2017

Enhanced Handheld Engine Ethanol Study

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By

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A Thesis Submitted in Partial Fulfillment of the

Requirements for the Degree of

Masters of science

In

Manufacturing Engineering Technology

Minnesota State University, Mankato

Mankato, Minnesota

December 2017

11/14/2017

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Enhanced Handheld Engine Ethanol Study

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Abstract

This study examined consumer and professional grade handheld engines. Twenty-four consumer grade 50 hour Emissions Determination Period (EDP) trimmers and 24 professional grade 300 hour EDP backpack leaf blowers were run on four different ethanol fuel concentrations; E0, E10, E15, and E20. Six engines of each type were run on each of the fuel blends through their full EDP.

All engines were broken-in and adjusted to manufacturer specifications on E0. Then engines were emissions tested on E0 to provide a baseline and to determine the rich to lean order of the engines. Next, the leanest operating engine received E20 and the richest operating engine received E0 to simulate a worst-case scenario in the field. The engines' emissions, performance, temperatures, and wear were measured during the study to see if E15 or E20 would cause any other issues than E0 or E10 which the engines are design to consume. Measurements were taken at the beginning of the study along with half way through the EDP and at the end of the EDP.

Introduction

Small engines play an important role in our world. Any time there is natural disaster small engines found on generators, chainsaws, and pumps are needed in order to help return everything back to working order.

Small engines have additional concerns when compared to automobile engines. They have carbureted fuel systems and are unable to automatically adapt to changes in fuel composition. The use of different ethanol blends may require changes in the fuel/air mixture, something that carbureted small engines do not have the ability to automatically do.

Therefore, studies and experiments need to be conduct to determine what, if any, of issues or problems could show up in commercial and residential equipment. These studies include the possible increase in emissions along with running, and startability issues in these engines.

Fuel used

Pump grade non-oxygenated gasoline was the primary fuel used in this study. However, (Tier II EEE) indolene: emissions grade fuel was used in all emission testing periods. In order to obtain the desired ethanol concentrations in both the aging fuel and emission, performance testing fuel, the pump grade non-oxygenated fuel was splash blended with 98% ethanol. The fuel was then tested using a fuel composition meter to ensure proper concentration as shown in Figure 1.

Figure 1 -Fuel being test using fuel composition meter

Fuel used for aging was as follows:

- PE0, 91 octane non-oxygenated pump gasoline
- PE10, pump gasoline with 10% ethanol
- PE15, pump gasoline with 15% ethanol
- PE20, pump gasoline with 20% ethanol

Fuel used for all emission and performance testing was as follows:

- TE0, Tier II EEE indolene: emissions grade fuel
- TE10, Tier II EEE with 10% ethanol
- TE15, Tier II EEE with 15% ethanol
- TE20, Tier II EEE with 20% ethanol

Engines

The engines selected for use in this study were chosen based on several criteria. The Troy-bilt TB32EC (Figure 3) weed trimmer use a 25cc single cylinder 2-stroke engine that requires a 40:1 oil/fuel premixed. The engine has a 50-hour Emissions Determination Period (EDP). The engine uses a cube carburetor for fuel delivery. The oil in the fuel is used to lubricate the internal parts of the engine and therefore is in contact with the crankshaft and present in the crankcase at all times.

This was important to see if the higher ethanol content affected rotating assembly components in an adverse way.

This engine and fuel system is very representative to a wide variety of 2-stroke handheld engines that are used in consumer equipment from leaf blowers to chainsaws. Finally, the ease of loading the engine with an air blower attachment factored into its choice. The TB32EC engine will be referred to as the trimmer from here on.

A Stihl BR600 (Figure 2) 4-stroke hybrid engine that lubricates via pre-mixed 2-stroke 50:1 oil/fuel mixture was also selected. It has a displacement of 64.8 cm and EDP of 300 hours.

Figure 2- BR 600 Stihl Magnum blower

Figure 3-Troy built TB32EC weed trimmer

Even though this engine is a 4-stroke, the internal components are lubricated from the fuel oil mixture similar to a 2-stroke. Because of this, the moving parts are also exposed to the fuel mixture too. This engine was selected to represent the type of handheld equipment that would be used in a commercial or industrial setting. This engine also used a cube type and had the ability to operate at all angles including upside down. This engine was also selected because it is self-loading which greatly reduces the difficulties of testing. The BR600 backpack blowers will be referred to as the blowers from here on.

This study measured a total of 48 engines, 24 blowers and 24 trimmers. Six of each engine type was run on one of the four fuels; gasoline (E0), E10, E15, and E20

(6 engines X 4 fuels =24 engines for each type X 2 types of engines = 48 total engines).

Thermocouples

The engines were outfitted with hour-meters (Figure 4) and tachometers to keep track of time on the engines and measure the engine rpm.

Figure 4- Hour meter

Thermocouples were also installed in preparation for the study. They were attached in the exact same place on every engine to ensure compatibility but however the trimmer thermocouple locations were slightly different than blowers as shown below. Four thermocouples were installed for temperature monitoring on each engine:

<u>Blower's thermocouple locations</u>

•Air intake: Mounted in air filter box

•Cylinder head: A ring thermocouple under the spark plug

•Exhaust surface: Mounted underneath a muffler bolt on the surface of the muffler

•Exhaust gas: Probe inserted into the muffler to measure temperature of exhaust gases flowing past

<u>Trimmer's Thermocouple locations</u>

•Air intake: Mounted in air filter box

•Cylinder head: Hole drilled and tapped on the cylinder head cooling fin near the spark plug

•Exhaust surface: Mounted underneath a muffler bolt on the surface of the muffler

•Exhaust gas: Probe inserted into the muffler to measure temperature of exhaust gases flowing past

Thermocouples connecting wires from each engine were plugged in to one of three chassis plugs. These plugs connected to the National Instruments cDAQ-9172 data acquisition chassis. This was then connected to a computer which displayed temperature data via LabVIEW as shown in Figure 5.

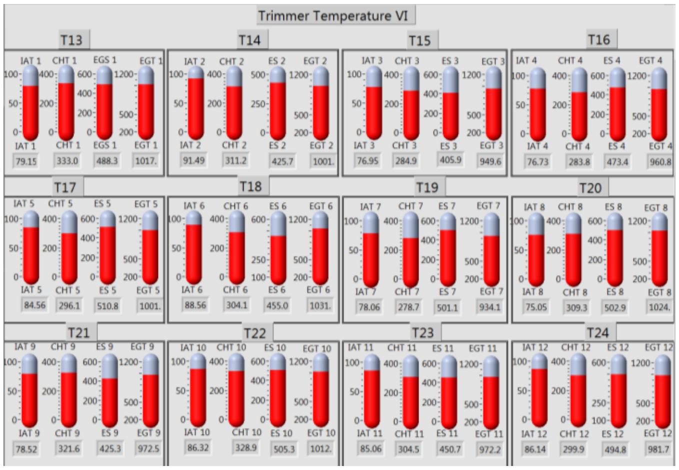

Figure 5-Displayed temperatures via LabVIEW

Testing

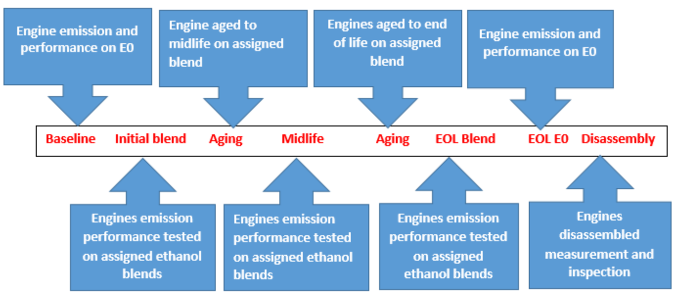

Figure 6--Test Plan for engines

Test plan (Figure 6) was followed throughout the study. After receiving the engines, each unit was inspected, labeled, and the compression and spark plug gap were measured. Next thermocouples were installed, and the engines were placed onto the test rack. Also throughout the emission determination period, all manufacturer recommended maintenance was performed at its recommended hour interval.

The engines were tested in four groups. The first two groups, 12 trimmers (T1–T12) and 12 blowers (P1-P12), received performance, temperature, material compatibility, and wear measurements through their EDP. The next two groups of 12 trimmers (T12-T24) and 12 blowers (P12-P24) were emissions tested and had their power and torque measured along with performance and material compatibility and wear testing through their EDP.

The study was conducted in this manner because of the extra level of complexity that emissions and dynamometer testing add to the study. If the engines could not perform correctly or would not last through their EDP, there would be no point in adding the extra level of complexity. Both, the first two (T1-T12, P1-P12) and second two (P1-P12, P13-P24) groups performed similarly in terms of performance, aging, wear and material compatibility.

First, the engines were broken-in according to manufacturer's specifications. However, the blowers P1-P12 were broken in for 30 minutes and P13-P24 of blowers were broken in for 6 hours due to short of hours in the P1-P12 break in. P13-P24 engines were given an emissions test to determine baseline emissions and performance. This

was done with Tier II EEE emission certified fuel on all engines. This baseline emission test determined each engine's ethanol blend concentration assignment. Carbon monoxide in grams/hour emitted was used to determine the air fuel ratio and order engines from rich to lean. The leanest 3 engines received the highest concentration of ethanol as to make the effects of ethanol more apparent. The richest running engines were assigned fuel with 0% ethanol. Table 1 and Table 2 shows the fuel assignment for trimmers and blowers.

E0	T2	T3	T7	T18	T19	T20
E10	T5	T1	T4	T16	T21	T24
E15	T8	T10	T12	T13	T14	T15
E20	T11	T6	T9	T17	T22	T23

Table 1-Fuel assignment for trimmers

E0	P5	P6	P7	P14	P16	P22
E10	P2	P9	P12	P13	P19	P24
E15	P8	P10	P11	P17	P20	P23
E20	P1	P3	P4	P15	P18	P21

Table 2-Fuel assignment for blowers

Figure 7-All 12 trimmers in two cycle mounted to aging rack

Figure 8-BR 600 STIHL mounted to aging rack

Next, the engines ran another emissions test on the fuels assigned to them along with a performance test. Afterward, the engines were aged to their midlife (trimmers 25 hours and blowers 150 hours). As shown in the figure 7 and 8 the blower attachments were mounted to a wire rack that held all 12 engines.

A pneumatic air cylinder that applied wide-open throttle at every cycle as programmed as shown in figure 9 and 10 controlled the throttle on each engine

Figure 9-Pneumatic air cylinder system

Figure 10-Pneumatic throttle actuator on blower

The aging cycle was 51 seconds of wide-open throttle (WOT) and 9 seconds of idle for trimmers while blowers were cycle 1020 second WOT; 180 second idle.

After the engines reached midlife, they went through midlife emissions tests, and midlife performance tests. Then engines were placed back in the rack and continue aging until they reached their Emissions Determination Period (trimmers 50 hours and blowers 300 hours). Once the engines reached their EDP they were emission and performance tested on their assigned blend (end of life blend). After the end-of-life blend tests, the engines were tested on E0 (E0 end-of-life). Finally, after all tests that required the engine to run were finished, the engines were disassembled and checked for wear.

Emission Testing

All emission testing done in the study used utilized California Analytical Instruments constant volume sampling analyzer and Tier II indolene was used as emission testing fuel with their blends. The exhaust gases sampled were hydrocarbons (HC), nitrogen oxides (NOX), carbon monoxide (CO), and carbon dioxide (CO2). The raw form of this data is given by the analyzer software in ppm for HC, NOX, and CO, and a percentage for CO2

The emission bench values, dynamometer values, environmental conditions, and test fuel data were all inputted into a spreadsheet calculator that gave an output of HC, NOX, CO, CO2, and BSFC in grams/kW-hr. These values were put into an emissions comparison to be analyzed.

Per the Federal Code of Regulations Title 40 part 90.410 on two cycle handheld small engines these underwent two mode emission tests:

- Mode 1: Wide open throttle, 85% weight in calculated emissions.
- Mode 11: Idle. 15% weight in calculated emissions.

Each mode was sampled for a period of 120 seconds after the engine had reached thermal stability. Thermal stability was defined as the point at which the cylinder head thermocouple stabilized within ±25°F window for at least 3 minutes. Data from the sample window is then outputted into an excel file in ppm. This includes average values from the sample. Trimmer engines were mounted to a Magtrol Hysteresis Dynamometer with a capacity of about 4 horsepower for emission testing (Figure 11).

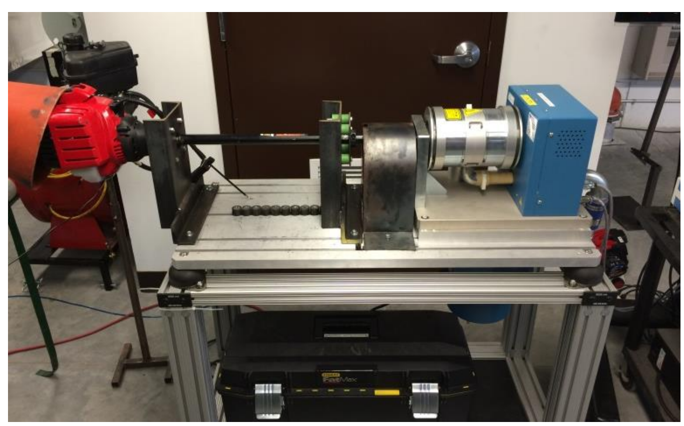

Figure 11-Magtrol Hysteresis Dynamometer

However, Blowers were mounted on Magtrol eddy current dynamometer (Figure 12) with water cooling system. A custom-built driveshaft was used to connect the engine to the dynamometer. A fixture to hold the blower were constructed from two plates.

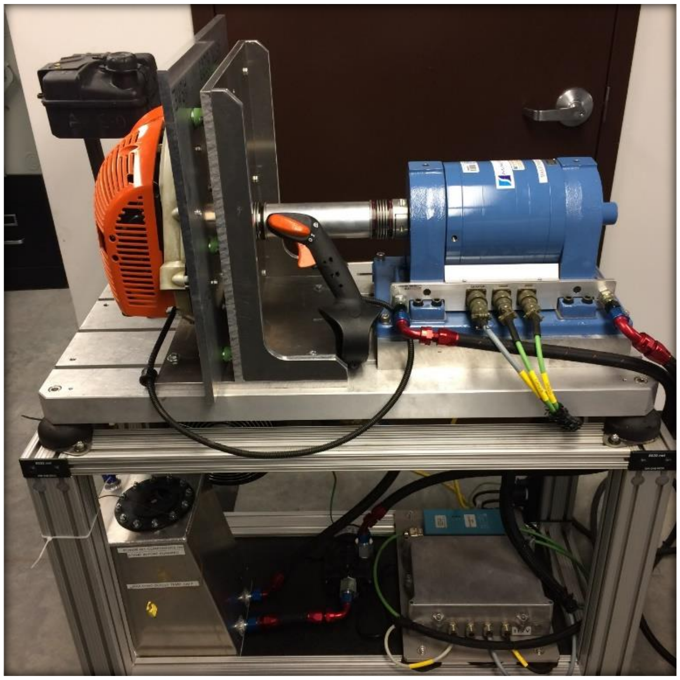

Figure 12-Magtrol eddy current dynamometer

Both dynamometer were controlled through a software program called M-TEST 7 Motor Testing Magtrol. During the 120 second sampling window horsepower, torque, and RPM data values were taken once every second. These values were manually averaged to be used in conjunction with the average emission bench values.

From here the emission bench values, dynamometer values, test lab environmental conditions, and test fuel data were input into a spreadsheet calculator that gave an output of HC, NOX, CO, CO2, and BSFC in grams/kW-hr. These values were put into an emissions comparison to be analyzed after all testing was completed.

Performance Testing

Performance tests done on each engine consisted of a set of three stages of tests. These tests included starting, acceleration, hot start/restart, full throttle stability, maximum RPM under load, and multi-position stability.

For startability, the engines were tested to determine the amount of pulls needed to start the engine including number of primer-bulb primes, and choke lever position. A fail condition was the engines would require more than 5 pulls or primes to start, or not start at all.

Acceleration tests consisted of timing the engine's ability to accelerate from idle to maximum RPM. A failure condition during this test was when the engine would not accelerate to maximum RPM in 15 seconds. Idle stability and RPM tests consisted of measuring the RPM of the engines and determining the fluxuations of the engines idle RPM. Engines failed if they were not able to maintain stable RPM within the manufacturer's recommended range. Maximum RPM of the engines were measured at WOT when the RPMs stabilized, and engines were failed if they were unable to maintain RPM in the 6000 to 7500 range for both engines

A multi-positional test was incorporated into the performance test, so full throttle and idle tests were repeated at different engine angles. RPM changes, as well as any temperature changes were recorded.

Different engine positions can determine the ability to deliver fuel in various positions and placements. The positions tested were left-side down, right-side down, nozzle pointing straight up, and nozzle pointing straight down as shown in Figure 13 and 14. The tests were considered a pass only if they were able to remain operating without stalling the engine.

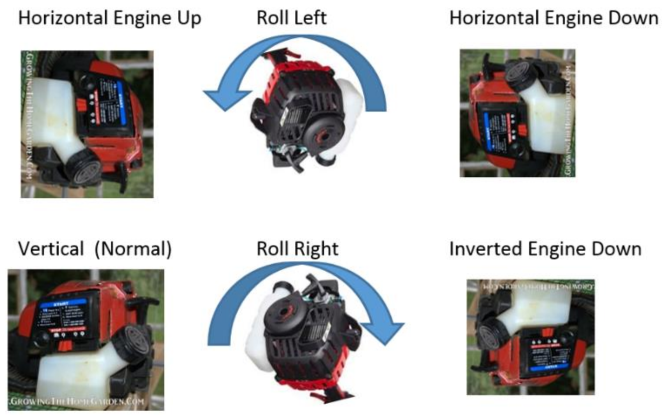

Figure 13-Different engine position on trimmer

Figure 14-Different engine position on blowers

Hot restart test was performed to check for vapor-lock, a condition where the fuel vaporizes inside the fuel system making it difficult to restart the engine. To do this, the engines were warmed up at WOT for 15 minutes while monitoring the cylinder head temperature to ensure the engine reached thermal stability (cylinder head temperature ±25°F for at least 3 minutes). Once they had reached thermal stability they were shut off, and let sit until the carburetor temperatures peaked. They were then started while monitoring the number of pulls required to start the engine.

Issues/failures during Testing

Trimmers

When attempting the initial TE0 emission tests on engines T16 and T19 neither engine would make adequate power. Both were showing signs of lean shifts while on the dyno. Troubleshooting this problem began with a simple mechanical check of spark and fuel delivery. When no issues were found in these areas, the carburetors were disassembled and cleaned. This did not solve the problem on either engine.

Carburetor adjustments were attempted after this. A small adjustment to T16's carburetor solved its problem but T19 still failed to produce enough horsepower on the dynamometer.

In order to determine if the carburetor was defective on engine T19 it was swapped with a known working carburetor from another engine not participating in the study. T19 made adequate power using this carburetor so adjustments were attempted on it as well. This created idling issues for the engine. Following this, the decision was made to order a replacement carburetor from the manufacturer. Using the new carburetor solved all engine issues with T19 at the time.

At the midlife blended emission test T19 again exhibited problems with obtaining proper horsepower. After inspection, the high speed mixture screw on the carburetor was adjusted about 1/8 turn counter clockwise. This solved any issue present and allowed emission testing to continue.

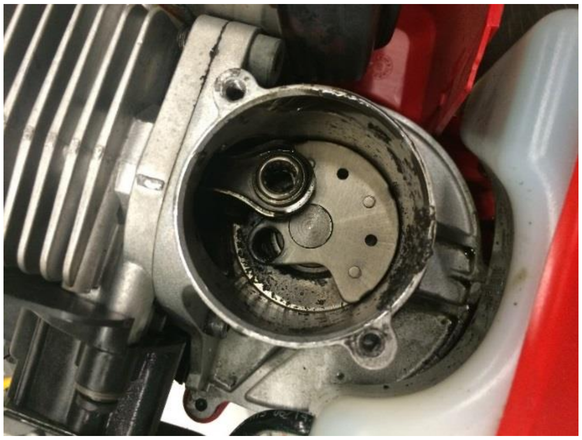

Figure 15-Removal of the crankcase cover

At hour 47 of aging, engine T14 would no longer idle and while running at WOT made a lot of internal engine noise. Checking compression indicated that the engine was down about 40 PSI from the previous test done at midlife. Removal of the crankcase cover showed a large amount of metal shavings. The connecting rod pin was also out of place (Figure 15). This engine's participation in the study ended at this point as it was unable to complete further testing.

During end of life warmup, engine T13's second TE0 emission test power output suddenly dropped to only about .15 horsepower. The engine also seemed to be making a lot of internal noise. Emission testing was stopped on this engine at this point. A mechanical check showed compression was down by about 10 PSI. Some metal shavings were also found in the crank case. The team believed this was probably a less advanced case of what happened to engine T14. Only the first end of life (EOL) TE0 emission test was used in the overall comparison for engine T14.

Blowers

Twenty-Three engines completed 300 hours of testing without mechanical problems. One E10 engine, suffered internal damage caused by extreme temperatures during emission testing. While testing, the engine was damaged because proper cooling wasn't provided, but the problem was notice too late and the damage was already done. As a result of the failure the blower wasn't included in any results. The failure was not fuel related, but a testing error.

Thermocouple failures that were experienced were found to be caused by poor mounting practices or unsuspected interference. These thermocouples were replaced, and further problems were eliminated by improving mounting methods.

Results

Performance test

Performance test data was gathered during initial E0, initial blend, midlife blend, end of life blend and end of life E0. Wide open throttle rpm, stable idle rpm was recorded during cold startability test, multiposition test and hot restarbility test. Also, the temperatures were recorded in cold start and hot restarter evaluation test.

Cold start number of pulls

Number of pulls to start the engines were recorded at the beginning of the cold start test. Engines were started at full choke, half choke and no choke conditions as necessary. More than 10 pulls to start the engine was considered as a failed start. All the blowers started easily with 1 to 2 pulls cold. The trimmers T1-T12 were started at 2 to 3 pulls during initial E0 and afterwards engines were started 5 to 6 pulls during its life time. Second set of trimmers (T13-T24) also started between 2 to 3 pulls during initial E0 however the number of pulls increased to 4-7 during rest of its lifetime. All the recorded numbers can be found in Appendix U

Hot restart numbers of pulls

All the blowers started easily with 1 to 2 pulls during the hot restart. Trimmers took 5 pulls to start the engines at initial E0 and most engines required 3-4 pulls during its lifetime. Trimmer (T13-T24) started at 4-8 pulls at initial E0 and some engines increase to 9 while other engines reduce to 2 pulls throughout the testing.

