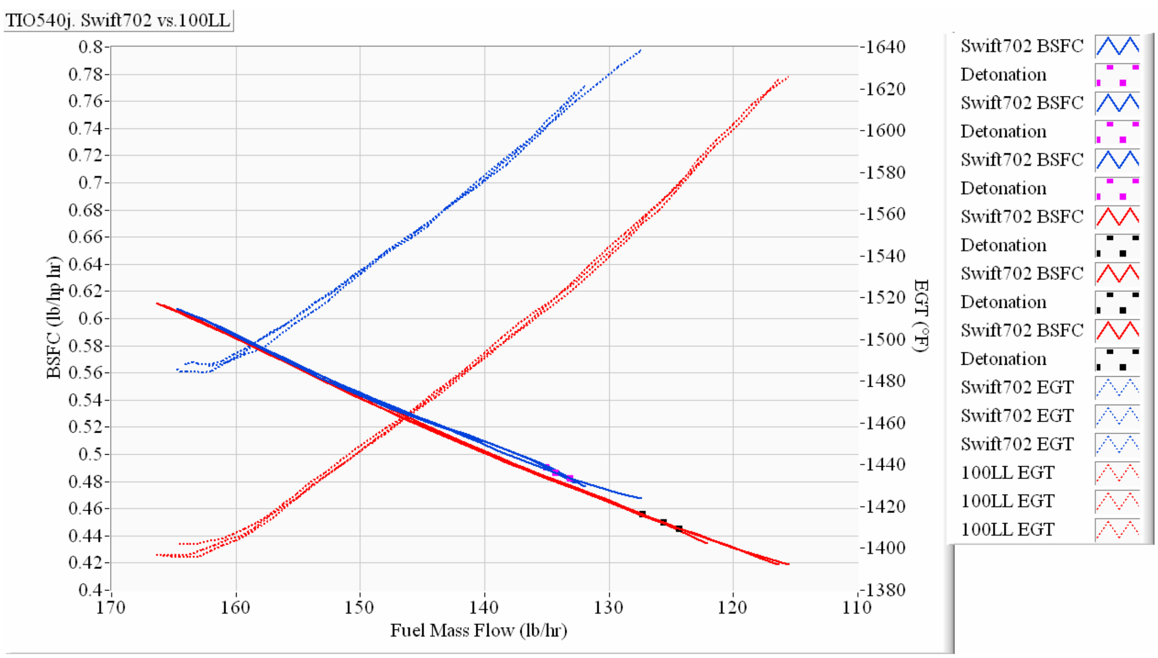


Figure E-24. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2400 rpm, 80% Power

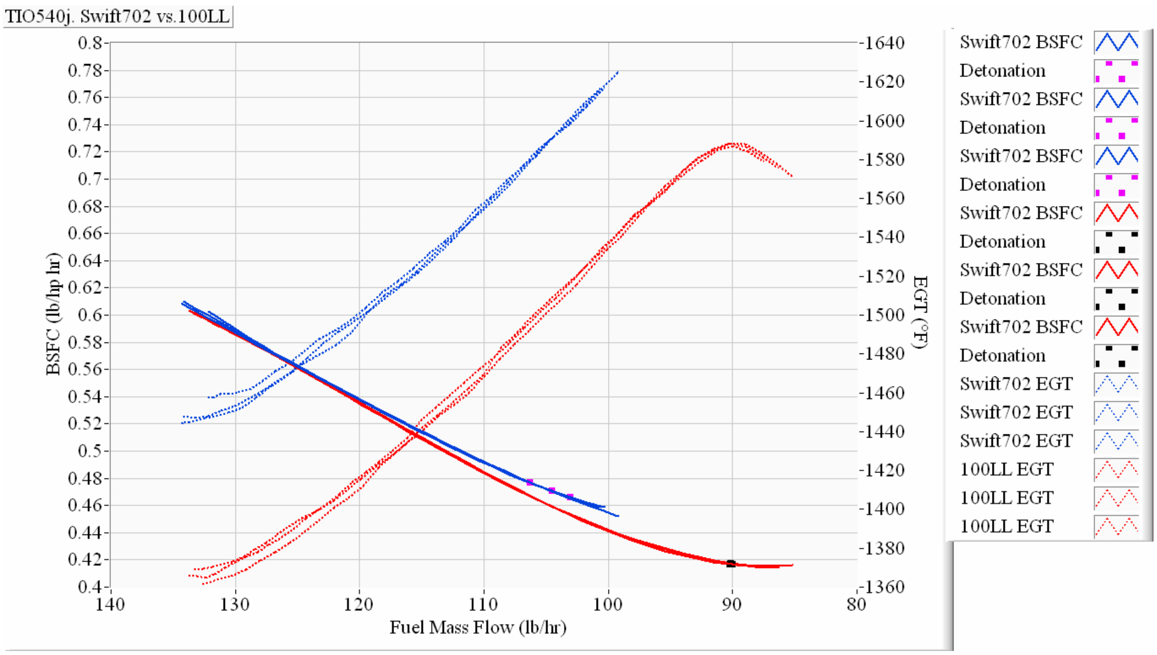


Figure E-25. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2200 rpm, 65% Power