Multi position

Blowers ran with no issues in left-side down, right-side down, nozzle pointing straight up, and nozzle pointing straight positions. However, trimmer died mostly when roll over to right side and engine inverted in WOT. Appendix X summarize the multiportion results for the trimmers.

IDLE PERFORMANCE TEST DATA

Idle performance test data was gathered from the cold startability test where engines ran for 3 minutes of wot and return to stable idle. All the data was recorded for same scenario for trimmers and blowers.

Trimmers

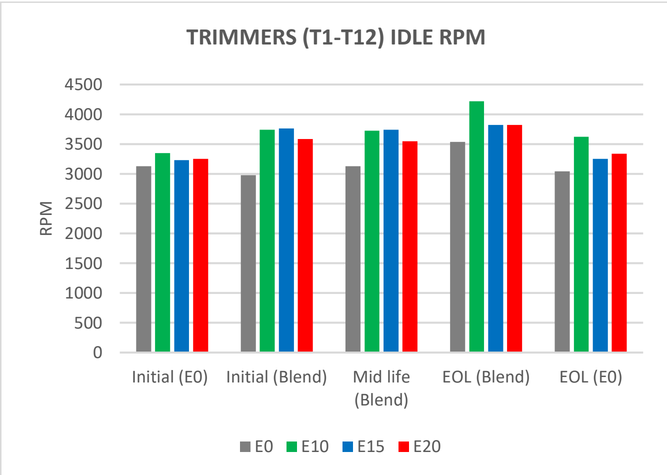

Figure 16-Stable RPM at Idle (T1-T12)

Trimmers T1-T12 data shows an increase in idle rpm with ethanol blends but however, end of life E0 idle rpm are lower than the blended end of life idle rpm (Figure 16). Also, the end of life E0 idle rpm are similar to the initial idle rpm as shown in the graph. E10 idle has increase thought its lifetime and end of life blend E10 has the highest rpm out of all the idle rpm. E15 and E20 have closer rpm numbers.

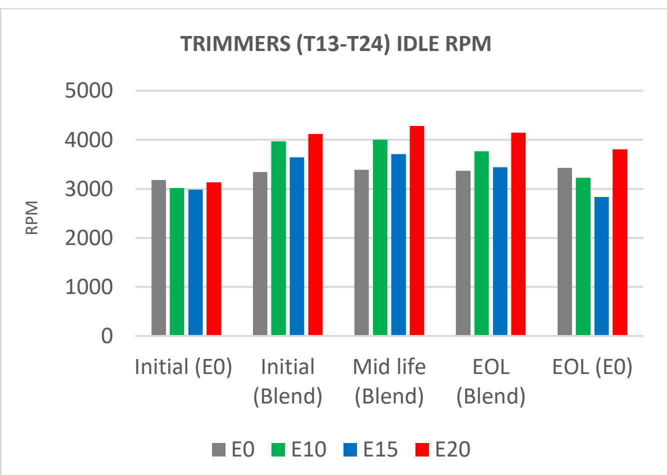

Figure 17-Stable RPM at Idle (T13-T24)

Trimmer T13-T24 also got idle increased throughout its life time. However, E20 has the highest idle rpm out of all the engines (Figure 17). All the fuel has slightly increased idle rpm till it reached the max RPM at midlife blend and slightly drops at the end of life blend. Except E0, all the fuel has reached its highest idle rpm at the midlife blend performance testing.

Trimmer's T1-T12 and T13-T24 test stable idle rpm has varied from 3000 RPM to 4100 RPM. Idle was set per the manufacturer's recommendation at 5.5 hours but this may have been before the engines were completely broken in.

Blowers

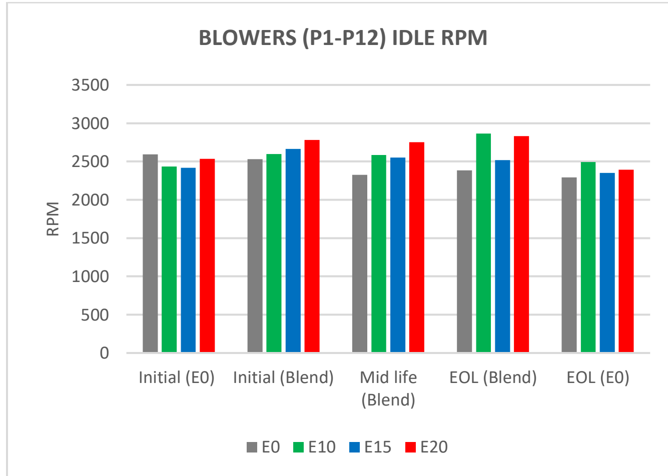

Figure 18-Stable RPM at IDLE (P1-P12)

Blowers P1-P12 idle rpm consistently increased and drop back at the end of life E0 (Figure 18). E10 end of life blend had the highest idle RPM while E20 had the next highest idle RPM. End of life E0 has lower RPM than initial E0 idle values.

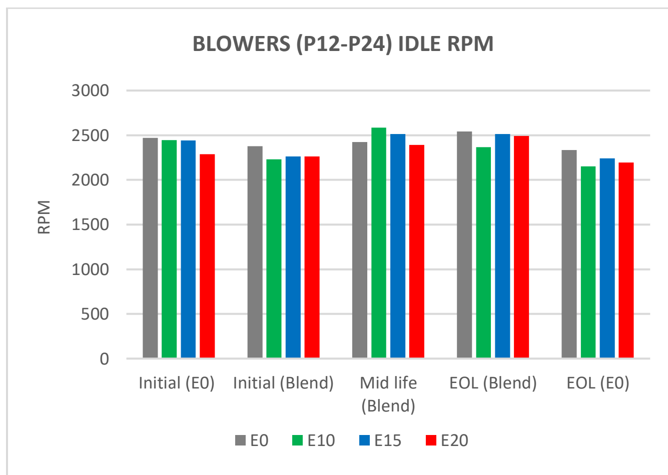

Figure 19-Stable RPM at IDLE (P13-P24)

Similar to P1-P12 set, P13-P24 set also gradually increased idle rpm till it reached end of life blend (Figure 19). Also, Initial E0 and end of life blend had similar idle rpm and midlife had the highest idle rpm out of all the engines. End of life E0 had the lowest idle rpm and was lower than initial E0 idle values. E15 has similar idle rpm at midlife blend and end of life blend where E10 drop rpm while E20 increases rpm.

WOT PERFORMACE TEST DATA

WOT data was gathered from hot restart test where engine ran for 15 minutes until it reached thermal stability.

Trimmers

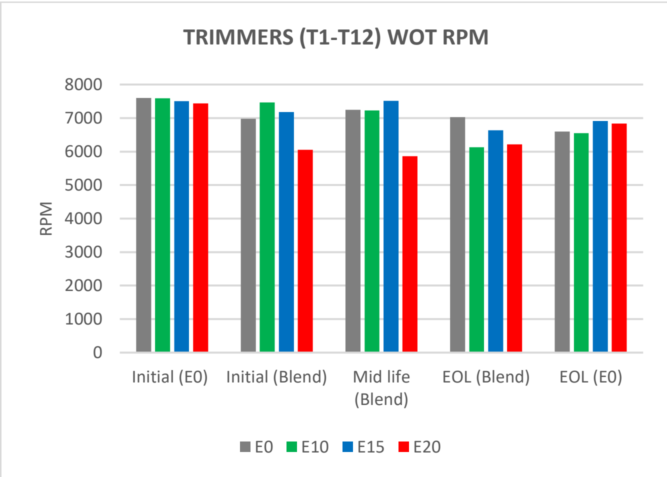

Figure 20-Stable RPM at WOT (T1-T12)

Initial E0 had the highest WOT stable rpm out of all the engines. E0 engines had the same WOT rpm during initial blend and end of life blend where it reached maximum wot rpm at midlife blend (Figure 20). E15 and E20 engines both lower their WOT rpm during its life time. End of life E0 WOT rpm are lower than initial E0 values.

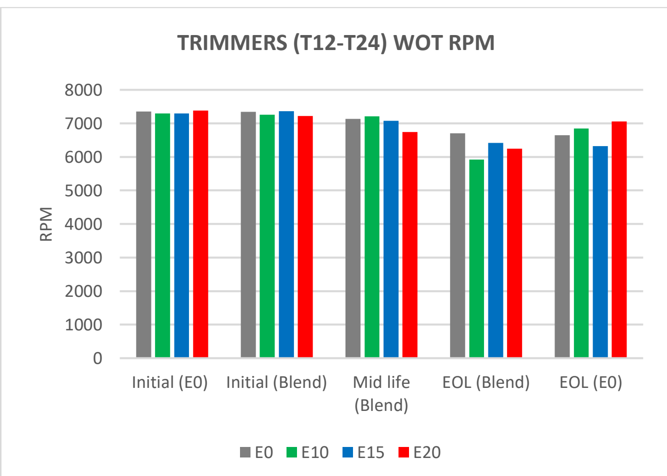

Figure 21-Stable RPM at WOT (T12-T24)

Trimmers T13-T24 engines WOT rpm had slightly decrease over their lifetime (Figure 21). Initial E0 had the highest WOT rpm and end of life blend has the lowest WOT rpm. Initial E0, initial blend and Midlife blend have a consistence WOT rpm and it drops at end of life blend WOT rpms.

Blowers

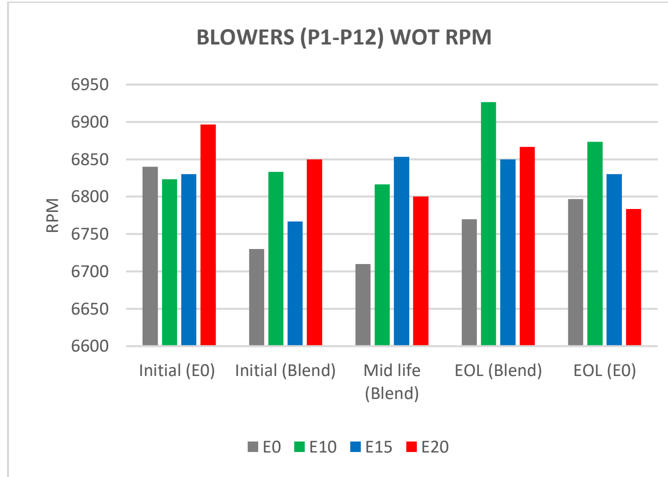

Figure 22-Stable RPM at WOT (P1-P12)

Blower P1-P12 (figure22) had varying rpm during their life time. During Initial E0, Initial blend testing E20 had the highest rpm until end of life E0; where it reached the lowest rpm out of all the engines. On the other hand, E10 gradually increased rpm until the initial blend and EOL blend it reached to the max rpm out of all the engines. However, E10 lower its rpm during the EOL E0 but E10 had the highest rpm EOL E0 out of all the engines.

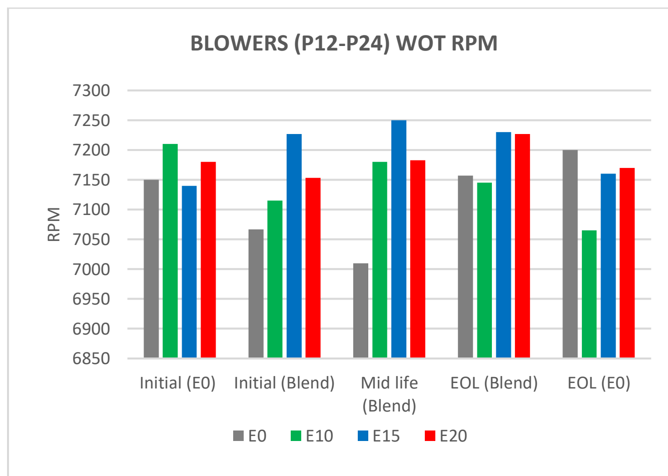

Figure 23-Stable RPM at WOT (P13-P24)

The second set P13-P24(figure 23) shows the similar pattern when it comes to E0. However, E10 has increased WOT rpm until midlife blend and decreased rest of its lifetime. The second set EOL E0 has the lowest rpm while E0 has the highest rpm.

EMISSION TEST

EMISSION TESTING – HORSEPOWER DATA

The following horsepower numbers were collected during the two minutes WOT test window while emission testing using Magtrol m-test software.

The emission testing graphs are displayed in two ways, the first graphs are labeled A and second graphs are labeled as B. A set graphs will show the data from each engine as an individual column while B set of graphs shows the average of each fuel group.

Trimmers

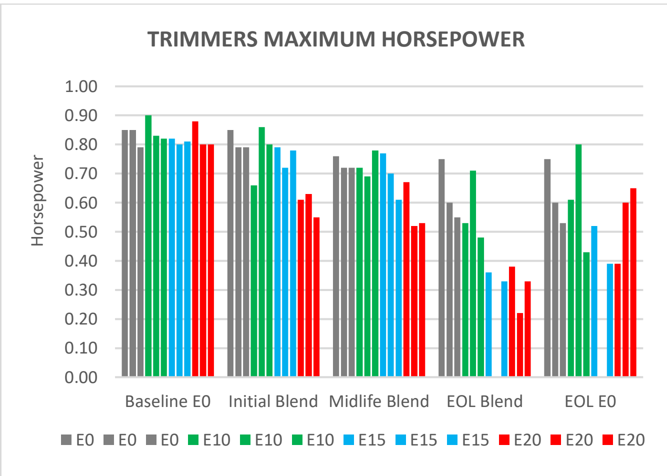

Figure 24A-Maximum Horsepower (T13-T24)

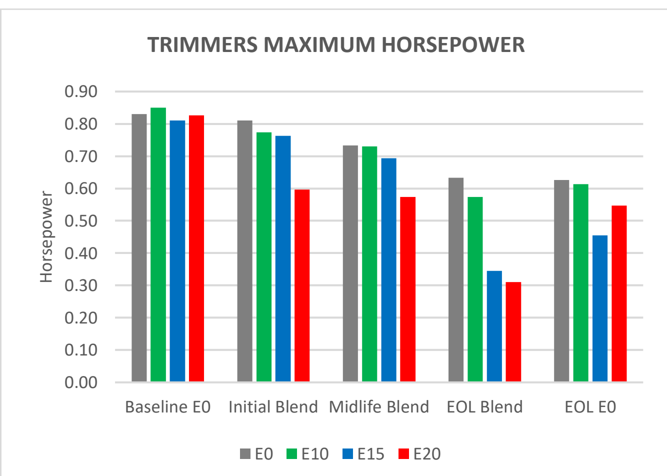

Figure 25B-Maximum Horsepower (T13-T24)

During initial testing, break in all engines produced similar horsepower numbers (Figure 24A and 25B). Once assigned and tested on their ethanol blends the trend seems to follow what has been seen in the past with E20 producing the smallest amount of horsepower. The graph shows that throughout the study all engines experienced a decrease in power due to normal wear.

When comparing the average percent of horsepower lost between the initial baseline tests on TE0 and the EOL tests also on TE0, the E0 and E10 engines both lost 24.5% and 27.8% power, respectively. E15 engines lost 43.8% power while the E20 engines lost 33.9% power.

E0 engines gained back the highest amount of horsepower after being returned to E0 at the end of testing.

Blowers

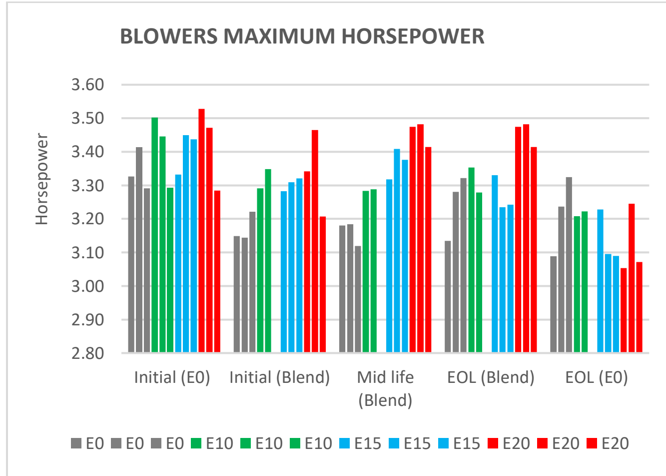

Figure 26A-Maximum Horsepower (P13-P24)

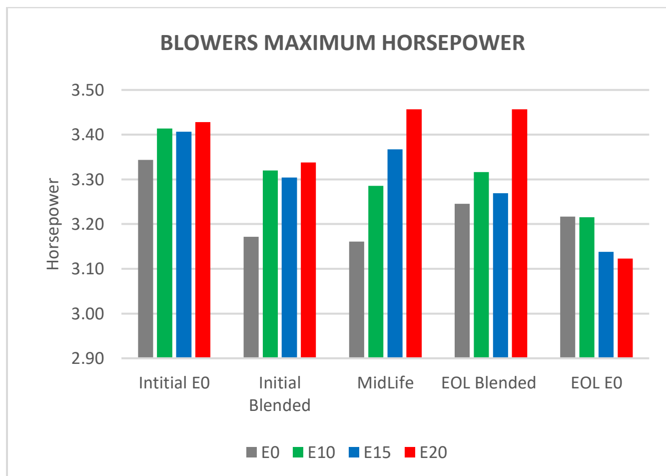

Figure 27B-Maximum Horsepower (P13-P24)

Compare to initial E0, all the engines had lower power when first introduced to the initial blend (Figure 26A and 27B). At midlife E15 and E20 horsepower had increased while E0 and E15 lower the horsepower. EOL blend E20 had reached its highest horsepower during its life time while E0 and E10 increased the horsepower compare to midlife. When the E0 was introduced back in, the engine horsepower has decreased.

When comparing the blowers to average percent of horsepower lost between the initial baseline tests on TE0 and the EOL tests also on TE0 the E0 and E10 engines both lost 3.8 % and 5.8% power, respectively. However, E15 engines lost 7.9% power while the E20 engines lost 8.9% power.

EMISSION TESTING –EMISSION GAS DATA

Hydrocarbon

Hydrocarbons are unburned fuel. High hydrocarbon emissions can be an indicator of a worn engine or simply an engine that is not running efficiently, letting fuel escape and end up in exhaust gases.

Trimmers

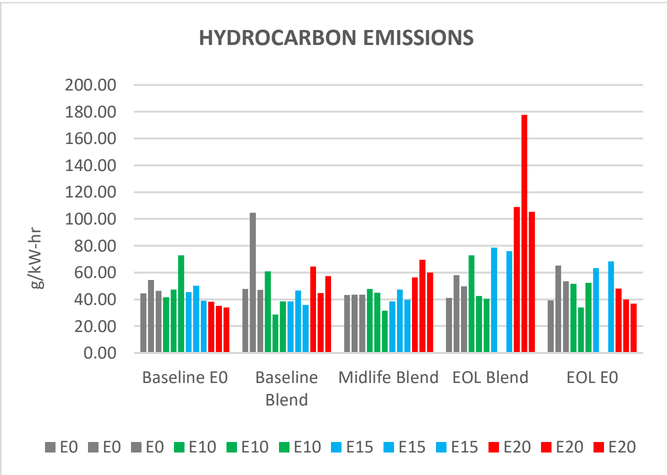

Figure 28A-Trimmers HC emission (T13-T24)

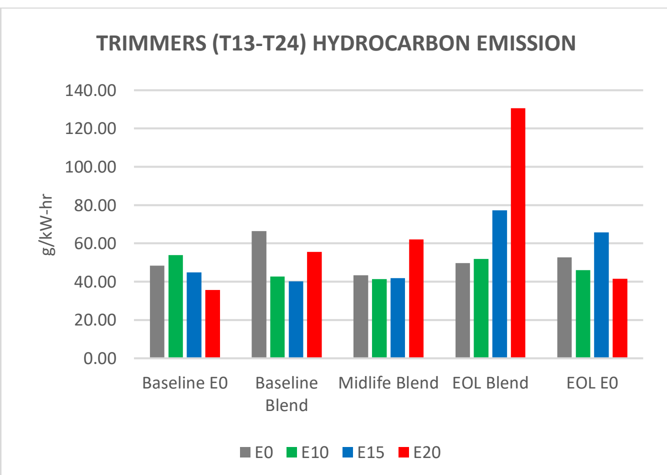

Figure 29B-Trimmers HC emission (T13-T24)

All engines increased hydrocarbon emissions throughout their lifetime (Figure 28A and 29B). The low power created by the E20 engines during the EOL blended emission tests resulted in very high weighted hydrocarbon emissions. When all engines were returned to E0 fuel average numbers were very close to the initial baseline E0 tests.

Blowers

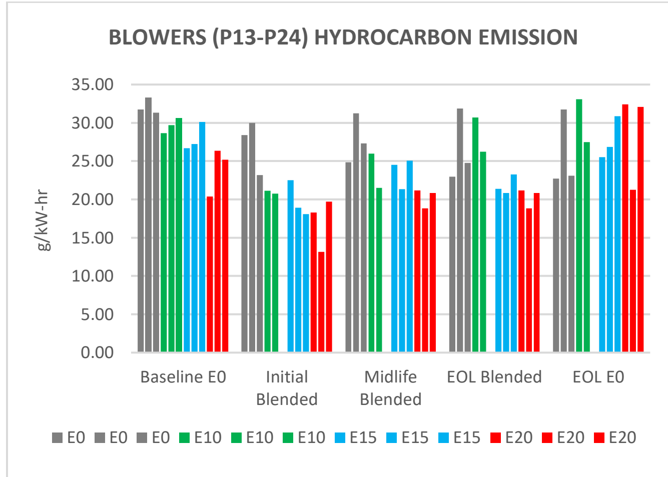

Figure 30A-Blowers (P13-P24) HC emission data

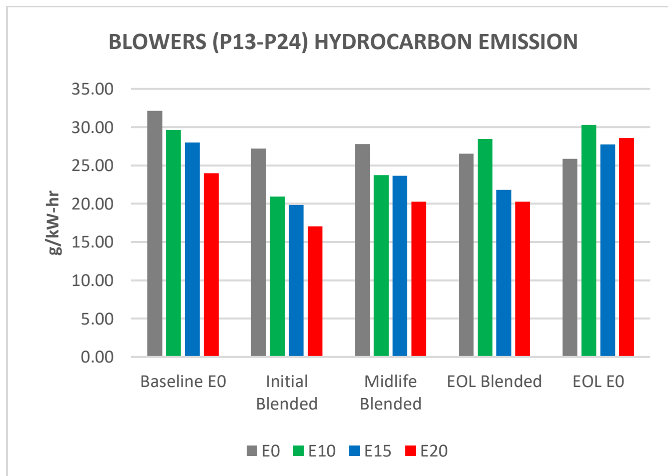

Figure 31B-Blowers (P13-P24) HC emission data

All engines experienced a drop in HC when they were switched to their assigned blend, most likely due to the engines still being broken in (Figure 30A and 31B). At the E0 End of Life all engines with an ethanol blend experience and increase in hydrocarbons when they were switched back to E0. End of life E0 low horsepower number might be the cause for high level of hydrocarbons.

Nitrogen Oxides

Nitrogen Oxides are a byproduct of the combustion process. High NOx emissions are a result of high combustion temperatures, which can be caused by a lean mixture.

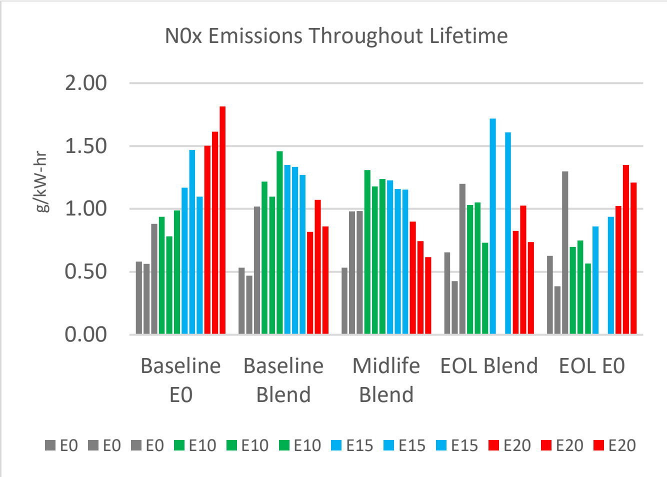

Figure 32A-Trimmers (T14-T24) NOx emission data

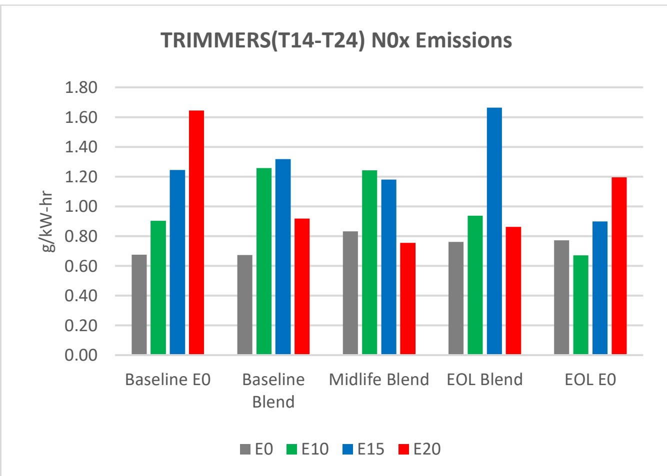

Figure 33B- Trimmers (T14-T24) NOx emission data

There was an upward trend of NOx emissions during the initial baseline E0 tests which was a good validation of the rich to lean ordering, which was based on carbon monoxide emissions (Figure 32A and 33B). After returning the engines to E0 at the end of the study the same general trend as the baseline tests are shown

Blowers

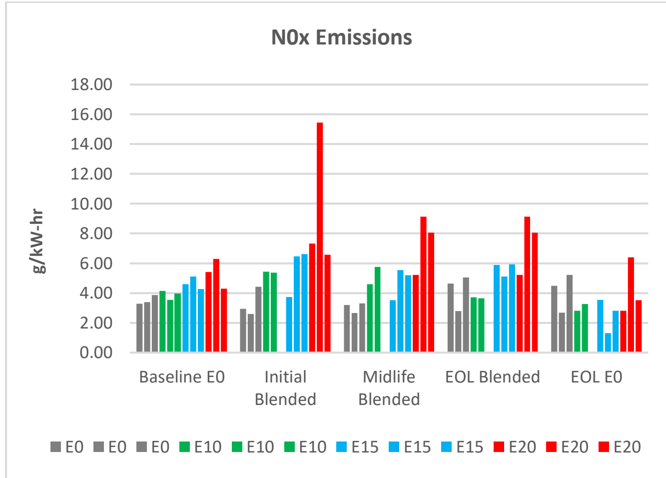

Figure 34A-Blowers (P14-P24) NOx emission data

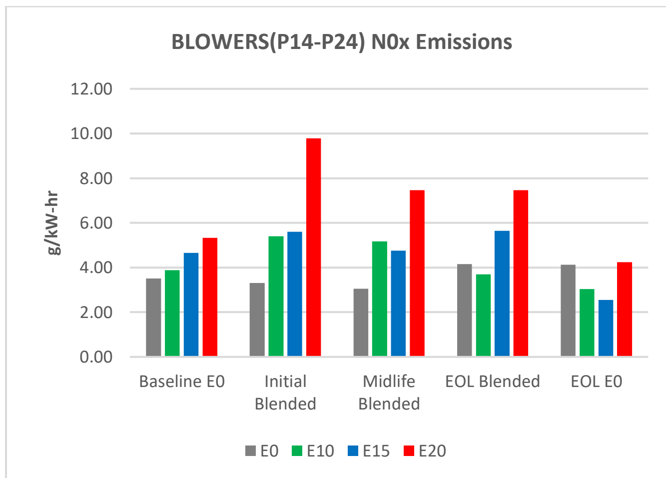

Figure 35B-Blowers (P14-P24) NOx emission data

The E20s has the highest NOx emissions since the initial E0 and throughout the whole study followed by the E15s, E10s and E0s (Figure 34A and 35B). This was expected since as the ethanol level is increased the leaner the mixture gets. Also, the NOx levels agree with the carbon monoxide which were used to assign the fuel after the initial E0 test. As the carbon monoxides levels increase the nitrogen oxides decrease.

Carbon monoxide

Carbon monoxide emissions was the basis of the rich to lean ordering. The more fuel an engine is burning the higher the CO emitted.

Trimmers

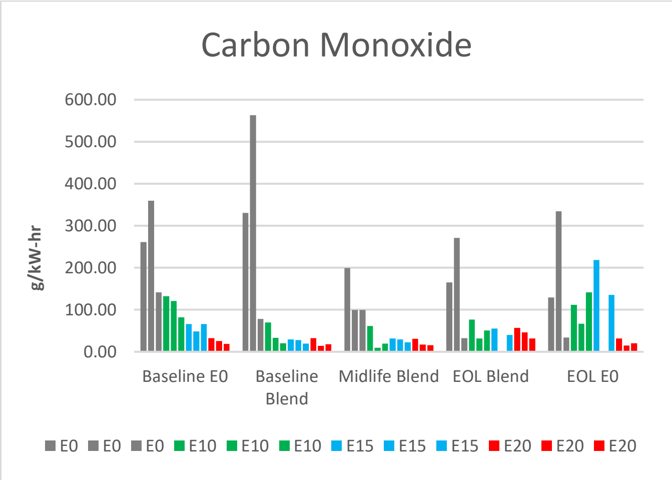

Figure 36A-Trimmers T14-T24 CO Data

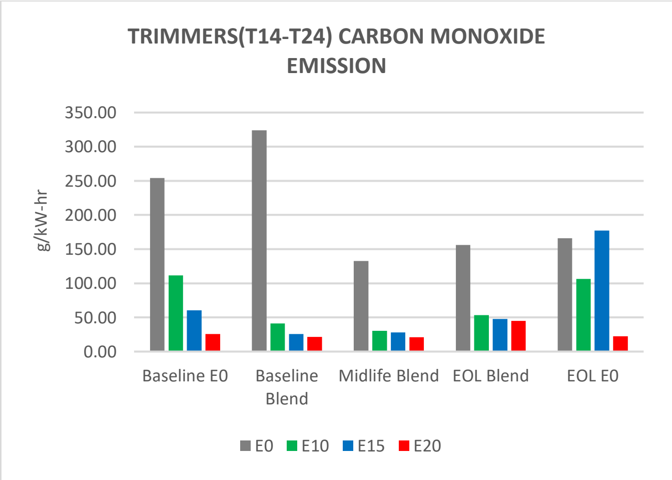

Figure 37B-Trimmers T14-T24 CO Data

There is a good downward trend during the initial baseline E0 tests (Figure 36A and 37B). The same trend generally continues throughout the study, with the ethanol content of the fuels further leaning the engines once blends were assigned.

Blowers

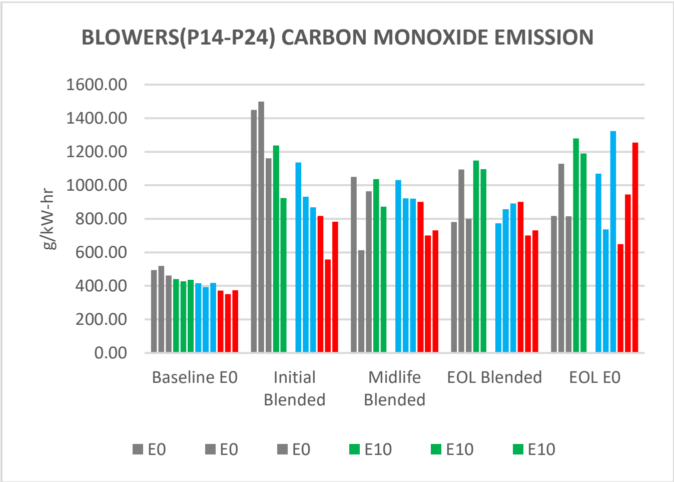

Figure 38A-Blowers P14-P24 CO data

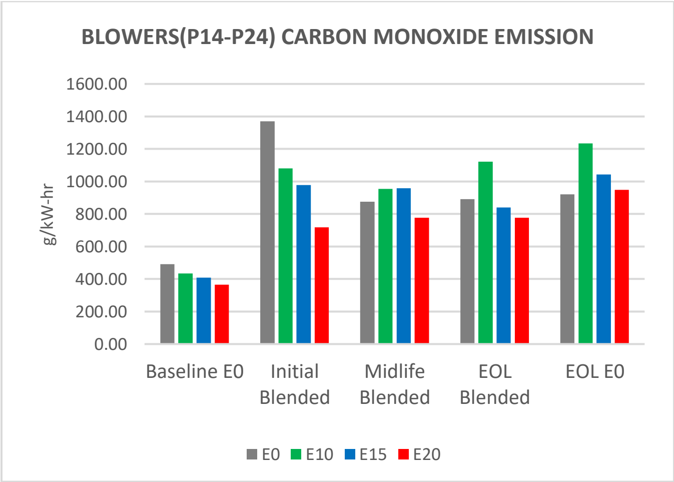

Figure 39B-Blowers P14-P24 CO data

The CO results in (Figure 38A and 39B) agrees with the NOx results, and shows that during the initial E0 test the E0s had the highest CO emissions followed by the E10s, E15s and E20s. The trend was the same in all the blended tests the richer the blends the higher CO emissions. Once all the engines went back to E0 most engines experienced an increased in CO emissions as expected due to the fuel.

Carbon Dioxide

Carbon Dioxide is a byproduct of the combustion process. Carbon dioxide is an indicator of combustion efficiency of the engines

Trimmers

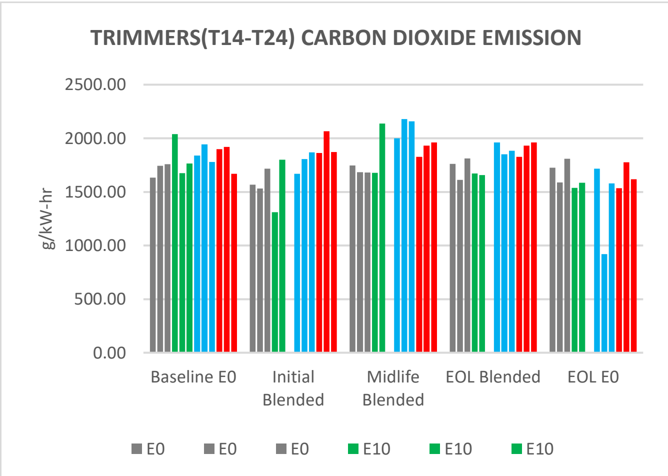

Figure 40A-Trimmers T14-T24 Co2 data

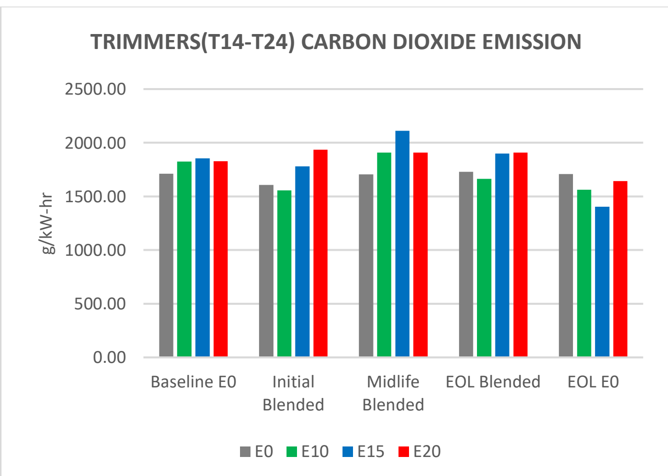

Figure 41B-Trimmers T14-T24 Co2 data

The upward trend seen in the E15 and E20 engines was the result of the downward trend in power output of these engines (Figure 40A and 41B). Until the engines began to lose power with age carbon dioxide values were very similar.

Blowers

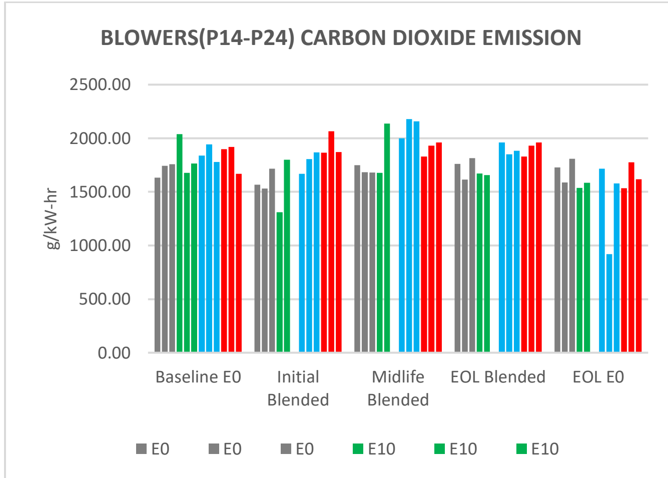

Figure 42A-P14-P24 Co2 data

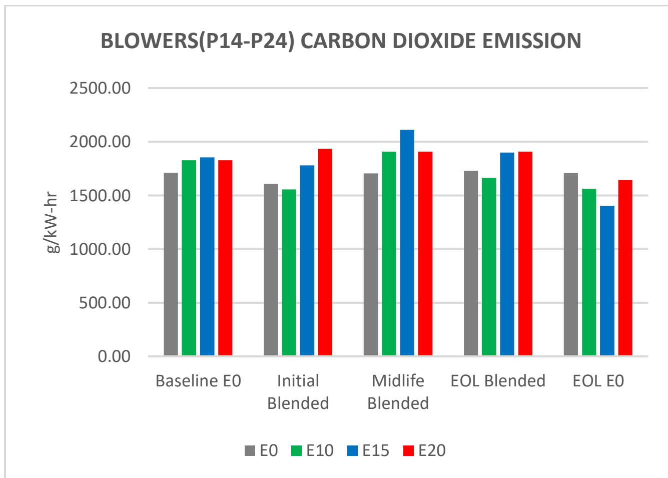

Figure 43B-P14-P24 Co2 data

Carbon dioxide shows the similar trend to the trimmer results (Figure 42A and 43B).

TEMPERATURE

CYLINDER HEAD TEMPERATURE

Trimmers

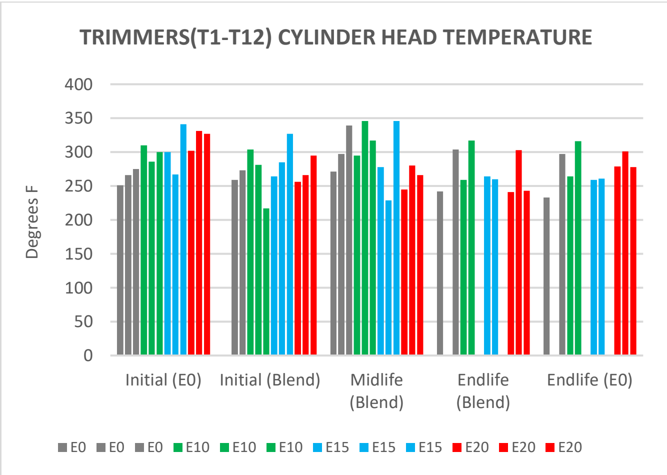

Figure 44A-Trimmers T1-T12 Cylinder Head temperature

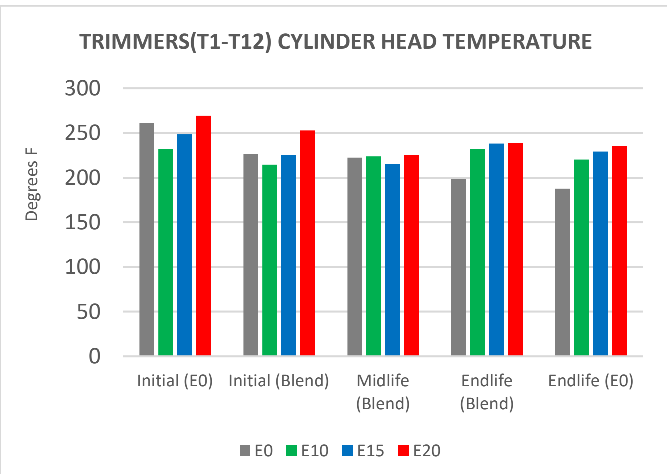

Figure 45B-Trimmers T1-T12 Cylinder Head temperature

E20 had the highest cylinder head temperature through the life time of the engines (Figure 44A and 45B). Also, E10, E15 seems to be the next lowest cylinder head temperatures. Initial E0 had all engines running head cylinder head temperatures assuming it was still breaking in the engines. After the initial E0 cylinder head temperatures slightly increases

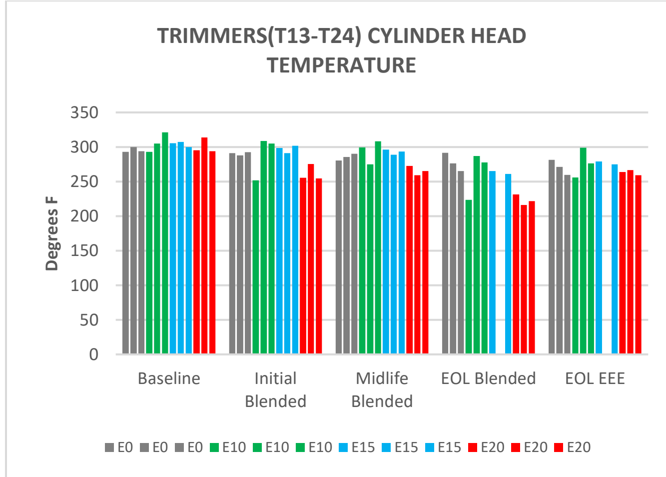

Figure 46A-Trimmers T14-T24 Cylinder Head temperature

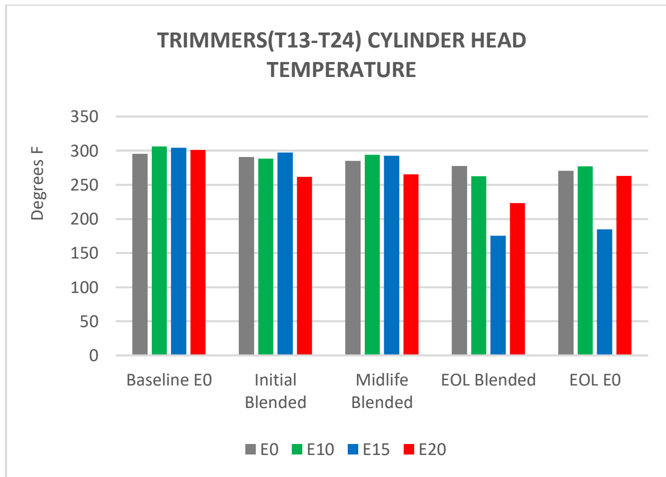

Figure 47B-Trimmers T14-T24 Cylinder Head temperature

Baseline E0 to midlife blended duration engines shows similar pattern in cylinder head temperatures and end of life blend and E0 E15 cylinder head temperature were lower than others (Figure 46A and 47B). The richest engines (E0) operated slightly cooler than the leaner E10 engines. The higher E10 temperatures were probably an indication that the combustion is slightly leaner than stoichiometric, creating more heat. The E15 and E20 engines are likely further past stoichiometric and are running cooler as a result (because of a lean combustion condition.)

Blowers

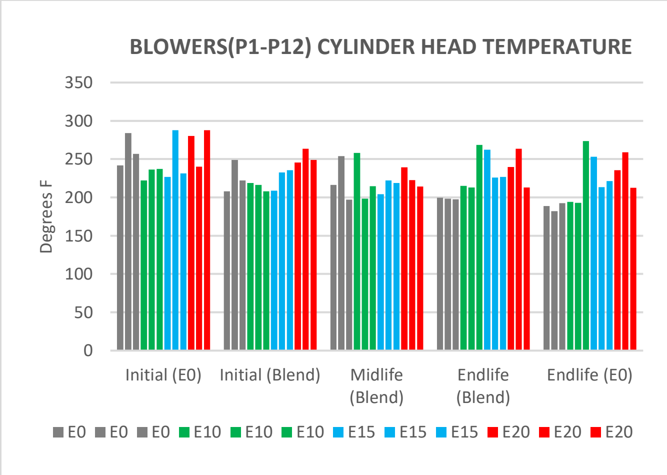

Figure 48A-Blowers P1-P12 Cylinder Head temperature

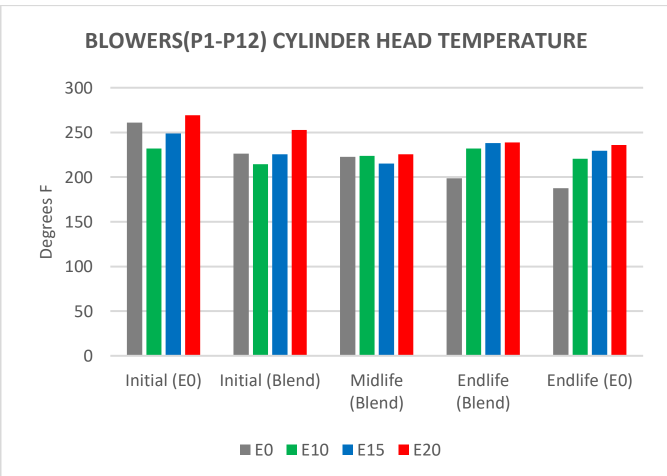

Figure 49B-Blowers P1-P12 Cylinder Head temperature

The leanest engine E20 has the highest cylinder head temperatures out of the engines followed by E15, E10.However E0 has continuously decreased its cylinder head temperatures (Figure 48A and 49B). End of life E0 and initial E0 has followed the same cylinder head temperatures.