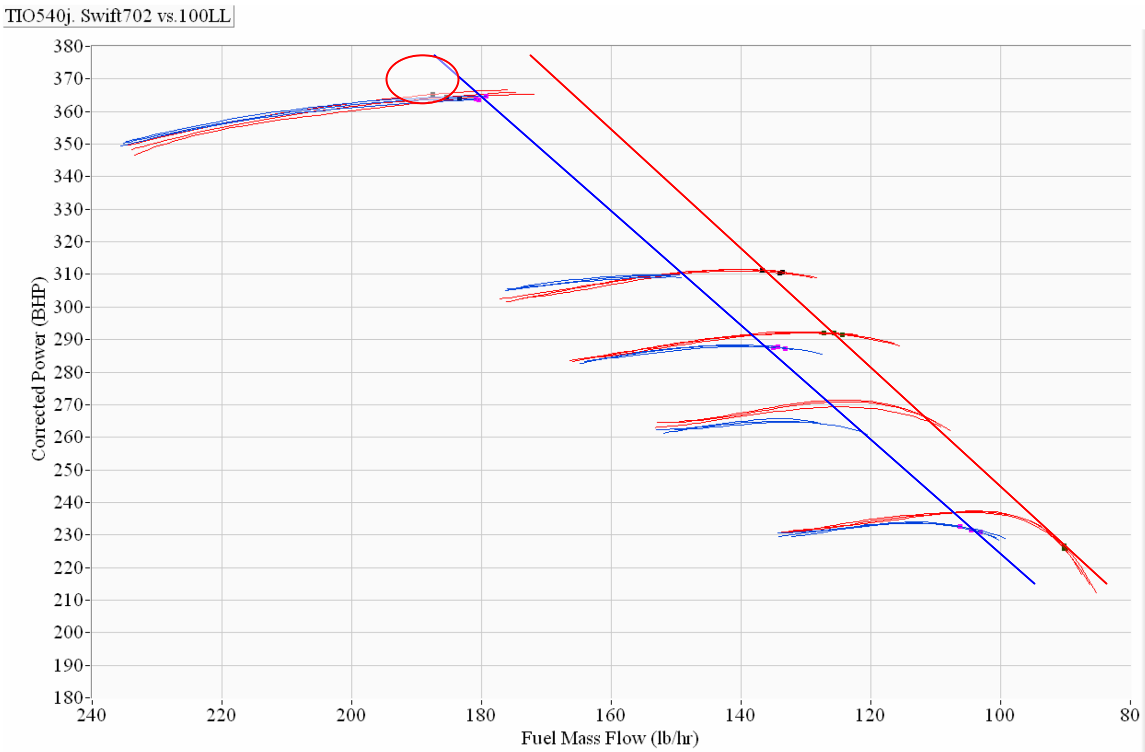


Figure E-26. All Power Settings; Swift 702 in Blue, 100LL in Red

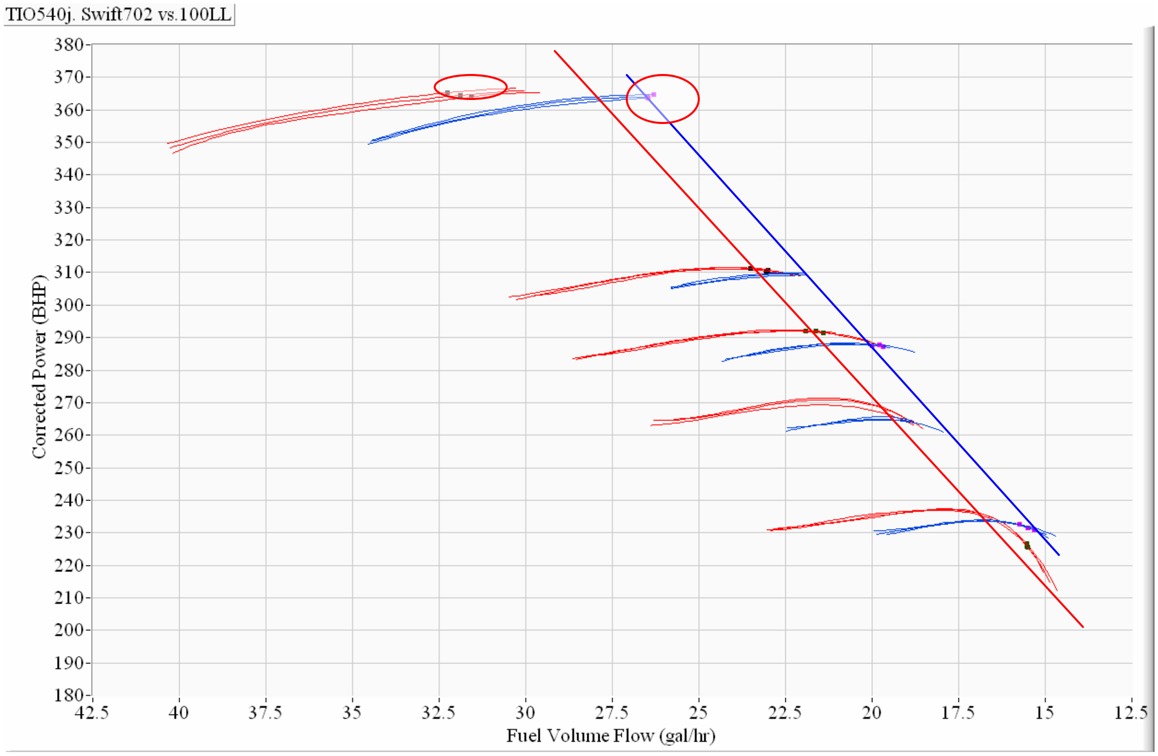


Figure E-27. All Power Settings; Swift 702 in Blue, 100LL in Red

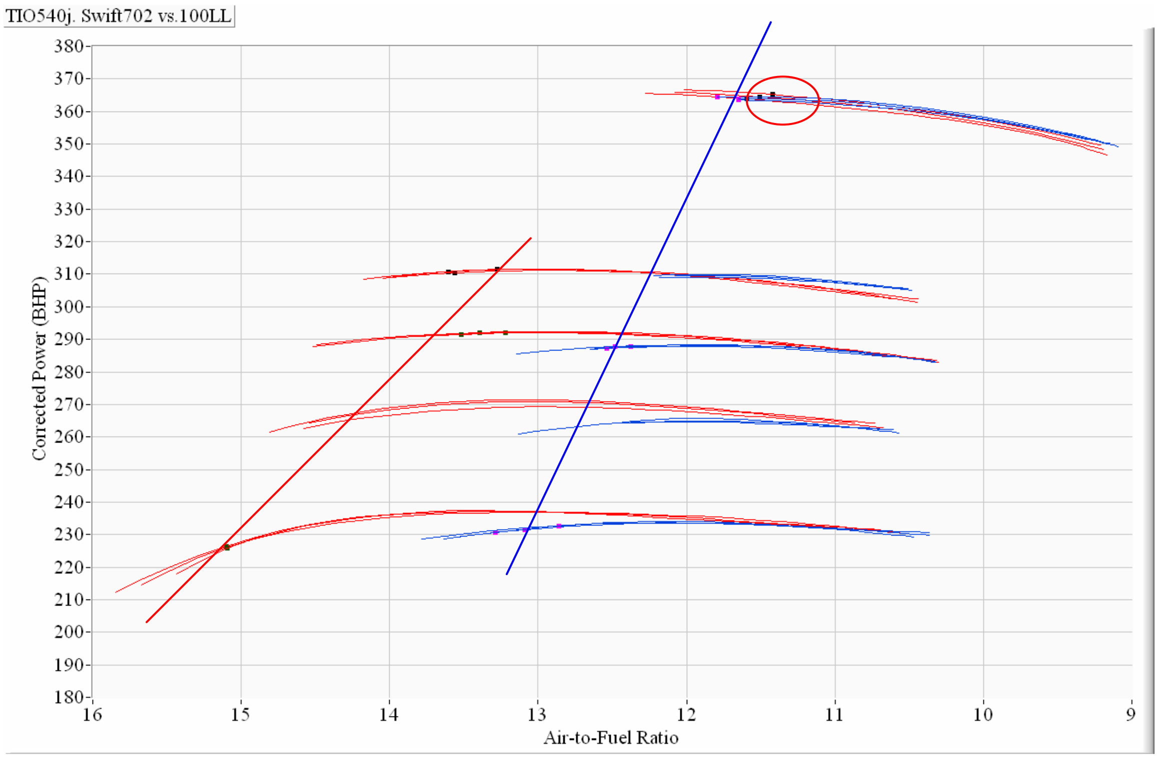


Figure E-28. All Power Settings; Swift 702 in Blue, 100LL in Red

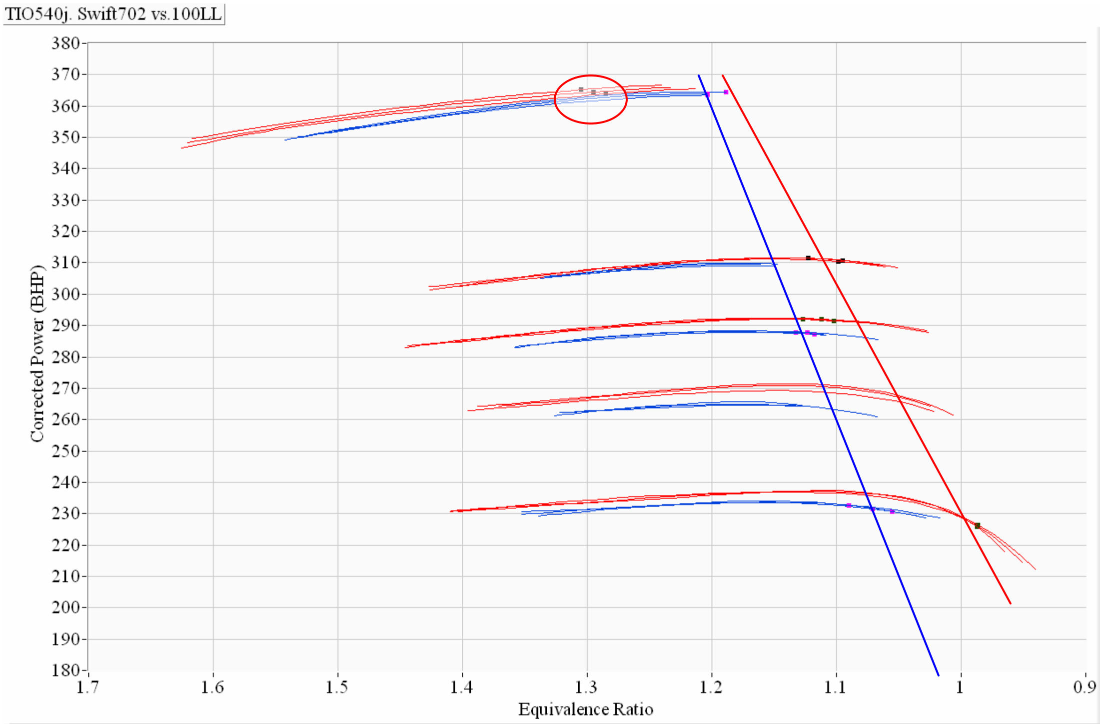


Figure E-29. All Power Settings; Swift 702 in Blue, 100LL in Red

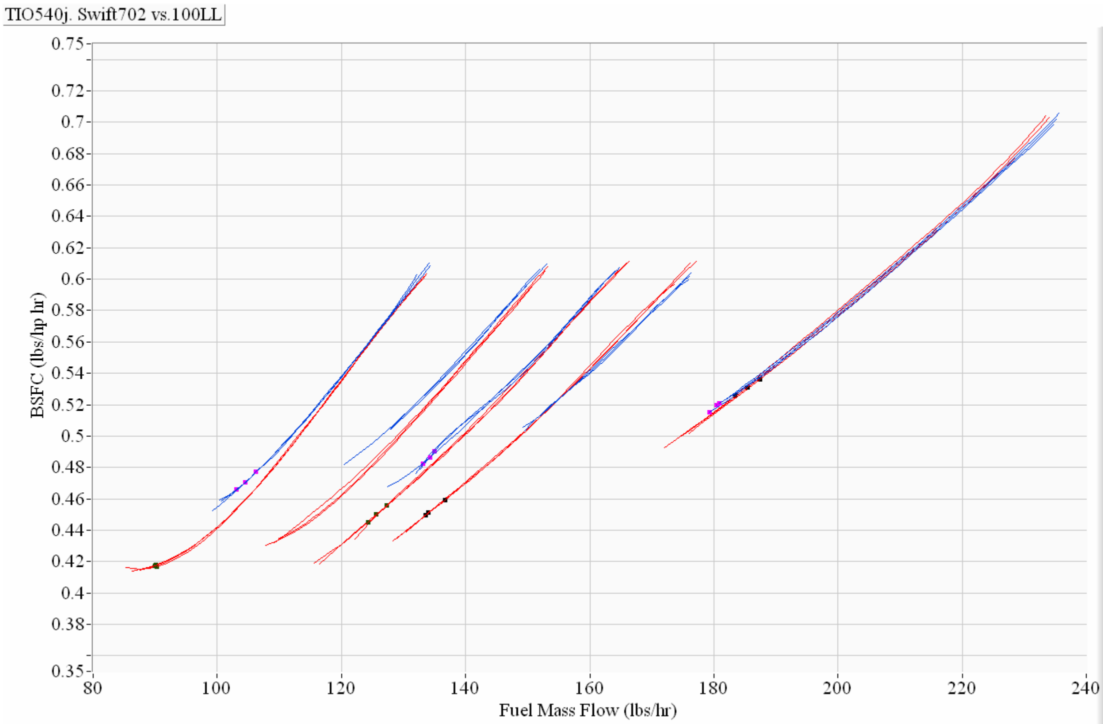


Figure E-30. All Power Settings; Swift 702 in Blue, 100LL in Red

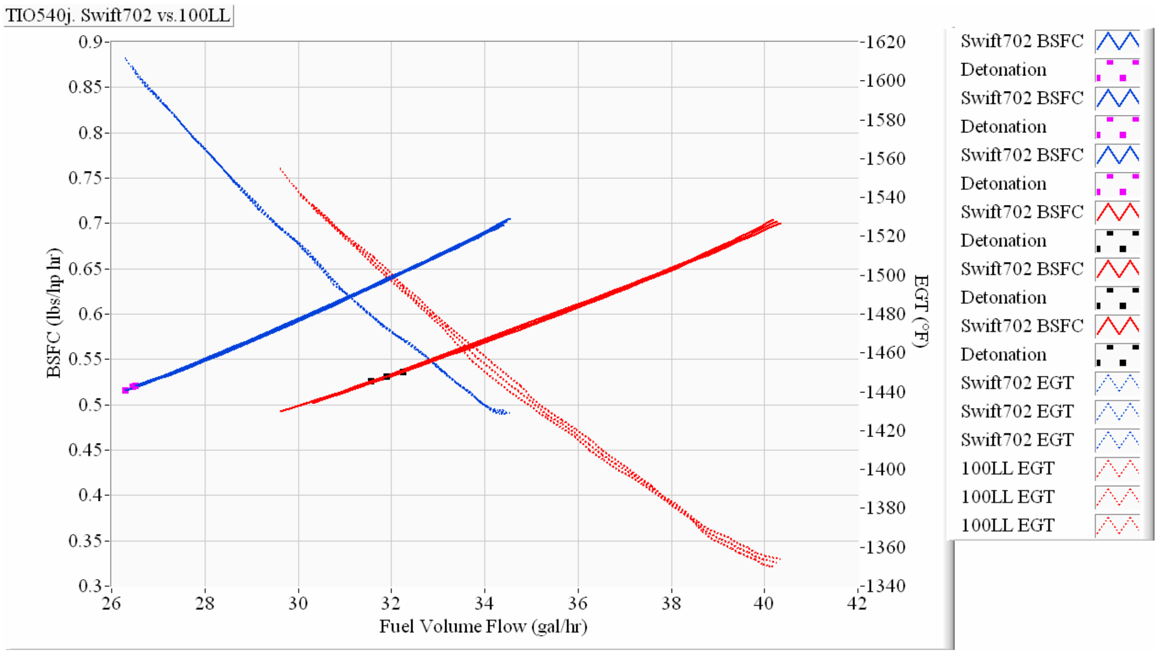


Figure E-31. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, TO

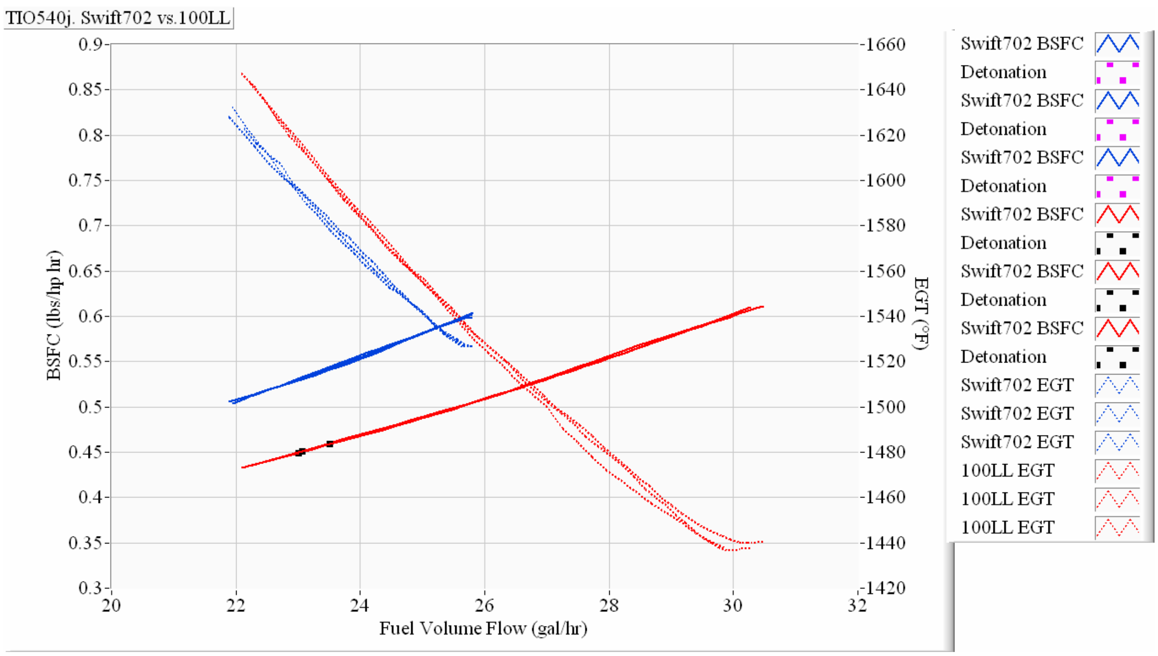


Figure E-32. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 85% Power

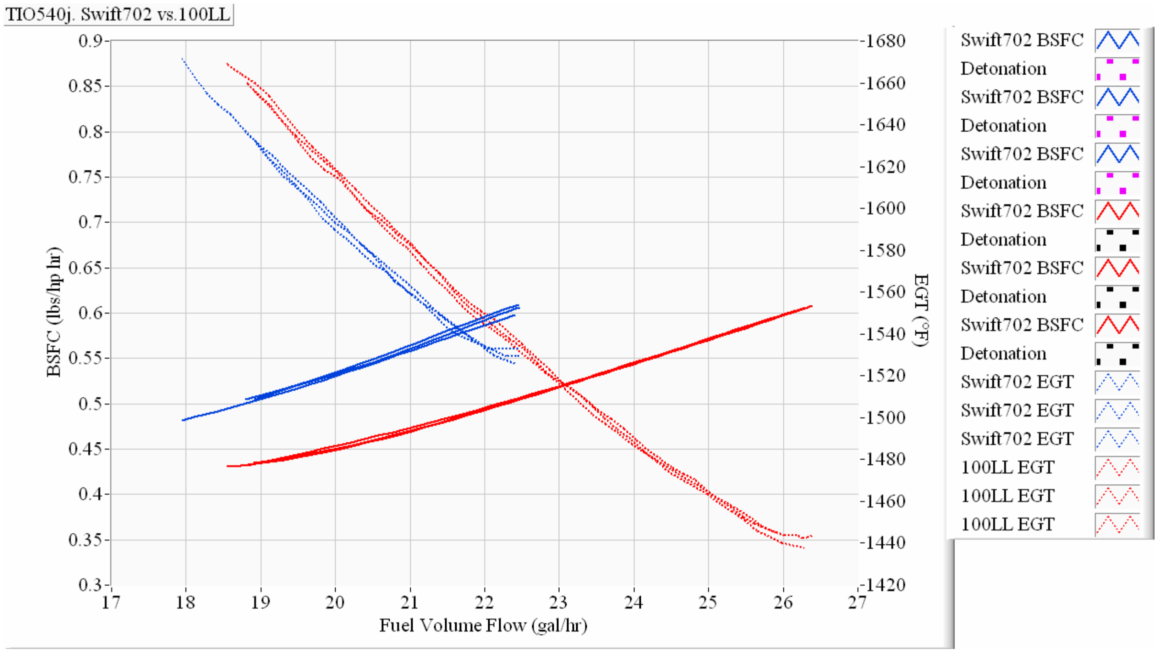


Figure E-33. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 75% Power

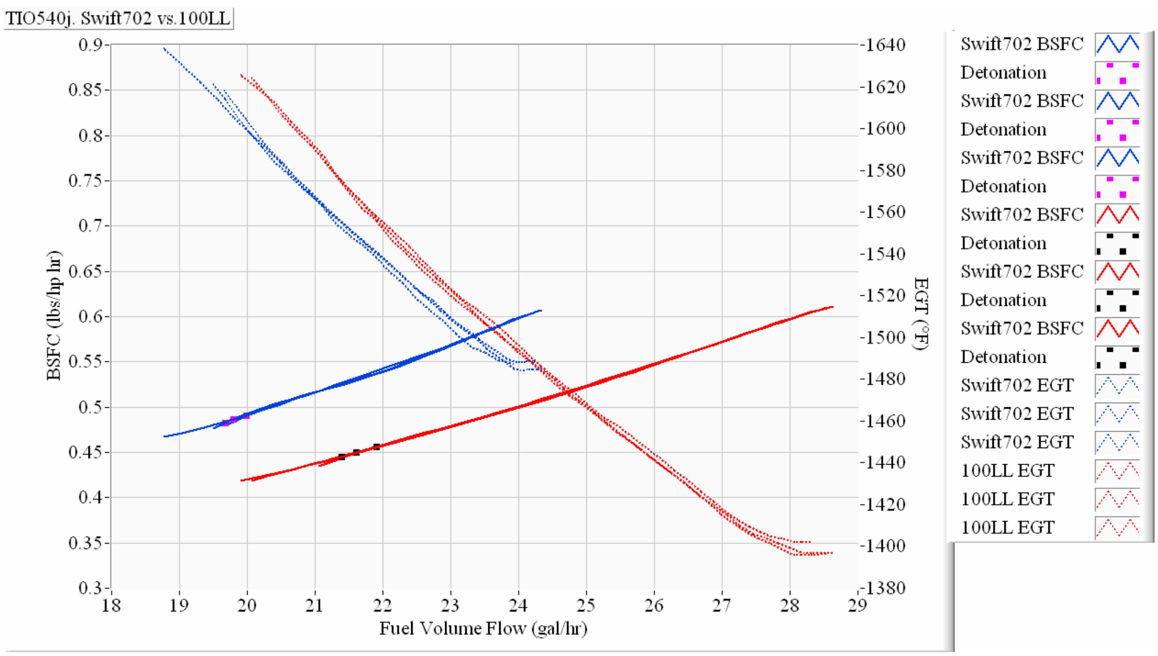


Figure E-34. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2400 rpm, 80% Power

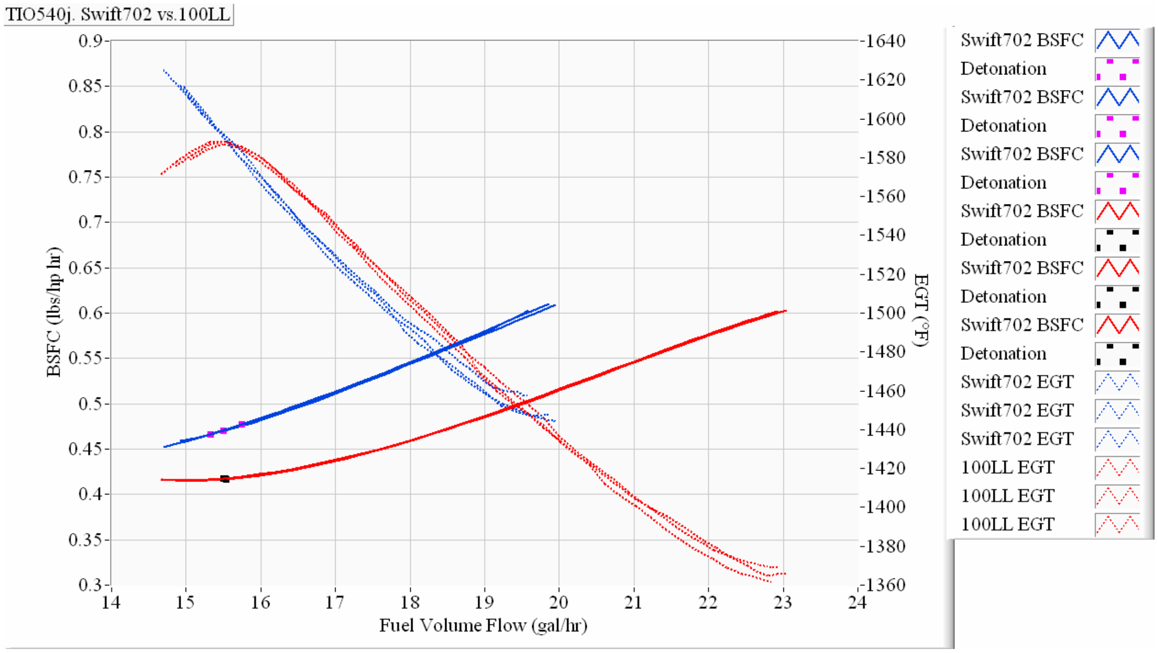


Figure E-35. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2200 rpm, 65% Power