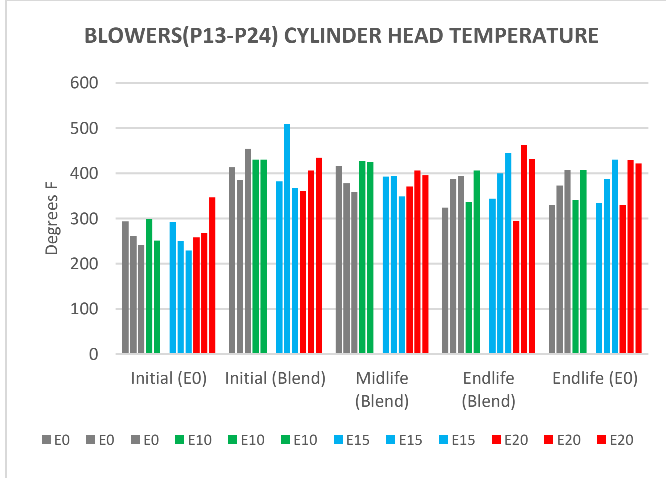

Figure 50A-Blowers P13-P24 Cylinder Head temperature

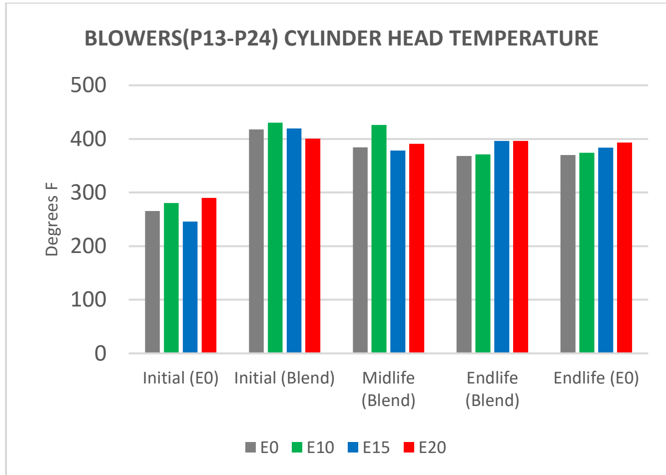

Figure 51B-Blowers P13-P24 Cylinder Head temperature

The E0 engines ran cooler throughout the whole study compared to the other blends (Figure 50A and 51B). The temperatures were higher for E10 and E15 blends as expected due to enleanment and decreased with the E20 blends since the fuel is further from the stoichiometric ratio as a result of a lean combustion conditions.

EXHUST GAS TEMPRETURE

Trimmers

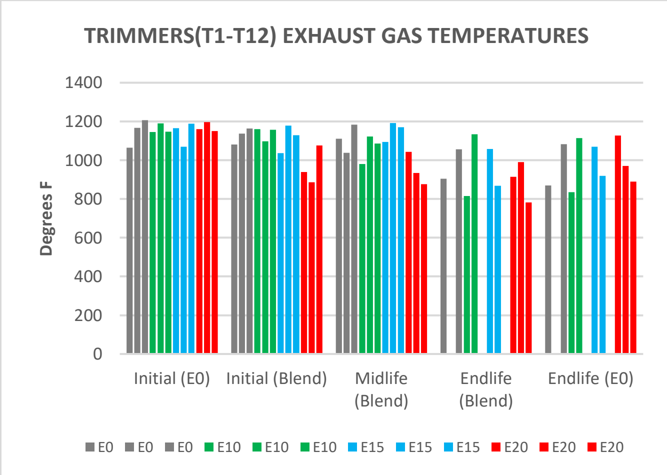

Figure 52A-Trimmers T1-T12 Exhaust Gas temperature

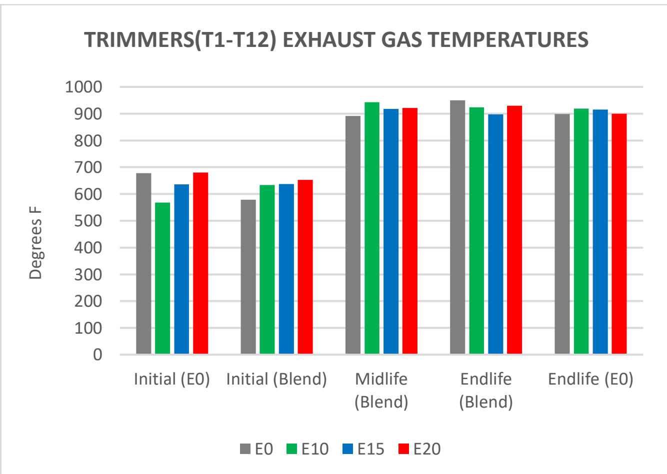

Figure 53B-Trimmers T1-T12 Exhaust Gas temperature

Initial E0 and initial blend shows lower exhaust gas temperatures throughout the trimmers' life time (Figure 52A and 53B). Also, E20 has the highest exhaust temperatures followed by E15, E10. Midlife blend, end of life blend and E0 shows a significant increase in exhaust gas temperatures.

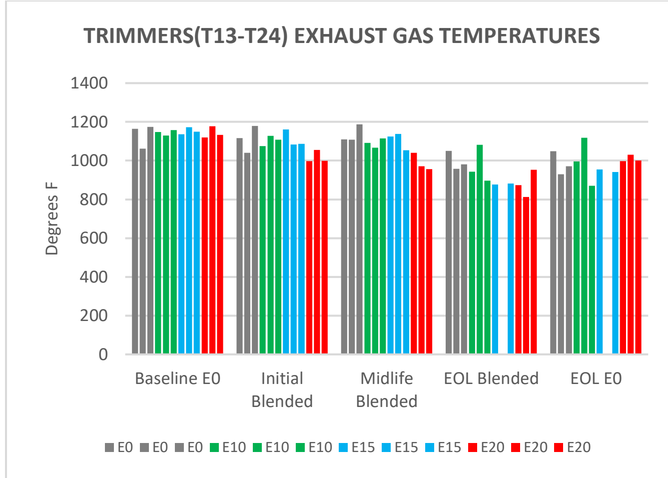

Figure 54A-Trimmers T13-T24 Exhaust Gas temperature

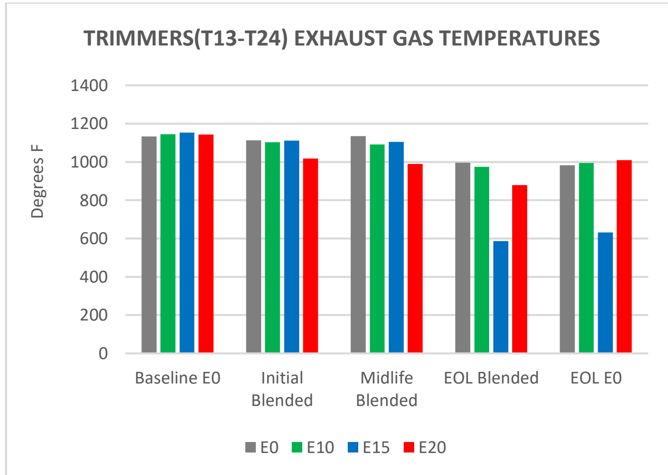

Figure 55B-Trimmers T13-T24 Exhaust Gas temperature

During the baseline tests all engines displayed very similar exhaust gas temperatures (Figure 54A and 55B). Once on their blends, the trends were as expected, with the trend becoming more apparent at the midlife test. As the engines made less power throughout their lifetime the exhaust gas temperature also dropped.

Blowers

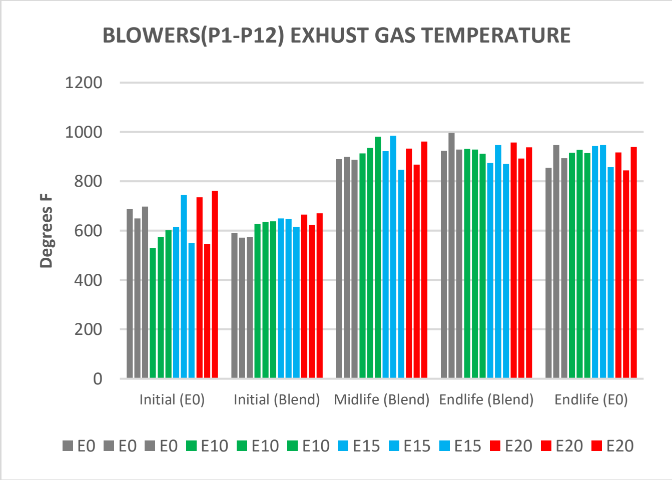

Figure 56A-Blowers P1-P12 Exhaust Gas temperature

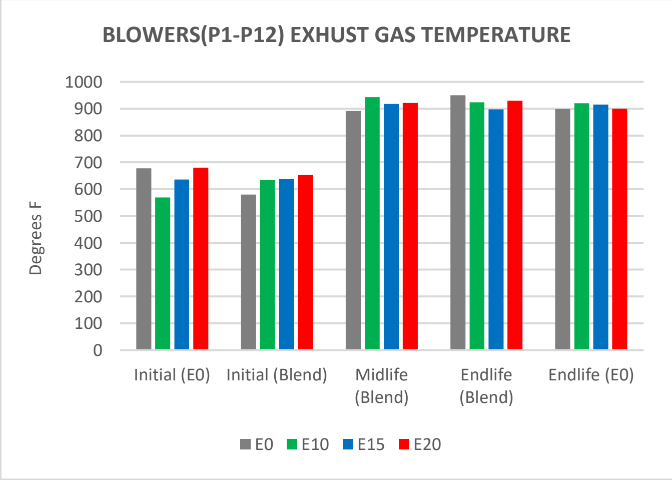

Figure 57B-Blowers P1-P12 Exhaust Gas temperature

As same as the first trimmers set the blowers shows the same trend in exhaust gas temperatures (Figure 56A and 57B).

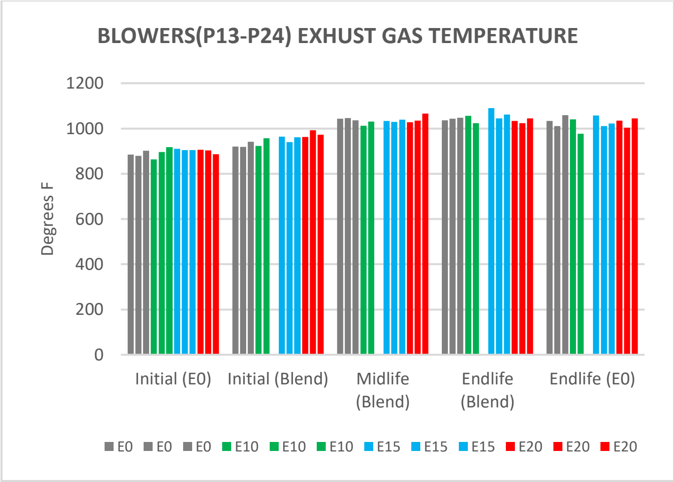

Figure 58A-Blowers P13-P24 Exhaust Gas temperature

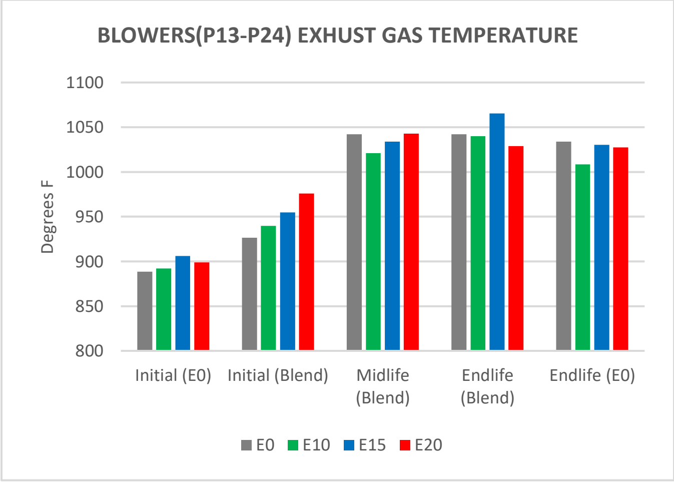

Figure 59B-Blowers P13-P24 Exhaust Gas temperature

The exhaust gas temperatures (Figure 58A and 59B) were similar for all the engines during the tests. Also, there is a noticeable trend where the temperatures increase throughout the lifetime of the engines. When switching to an ethanol blend the temperatures increased and when switching back to E0 most temperatures decreased.

EXHAUST SURFACE TEMPERATURE

Trimmers

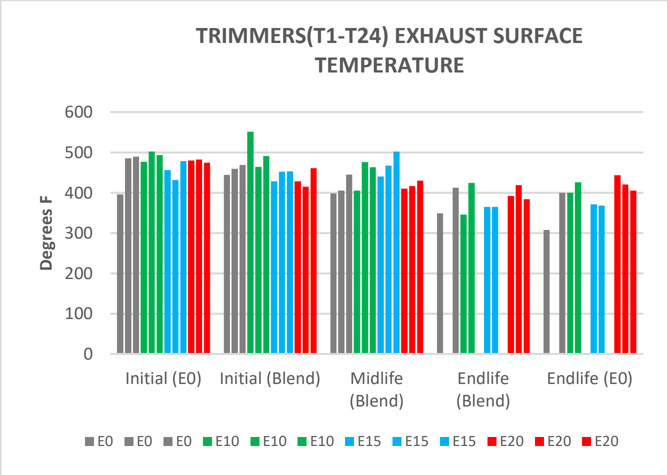

Figure 60A-Trimmer T1-T24 Exhaust Surface temperature

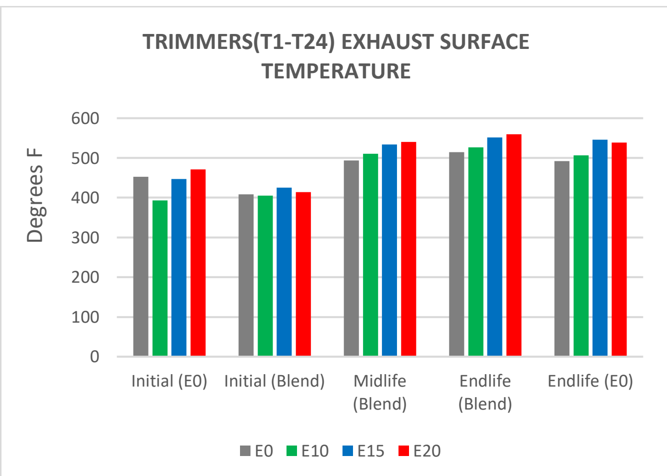

Figure 61B -Trimmer T1-T24 Exhaust Surface temperature

Exhaust surface temperatures has increased during its life time (Figure 60A and 61B). Also, higher ethanol concentration E20 has the higher exhaust surface temperatures followed by lower concentrations.

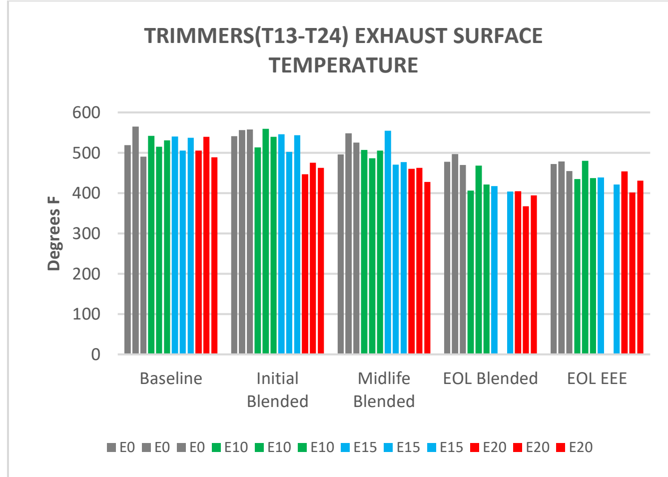

Figure 62A-Trimmers T13-T24 Exhaust Surface temperature

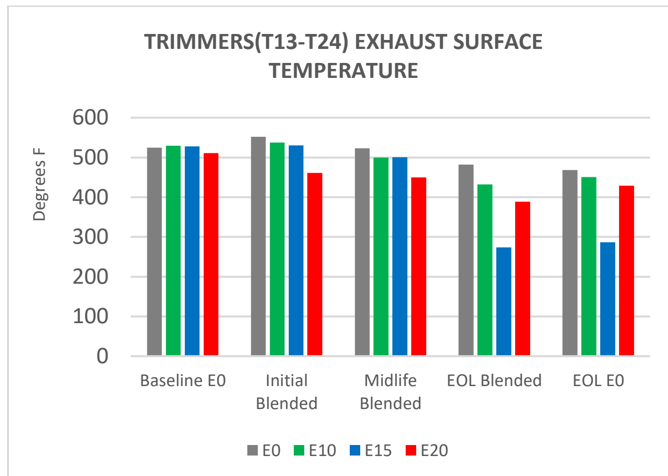

Figure 63B-Trimmers T13-T24 Exhaust Surface temperature

The exhaust surface temperature generally trends downward with the increase of ethanol content (Figure 62A and 63B).

Blowers

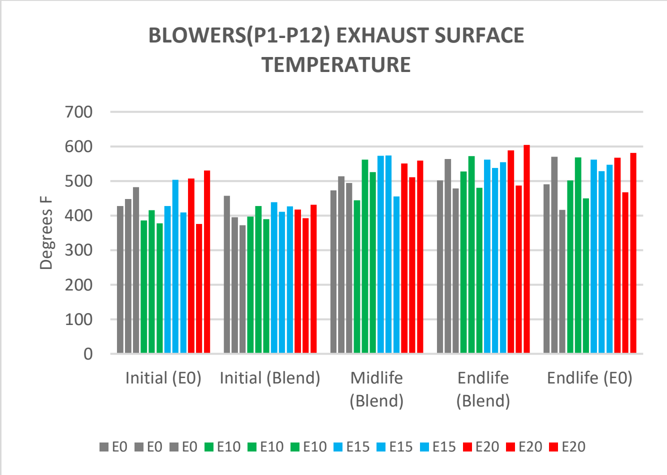

Figure 64A-Blowers P1-P12 Exhaust Surface temperature

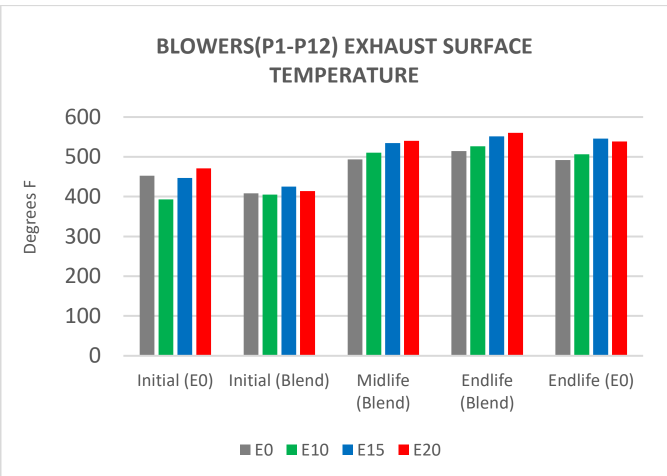

Figure 65B- Blowers P1-P12 Exhaust Surface temperature

Exhaust temperatures increased during life time but E20 had the highest temperatures followed by E15, E10 and E0 (Figure 64A and 65B). Also end of life blend had higher temperatures than initial blend.

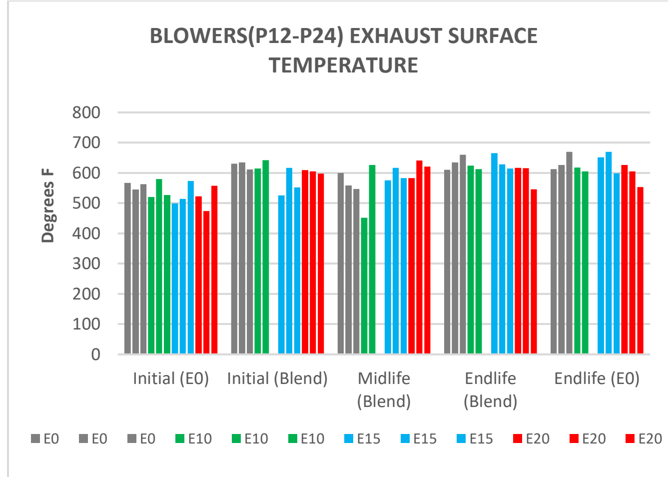

Figure 66A-Blowers P13-P24 Exhaust Surface temperature

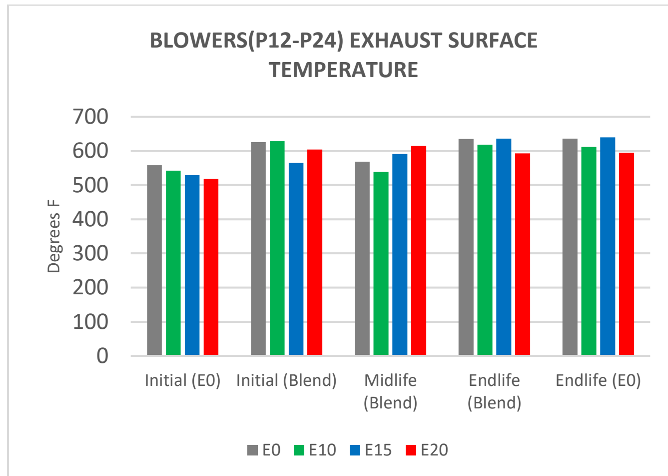

Figure 67B-Blowers P13-P24 Exhaust Surface temperature

The exhaust surface temperature data (Figure 66A and 67B) showed that the higher percentage of ethanol does not necessarily increase the temperatures compares to E0. All engines experience an increase in temperatures in the initial blended compared to the initial E0. This was thought to be from the engines not being fully broke-in. So, based on the data of all the tests is possible that an engine using E20 can have lower temperatures than an engine using E0.

Disassembly

Dimensional measurements (Appendix J and K) of engine components were carried out after all other testing had been completed. Based on the need for special tools and the specialized assembly processes and sealants that the manufacturers use, the engines were not disassembled before the study to avoid introducing another potential failure cause. Original manufacturer specifications were not available to compare the measurements to.

The fuel systems were inspected and disassembled at the end of the study. Fuel lines, gaskets, rubber and plastic components were checked for signs of swelling, shrinkage, softening, hardening and cracking.

Trimmers

T1-T12

Figure 68-Trimmer T1-T12 Exhaust ports

Figure 69-Trimmers T1-T12 Piston

T13-T14

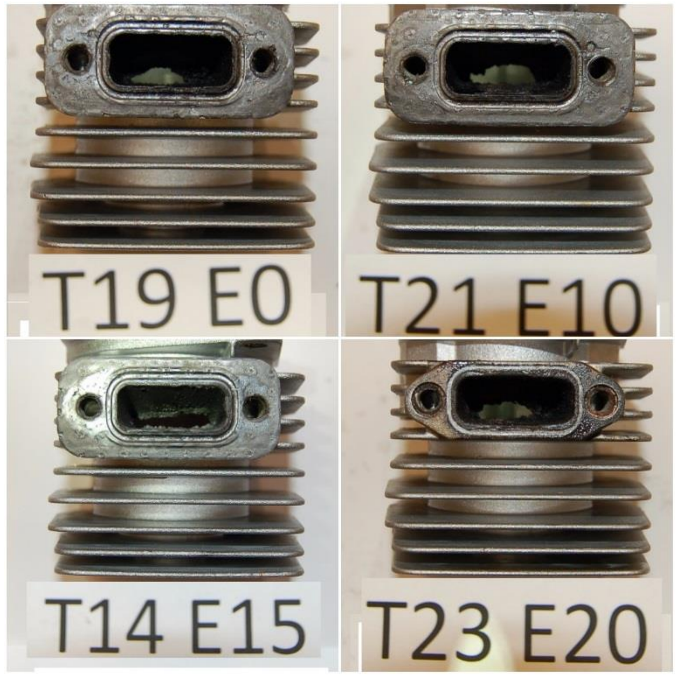

Figure 70-Trimmer T13-T24 Exhaust ports

Figure 71-Trimmers T13-T24 Piston

T1-T12 pistons and T13-T24 pistons did not show any correlation to the fuel study. All engines contained carbon buildup in the top of the Piston and there were no correlations to the fuel type (Figure 69 and Figure 71). Also large amounts of carbon buildup in the exhaust port (Figure 68 and 70). Exhaust ports were 50%-80% blocked by this buildup but there was no correlation between fuel type and blockage percentage.

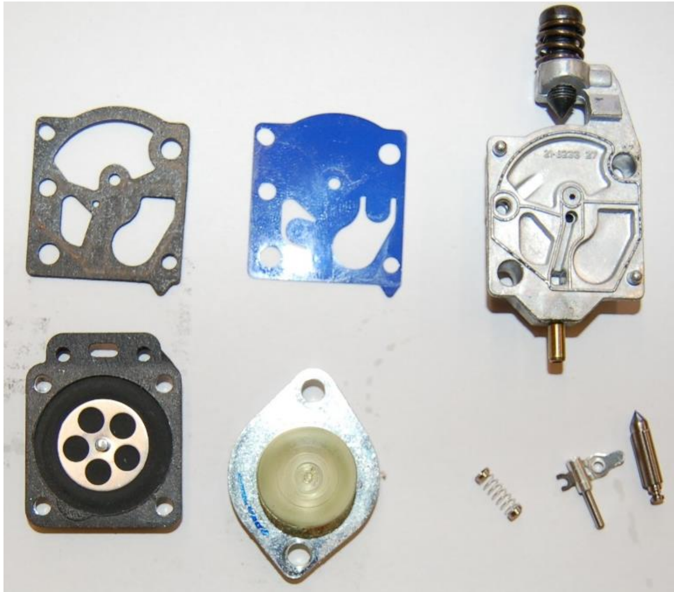

Figure 72-Trimmer carburetor

All carburetors were clean with no deposits formed (Figure 72). Most carburetors had minimal amounts of sediment in their screens. No corrosion was evident in any carburetors.

Blowers

P1-P12

Figure 73-Blowers P1-P12 piston

One characteristic that was noticeable was the carbon build-up within each engine. Figure 73 shows the carbon build-up for each engine piston at the end of testing, despite the de-carbonizing process that was completed earlier. Compare to E0 engines E20 has more carbon built up on the piston.

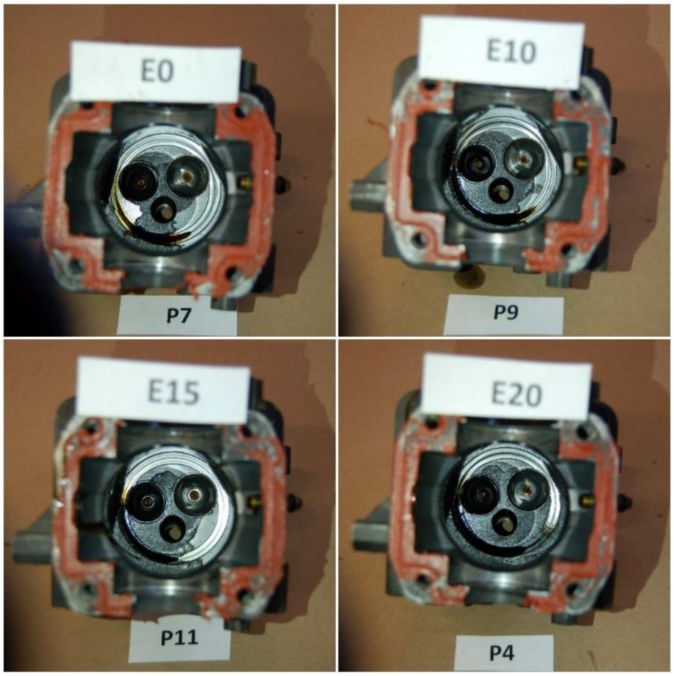

Figure 74-Blower P1-P12 Combustion Chamber

Figures 74 show the carbon build-up on the ceilings of the combustion chambers. Most E0 engines has less carbon built up compare to other engines. Carbon built up has increased respect to ethanol contain of the fuel.

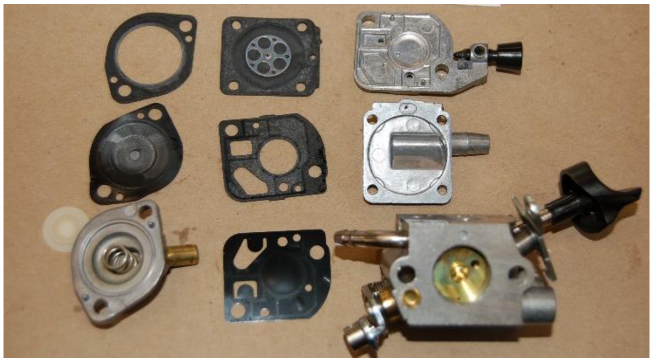

Figure 75-Blower P1-P12 carburetor

P13-P14

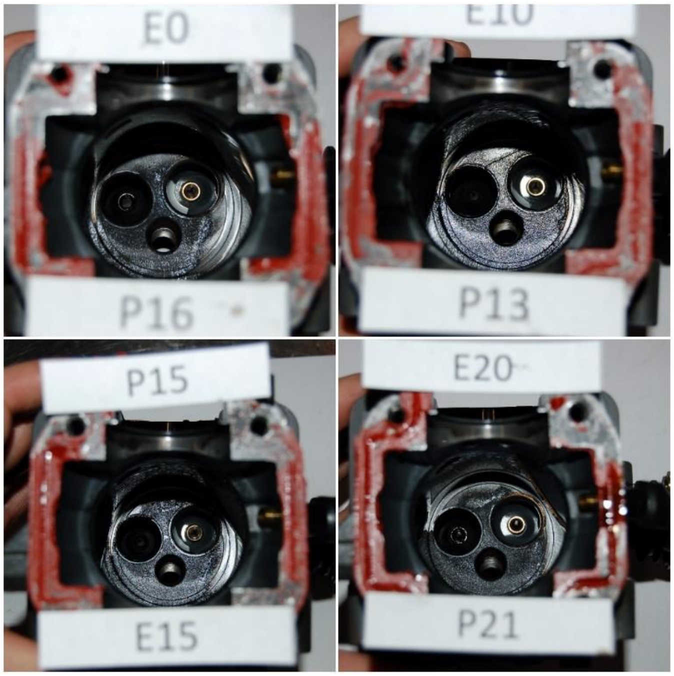

Figure 76-Blower P13-P24 Combustion Chamber

Figure 76 shows the carbon built up on the combustion chamber and carbon built up has increase respect to ethanol contain of the fuel.

Figure 77-Blowers P13-P24 piston

Figure 77 is a comparison of the piston carbon built up during their life time. E20 P18 engine and E10 P13 has the most carbon built up compare to other engines. In this case E0 and E15 has a similar amount of carbon built up.

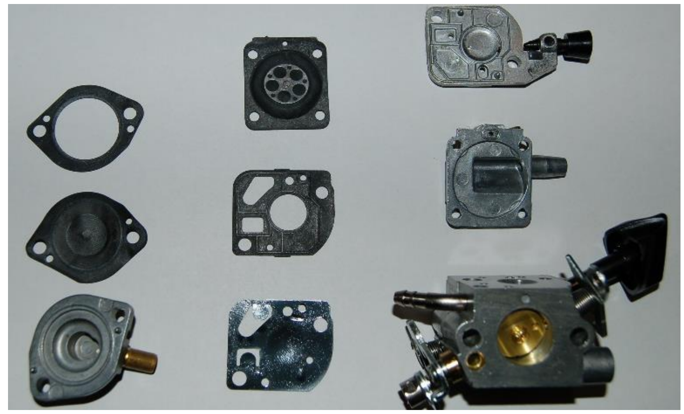

Figure 78-Blower P13-P24 carburetor

However, all the carburetors were clean as shown in Figure 78. More Comparison pictures are located under Appendix A, B, C and D

Disassembly Measurements

Physical measurements of the dimensions of engine components were carried out after all other testing had been completed. The engine components that were measured included; piston wear area, wrist pin bores, connecting rod bore, wrist pin is three separate locations, cylinder wear areas top, middle, and bottom, also the cylinder non-wear area, piston ring to land, cam shaft lobe height and inner diameter, upper and lower cam case shafts, intake and exhaust valves, and intake and exhaust valve guides.

The visual inspection revealed no apparent trends in discoloration, deposit type, or amount. Photos of the visual inspection can be found in the "Disassembly Pictures" portion of the Appendix.

No apparent pattern developed in wear amounts in relation to ethanol content of the engine's assigned fuel. Physical measurements can be found in the Disassembly Measurements portion of the Appendix J and Appendix K

Conclusions

Trimmers

T1-T12

This research has shown the engines were able to run through their engine determination period on 4 different fuel blends. The ethanol blends ran engines at higher temperatures and speeds. Also, engines did not experience longevity or reliability issues due to the introduction of ethanol blended fuels. No material compatibility issues were found in any of these components regardless of fuel including carburetors.

The trimmers had extensive carbon build up in the combustion chambers, piston crowns and the exhaust ports. The exhaust ports were 50%-80% obstructed with the carbon build-up limiting the exhaust flow. This carbon build up did not correlate with any particular fuel

T13-T14

This research indicates that ethanol blends above 10% produce less power throughout the lifetime of the engines tested. When comparing the power lost from the beginning of the engine's life to their end, E15 and E20 engines lost 19.3% and 9.4% more power than the E0 engines lost in their lifetime while E10 lost 3.3% power. This suggests that the E15 and E20 fuels permanently altered the engine in some way.

Both T13 and T14 failed to complete the study and both were assigned E15 blends. The third E15 engine did not display any signs of imminent failure during testing and nothing out of the ordinary was found when measuring its internal components. No conclusions could be made whether or not the E15 fuel used in these engines caused them to fail.

E15 and E20 engines produced much more hydrocarbons throughout their lifetime. This was likely due to the deficient performance exhibited by these engines. Rather than burning the fuel entering the combustion chamber, it was simply being pushed out the exhaust. When considering weighted emissions, these engines produce even more hydrocarbons per kilowatt hour.

The engines in this study did manage to run on ethanol blends up to E20 but produced less useable power throughout its life. At the end of life the engines using E15 and E20 would not have provided enough power to properly perform well as a weed trimmer. Finally, ethanol did not cause a considerable damage to the engine components, and fuel system.

Blowers

P1-P12

This research has shown the performance results of operating 300 hours, 4-stroke leaf blowers on intermediate ethanol blended fuel. The intermediate blends did operate at higher temperatures and engine speeds. No issues were found in any of these components in disassembly.

P13-P24

When comparing the power lost from the beginning of the engine's lifetimes to their end, E15 and E20 engines lost 4% and 5% more power than the E0 engines lost in their lifetime while E10 lost 2% power.

Based on the results there were small difference between the blends. The horsepower numbers were affected by the higher ethanol blends throughout the study. The engines with the higher blends average higher horsepower readings.

When all engines were returned to E0 at the end of their life, the engines with the higher blends did experience a bigger drop in power.

The temperature data and emissions were as expected because of the chemical characteristics of the blends and not because of deterioration of the engines.

Eleven out of the 12 engines made it with no problem throughout the whole study. One E10 engine, suffered internal damage caused by extreme temperatures during emission testing. Because of the failure the blower wasn't included in any results. The failure was not fuel related, but a testing error.

Based on the results a conclusion can be made that blends as high as 20 percent ethanol did not cause a significant damage to the engine components, and fuel system.

No issues were found in any of these components regardless of fuel. Also, the carburetors were inspected and disassembled to check for corrosion, build up or loose by-products. No issues were found in any of the carburetors regardless of fuel. It should be noted that due to the accelerated aging process compared to normal use, the fuel was only in these engines for a brief period of time, three to six months, so the exposure time was limited.

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Minnesota Corn Growers Association

Definitions/Abbreviations

WOT Wide Open Throttle

CHT Cylinder head temperature

EGT Exhaust gas temperature

EXT Exhaust gas surface

EOL End of Life

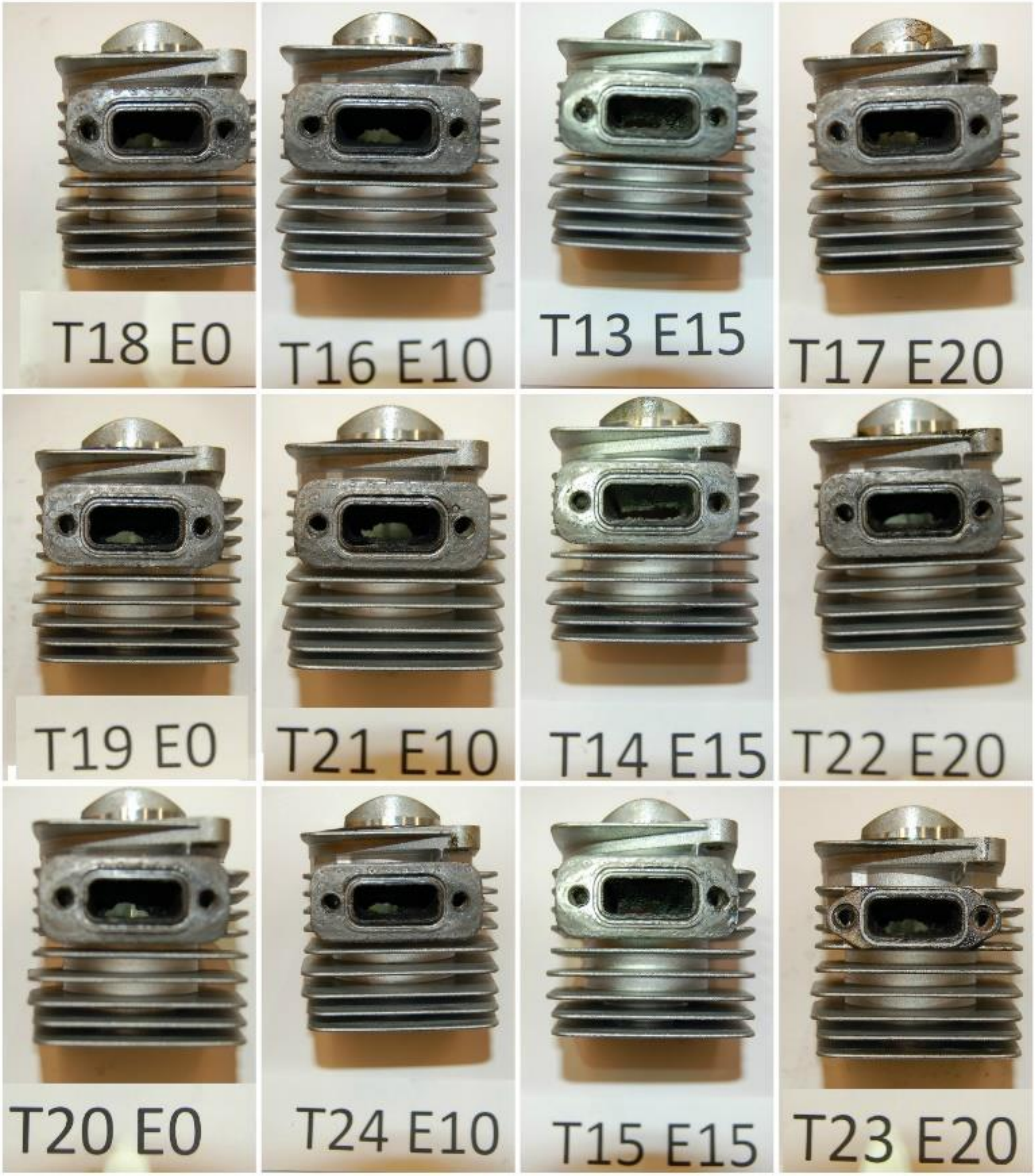
SNRE Small Non-Road Engines

EPA	Environmental Protection Agency
RPM	Rotations per minute
E0	Non-Oxygenated Gasoline
E10	10% Ethanol, 90% Gasoline
E15	15% Ethanol, 85% Gasoline
E20	20% Ethanol, 80% Gasoline
E85	85% Ethanol, 15% Gasoline
E100	Pure, denatured ethanol
DOE	Department of Energy
AFR	Air/Fuel Ratio
SAE	Society of Automotive Engineers
ASTM	American Society for Testing and Materials
EDP	Emissions Determination Period

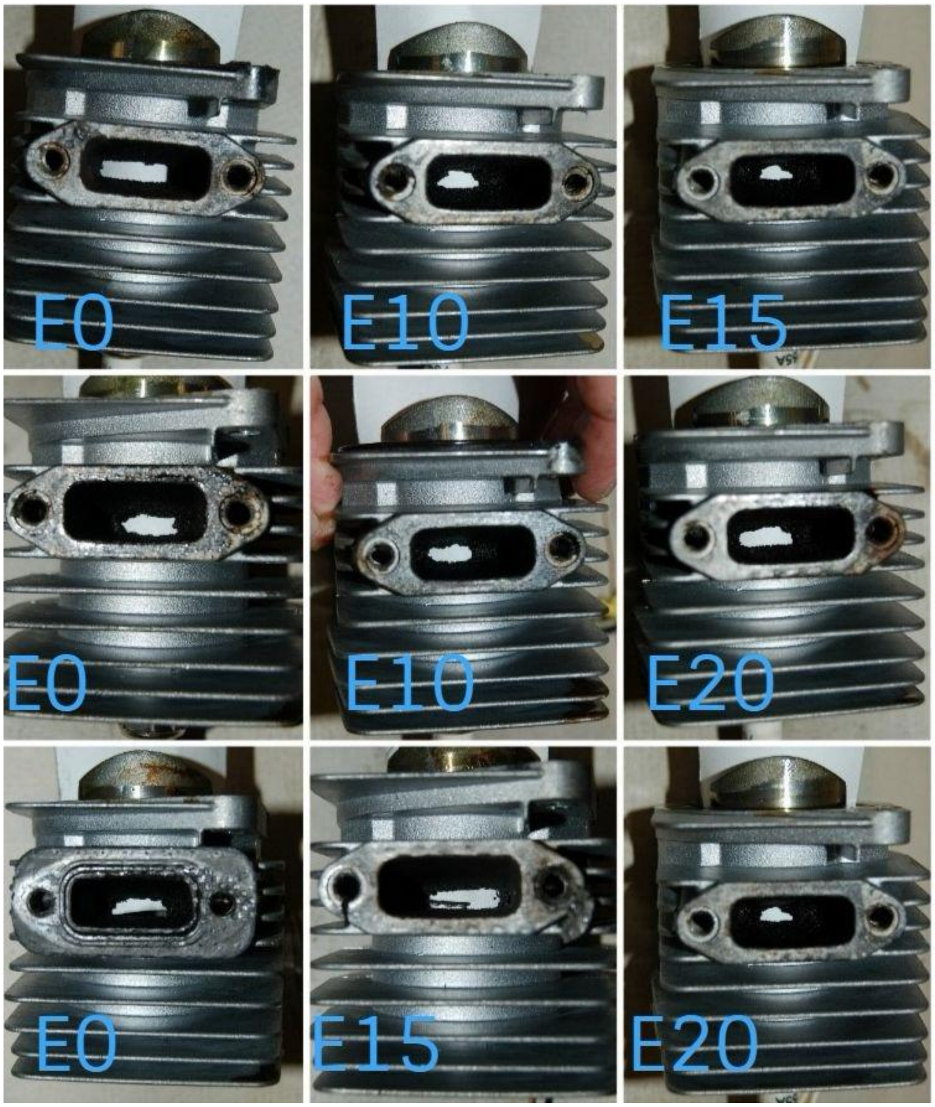
Appendix

Appendix A- **Trimmers T1-T12 Piston**

Appendix B-**Trimmers T13-T24 Piston**



Appendix D-Trimmer T13-T24 Exhaust ports



Appendix C-Trimmer T1-T12 Exhaust ports

Appendix E- 2Stroke Trimmer (TB32EC) Test Plan

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RE: 2-Stroke Trimmer (TB32EC) Test Plan

Scope:

This plan provides an overview of the test procedures that will be used on the 2-stroke trimmer 25cc (Troy-bilt TB32EC) for the Enhanced Engine Study.

Engine:

Troy-bilt TB32EC 25cc 2-stroke trimmer with modified blower attachment

NOTE: 2-stroke –ALL fuel must have premix oil 40:1!!!!