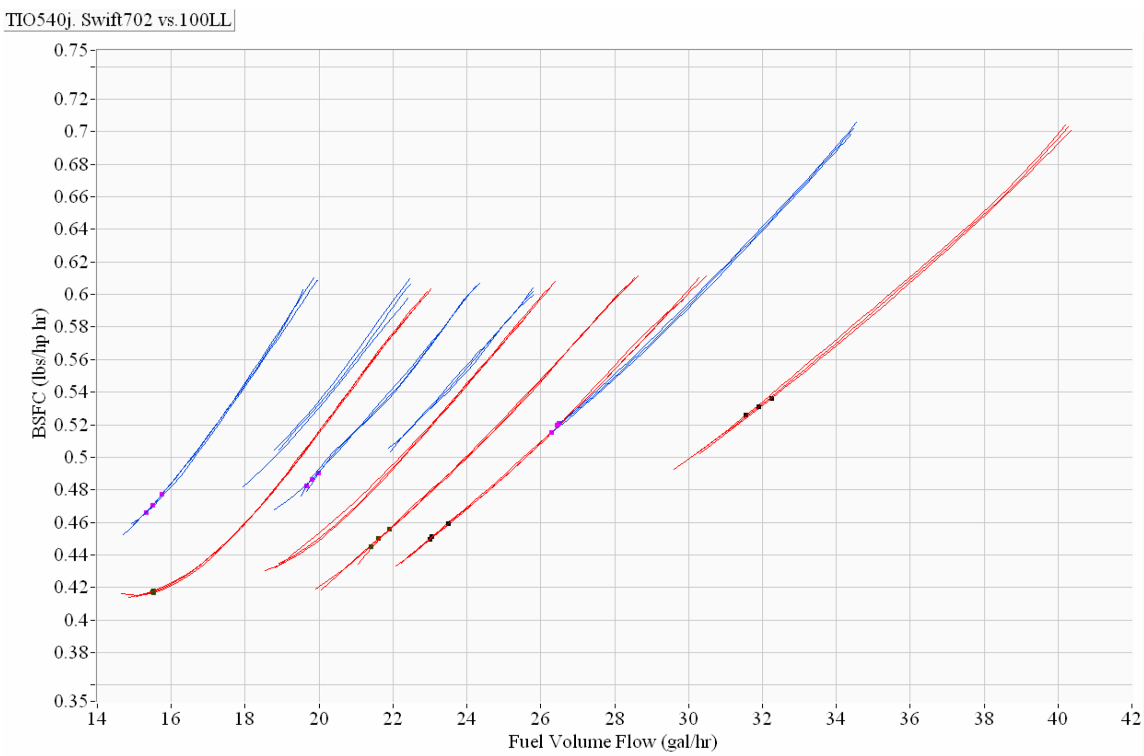


Figure E-36. All Power Settings; Swift 702 in Blue, 100LL in Red

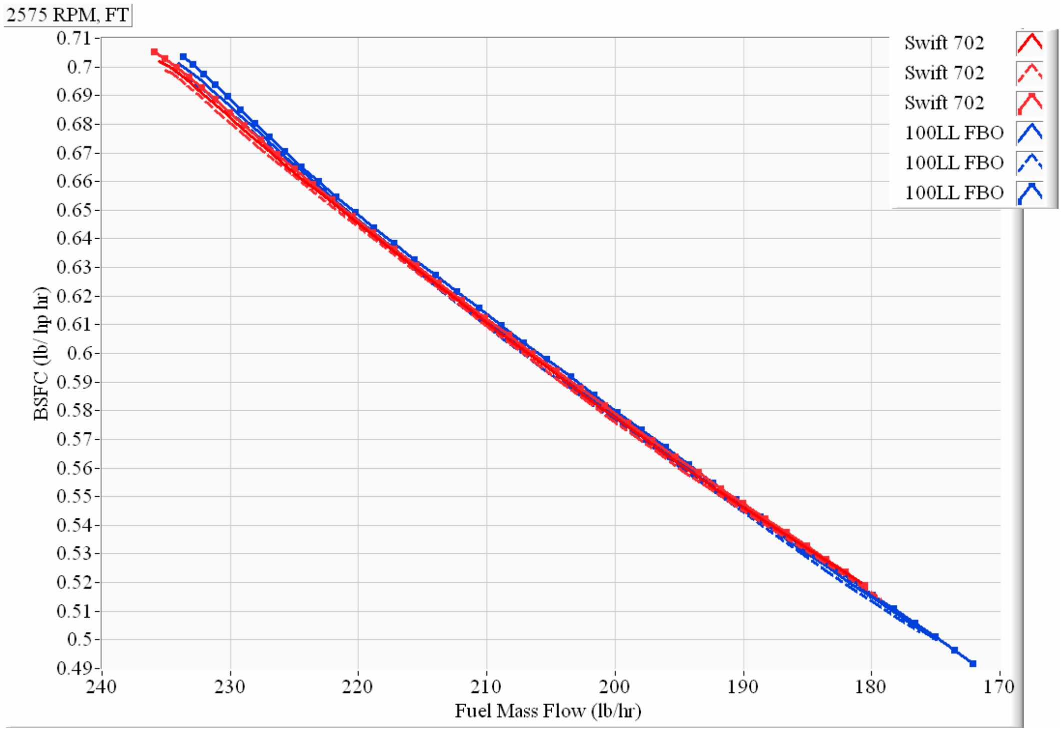


Figure E-37. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, FT

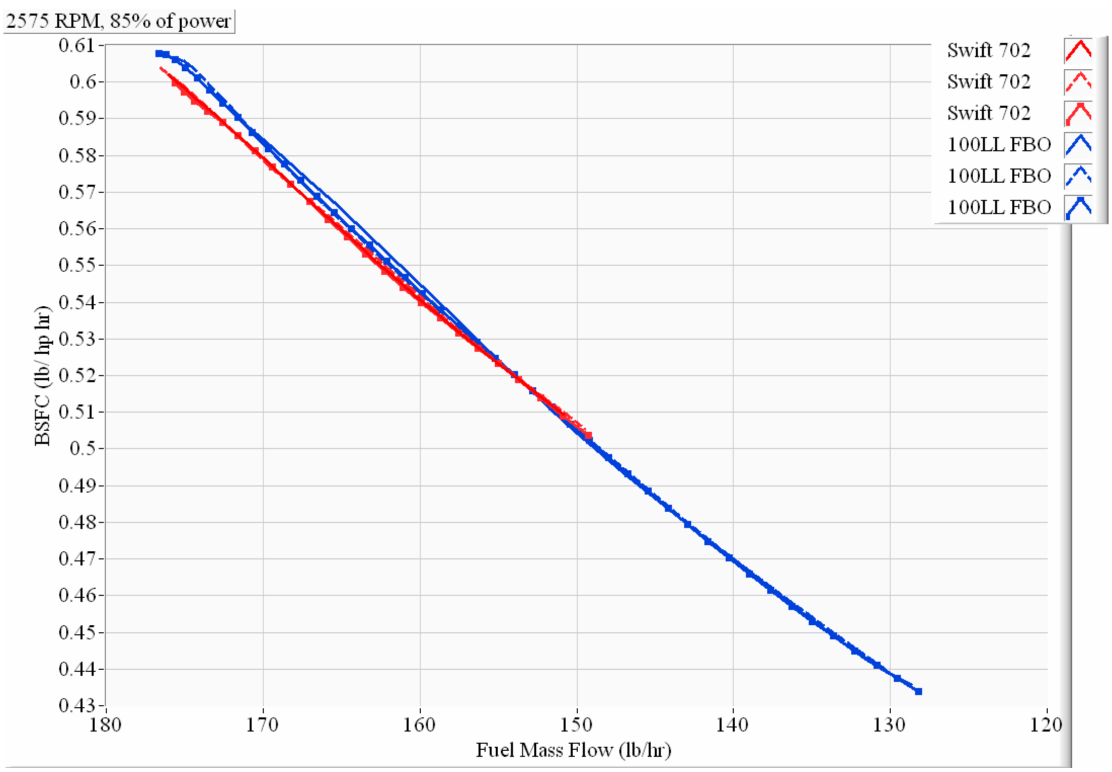


Figure E-38. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 85% Power

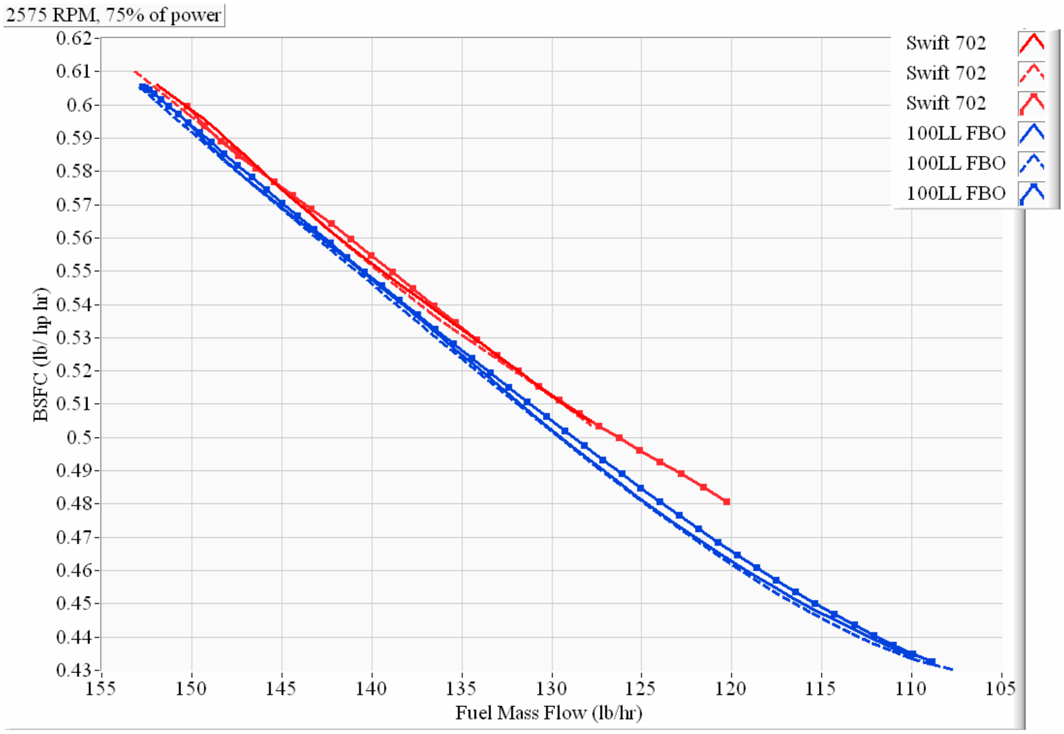


Figure E-39. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2575 rpm, 75% Power

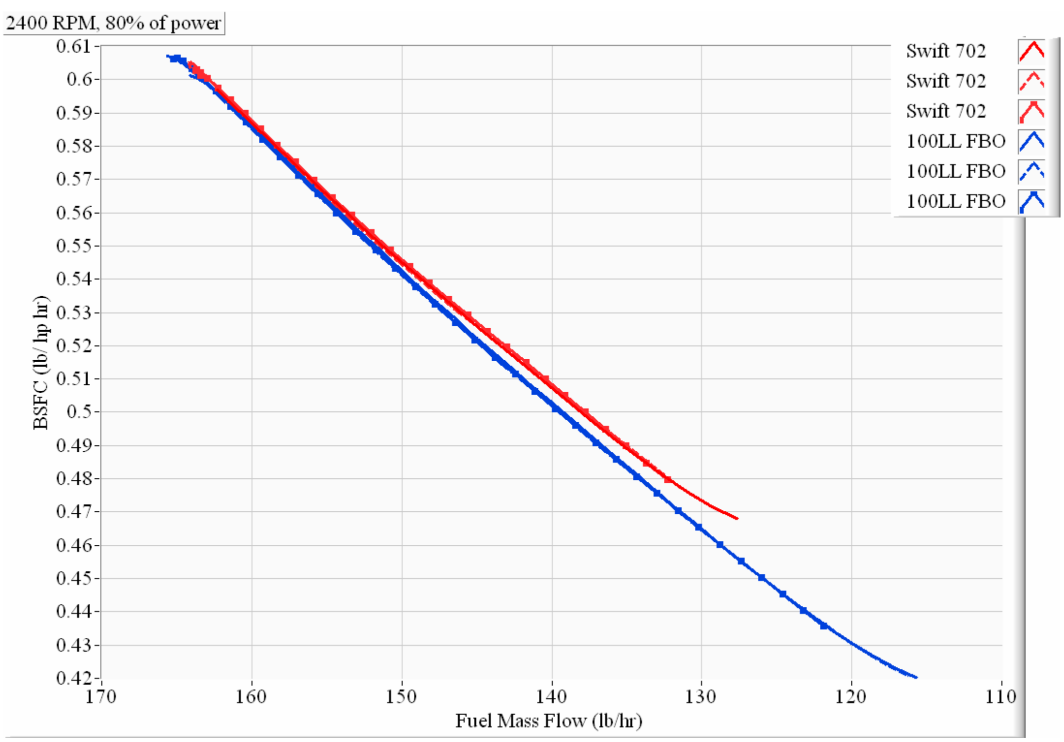


Figure E-40. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2400 rpm, 80% Power

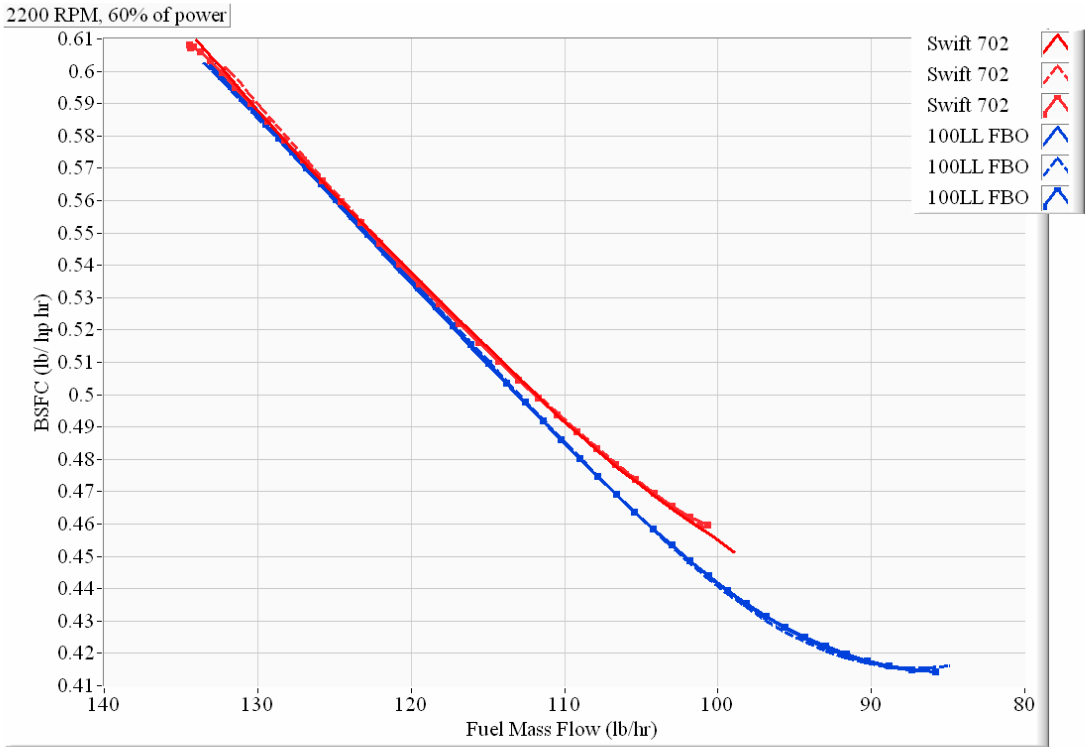


Figure E-41. Detonation Onset Comparison of Swift 702 Fuel to 100LL; 2200 rpm, 60% Power

Table F-1. Detonation Onset and Peak Power Data From Detonation Tests

Power Setting	Fuel	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)	Manifold Air Pressure (inHg)	Manifold Air Temp (°F)	Turbine Inlet Temp (°F)
2575 rpm, TO	Swift 702	Detonation Onset	180.8	26.5	363.9	11.67	1.201	0.521	1606	42.63	189	1625
		Best Power	180.8	26.5	363.9	11.67	1.201	0.521	1606	42.63	189	1625
	100LL	Detonation Onset	185.4	31.9	364.4	11.52	1.294	0.531	1501	42.61	189	1519
		Best Power	174.7	30.1	366.0	12.07	1.235	0.500	1541	42.54	189	1555
	Swift 702	Detonation Onset	179.4	26.3	364.7	11.93	1.176	0.515	1611	42.71	189	1629
		Best Power	179.4	26.3	364.7	11.93	1.176	0.515	1611	42.71	189	1629
	100LL	Detonation Onset	187.5	32.3	365.2	11.43	1.304	0.536	1495	42.71	190	1515
		Best Power	176.0	30.3	366.7	11.98	1.244	0.502	1536	42.59	189	1551
	Swift 702	Detonation Onset	180.5	26.5	363.6	11.65	1.203	0.520	1607	42.63	189	1627
		Best Power	180.5	26.5	363.6	11.65	1.203	0.520	1607	42.63	189	1627
	100LL	Detonation Onset	183.4	31.6	364.0	11.58	1.287	0.526	1507	42.49	189	1522
		Best Power	172.0	29.6	365.4	12.31	1.210	0.493	1555	42.53	189	1566

BHP = Brake horsepower
BSFC = Brake-specific fuel consumption
EGT = Exhaust gas temperature
FF = Fuel mass flow rate

Table F-1. Detonation Onset and Peak Power Data From Detonation Tests (Continued)

Power Setting	Fuel	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)	Manifold Air Pressure (inHg)	Manifold Air Temp (°F)	Turbine Inlet Temp (°F)
2575 rpm, 85% power	Swift 702	Detonation Onset	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Best Power	152.3	22.3	309.6	11.95	1.173	0.514	1616	37.62	180	1630
	100LL	Detonation Onset	136.7	23.5	311.3	13.32	1.119	0.459	1599	37.23	178	1592
		Best Power	140.6	24.2	311.6	12.92	1.153	0.472	1578	37.22	178	1574
	Swift 702	Detonation Onset	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Best Power	150.8	21.9	309.2	12.20	1.149	0.506	1628	37.56	180	1636
	100LL	Detonation Onset	134.0	23.1	310.4	13.54	1.100	0.451	1614	37.23	178	1609
		Best Power	141.7	24.4	311.0	12.80	1.165	0.476	1573	37.21	178	1576
	Swift 702	Detonation Onset	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Best Power	150.9	22.1	309.9	12.15	1.154	0.509	1625	37.68	180	1636
	100LL	Detonation Onset	133.6	23.0	310.7	13.60	1.096	0.449	1618	37.28	179	1613
		Best Power	141.5	24.4	311.5	12.85	1.160	0.475	1575	37.27	179	1581

BHP = Brake horsepower
BSFC = Brake-specific fuel consumption
EGT = Exhaust gas temperature
FF = Fuel mass flow rate

Table F-1. Detonation Onset and Peak Power Data From Detonation Tests (Continued)

Power Setting	Fuel	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)	Manifold Air Pressure (inHg)	Manifold Air Temp (°F)	Turbine Inlet Temp (°F)
2575 rpm, 75% power	Swift 702	Detonation Onset	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Best Power	133.9	19.8	264.8	11.85	1.183	0.528	1599	32.77	163	1600
	100LL	Detonation Onset	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Best Power	124.3	21.4	270.9	13.02	1.144	0.479	1569	32.86	162	1554
	Swift 702	Detonation Onset	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Best Power	133.6	19.7	265.7	11.94	1.174	0.525	1608	32.86	162	1607
	100LL	Detonation Onset	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Best Power	124.3	21.4	271.5	12.96	1.150	0.478	1569	32.85	163	1557
	Swift 702	Detonation Onset	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Best Power	132.0	19.6	264.7	12.08	1.161	0.521	1604	32.81	162	1599
	100LL	Detonation Onset	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Best Power	125.0	21.5	269.3	12.77	1.167	0.484	1561	32.69	162	1555

BHP = Brake horsepower
BSFC = Brake-specific fuel consumption
EGT = Exhaust gas temperature
FF = Fuel mass flow rate

Table F-1. Detonation Onset and Peak Power Data From Detonation Tests (Continued)

Power Setting	Fuel	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)	Manifold Air Pressure (inHg)	Manifold Air Temp (°F)	Turbine Inlet Temp (°F)
2400 rpm, 80% power	Swift 702	Detonation Onset	134.3	19.8	287.7	12.48	1.124	0.487	1606	36.93	173	1606
		Best Power	140.4	20.7	288.3	11.99	1.170	0.509	1577	36.99	172	1585
	100LL	Detonation Onset	124.4	21.4	291.4	13.54	1.101	0.445	1574	37.01	174	1565
		Best Power	130.2	22.4	291.9	12.92	1.154	0.465	1544	36.91	174	1541
	Swift 702	Detonation Onset	133.1	19.7	287.2	12.57	1.116	0.483	1614	37.01	175	1616
		Best Power	142.3	21.0	288.0	11.75	1.193	0.517	1566	37.03	175	1583
	100LL	Detonation Onset	125.6	21.6	291.9	13.40	1.112	0.450	1567	37.02	175	1562
		Best Power	131.1	22.5	292.4	12.87	1.158	0.469	1536	36.98	175	1539
	Swift 702	Detonation Onset	135.0	20.0	287.6	12.45	1.126	0.490	1605	37.09	175	1611
		Best Power	138.8	20.5	287.8	12.11	1.158	0.506	1583	37.07	175	1597
	100LL	Detonation Onset	127.3	21.9	292.0	13.20	1.129	0.456	1556	36.95	175	1552
		Best Power	130.0	22.4	292.1	12.93	1.152	0.466	1540	36.90	175	1541

BHP = Brake horsepower
BSFC = Brake-specific fuel consumption
EGT = Exhaust gas temperature
FF = Fuel mass flow rate

Table F-1. Detonation Onset and Peak Power Data From Detonation Tests (Continued)

Power Setting	Fuel	Mixture Setting	FF (lb/hr)	FF (gal/hr)	BHP	Air-to-Fuel Ratio	Equivalence Ratio	BSFC (lb/hp hr)	EGT (°F)	Manifold Air Pressure (inHg)	Manifold Air Temp (°F)	Turbine Inlet Temp (°F)
2200 rpm, 65% power	Swift 702	Detonation Onset	106.3	15.7	232.6	12.92	1.085	0.477	1579	33.54	162	1560
		Best Power	114.0	16.9	233.6	11.98	1.171	0.509	1530	33.37	162	1531
	100LL	Detonation Onset	90.0	15.5	225.7	15.02	0.992	0.417	1587	33.40	162	1562
		Best Power	103.8	17.9	237.1	13.28	1.122	0.456	1508	33.20	161	1489
	Swift 702	Detonation Onset	104.6	15.5	231.5	13.05	1.074	0.471	1591	33.47	162	1577
		Best Power	113.2	16.8	233.6	12.11	1.158	0.506	1538	33.49	162	1543
	100LL	Detonation Onset	90.2	15.5	226.6	14.95	0.997	0.417	1588	33.33	161	1563
		Best Power	103.4	17.8	237.3	13.42	1.111	0.454	1515	33.29	161	1497
	Swift 702	Detonation Onset	103.1	15.3	230.8	13.23	1.060	0.466	1598	33.42	162	1579
		Best Power	112.9	16.8	234.0	12.09	1.160	0.504	1538	33.49	162	1537
	100LL	Detonation Onset	90.2	15.5	225.8	14.99	0.994	0.418	1589	33.33	161	1564
		Best Power	104.3	17.9	236.8	13.26	1.124	0.458	1509	33.24	161	1496

BHP = Brake horsepower
BSFC = Brake-specific fuel consumption
EGT = Exhaust gas temperature
FF = Fuel mass flow rate

APPENDIX G—LYCOMING TIO-540-J2BD DETONATION DATA MIXTURE LEAN-OUTS

All the graphs in figures G-1 through G-10 represent mixture lean-outs on the Swift 702 fuel and the 100 low-lead (100LL) fixed-base operator (FBO) fuel at different power settings. These do not represent all the test points reviewed, as the blends were tested between 3 and 5 times each at each respective power setting. Furthermore, the dotted cursor does not necessarily represent a point of interest, but was merely the location of the cursor at the time the screen capture was taken. The data contained in the body of this report is from the average of the repeated tests, based on degree of repeatability, and the graphs following are some of the individual test runs. Not all the data or all the test runs are represented in graphical form in this appendix due to the enormous volume of data generated from this test.