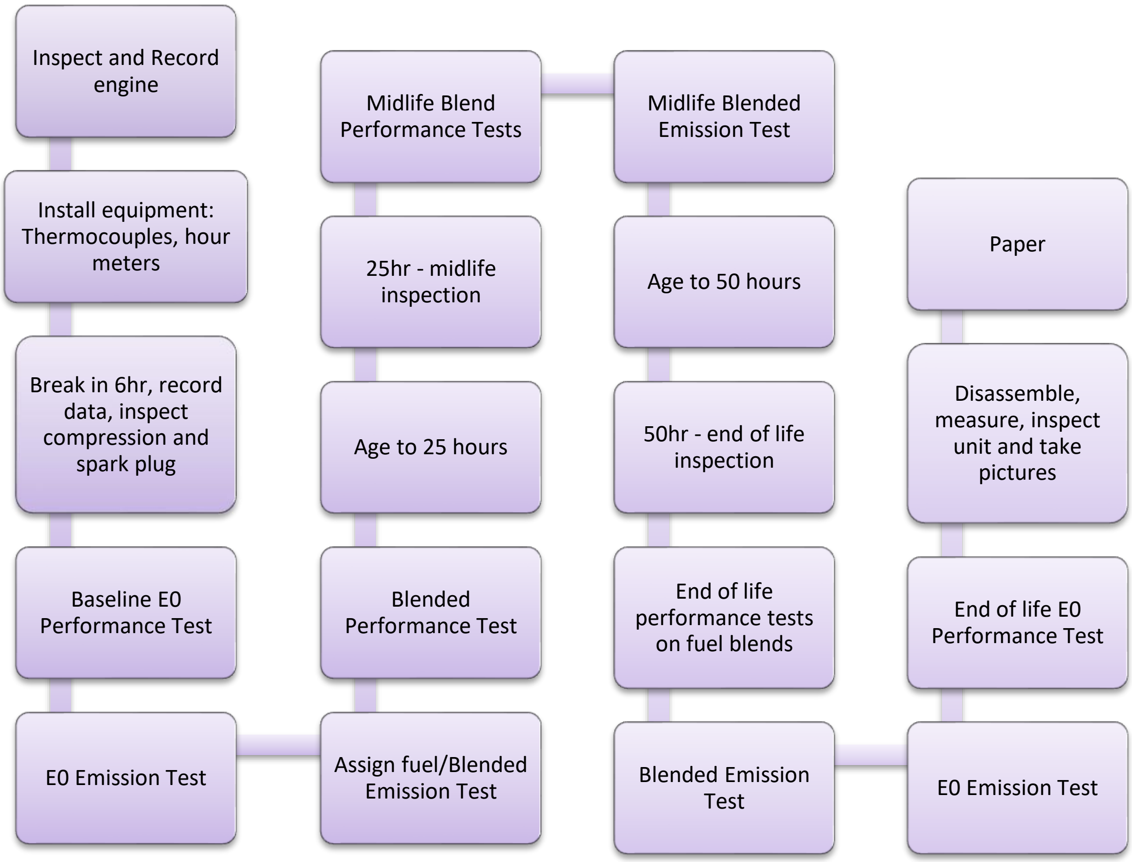
Test Plan:

1. Unpack and inspect engine for damage/ issues
2. Record engine serial numbers and label engine appropriately (NOTE: fuel is assigned after break-in)
3. Perform initial compression test and check/set sparkplug gap to .025, torque plug to 110-120 in-lbs
4. Inspect air filter element for light oil, if dry lightly apply SAE 30 oil to the filter and squeeze out excess oil (NOTE: this is done every 10hrs of operation).
5. Install thermocouples
    a. Cylinder Head
    b. Exhaust gas
    c. Exhaust surface
    d. Intake Air
6. Install new hour meter / Tachometer
7. Fill unit with E0 fuel. All fuel must be 40:1 premix with 2-stroke oil. All units will be broken-in on E0.
8. Place unit on aging rack
    a. Install trigger actuator
    b. Verify thermocouple are reading correctly
9. Follow manufacturer’s starting/warm up recommendation
    a. COLD START Press primer bulb 10 times, slowly. Fuel should be visible in bulb, if not press and release bulb until fuel is visible. Choke in position 1. Squeeze/hold throttle, pull rope 5 times. Place choke in position 2. Squeeze/hold throttle and pull rope 3-5 times. After unit starts, continue to hold throttle 30-60 second to warm up. Move choke to position 3 and continue to warm-up an additional 60 seconds. Unit is considered warmed up when it accelerated without hesitation. SEE manual if unit does not start (p.3).
    b. HOT START Place choke in position 2. Squeeze/hold throttle and pull rope 3-5 times. After unit starts, continue to hold throttle 30-60 second to warm up. Move choke to position 3 and continue to warm-up an additional 60 seconds. Unit is considered warmed up when it accelerated without hesitation. SEE manual if unit does not start (p.3).
    c. Verify Idle/WOT rpm and temps
10. Break-in for 6-hrs – cycle 51 second WOT; 9 second Idle
11. Record temp/rpm info every 30 minutes
12. Adjust idle speed (2800-3400 rpm) after 5.5 hours while the unit is at operating temperature and running on E0 fuel. See manual for adjustment procedure (p.4). The idle will not be adjusted after this initial adjustment.
13. After break-in inspect
    a. Visual engine, exhaust, and fuel system – leaks/ discoloration/ issues
    b. Check compression
    c. Visually inspect and note condition of plug

14. Baseline Performance tests – ALL on indolene E0 premix. Units must be purged of E0 and run dry before testing. Unit must cold soak at least 4hrs before testing.
    a. Tests – follow appropriate test sheets
        i. Starting – Dry start
        ii. Multipostion / WOT / idle / accel / stability / exhaust surface
        iii. Hot start/restart
15. E0 Emission Test – all on indolene E0 premix.
16. Blended Emission Test – ALL on indolene Ethanol premix. Units must be purged of E0 and run dry before testing.
17. Use exhaust emissions on each unit to determine rich to lean order.
18. Assign each unit its fuel blend. Richest running units receive E0 to leanest running unit receives E20.
19. Clearly label the assigned blend on the unit
20. Blend Performance tests – ALL on indolene Ethanol premix. Unit must cold soak at least 4hrs before testing.
    a. Tests – follow appropriate test sheets
        i. Starting – Dry start
        ii. Multipostion / WOT / idle / accel / stability / exhaust surface
        iii. Hot start/restart
21. Visually inspect unit – leaks/ discoloration etc.
22. Age units to 25 hrs on assigned premix blend of ethanol and pump gas. Aging cycle 51 second WOT; 9 second Idle.
23. Maintenance reminder – oil air filter every 10 hrs, check plug condition every 25hrs
24. At hour 25 – midlife inspection
    a. Visual engine, exhaust, and fuel system – leaks/ discoloration/ issues
    b. Check compression
    c. Visually inspect and note condition of plug
25. Midlife Blend Performance tests – ALL on indolene Ethanol premix. Units must be purged of fuel and run dry before testing. Unit must cold soak at least 4hrs before testing.
    a. Tests – follow appropriate test sheets
        i. Starting – Dry start
        ii. Multipostion / WOT / idle / accel / stability / exhaust surface
        iii. Hot start/restart
26. Midlife Blend Emission Test – ALL on indolene Ethanol premix.
27. Visually inspect unit – leaks/ discoloration etc.
28. Age units to 50 hrs on assigned premix blend of ethanol and pump gas. Aging cycle 51 second WOT; 9 second Idle.
29. Maintenance reminder – oil air filter every 10 hrs, check plug condition every 25hrs
30. At hour 50 – end-of-life inspection
    a. Visual engine, exhaust, and fuel system – leaks/ discoloration/ issues
    b. Check compression
    c. Visually inspect and note condition of plug
31. End-of-life Blend Performance tests – ALL on indolene Ethanol premix. Units must be purged of fuel and run dry before testing. Unit must cold soak at least 4hrs before testing.
    a. Tests – follow appropriate test sheets
        i. Starting – Dry start
        ii. Multipostion / WOT / idle / accel / stability / exhaust surface
        iii. Hot start/restart
32. End-of-life Blend Emission tests – ALL on indolene Ethanol premix.
33. End-of-life E0 Emission tests – ALL on indolene premix. Units must be purged of fuel and run dry before testing.
34. Visually inspect unit – leaks/ discoloration etc.
35. End-of-life Baseline Performance tests – ALL on indolene E0 premix. Unit must cold soak at least 4hrs before testing.
    a. Tests – follow appropriate test sheets
        i. Starting – Dry start
        ii. Multipostion / WOT / idle / accel / stability / exhaust surface
        iii. Hot start/restart
36. Visually inspect unit – leaks/ discoloration etc.
37. Disassemble measure and inspect the units taking careful photos.

Appendix F-2-Stroke Trimmer Flow Chart

2-Stroke Trimmer Flow Chart



Appendix G –Trimmer hot restart avaluation sheet

Trimmer Hot Restart Evaluation

Run Engine at WOT for 15 Minutes or until Thermal Stability

Thermal Stability is reached when the Cylinder Head has reached a constant stable temperature(+-25 Degrees) for longer then 3 min

Exhaust Gas Temp:		IAT:		Stable WOT RPM:	
(Ex)haust Surface Temp:		Cylinder Head Temp:			

Shut off engine and check carb temp every 3 min

	0 min	3 min	6 min	9 min	12 min	15 min	18 min	21 min
Carb temps								
	24 min	27 min	30 min	33 min	36 min	39 min	42 min	45 min
Carb temps								

after carb temp peaks, go onto hot restart test

hot restart at half choke, and run at half choke for 30-60 sec

# of pulls to start		Pulls	
return to no choke			
go to WOT for 60 seconds			
Stable WOT		RPM	
Idle RPM after 30 sec		RPM	
Time to stable WOT		Seconds	*200 RPM variation from Stable WOT RPM
Idle RPM		RPM	
Time to stable WOT		Seconds	*200 RPM variation from Stable WOT RPM
Idle RPM		RPM	
Time to stable WOT		Seconds	*200 RPM variation from Stable WOT RPM

Visual note on fuel level:		
Visual Inspection of Unit:		leaks/problems

Comments

Trimmer Multiposition Evaluation

Descriptions to be used

Normal	Slow	Die
Hesitate	Wander	

Record RPM after 15 seconds of WOT then repeat 15 seconds of idle

Spark Plug Position	RPM WOT	RPM Idle	Acceleration - Describe	Describe Overall Performance
Horizontal (Engine UP) ↑				
Vertical (Normal) ↔				
Roll Left ←				
Roll Right →				
Horizontal (Engine Down) ↓				
Inverted (Engine Down)				

Comments:

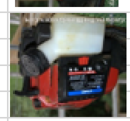
Horizontal Engine Up  Spark plug

Roll Left 

Horizontal Engine Down 

Vertical (Normal) 

Roll Right 

Inverted Engine Down 

Go Directly To Hot Restart TEST

Appendix I-Trimmer cold startabilty test

Trimmer COLD Startability test

Engine Model: TB32EC		Fuel/Oil Ratio 40:1	
Engine number		Ambient Temp	
Soak time (4HRS)		Humidity	
Fuel Temp		Baro Pressure	
Technician		Date	
Fuel Type		Time	

***Unit must have been ran dry and cold soaked for at least 4 hours prior to starting test**

Start test with full Tank (DRY Start) **Add Fuel Immediately before testing**

Circle which test is being ran

Initial E0 Test Initial Blend Test Midlife Blend Test End of Life Blended Test End of Life E0 Test

Engine Hours			
# of fuel primes (10 or until fuel is visible in bulb)			
# of full choke pulls (idle)		Pulls	Comments:
# of half choke pulls (idle)		Pulls	
# of no choke pulls (idle)		Pulls	
Go to WOT			
WOT RPM 1 MIN		RPM	
WOT RPM 2 MIN		RPM	
WOT RPM 3 MIN		RPM	
Return to IDLE			
stable Idle RPM		RPM	
Time to stable WOT		Seconds	*200 RPM variation from Stable MIN 3 WOT RPM
Idle RPM		RPM	
Time to stable WOT		Seconds	*200 RPM variation from Stable MIN 3 WOT RPM
Idle RPM		RPM	
Time to stable WOT		Seconds	*200 RPM variation from Stable MIN 3 WOT RPM
Return to Idle and Record Temps			
IAT		°F	
Cylinder Head Temp		°F	
Exhaust Surface Temp		°F	
Exhaust Gas Temp		°F	
Fuel Temp		°F	
Idle RPM		RPM	

Appendix J- Trimmers Measurement Data

	Engine T13	Engine T14	Engine T15	Engine T16	Engine T17	Engine T18
Piston						
wear area top	1.372	1.372	1.372	1.373	1.372	1.372
wear area mid	1.375	1.376	1.375	1.374	1.374	1.374
wear area bot	1.375	1.375	1.374	1.379	1.375	1.374
no wear area	1.377	1.375	1.379	1.376	1.374	1.374
Visual Inspection	Carbon on top and sides of piston	Carbon on top and sides of piston	Carbon on top and sides of piston	Carbon on top and sides of piston	Carbon on top and sides of piston	Carbon on top and sides of piston
Wrist Pin						
wear area cam side	0.313	0.313	0.313	0.313	0.313	0.313
wear area mid	0.313	0.313	0.313	0.313	0.313	0.313
wear area far from cam	0.313	0.313	0.313	0.313	0.313	0.313
Visual Inspection	Normal	Normal	Normal	Normal	Normal	Normal
Cylinder						
wear area top	1.379	1.378	1.378	1.377	1.378	1.379
wear area mid	1.379	1.381	1.384	1.377	1.377	1.381
wear area bot	1.378	1.382	1.386	1.378	1.377	1.381
no wear area	1.378	1.378	1.377	1.378	1.378	1.374
Visual Inspection	Carbon in top, some scoring	Carbon in top, some scoring	Carbon in top, very light scoring	Carbon in top, very light scoring	Carbon in top, very light scoring	Carbon in top, very light scoring
Crank wear area						
Shaft Diameter	0.311	0.311	0.311	0.311	0.311	0.311
Visual Inspection	Normal	Normal	Normal	Normal	Normal	Normal
Piston Ring End Gap						
Top Ring	0.012	0.012		0.013	0.012	0.012
Bottom Ring	0.012	0.012	0.012	0.013		0.012

Visual Inspection	Normal	Normal	Normal	Normal	Normal	Normal
Carburetor						
Bulb	Normal	Normal	Normal	Normal	Normal	Normal
Bulb Diaphram	Normal	Normal	Normal	Normal	Normal	Normal
Injector Diaphram	Normal	Normal	Normal	Normal	Normal	Normal
Desposits	Minimal deposits in screen	Minimal deposits in screen	Minimal deposits in screen	Minimal deposits in screen	Minimal deposits in screen	Minimal deposits in screen
Visual Inspection	Good	Good	Good	Good	Good	Good
Intake Deposits	None	None	None	None	None	None
Exhaust Deposits (% blocked by carbon)	60%	50%	75%	60%	50%	50%

	Engine T19	**Engine T20**	**Engine T21**	**Engine T22**	**Engine T23**	**Engine T24**
Piston						
wear area top	1.372	1.372	1.372	1.373	1.374	1.372
wear area mid	1.375	1.376	1.374	1.374	1.375	1.374
wear area bot	1.375	1.375	1.375	1.375	1.375	1.374
no wear area	1.377	1.375	1.375	1.375	1.374	1.375
Visual Inspection	Carbon on top and sides of piston	Carbon on top and sides of piston	Carbon on top and sides of piston	Carbon on top and sides of piston	Carbon on top and sides of piston	Carbon on top and sides of piston
Wrist Pin						
wear area cam side	0.313	0.313	0.313	0.313	0.313	0.313
wear area mid	0.313	0.313	0.313	0.313	0.313	0.313
wear area far from cam	0.313	0.313	0.313	0.313	0.313	0.313
Visual Inspection	Normal	Normal	Normal	Normal	Normal	Normal
Cylinder						
wear area top	1.379	1.378	1.378	1.379	1.379	1.377
wear area mid	1.380	1.382	1.379	1.38	1.38	1.37
wear area bot	1.381	1.385	1.38	1.381	1.378	1.38
no wear area	1.380	1.383	1.378	1.379	1.381	1.379
Visual Inspection	Carbon in top, no scoring	Carbon in top, light scoring	Carbon in top, light scoring	Carbon in top, light scoring	Carbon in top, light scoring	Carbon in top, light scoring

Crank wear area						
Shaft Diameter	0.311	0.311	0.311	0.311	0.311	0.311
Visual Inspection	Normal	Normal	Normal	Normal	Normal	Normal
Piston Ring End Gap						
Top Ring	0.012	0.012	0.012	0.012	0.012	0.012
Bottom Ring	0.012	0.012	0.012	0.012	0.012	0.012
Visual Inspection	Normal	Normal	Normal	Normal	Normal	Normal
Carburetor						
Bulb	Normal	Normal	Normal	Normal	Normal	Normal
Bulb Diaphram	Normal	Normal	Normal	Normal	Normal	Normal
Injector Diaphram	Normal	Normal	Normal	Normal	Normal	Normal
Desposits	Minimal deposits in screen	Minimal deposits in screen	Minimal deposits in screen	Minimal deposits in screen	Minimal deposits in screen	Minimal deposits in screen
Visual Inspection	Good	Good	Good	Good	Good	Good
Intake Deposits	None	None	None	None	None	None
Exhaust Deposits (% blocked by carbon)	75%	60%	50%	50%	60%	80%

Appendix k- Measurement Data blower

	E0	E0	**E0**	**E10**	**E10**	**E10**	**E15**	**E20**
	Engine 7	**Engine 2**	**Engine 3**	**Engine 1**	**Engine 4**	**Engine 5**	**Engine 8**	**Engine 6**
Intake Valve Stem Guide								
wear area top	0.1396	0.1398	0.1394	0.1397	0.1394	0.1393	0.1396	0.1398
Exhaust Valve Stem Guide								
wear area top	0.1395	0.1393	0.1395	0.1395	0.1394	0.1397	0.1392	0.1398

Intake Valve								
recession								
1.0000	0.5115	0.5140	0.5121	0.5136	0.5111	0.5115	0.5137	0.5128
2.0000	0.5115	0.5140	0.5120	0.5130	0.5112	0.5112	0.5130	0.5127
3.0000	0.5117	0.5138	0.5124	0.5132	0.5110	0.5110	0.5134	0.5126
4.0000	0.5118	0.5137	0.5123	0.5128	0.5111	0.5111	0.5133	0.5126
avg.	0.5116	0.5139	0.5122	0.5132	0.5111	0.5112	0.5134	0.5127
Valve Stem								
wear area top								
1.0000	0.1378	0.1379	0.1373	0.1378	0.1377	0.1378	0.1377	0.1378
2.0000	0.1377	0.1379	0.1378	0.1377	0.1378	0.1378	0.1377	0.1378
3.0000	0.1377	0.1379	0.1378	0.1378	0.1378	0.1378	0.1377	0.1378
avg.	0.1377	0.1379	0.1376	0.1378	0.1378	0.1378	0.1377	0.1378
wear area mid								
1.0000	0.1378	0.1379	0.1379	0.1378	0.1377	0.1378	0.1377	0.1377
2.0000	0.1378	0.1378	0.1379	0.1378	0.1377	0.1378	0.1377	0.1377
3.0000	0.1378	0.1378	0.1379	0.1377	0.1377	0.1378	0.1377	0.1377
avg.	0.1378	0.1378	0.1379	0.1378	0.1377	0.1378	0.1377	0.1377
wear area bot								
1.0000	0.1380	0.1382	0.1387	0.1381	0.1388	0.1382	0.1388	0.1383
2.0000	0.1383	0.1388	0.1384	0.1380	0.1388	0.1387	0.1388	0.1381
3.0000	0.1386	0.1383	0.1382	0.1382	0.1385	0.1382	0.1387	0.1381
avg.	0.1383	0.1384	0.1384	0.1381	0.1387	0.1384	0.1388	0.1382
no wear area								
1.0000								
2.0000								
3.0000								
avg.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Exhaust Valve								
recession								
1.0000	0.5131	0.5114	0.5122	0.5110	0.5118	0.5124	0.5120	0.5130

2.0000	0.5126	0.5116	0.5122	0.5110	0.5118	0.5120	0.5115	0.5130
3.0000	0.5126	0.5116	0.5122	0.5110	0.5116	0.5122	0.5121	0.5128
4.0000	0.5125	0.5115	0.5122	0.5110	0.5118	0.5118	0.5122	0.5130
avg.	0.5127	0.5115	0.5122	0.5110	0.5118	0.5121	0.5120	0.5130
Valve Stem								
wear area top								
1.0000	0.1378	0.1378	0.1380	0.1378	0.1380	0.1377	0.1376	0.1377
2.0000	0.1375	0.1378	0.1379	0.1379	0.1380	0.1377	0.1376	0.1376
3.0000	0.1377	0.1378	0.1380	0.1378	0.1379	0.1377	0.1377	0.1377
avg.	0.1377	0.1378	0.1380	0.1378	0.1380	0.1377	0.1376	0.1377
wear area mid								
1.0000	0.1377	0.1377	0.1382	0.1378	0.1378	0.1382	0.1377	0.1377
2.0000	0.1376	0.1377	0.1383	0.1378	0.1378	0.1383	0.1377	0.1380
3.0000	0.1377	0.1377	0.1330	0.1378	0.1378	0.1383	0.1377	0.1377
avg.	0.1377	0.1377	0.1365	0.1378	0.1378	0.1383	0.1377	0.1378
wear area bot								
1.0000	0.1380	0.1388	0.1383	0.1383	0.1393	0.1383	0.1385	0.1386
2.0000	0.1383	0.1393	0.1383	0.1386	0.1392	0.1384	0.1381	0.1388
3.0000	0.1381	0.1395	0.1382	0.1388	0.1390	0.1384	0.1384	0.1384
avg.	0.1381	0.1392	0.1383	0.1386	0.1392	0.1384	0.1383	0.1386
no wear area								
1.0000								
2.0000								
3.0000								
avg.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Intake Push Rod								
rocker arm side wear								
1.0000	0.1163	0.1163	0.1162	0.1162	0.1160	0.1162	0.1162	0.1162
2.0000	0.1163	0.1162	0.1161	0.1163	0.1162	0.1161	0.1162	0.1163
3.0000	0.1163	0.1161	0.1161	0.1163	0.1163	0.1163	0.1161	0.1163
avg.	0.1163	0.1162	0.1161	0.1163	0.1162	0.1162	0.1162	0.1163
wear area mid								