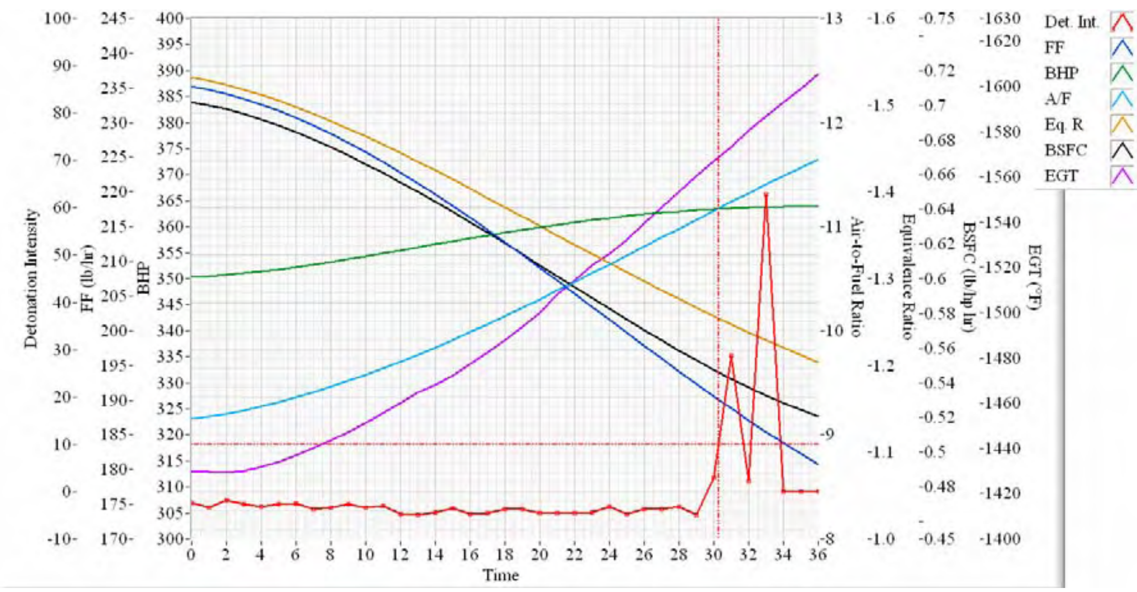


Figure G-1. Swift 702 Fuel, 2575 rpm, FT

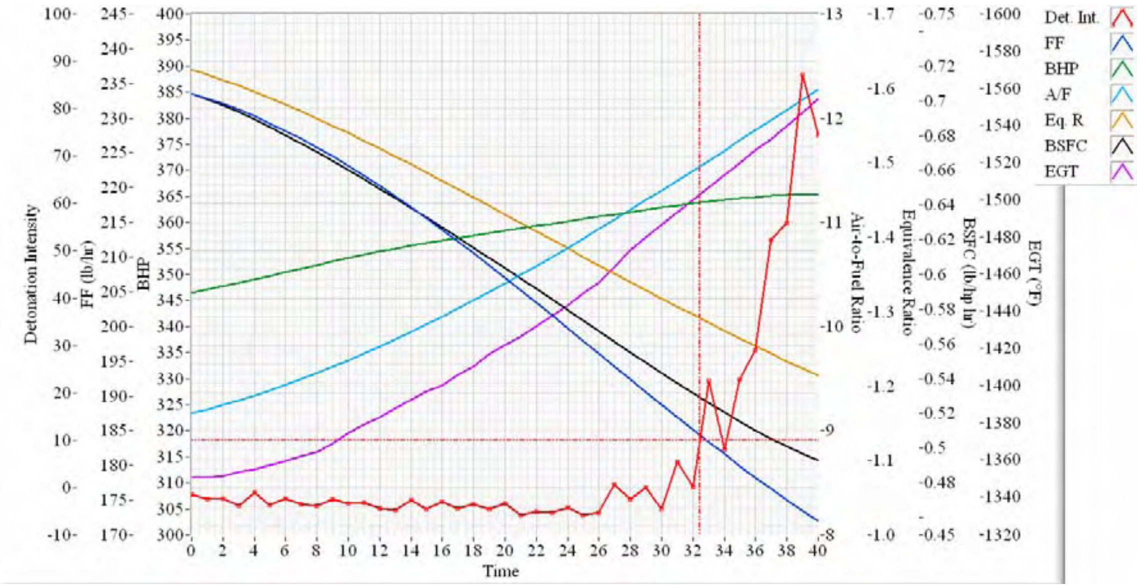


Figure G-2. The 100LL FBO Fuel, 2575 rpm, Full Throttle

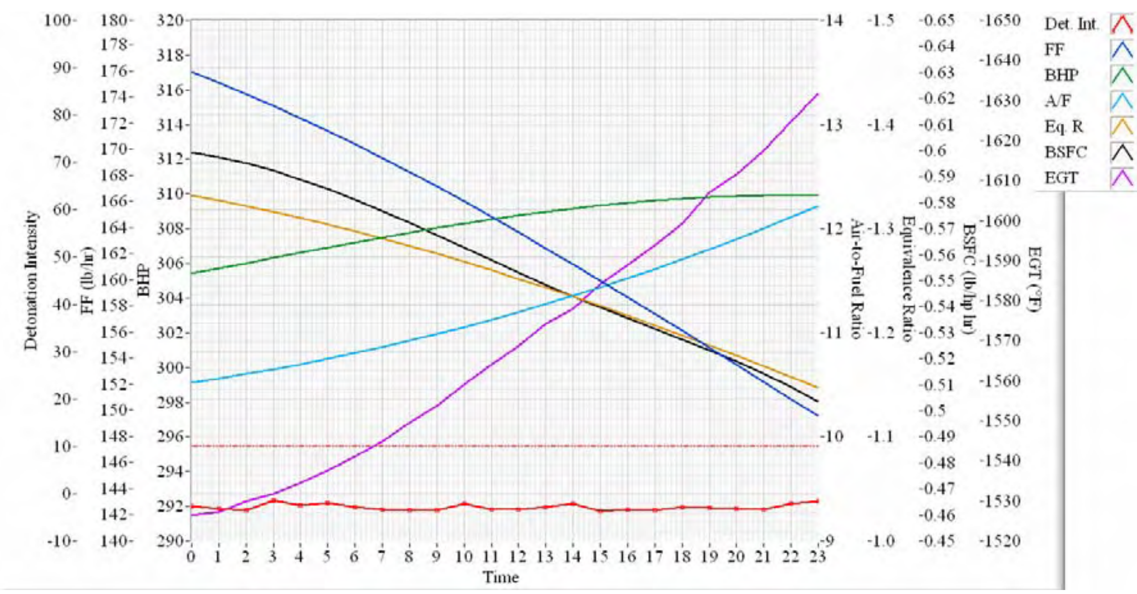


Figure G-3. Swift 702 Fuel, 2575 rpm, 85% Power

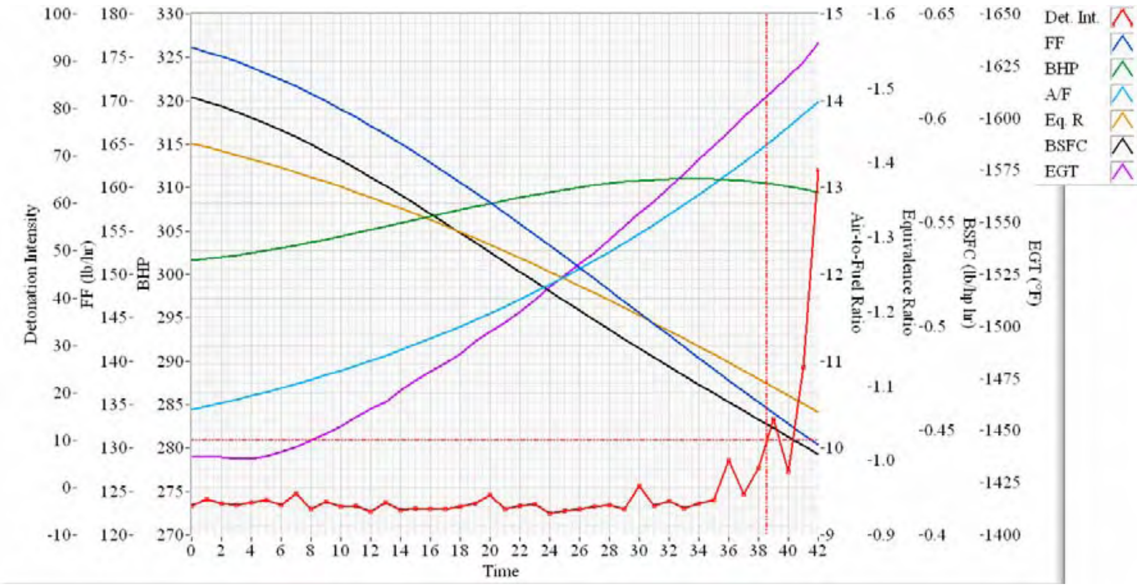


Figure G-4. The 100LL FBO Fuel, 2575 rpm, 85% Power

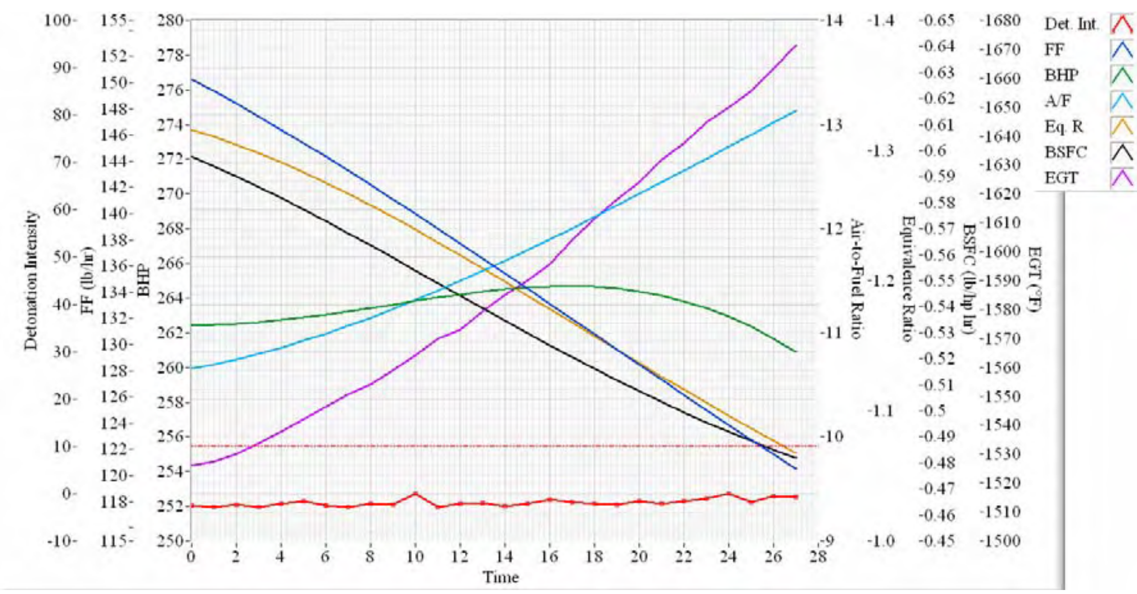


Figure G-5. Swift 702 Fuel, 2575 rpm, 75% Power

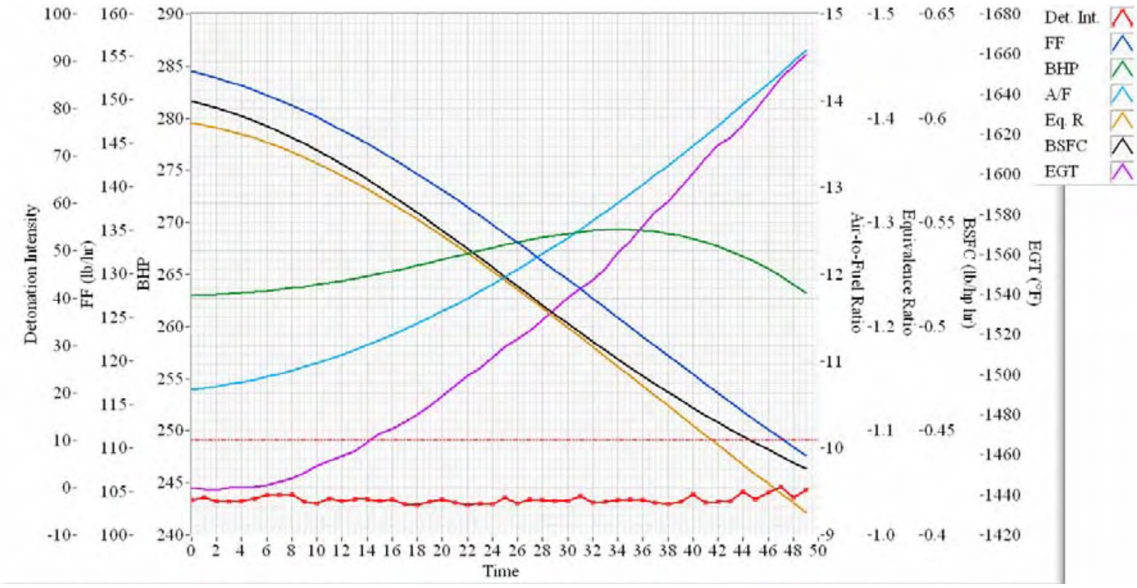


Figure G-6. The 100LL FBO Fuel, 2575 rpm, 75% Power

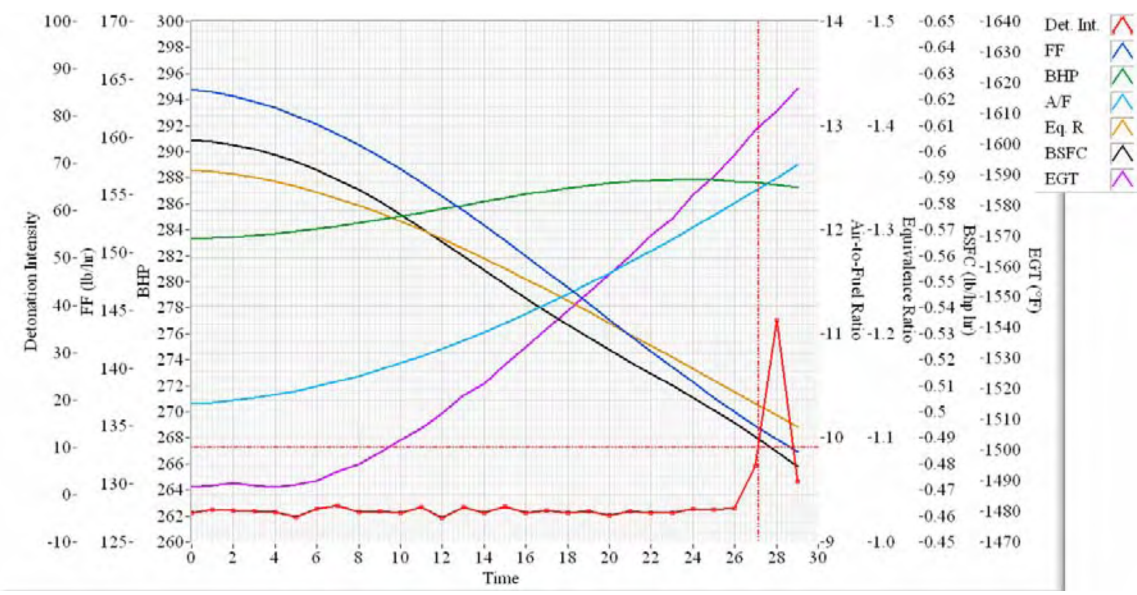


Figure G-7. Swift 702 Fuel, 2400 rpm, 80% Power

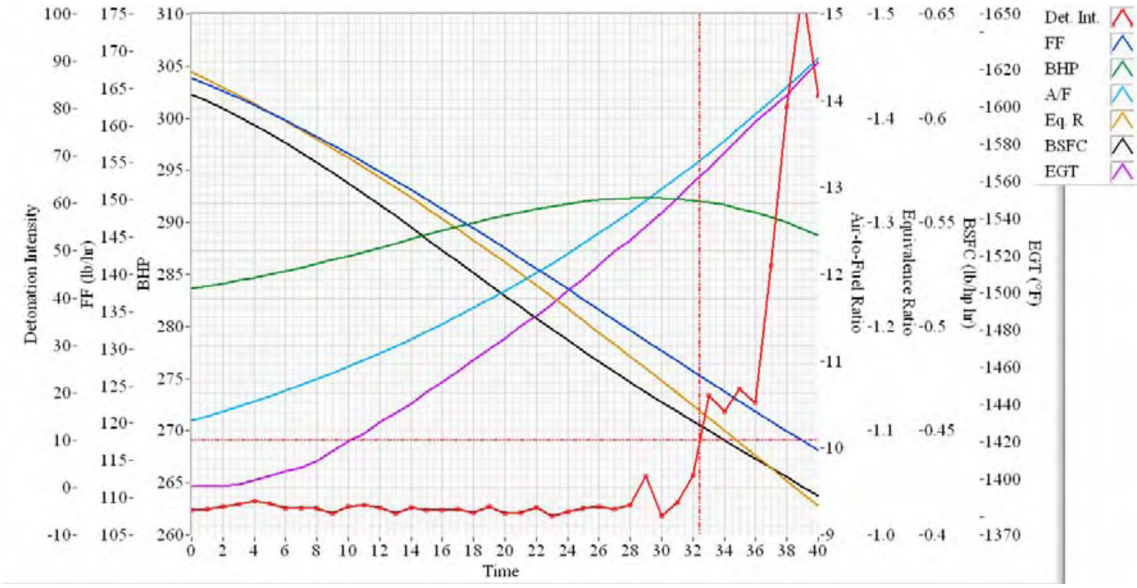


Figure G-8. The 100LL FBO Fuel, 2400 rpm, 80% Power

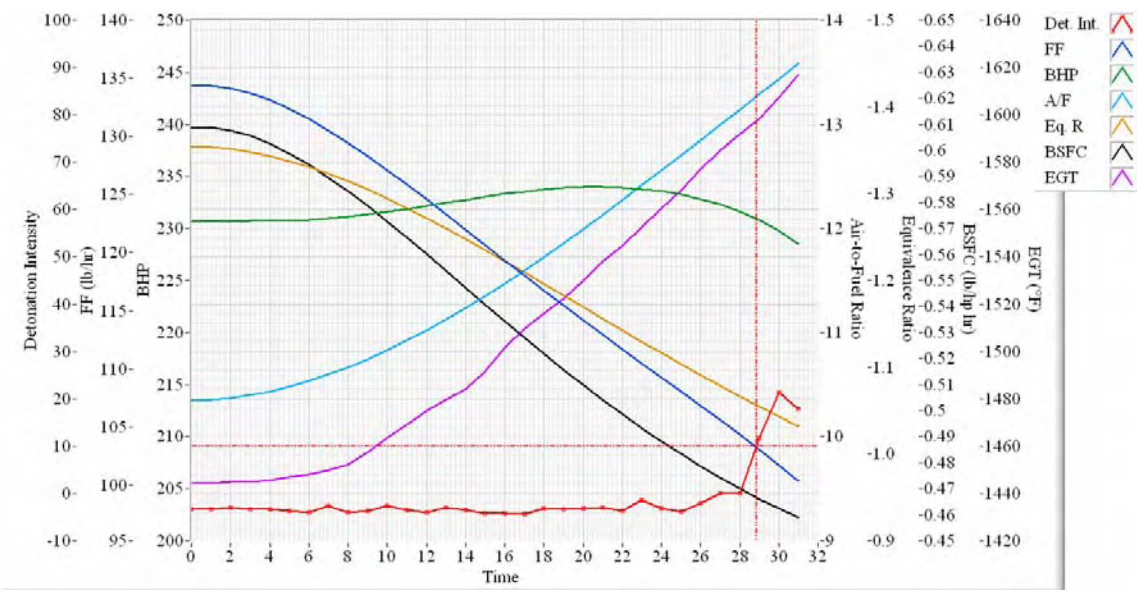


Figure G-9. Swift 702 Fuel, 2200 rpm, 60% Power

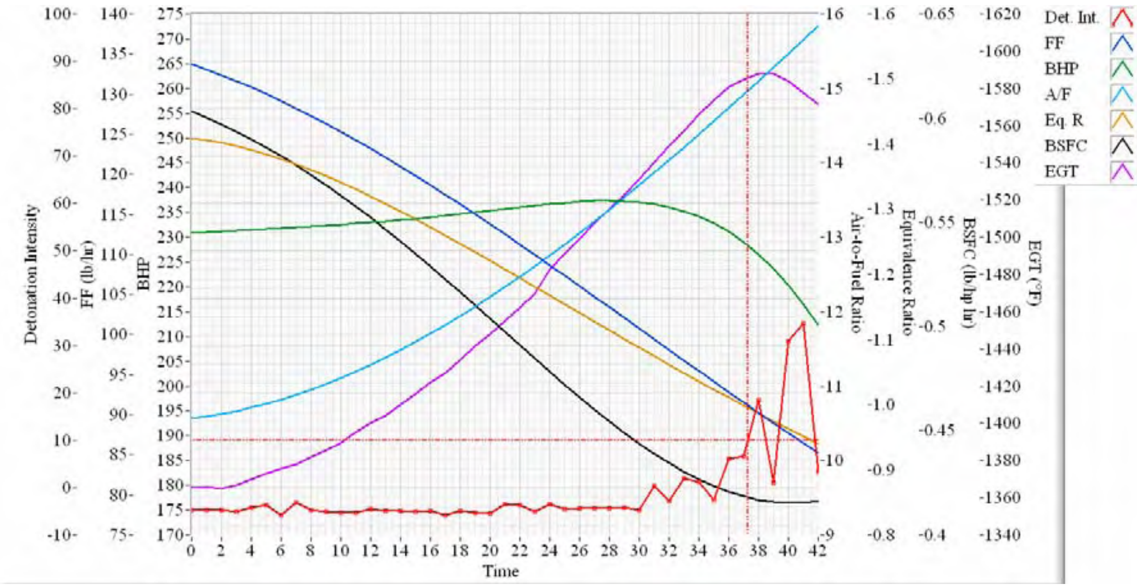


Figure G-10. The 100LL FBO Fuel, 2200 rpm, 60% Power

APPENDIX H—LYCOMING IO-540-K IGNITION TIMING CHANGE EFFECTS ON AVERAGE PEAK CYLINDER PRESSURE AND AVERAGE LOCATION OF PEAK CYLINDER PRESSURE

Figures H-1 through H-6 show the peak cylinder pressure and location of peak cylinder pressure for the Swift 702 fuel with 20°, 23°, and 26° ignition timing and for the 100LL at 20° standard ignition timing.

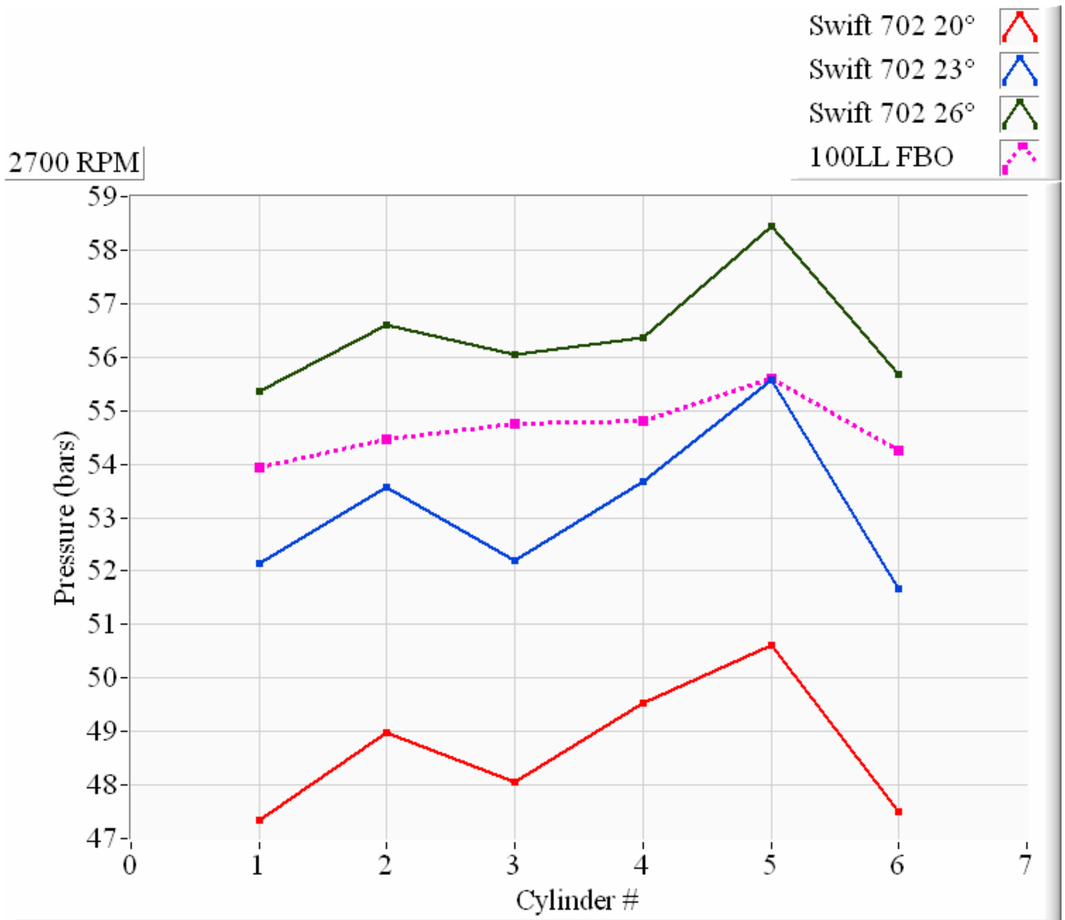


Figure H-1. Peak Pressure, 2700 rpm

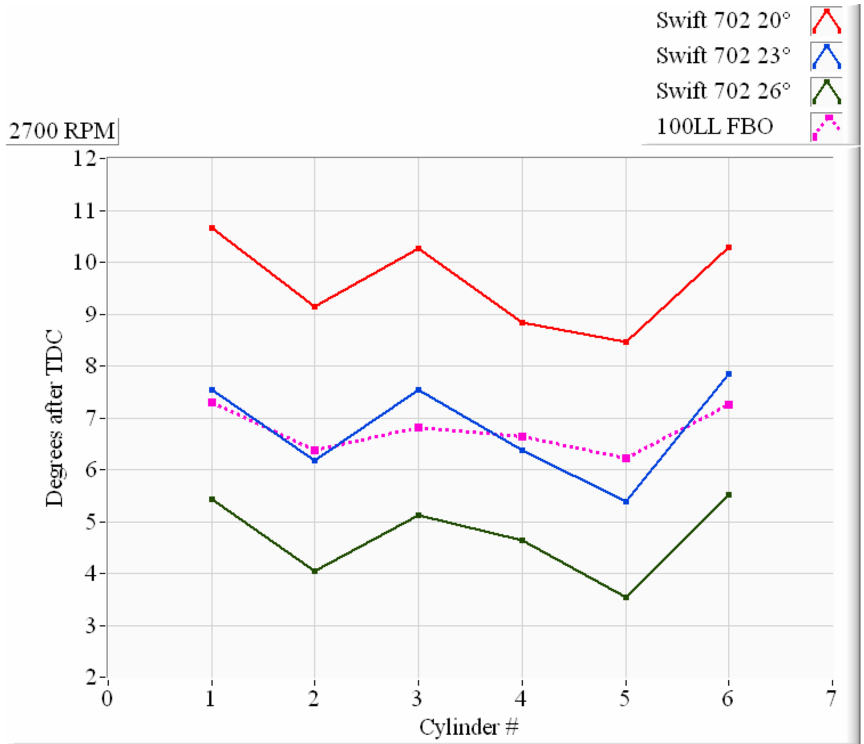


Figure H-2. Location of Peak Pressure, 2700 rpm

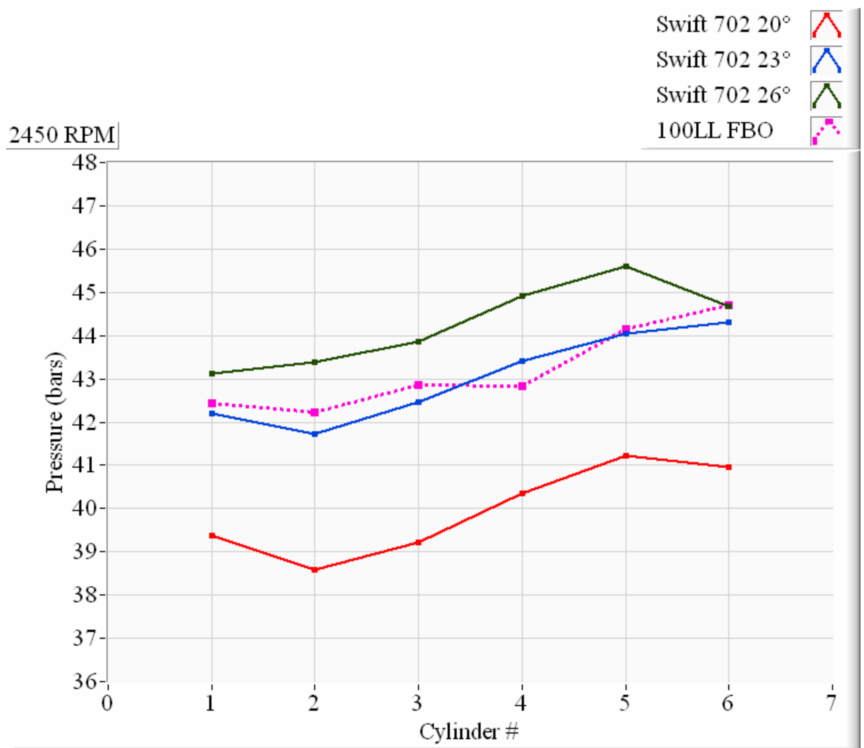


Figure H-3. Peak Pressure, 2450 rpm

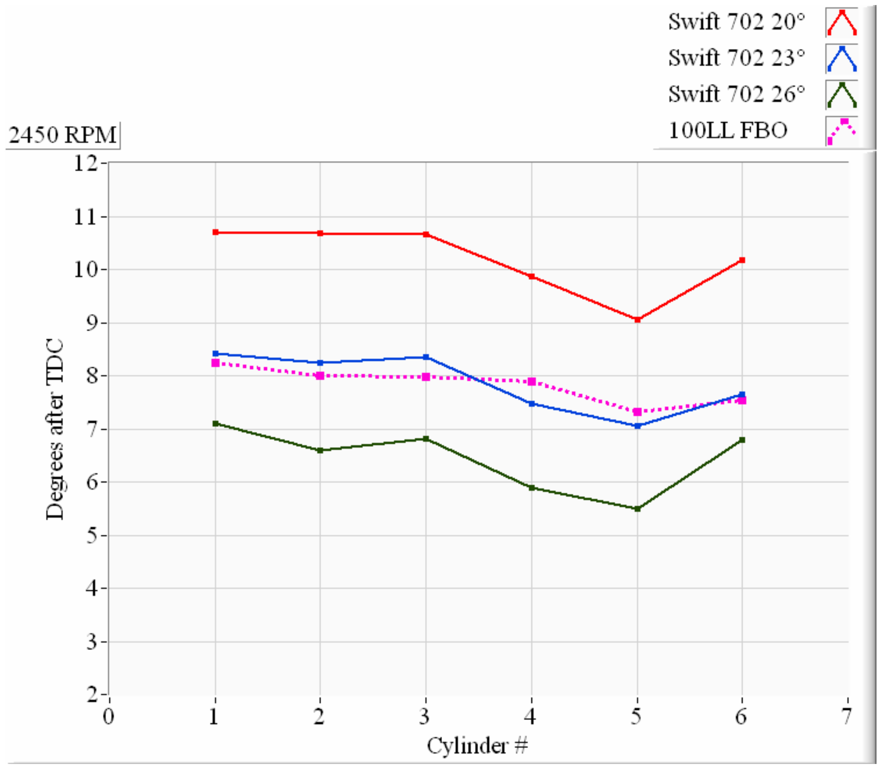


Figure H-4. Location of Peak Pressure, 2450 rpm

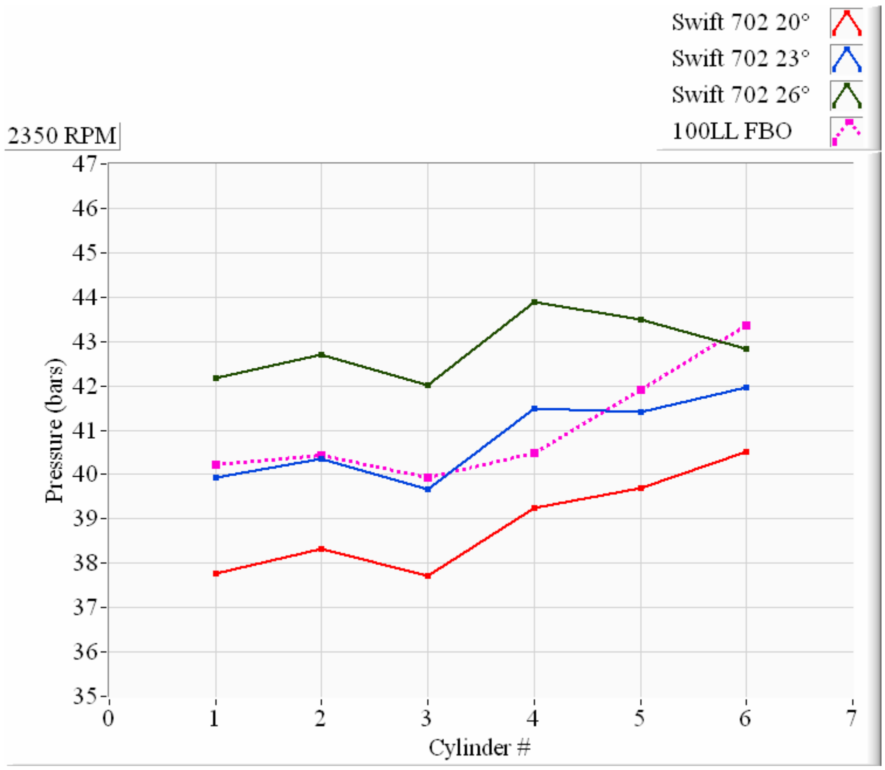


Figure H-5. Peak Pressure, 2350 rpm

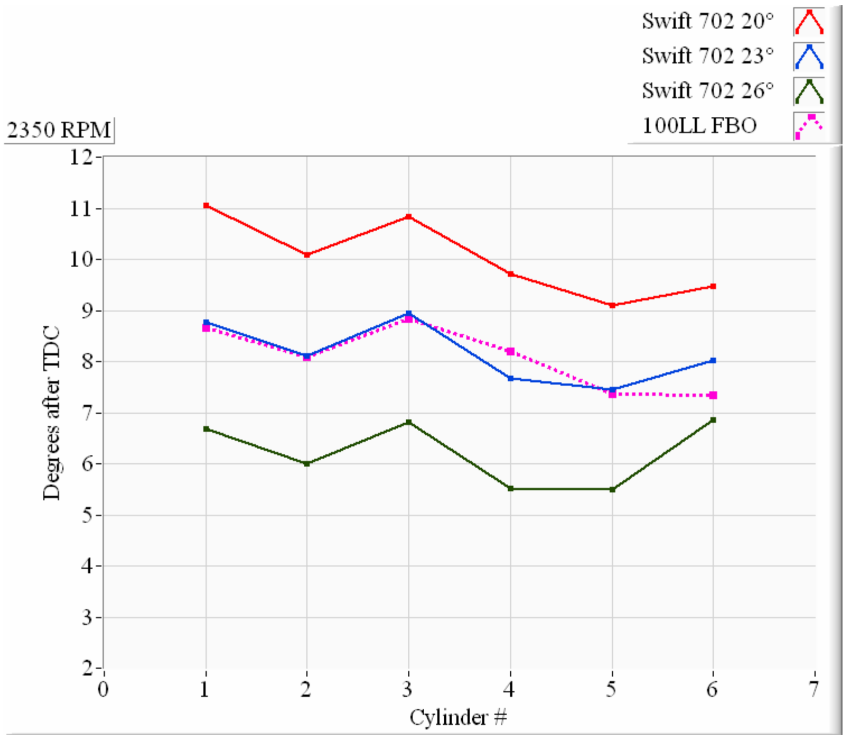


Figure H-6. Location of Peak Pressure, 2350 rpm

APPENDIX I—LYCOMING IO-540-K IGNITION TIMING CHANGE EFFECTS ON DETONATION ONSET

Figures I-1 through I-20 show the detonation onset data for the Swift 702 fuel tested at the 20°, 23°, and 26° degree ignition timing.