1.0000	0.1162	0.1163	0.1163	0.1162	0.1162	0.1163	0.1162	0.1164
2.0000	0.1161	0.1163	0.1161	0.1163	0.1163	0.1163	0.1163	0.1163
3.0000	0.1163	0.1162	0.1161	0.1163	0.1164	0.1162	0.1163	0.1163
avg.	0.1162	0.1163	0.1162	0.1163	0.1163	0.1163	0.1163	0.1163
rod lifter side wear								
1.0000	0.1162	0.1163	0.1163	0.1162	0.1163	0.1161	0.1163	0.1162
2.0000	0.1161	0.1161	0.1161	0.1162	0.1163	0.1163	0.1162	0.1162
3.0000	0.1162	0.1162	0.1163	0.1162	0.1162	0.1163	0.1162	0.1163
avg.	0.1162	0.1162	0.1162	0.1162	0.1163	0.1162	0.1162	0.1162
no wear area								
1.0000								
2.0000								
3.0000								
avg.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Exhaust Push Rod								
wear area top								
1.0000	0.1162	0.1161	0.1162	0.1162	0.1161	0.1162	0.1161	0.1161
2.0000	0.1161	0.1162	0.1161	0.1161	0.1162	0.1163	0.1161	0.1163
3.0000	0.1163	0.1161	0.1163	0.1163	0.1162	0.1161	0.1162	0.1163
avg.	0.1162	0.1161	0.1162	0.1162	0.1162	0.1162	0.1161	0.1162
wear area mid								
1.0000	0.1161	0.1161	0.1162	0.1162	0.1162	0.1163	0.1161	0.1161
2.0000	0.1162	0.1161	0.1162	0.1161	0.1162	0.1162	0.1161	0.1161
3.0000	0.1161	0.1162	0.1161	0.1163	0.1161	0.1163	0.1163	0.1161
avg.	0.1161	0.1161	0.1162	0.1162	0.1162	0.1163	0.1162	0.1161
rod lifter side wear								
1.0000	0.1162	0.1161	0.1161	0.1161	0.1161	0.1162	0.1162	0.1161
2.0000	0.1163	0.1162	0.1163	0.1161	0.1161	0.1161	0.1161	0.1163
3.0000	0.1163	0.1161	0.1163	0.1161	0.1161	0.1162	0.1161	0.1161
avg.	0.1163	0.1161	0.1162	0.1161	0.1161	0.1162	0.1161	0.1162
no wear area								

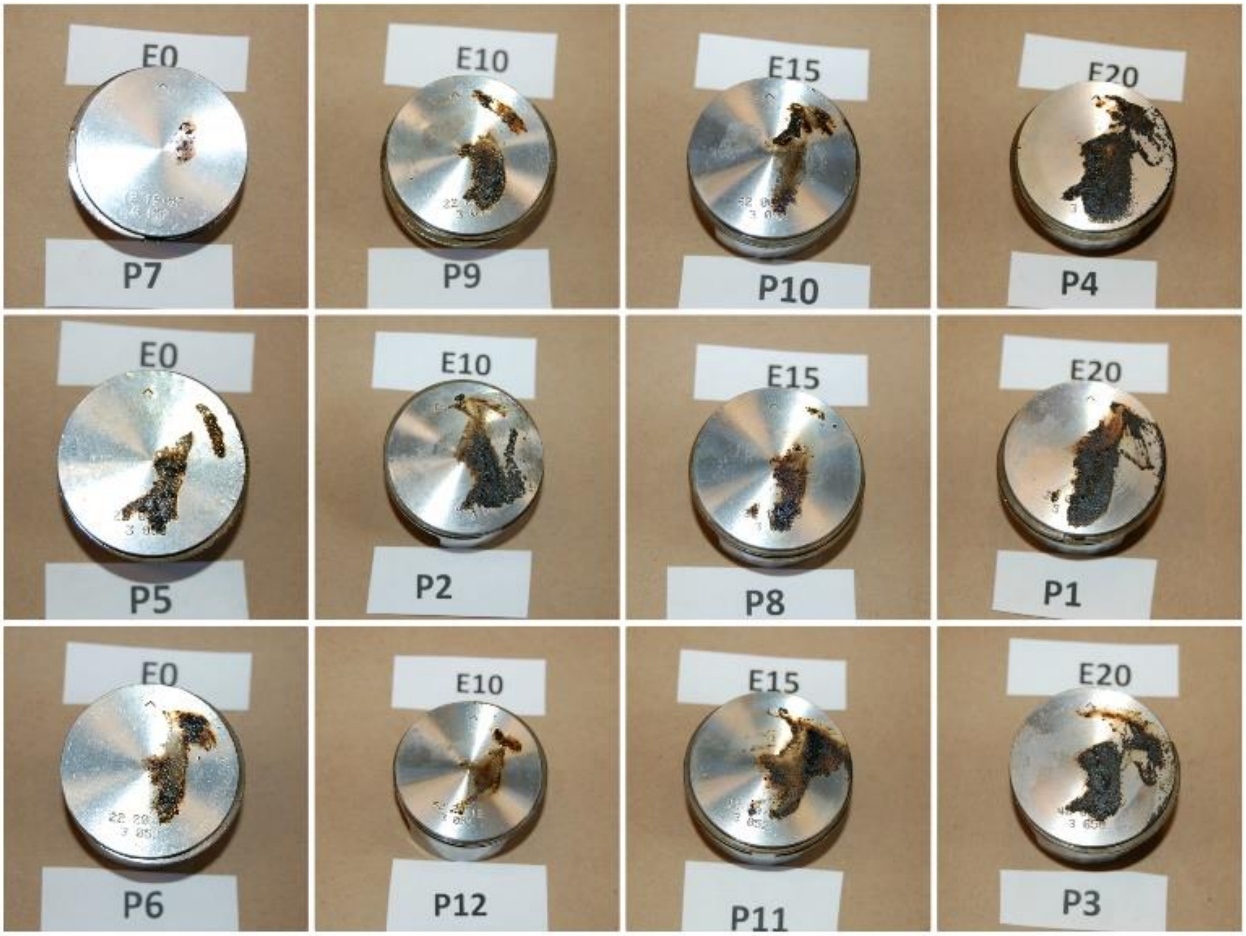
1.0000								
2.0000								
3.0000								
avg.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	E0	E0	**E0**	**E10**	**E10**	**E10**	**E15**	**E20**

	Engine 7	**Engine 2**	**Engine 3**	**Engine 1**	**Engine 4**	**Engine 5**	**Engine 8**	**Engine 6**
1.0000	1.4837	1.4870	1.4885	1.4856	1.4855	1.4873	1.4917	1.4864
2.0000	1.4790	1.4868	1.4889	1.4850	1.4852	1.4872	1.4898	1.4866
3.0000	1.4787	1.4872	1.4885	1.4861	1.4853	1.4877	1.4885	1.4856
wear area top	1.4805	1.4870	1.4886	1.4856	1.4853	1.4874	1.4900	1.4862
1.0000	1.4921	1.4956	1.4958	1.4930	1.4952	1.4950	1.4942	1.4950
2.0000	1.4892	1.4952	1.4954	1.4927	1.4951	1.4951	1.4913	1.4930
3.0000	1.4923	1.4951	1.4954	1.4945	1.4947	1.4954	1.4954	1.4938
wear area mid	1.4912	1.4953	1.4955	1.4934	1.4950	1.4952	1.4936	1.4939
1.0000	1.4916	1.4955	1.4957	1.4945	1.4953	1.4953	1.4943	1.4950
2.0000	1.4891	1.4955	1.4955	1.4926	1.4954	1.4951	1.4913	1.4947
3.0000	1.4921	1.4952	1.4956	1.4951	1.4948	1.4952	1.4934	1.4936
wear area bot	1.4909	1.4954	1.4956	1.4941	1.4952	1.4952	1.4930	1.4944
no wear area								
1.0000								
2.0000								
3.0000								
avg.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wrist Pin								
wear area cam side								
1.0000	0.3134	0.3136	0.3144	0.3136	0.3136	0.3136	0.3134	0.3144
2.0000	0.3134	0.3135	0.3150	0.3136	0.3136	0.3135	0.3135	0.3144
3.0000	0.3134	0.3135	0.3146	0.3136	0.3136	0.3135	0.3135	0.3145
avg.	0.3134	0.3135	0.3147	0.3136	0.3136	0.3135	0.3135	0.3144

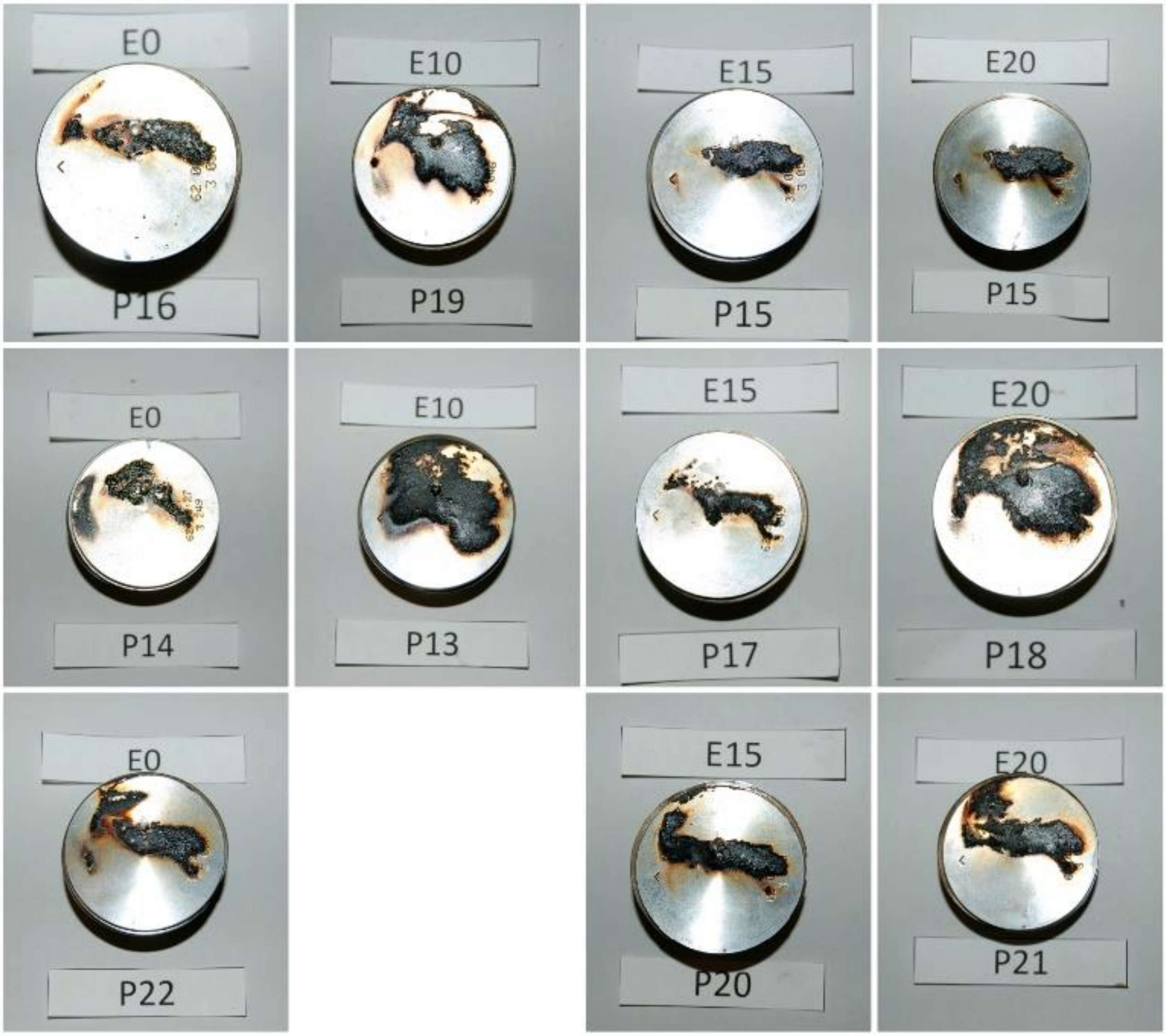
wear area mid								
1.0000	0.3132	0.3135	0.3142	0.3136	0.3135	0.3135	0.3133	0.3134
2.0000	0.3132	0.3135	0.3132	0.3136	0.3135	0.3135	0.3133	0.3135
3.0000	0.3132	0.3135	0.3137	0.3136	0.3135	0.3135	0.3133	0.3135
avg.	0.3132	0.3135	0.3137	0.3136	0.3135	0.3135	0.3133	0.3135
wear area far from cam								
1.0000	0.3135	0.3137	0.3135	0.3135	0.3136	0.3135	0.3130	0.3136
2.0000	0.3135	0.3137	0.3140	0.3135	0.3136	0.3135	0.3130	0.3136
3.0000	0.3135	0.3137	0.3135	0.3136	0.3136	0.3135	0.3130	0.3136
avg.	0.3135	0.3137	0.3137	0.3135	0.3136	0.3135	0.3130	0.3136
no wear area								
1.0000								
2.0000								
3.0000								
avg.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	E0	E0	**E0**	**E10**	**E10**	**E10**	**E15**	**E20**

	Engine 7	**Engine 2**	**Engine 3**	**Engine 1**	**Engine 4**	**Engine 5**	**Engine 8**	**Engine 6**
1.0000	0.1966	0.1966	0.1965	0.1966	0.1966	0.1965	0.1966	0.1966
2.0000	0.1966	0.1965	0.1965	0.1966	0.1966	0.1965	0.1966	0.1965
3.0000	0.1966	0.1965	0.1964	0.1965	0.1966	0.1965	0.1966	0.1965
bearing wear area	0.1966	0.1965	0.1965	0.1966	0.1966	0.1965	0.1966	0.1965
1.0000	1.1043	1.1033	1.1044	1.1043	1.1047	1.1037	1.1046	1.1043
2.0000	1.1045	1.1030	1.1045	1.4046	1.1047	1.1043	1.1044	1.1037
3.0000	1.1043	1.1034	1.1045	1.1043	1.1047	1.1044	1.1047	1.1043
lobe height	1.1044	1.1032	1.1045	1.2044	1.1047	1.1041	1.1046	1.1041

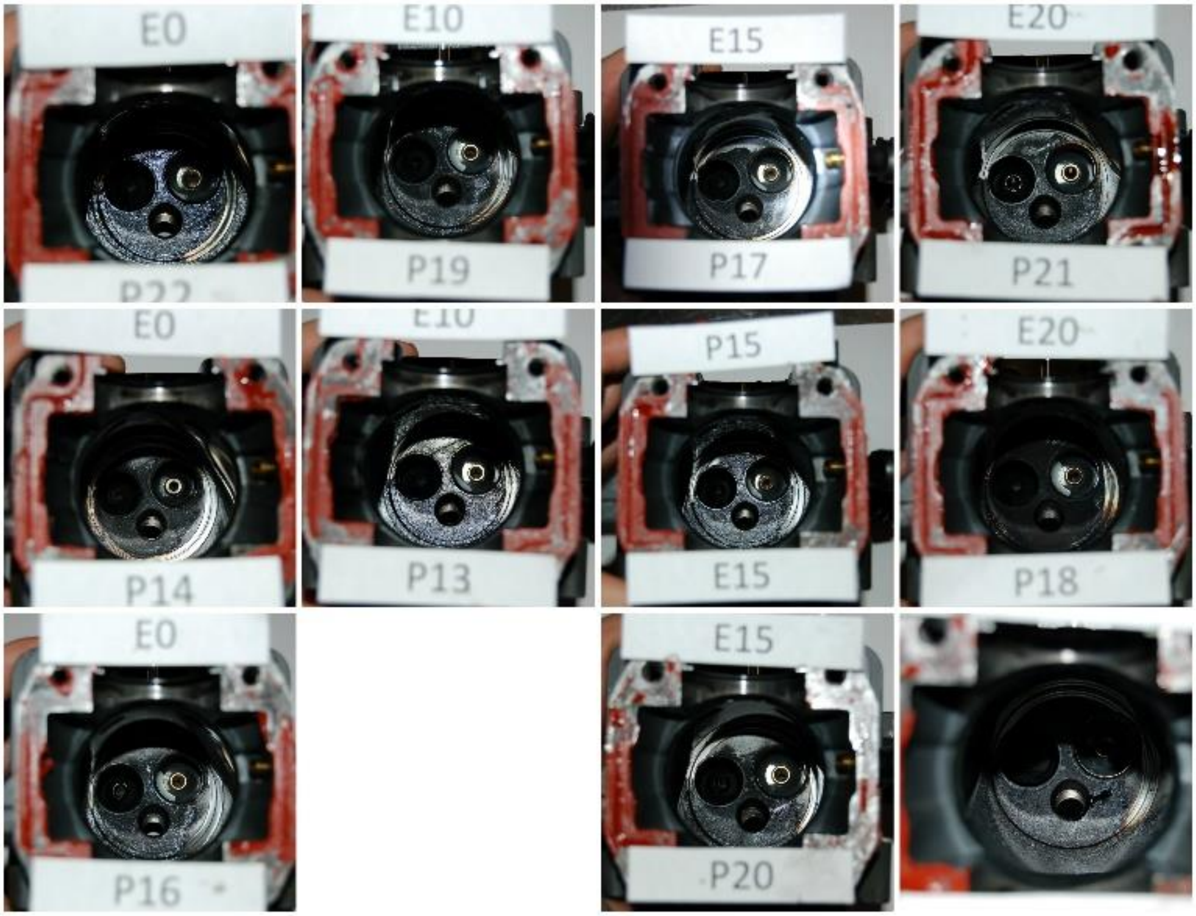
Appendix I- Bowers P1-P12 piston comparison picture

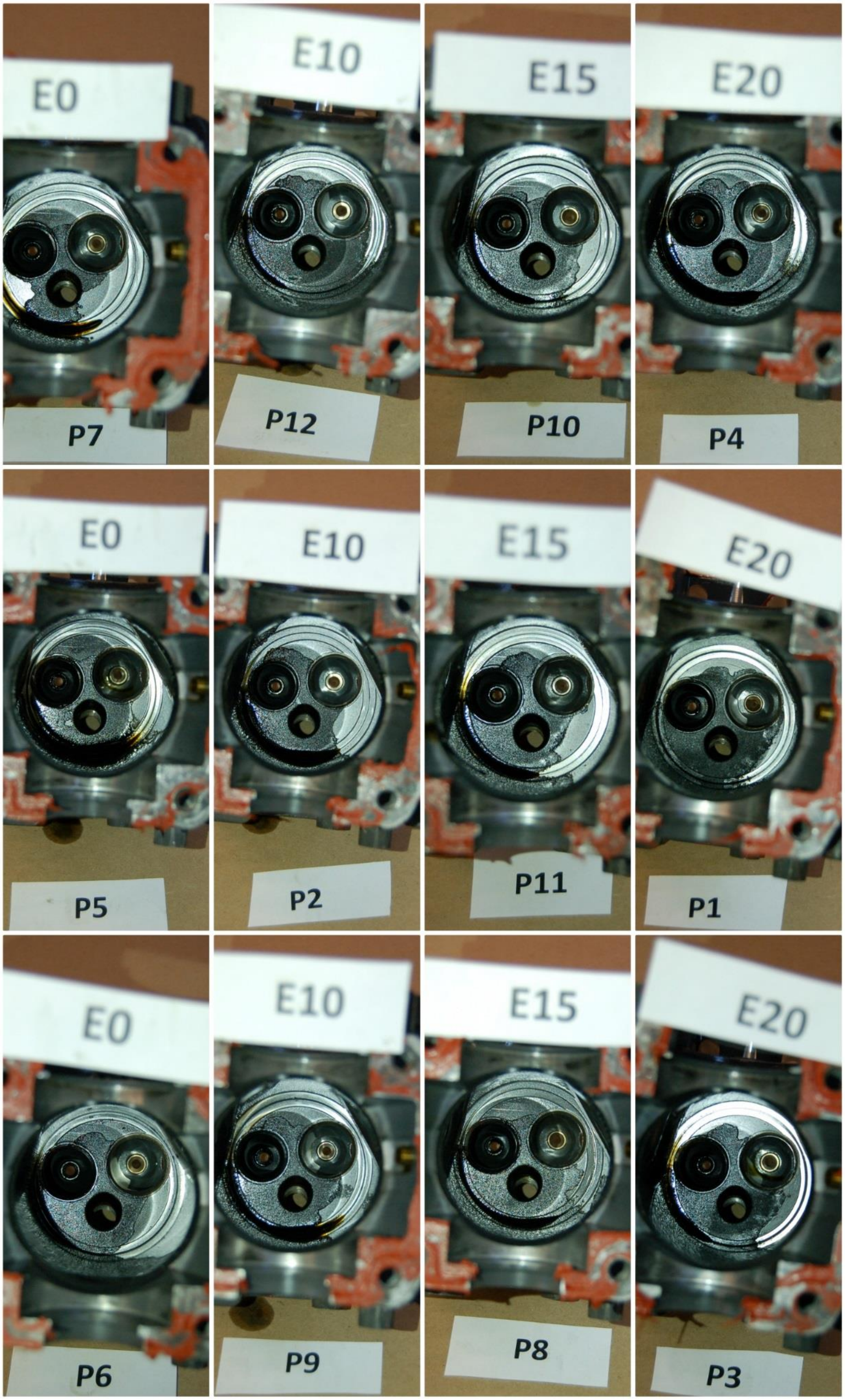


Appendix M – Blowers P13-P24 comparison picture



Appendix N - Blowers combustion chamber




E0
P7
E10
P12
E15
P10
E20
P4
E0
P5
E10
P2
E15
P11
E20
P1
E0
P6
E10
P9
E15
P8
E20
P3

Appendix O - 4-Stroke Backpack Blower (BR600) Test Plan

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RE: 4-Stroke Backpack Blower (BR600) Test Plan

Scope:

This plan provides an overview of the test procedures that will be used on the 4-stroke backpack blower 65cc (Stihl BR600) for the Enhanced Engine Study.

Engine:

Stihl BR600 65cc 4-stroke (4-MIX) backpack blower

NOTE: 4-stroke (4-MIX) –ALL fuel must be premixed with Stihl HP Ultra 2-Cycle engine oil at ratio of 50:1!!!!

Test Plan:

1. Unpack and inspect engine for damage/ issues.
2. Record engine serial numbers and label engine appropriately. (NOTE: fuel is assigned after break-in)
3. Perform initial compression test and check/set sparkplug gap to .028", torque plug to 110-120 in-lbs.
4. Inspect air filter element for dirt/dust/debris and ensure it is set in summer mode.
5. Adjust throttle cable:
   a. Set throttle trigger to the full throttle position.
   b. Carefully turn screw on trigger clockwise until you feel initial resistance.
6. Install thermocouples:
   a. Cylinder Head
   b. Exhaust gas
   c. Exhaust surface
   d. Intake Air
7. Install new hour meter / Tachometer.
8. Fill unit with E0 fuel. All fuel must be 50:1 premix with 2-stroke oil. All units will be broken-in on E0. Fuel assignment will be done after emissions testing on E0.
9. Place unit on aging rack.
   a. Install trigger actuator.
   b. Verify thermocouples are reading correctly.