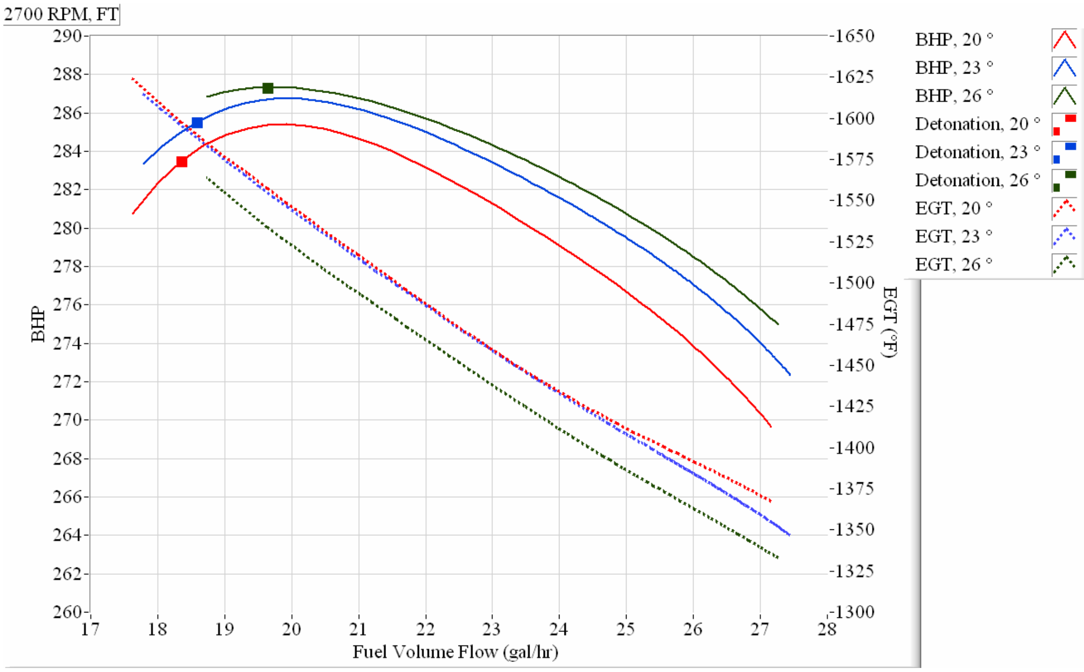


Figure I-1. Detonation Onset; 2700 rpm, FT

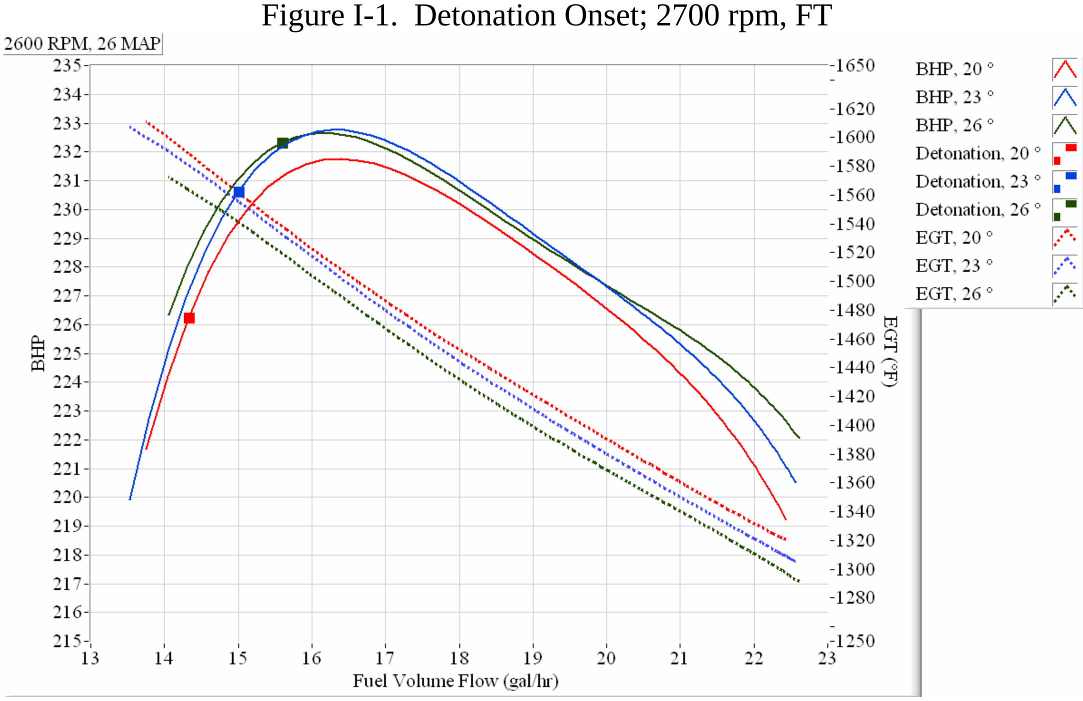


Figure I-2. Detonation Onset; 2600 rpm, 26 inHg MAP

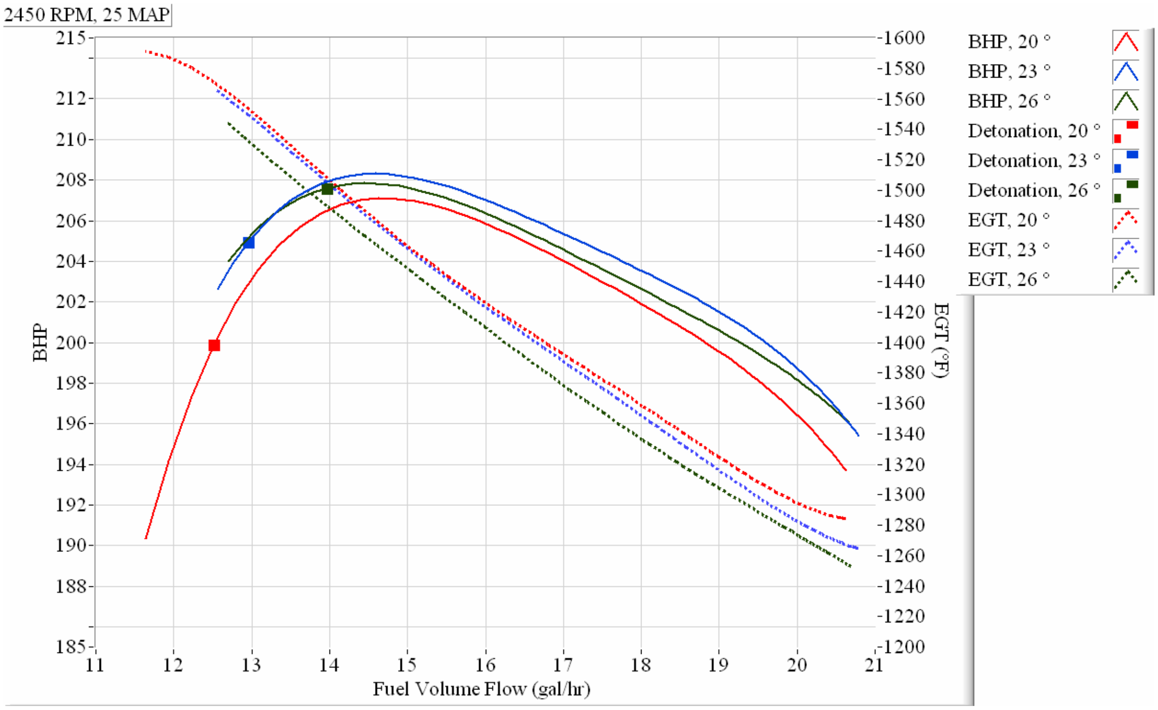


Figure I-3. Detonation Onset; 2450 rpm, 25 inHg MAP

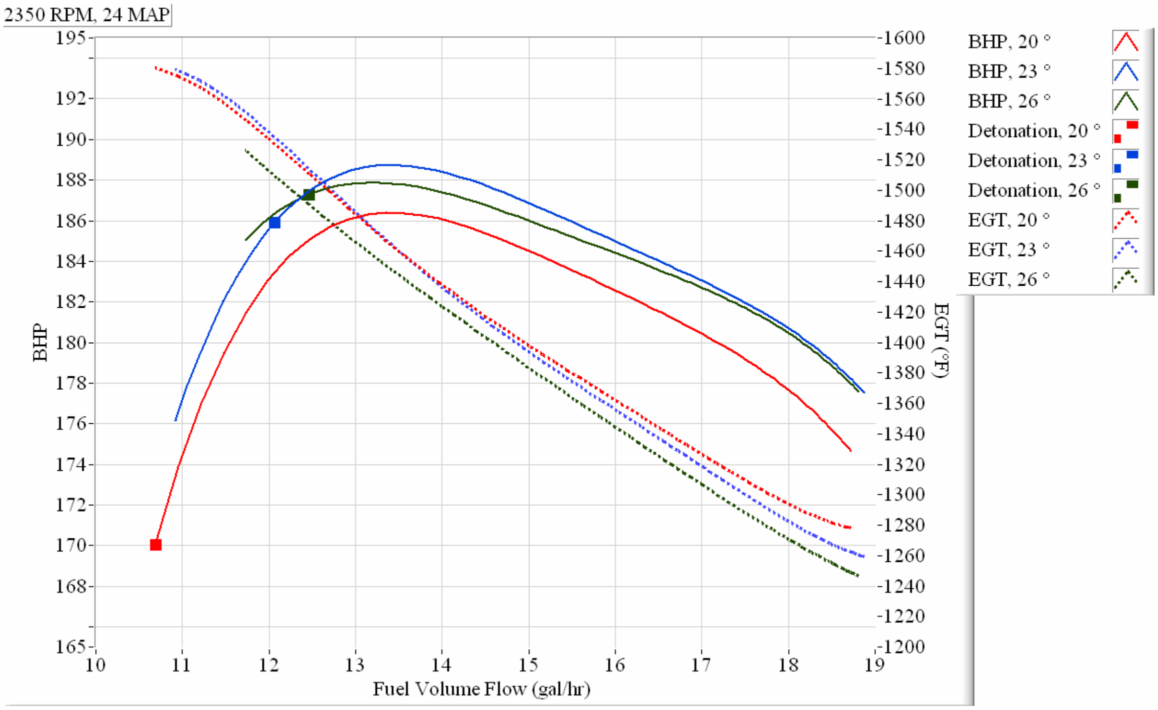


Figure I-4. Detonation Onset; 2350 rpm, 24 inHg MAP

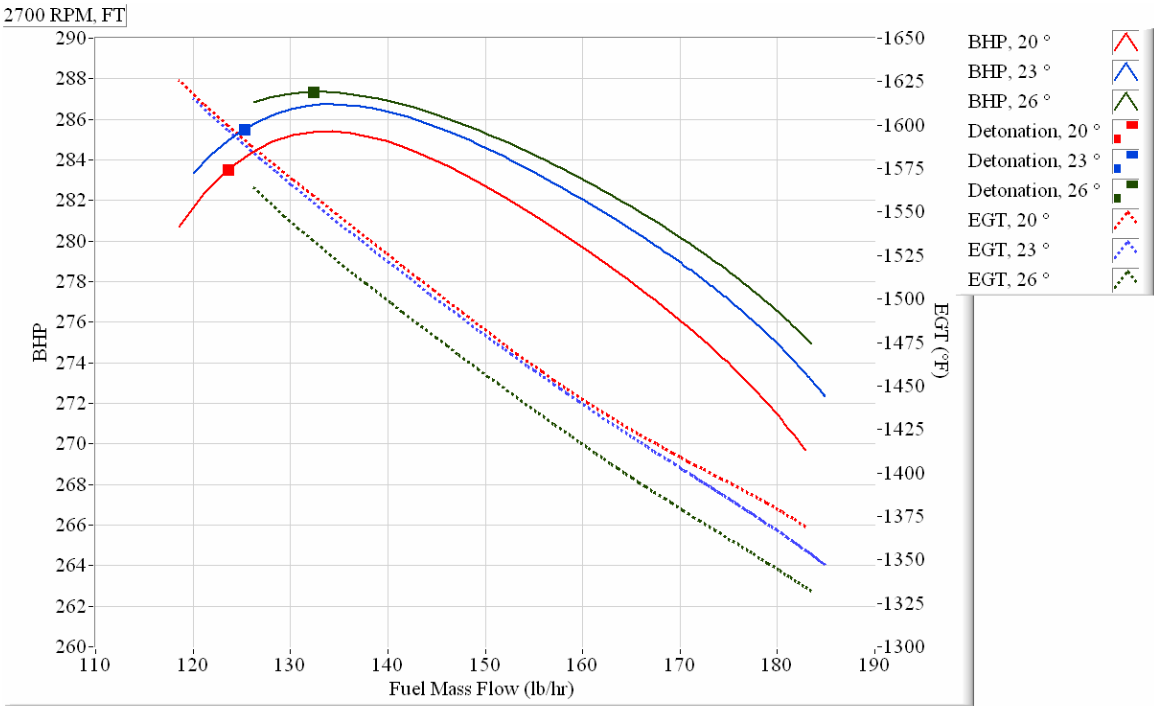


Figure I-5. Detonation Onset; 2700 rpm, FT

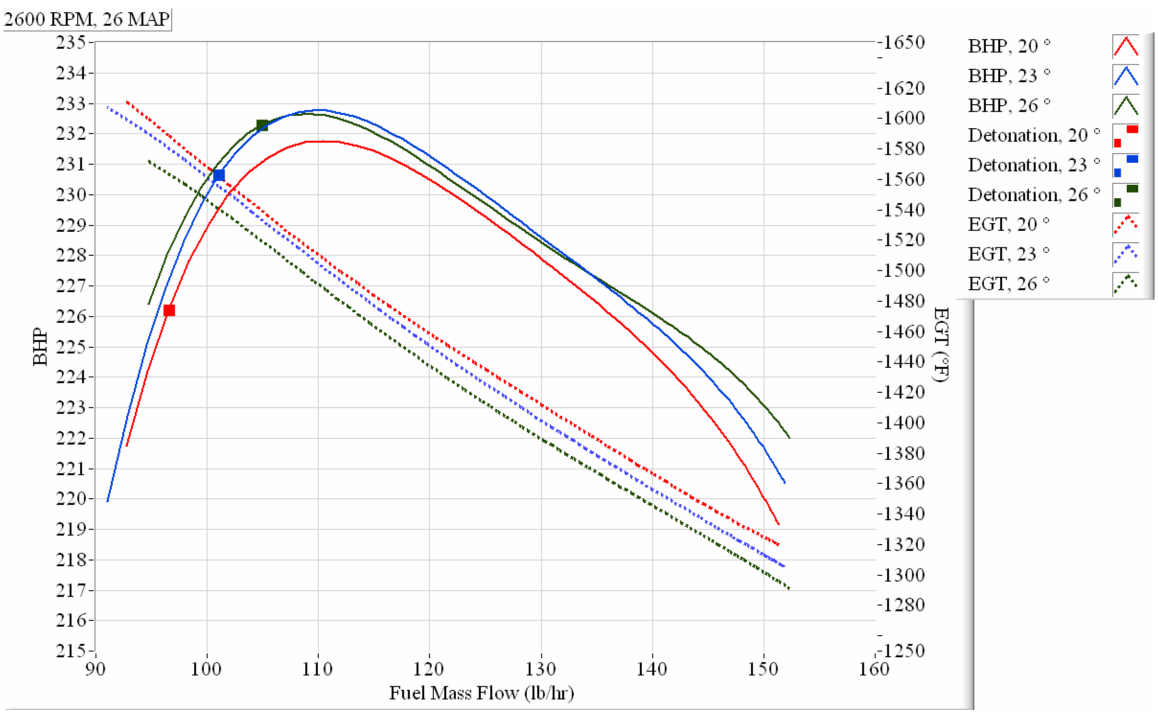


Figure I-6. Detonation Onset; 2600 rpm, 26 inHg MAP

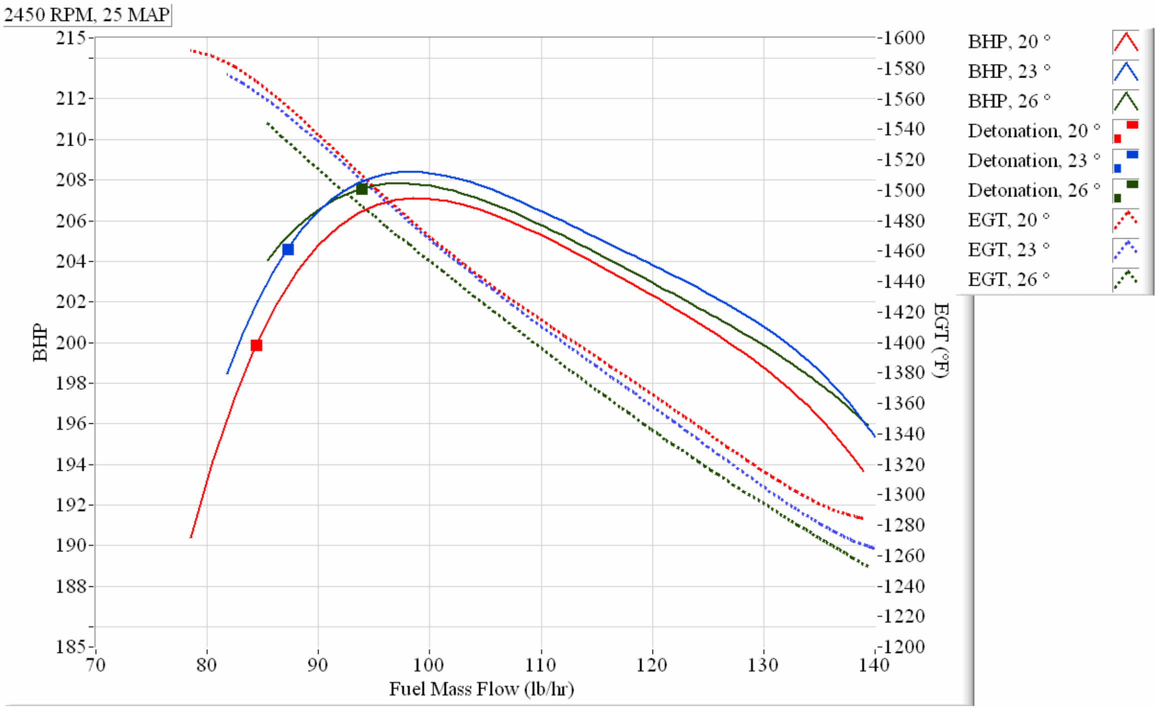


Figure I-7. Detonation Onset; 2450 rpm, 25 inHg MAP

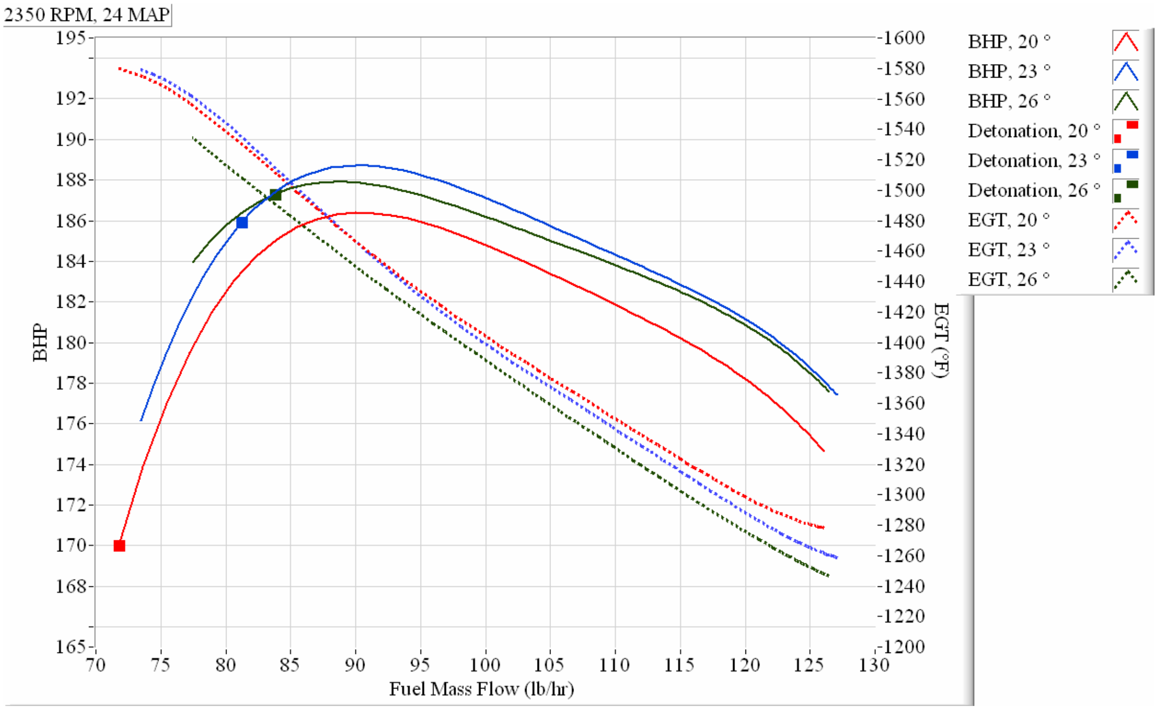


Figure I-8. Detonation Onset; 2350 rpm, 24 inHg MAP

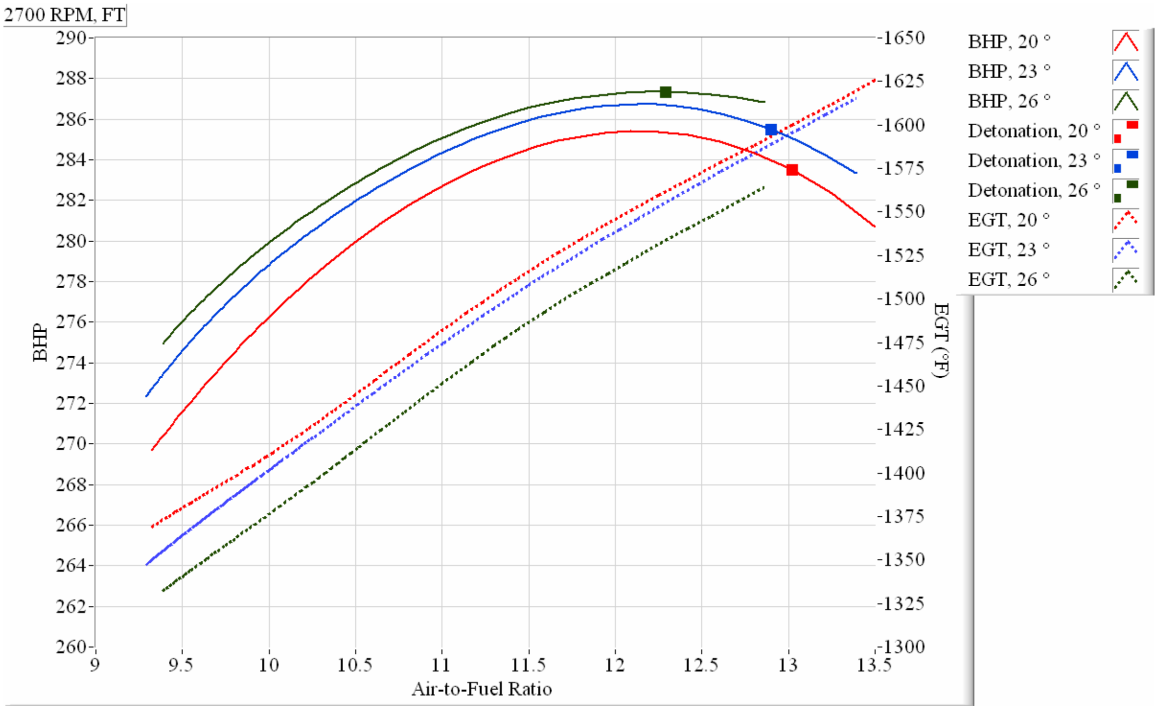


Figure I-9. Detonation Onset; 2700 rpm, FT

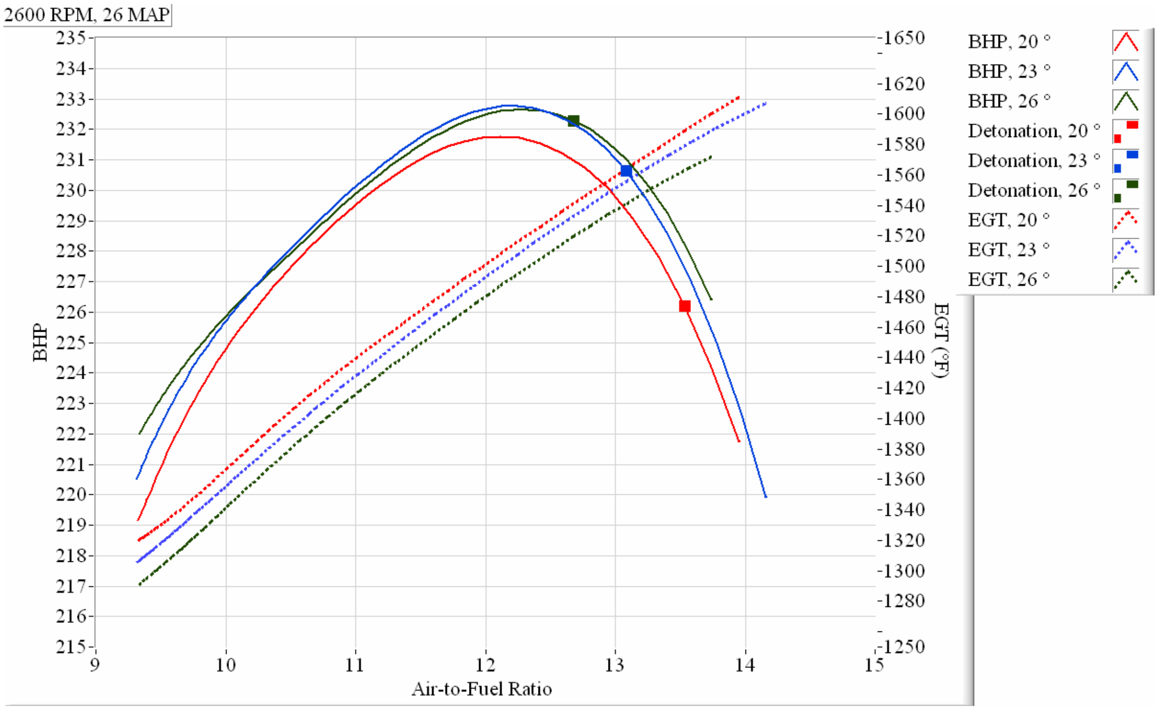


Figure I-10. Detonation Onset; 2600 rpm, 26 inHg MAP

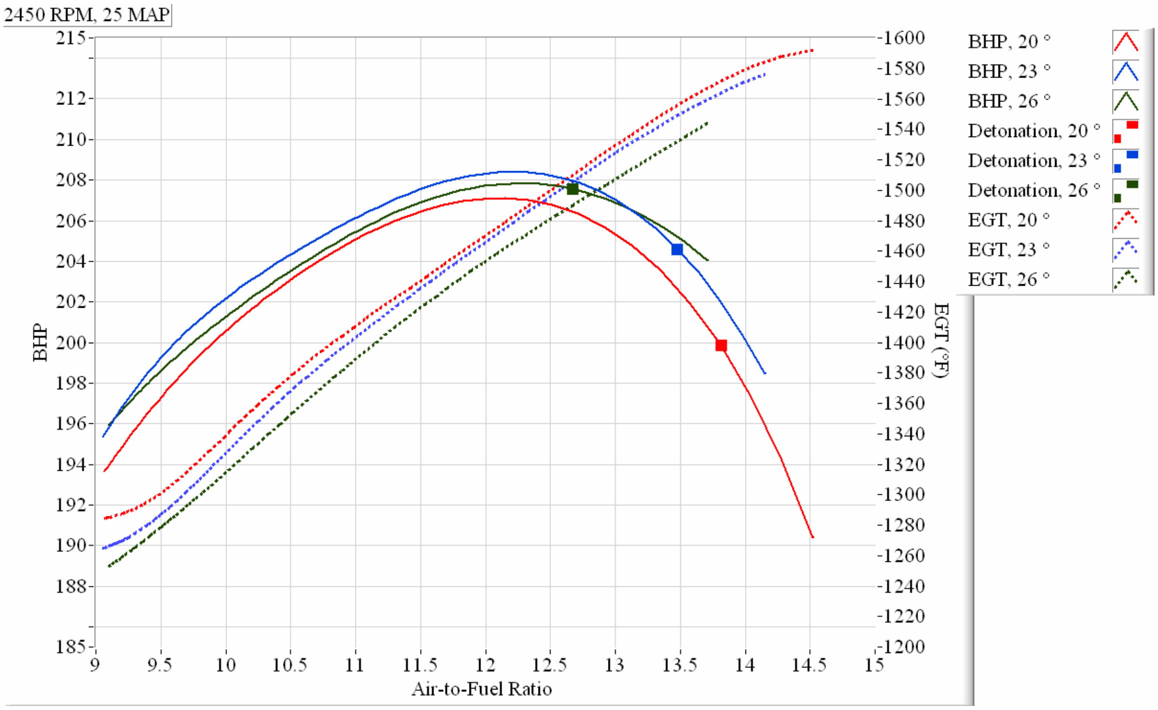


Figure I-11. Detonation Onset; 2450 rpm, 25 inHg MAP

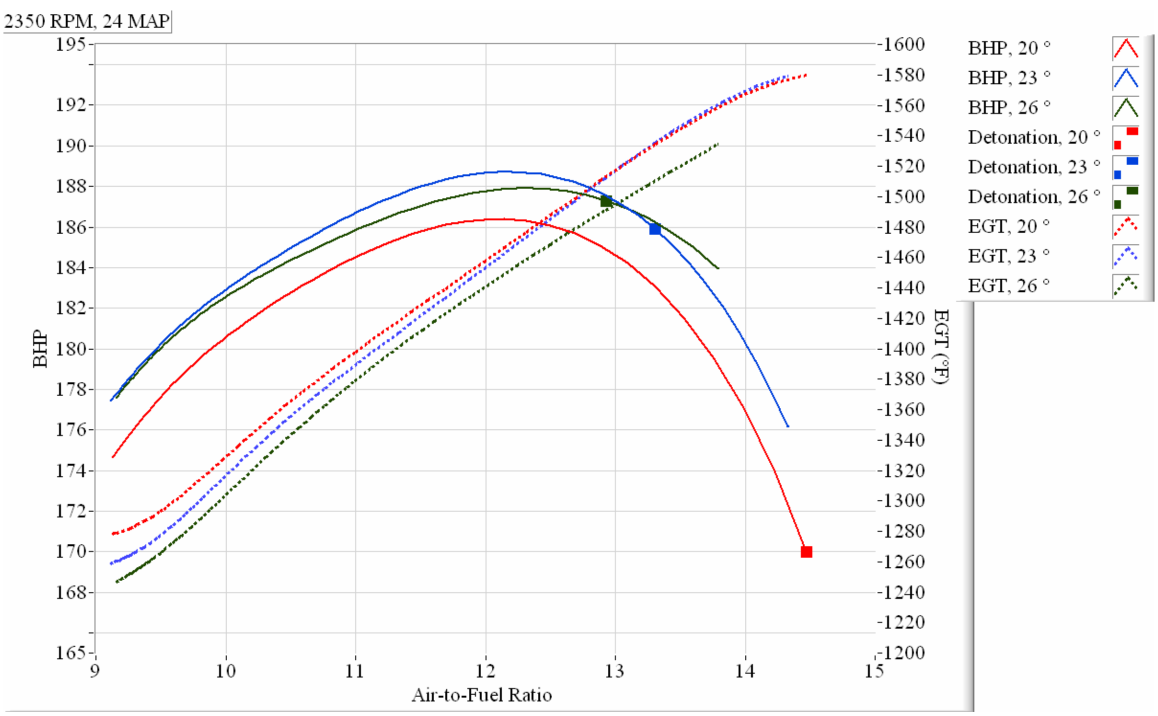


Figure I-12. Detonation Onset; 2350 rpm, 24 inHg MAP

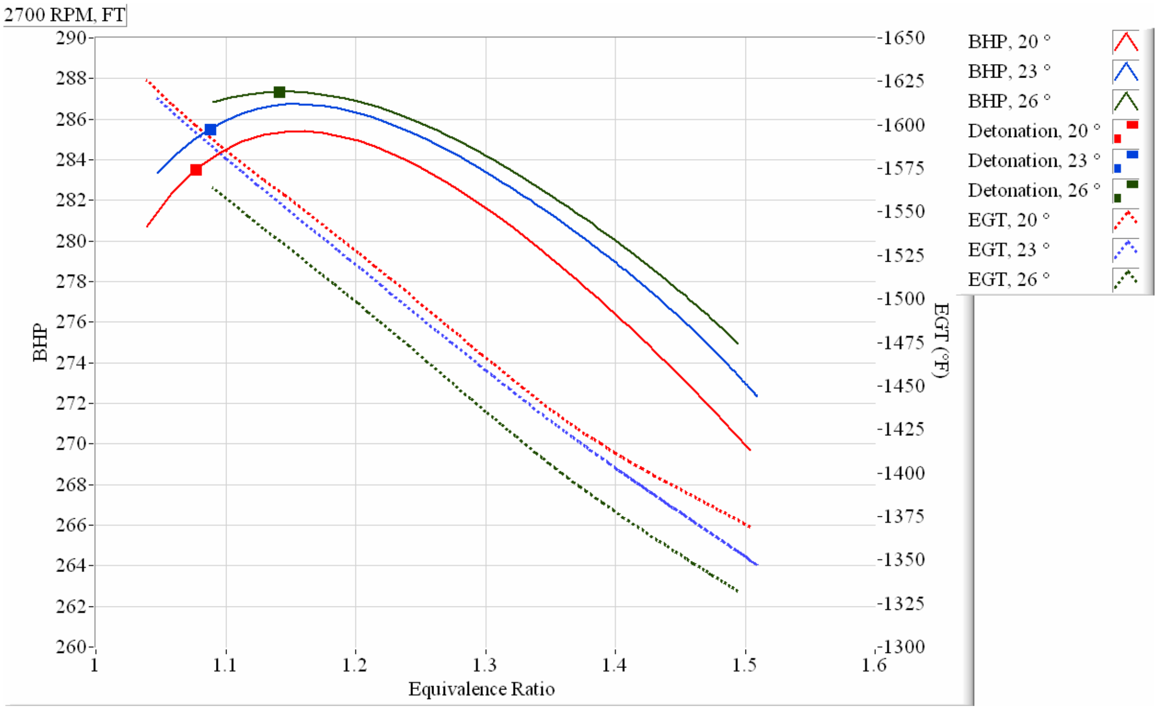


Figure I-13. Detonation Onset; 2700 rpm, FT

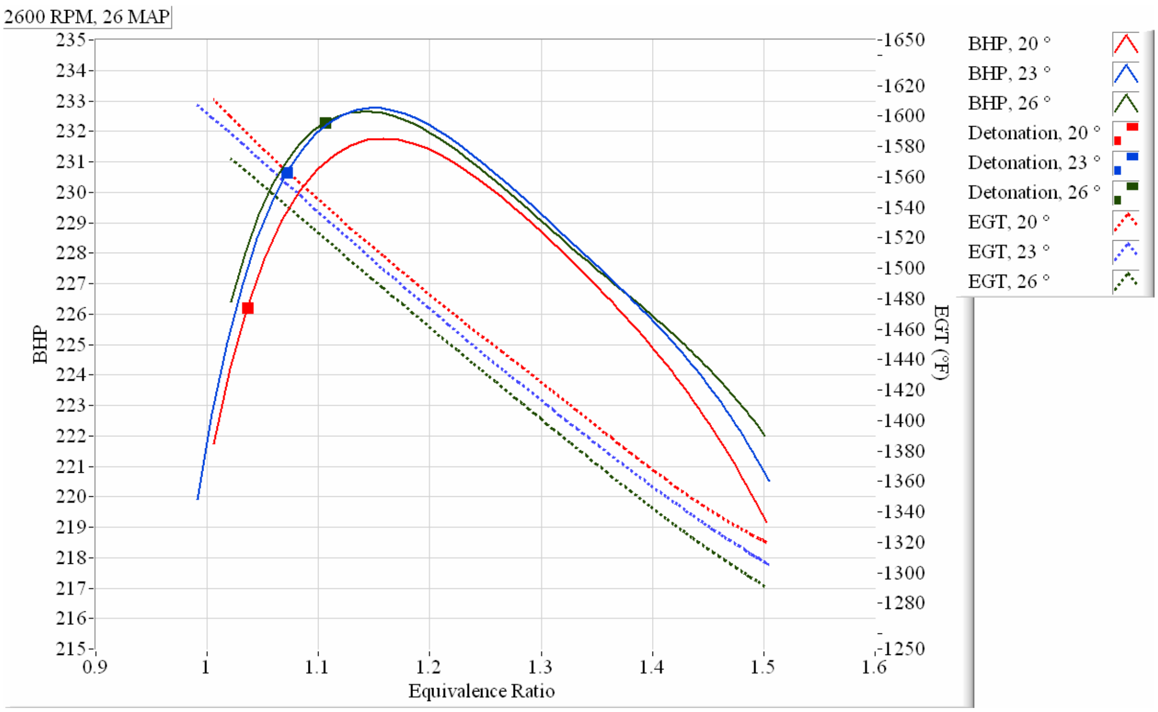


Figure I-14. Detonation Onset; 2600 rpm, 26 inHg MAP

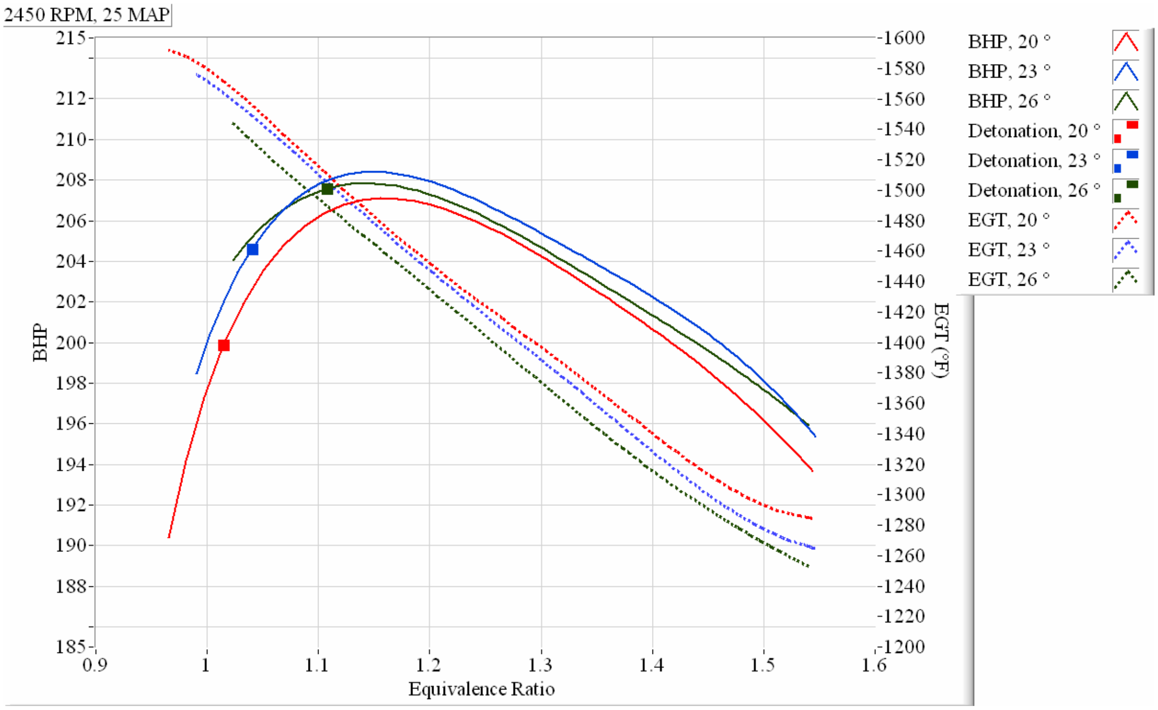


Figure I-15. Detonation Onset; 2450 rpm, 25 inHg MAP

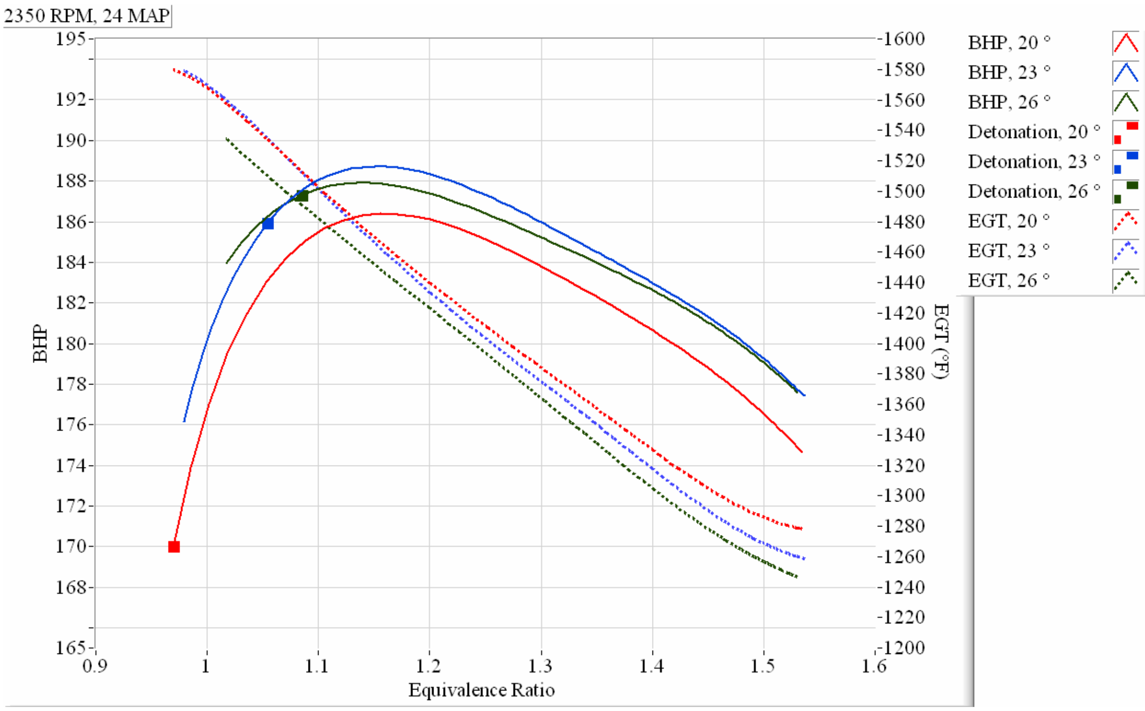


Figure I-16. Detonation Onset; 2350 rpm, 24 inHg MAP

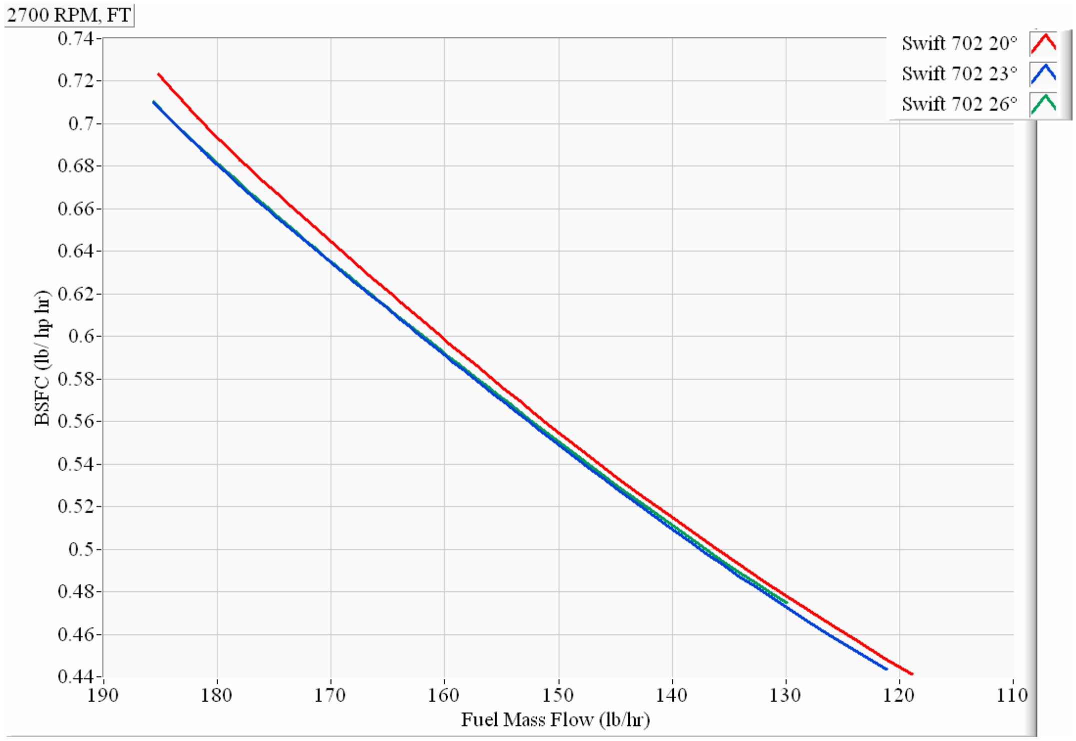


Figure I-17. Detonation Onset; 2700 rpm, FT

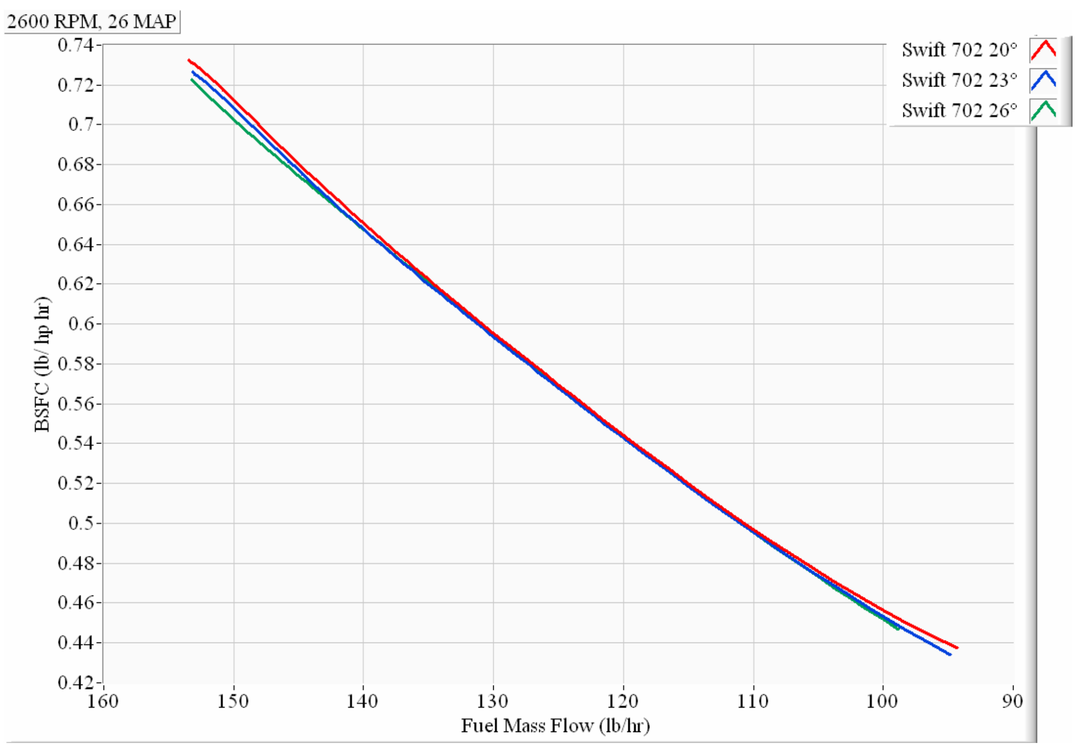


Figure I-18. Detonation Onset; 2600 rpm, 26 inHg MAP

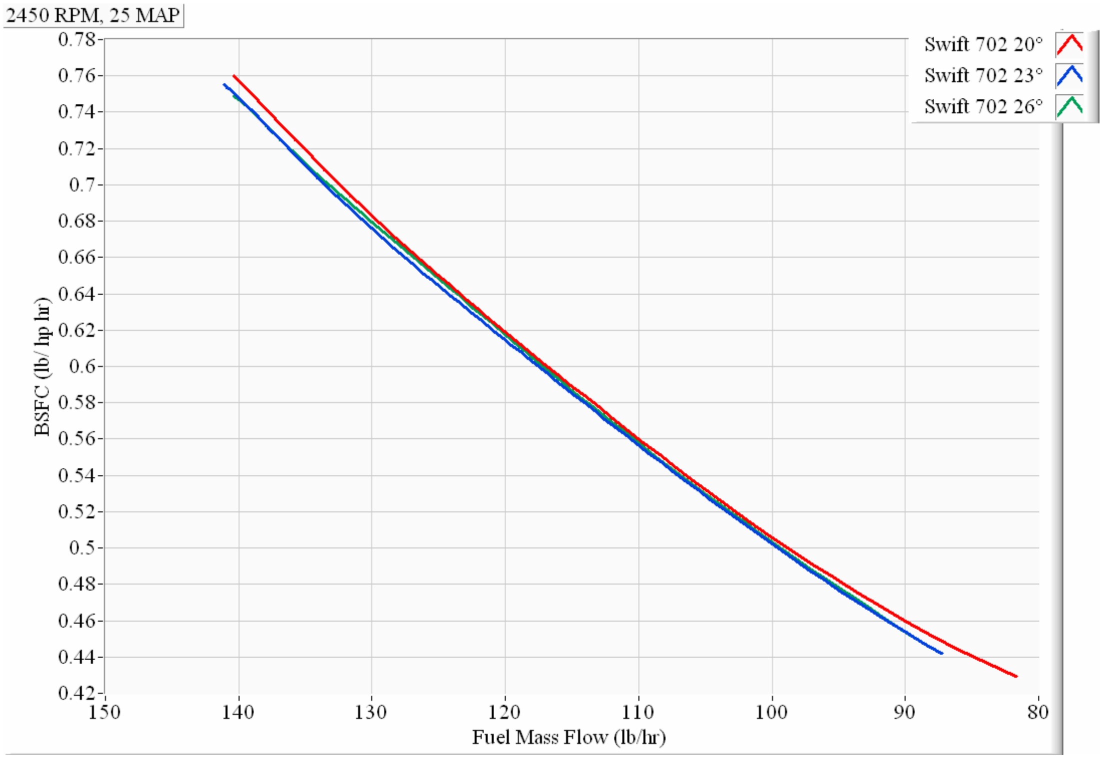


Figure I-19. Detonation Onset; 2450 rpm, 25 inHg MAP

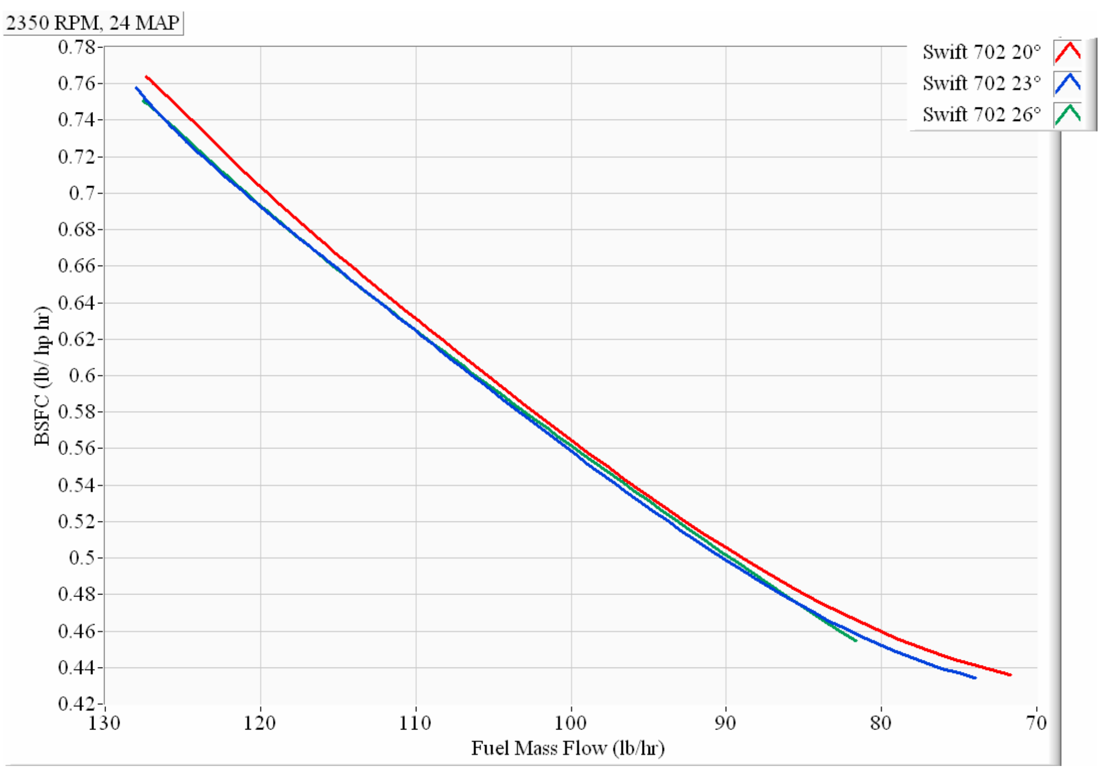


Figure I-20. Detonation Onset; 2350 rpm, 24 inHg MAP