10. Follow manufacturer's starting/warm up recommendation.
    a. COLD START: Place the handle setting lever to "**I**" position. Press primer bulb 5 times, slowly. Fuel should be visible in bulb, if not press and release bulb until fuel is visible. Move choke to full choke position (12 o'clock position). Pull the starter three times. If it does not start, move the choke

to half choke (10 o'clock position). Pull the starter until engine runs. Return choke to "**I"** position after engine starts. Allow engine to warm up at idle for 60 sec.

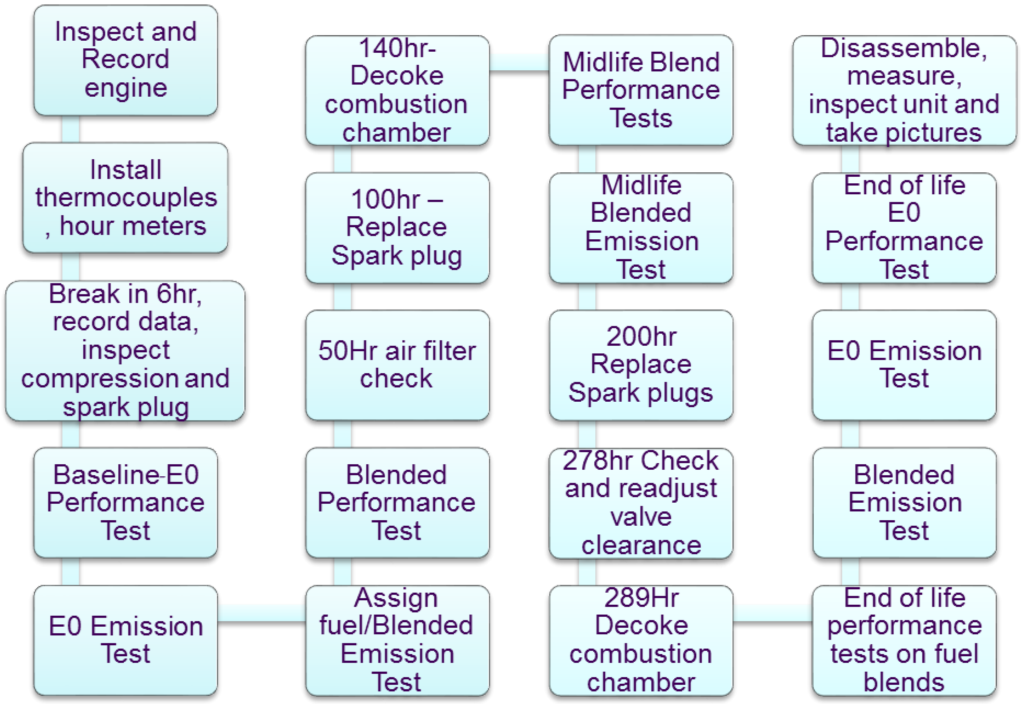
   b. HOT START: Place the handle setting lever to "**I"** position. Press primer bulb 5 times, slowly. Fuel should be visible in bulb, if not press and release bulb until fuel is visible. Move choke to half choke position (10 o'clock position). Pull the starter until engine runs. Return choke to "**I"** position after engine starts. Allow engine to warm up at idle for 60 sec.
   c. Verify Idle-2500/WOT-7200 rpm and temps.

11. Break-in for 6 hrs – cycle 1020 second WOT; 180 second Idle. (17min WOT, 3min idle)
12. Record temp/rpm info at 30 minutes.
13. **Adjust idle speed** (2500 rpm) after 2hrs while the unit is at operating temperature and running on E0 fuel. See manual for adjustment procedure (p.22). The idle will not be adjusted after this initial adjustment.
14. **After break-in inspect**:
    a. Visual engine, exhaust, and fuel system – leaks/ discoloration/ issues.
    b. Check compression.
    c. Visually inspect and note condition of plug.
15. Baseline E0 Performance tests – ALL on indolene E0 premix. Units must be purged of E0 and run dry before testing. Unit must cold soak at least 4hrs before testing.
    a. Tests – follow appropriate test sheets:
       i. Cold Startability
       ii. Multiposition
       iii. Hot Restart
16. Baseline E0 Emission tests – ALL on indolene E0 premix. Refer to specific emissions test procedures.
17. Assign each unit its fuel blend. Richest running units receive E0 to leanest running unit receives E20.
18. Clearly label the assigned blend on the unit and on all premix fuel containers.
19. Blended Initial Emissions tests – ALL on indolene Ethanol premix. Units must be purged of E0 before testing. Units tested on their assigned ethanol blend. Refer to specific emissions test procedures.
20. Blend Initial Performance tests – ALL on indolene Ethanol premix. Units must be run dry before testing. Unit must cold soak at least 4hrs before testing.
    a. Tests – follow appropriate test sheets:
       i. Cold Startability
       ii. Multiposition
       iii. Hot Restart
21. **Visually inspect unit – leaks/ discoloration etc.**
22. **Check air filter every 50 hrs. and replace as necessary.**
23. **Age units to 100 hrs. on assigned premix blend of ethanol and pump gas. Aging cycle 1020 second WOT; 180 second Idle.**
24. **At hour 100 replace spark plug and check gap (0.028"). Note condition and take pic of removed plug.**
25. **At hour 139 check and readjust valve clearance and decoke combustion chamber. Note any adjustments.**
26. At hour 150 – midlife inspection:
    a. Visual engine, exhaust, and fuel system – leaks/ discoloration/ issues.
    b. Check compression.
    c. Visually inspect and note condition of plug.
27. Midlife Blended Performance tests – ALL on indolene Ethanol premix. Units must be purged of fuel and run dry before testing. Unit must cold soak at least 4hrs before testing.
    a. Tests – follow appropriate test sheets:
       i. Cold Startability

    ii. Multiposition
    iii. Hot Restart

28. Midlife Blended Emissions tests – ALL on indolene Ethanol premix. Units must be purged of E0 before testing. Units tested on their assigned ethanol blend. Refer to specific emissions test procedures.
29. Visually inspect unit – leaks/ discoloration etc.
30. Age units to 200 hrs. on assigned premix blend of ethanol and pump gas. Aging cycle 1020 second WOT; 180 second Idle.
31. At hour 200 replace spark plug and check gap (0.028”). Note condition and take pic of removed plug.
32. At hour 278 check and readjust valve clearance. Note any adjustments.
33. At hour 289 decoke combustion chamber.
34. At hour 300 – end-of-life inspection:
    a. Visual engine, exhaust, and fuel system – leaks/ discoloration/ issues.
    b. Check compression.
    c. Visually inspect and note condition of plug.
35. End-of-life Blended Performance tests – ALL on indolene Ethanol premix. Units must be purged of fuel and run dry before testing. Unit must cold soak at least 4hrs before testing.
    a. Tests – follow appropriate test sheets:
        i. Cold Startability
        ii. Multiposition
        iii. Hot Restart
36. End-of-life Blended Emissions tests – ALL on indolene Ethanol premix. Units must be purged of E0 before testing. Units tested on their assigned ethanol blend. Refer to specific emissions test procedures.
37. Unit must be purged of the blended fuels and filled with indolene E0 mix.
38. End-of-life E0 Emission tests – ALL on indolene E0 premix. Refer to specific emissions test procedures.
39. End-of-life E0 Performance tests – ALL on indolene E0 premix. Units must be purged of fuel and run dry before testing. Unit must cold soak at least 4hrs before testing.
    a. Tests – follow appropriate test sheets:
        i. Cold Startability
        ii. Multiposition
        iii. Hot Restart
40. Visually inspect unit – leaks/ discoloration etc.
41. Disassemble measure and inspect the units taking careful photos.

Appendix P – Blowers procedure flow chart



Appendix Q-blower cold startability test sheet

BR600 Blower cold startability Test

Circle test performed

Initial E0 Test   Initial Blend Test   Midlife Blend Test   End of Life Blended Test   End of Life E0 Test

Unit must have been ran dry and cold soaked for at least 4 hrs prior to starting test

Engine number		
Fuel Type 50:1		
Soak Time (4 HR)		

COLD START: Place the handle setting lever to "I" position. Press primer bulb 5 times, slowly. Fuel should be visible in bulb, if not press and release bulb until fuel is visible. Move choke to full choke position (12 o'clock position). Pull the starter three times. If it does not start, move the choke to half choke (10 o'clock position). Pull the starter until engine runs. Return choke to "I" position after engine starts. Allow engine to warm up at idle for 60 sec.

Engine Hours			
# of fuel primes (5 or until fuel is visible in bulb)			
# of full choke pulls (idle)		Pulls	
# of half choke pulls (idle)		Pulls	
# of no choke pulls (idle)		Pulls	
Go to WOT			
WOT RPM 1 MIN		RPM	Turn choke off after 30-60 seconds WOT
WOT RPM 2 MIN		RPM	
WOT RPM 3 MIN		RPM	Use as stable WOT RPM
Return to IDLE			
stable Idle RPM		RPM	
Time to stable WOT		Seconds	
Idle RPM		RPM	
Time to stable WOT		Seconds	
Idle RPM		RPM	
Time to stable WOT		Seconds	
Return to Idle and Record Temps			
IAT		°F	
Cylinder Head Temp		°F	
Exhaust Surface Temp		°F	
Exhaust Gas Temp		°F	
Fuel Temp		°F	
Idle RPM		RPM	

Go Directly INTO Multiposition TEST

Comments	

Appendix R – blowers multiposition test sheet

BR600 Blower Multiposition Evaluation

Circle test performed — **Initial E0 Test** **Initial Blend Test** **Midlife Blend Test** **End of Life Blended Test** **End of Life E0 Test**

Engine Number

Descriptions to be used

Normal	Slow	Die	Hesitate	Wander

Record RPM after 15 seconds of WOT then repeat 15 seconds of idle

Air Nozzle Position	RPM WOT	RPM Idle	Acceleration - Describe	Describe Overall Performance
Vertical (Nozzle UP)				
Horizontal (Normal)				
Horizontal Roll Left				
Horizontal Roll Right				
Vertical (Nozzle Down)				

Comments:

Vertical (Nozzle UP) | Horizontal (Normal) | Horizontal Roll Left | Horizontal Roll Right | Vertical (Nozzle Down)

Go Directly To Hot Restart TEST

Appendix S – Blowers hot restart test sheet

BR600 Blower Hot Restart Evaluation

Circle test performed

Initial E0 Test Initial Blend Test Midlife Blend Test End of Life Blended Test End of Life E0 Test

Engine Number ______

Run Engine at WOT for 15 Minutes or until Thermal Stability

Thermal Stability is reached when the Cylinder Head has reached a constant stable temperature(+-25 Degrees)

for longer then 3 min

Exhaust Gas Temp:		IAT:		Stable WOT RPM:	
Exhaust Surface Temp:		Cylinder Head Temp:		Stabile Idle RPM:	
Fuel Temp:					

Shut off engine and check carb temp every 3 min

	0 min	3 min	6 min	9 min	12 min	15 min	18 min	21 min
Carb temps								
	24 min	27 min	30 min	33 min	36 min	39 min	42 min	45 min
Carb temps								

HOT START: Place the handle setting lever to "I" position. Press primer bulb 5 times, slowly. Fuel should be visible in bulb, if not press and release bulb until fuel is visible. Move choke to half choke position (10 o'clock position). Pull the starter until engine runs. Return choke to "I" position after engine starts. Allow engine to warm up at idle for 60 sec.

after carb temp peaks, go onto hot restart test

hot restart at half choke, and run at half choke for 30-60 sec

# of pulls to start		Pulls
return to no choke		
go to WOT for 60 seconds		
Stable WOT		RPM
Idle RPM after 30 sec		RPM
Time to stable WOT		Seconds
Idle RPM		RPM
Time to stable WOT		Seconds
Idle RPM		RPM
Time to stable WOT		Seconds

Visual note on fuel level:		
Visual Inspection of Unit:		leaks/problems

Comments ______

Appendix S- Blowers(P1-P12) measurement Data

Measurements	E0	E0	E0	E10	E10	E10	E15	E15	E15	E20	E20
Piston	**Engine P5**	**Engine P6**	**Engine P7**	**Engine P9**	**Engine P2**	**Engine P12**	**Engine P8**	**Engine P10**	**Engine P11**	**Engine P1**	**Engine P3**
1	1.9649	1.9645	1.9652	1.9646	1.9654	1.9645	1.9652	1.9650	1.9654	1.9652	1.9652
2	1.9648	1.9645	1.9651	1.9646	1.9653	1.9646	1.9653	1.9648	1.9653	1.9652	1.9654
3	1.9648	1.9647	1.9653	1.9646	1.9653	1.9645	1.9651	1.9650	1.9654	1.9651	1.9654
Wear Area (Just under ring)	1.9648	1.9646	1.9652	1.9646	1.9653	1.9645	1.9652	1.9649	1.9654	1.9652	1.9653
1	0.4743	0.4739	0.4740	0.4745	0.4737	0.4740	0.4739	0.4734	0.4738	0.4744	0.4736
2	0.4740	0.4743	0.4742	0.4747	0.4732	0.4738	0.4736	0.4736	0.4736	0.4738	0.4739
3	0.4741	0.4740	0.4743	0.4745	0.4735	0.4739	0.4736	0.4737	0.4735	0.4741	0.4735
Piston Wrist Pin Bore (L)	0.4741	0.4741	0.4742	0.4746	0.4735	0.4739	0.4737	0.4736	0.4736	0.4741	0.4737
1	0.4749	0.4741	0.4742	0.4749	0.4733	0.4739	0.4733	0.4739	0.4742	0.4740	0.4738
2	0.4747	0.4738	0.4742	0.4747	0.4733	0.4739	0.4736	0.4738	0.4740	0.4738	0.4736
3	0.4748	0.4741	0.4744	0.4746	0.4735	0.4741	0.4736	0.4739	0.4745	0.4742	0.4733
Piston Wrist Pin Bore (R)	0.4748	0.4740	0.4743	0.4747	0.4734	0.4740	0.4735	0.4739	0.4742	0.4740	0.4736
Connecting Rod											
Inner Diameter											
1	0.4740	0.4742	0.4741	0.4744	0.4735	0.4739	0.4738	0.4742	0.4743	0.4734	0.4733
2	0.4738	0.4740	0.4740	0.4742	0.4732	0.4740	0.4736	0.4740	0.4740	0.4733	0.4735
3	0.4740	0.4744	0.4738	0.4742	0.4733	0.4738	0.4735	0.4743	0.4741	0.4734	0.4737
Avg.	0.4739	0.4742	0.4740	0.4743	0.4733	0.4739	0.4736	0.4742	0.4741	0.4734	0.4735
Wrist Pin											
Wear Area Outer (L)											
1	0.4720	0.4720	0.4720	0.4719	0.4720	0.4720	0.4719	0.4719	0.4720	0.4719	0.4719
2	0.4720	0.4720	0.4720	0.4720	0.4720	0.4720	0.4719	0.4720	0.4721	0.4720	0.4720
3	0.4720	0.4720	0.4720	0.4720	0.4719	0.4720	0.4720	0.4721	0.4720	0.4719	0.4720

Avg.	0.4720	0.4720	0.4720	0.4720	0.4720	0.4720	0.4719	0.4720	0.4720	0.4719	0.4720
Wear Area Middle											
1	0.4720	0.4719	0.4720	0.4721	0.4720	0.4720	0.4720	0.4721	0.4720	0.4720	0.4720
2	0.4720	0.4720	0.4721	0.4720	0.4720	0.4720	0.4720	0.4721	0.4720	0.4720	0.4719
3	0.4720	0.4720	0.4720	0.4720	0.4720	0.4720	0.4720	0.4720	0.4721	0.4719	0.4720
Avg.	0.4720	0.4720	0.4720	0.4720	0.4720	0.4720	0.4720	0.4721	0.4720	0.4720	0.4720
Wear Area Outer (R)											
1	0.4720	0.4719	0.4720	0.4720	0.4720	0.4721	0.4720	0.4720	0.4720	0.4719	0.4719
2	0.4719	0.4719	0.4720	0.4720	0.4720	0.4720	0.4719	0.4720	0.4720	0.4720	0.4719
3	0.4719	0.4720	0.4720	0.4720	0.4720	0.4721	0.4720	0.4720	0.4720	0.4720	0.4719
Avg.	0.4719	0.4719	0.4720	0.4720	0.4720	0.4721	0.4720	0.4720	0.4720	0.4720	0.4719
Cylinder											
Wear Area Top											
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2											
3											
Avg.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wear Area Middle											
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2											
3											
Avg.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wear Area Bottom											
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2											
3											
Avg.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No Wear Area											
1	0.0005	0.0005	0.0000	0.0005	0.0005	0.0005	0.0005	0.0005	0.0000	0.0005	0.0005
2											
3											

Avg.	0.0002	0.0002	0.0000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0000	0.0002	0.0002
Piston Ring											
Ring to Land (Top Ring)											
1	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0010	0.0005	0.0005	0.0010	0.0005
2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0010	0.0005	0.0005	0.0010	0.0005
3	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0010	0.0005	0.0005	0.0010	0.0005
Avg	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0010	0.0005	0.0005	0.0010	0.0005
Ring to Land (Bottom Ring)											
1	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0010	0.0005	0.0010	0.0010	0.0010
2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0010	0.0005	0.0010	0.0010	0.0010
3	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0010	0.0005	0.0010	0.0010	0.0010
Avg	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0010	0.0005	0.0010	0.0010	0.0010
Cam Shaft											
Lobe height											
1	0.1552	0.1557	0.1551	0.1546	0.1547	0.1545	0.1545	0.1549	0.1548	0.1545	0.1549
2	0.1553	0.1555	0.1552	0.1545	0.1546	0.1546	0.1546	0.1548	0.1549	0.1546	0.1547
3	0.1553	0.1555	0.1551	0.1546	0.1547	0.1545	0.1545	0.1549	0.1549	0.1545	0.1547
Avg.	0.1553	0.1556	0.1551	0.1546	0.1547	0.1545	0.1545	0.1549	0.1549	0.1545	0.1548
Inner Diameter											
1	0.2031	0.2037	0.2028	0.2025	0.2028	0.2024	0.2027	0.2037	0.2033	0.2024	0.2032
2	0.2033	0.2035	0.2030	0.2021	0.2026	0.2026	0.2029	0.2035	0.2035	0.2020	0.2028
3	0.2030	0.2034	0.2027	0.2023	0.2026	0.2024	0.2030	0.2034	0.2031	0.2023	0.2029
Avg.	0.2031	0.2035	0.2028	0.2023	0.2027	0.2025	0.2029	0.2035	0.2033	0.2022	0.2030
Lower Cam Case Shaft											
No Wear Area (Cover)											
1	0.1964	0.1964	0.1964	0.1964	0.1964	0.1963	0.1964	0.1963	0.1963	0.1965	0.1963
2	0.1964	0.1964	0.1964	0.1963	0.1965	0.1963	0.1963	0.1964	0.1964	0.1964	0.1964
3	0.1963	0.1963	0.1963	0.1963	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964
Avg.	0.1964	0.1964	0.1964	0.1963	0.1964	0.1963	0.1964	0.1964	0.1964	0.1964	0.1964
Wear Area Middle (Cam)											
1	0.1964	0.1964	0.1964	0.1964	0.1965	0.1963	0.1964	0.1964	0.1964	0.1964	0.1963

2	0.1963	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964
3	0.1963	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1963
Avg.	0.1963	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1963
No Wear Area (Block)											
1	0.1964	0.1964	0.1963	0.1964	0.1963	0.1963	0.1964	0.1963	0.1963	0.1963	0.1963
2	0.1963	0.1963	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964
3	0.1964	0.1964	0.1964	0.1963	0.1964	0.1963	0.1964	0.1964	0.1963	0.1964	0.1964
Avg.	0.1964	0.1964	0.1964	0.1964	0.1964	0.1963	0.1964	0.1964	0.1963	0.1964	0.1964
Upper Cam Case Shaft											
No Wear Area (Cover)											
1	0.1963	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964
2	0.1963	0.1965	0.1963	0.1964	0.1964	0.1965	0.1964	0.1964	0.1964	0.1965	0.1964
3	0.1964	0.1965	0.1964	0.1964	0.1964	0.1965	0.1964	0.1964	0.1964	0.1964	0.1964
Avg.	0.1963	0.1965	0.1964	0.1964	0.1964	0.1965	0.1964	0.1964	0.1964	0.1964	0.1964
Middle Wear Area (Follower)											
1	0.1964	0.1965	0.1964	0.1965	0.1964	0.1965	0.1964	0.1964	0.1965	0.1964	0.1964
2	0.1964	0.1964	0.1965	0.1965	0.1964	0.1965	0.1965	0.1964	0.1964	0.1964	0.1964
3	0.1964	0.1964	0.1964	0.1965	0.1965	0.1965	0.1965	0.1964	0.1964	0.1964	0.1964
Avg.	0.1964	0.1964	0.1964	0.1965	0.1964	0.1965	0.1965	0.1964	0.1964	0.1964	0.1964
No Wear Area (Block)											
1	0.1964	0.1964	0.1964	0.1963	0.1965	0.1964	0.1964	0.1966	0.1964	0.1964	0.1965
2	0.1963	0.1964	0.1964	0.1963	0.1964	0.1964	0.1964	0.1964	0.1965	0.1964	0.1964
3	0.1963	0.1963	0.1964	0.1962	0.1964	0.1963	0.1964	0.1963	0.1963	0.1963	0.1963
Avg.	0.1963	0.1964	0.1964	0.1963	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964	0.1964
Intake Valve											
No Wear Area (Top)											
1	0.1363	0.1364	0.1363	0.1364	0.1364	0.1363	0.1363	0.1364	0.1363	0.1364	0.1363
2	0.1364	0.1364	0.1363	0.1364	0.1364	0.1363	0.1363	0.1364	0.1363	0.1364	0.1362
3	0.1364	0.1364	0.1363	0.1364	0.1364	0.1363	0.1363	0.1364	0.1363	0.1363	0.1362
Avg.	0.1364	0.1364	0.1363	0.1364	0.1364	0.1363	0.1363	0.1364	0.1363	0.1364	0.1362
Wear Area (Middle)											

1	0.1365	0.1364	0.1364	0.1364	0.1364	0.1363	0.1364	0.1364	0.1363	0.1364	0.1364
2	0.1365	0.1364	0.1364	0.1364	0.1364	0.1363	0.1363	0.1363	0.1364	0.1364	0.1363
3	0.1365	0.1364	0.1363	0.1364	0.1364	0.1363	0.1363	0.1364	0.1363	0.1363	0.1364
Avg.	0.1365	0.1364	0.1364	0.1364	0.1364	0.1363	0.1363	0.1364	0.1363	0.1364	0.1364
Wear Area (Bottom)											
1	0.1366	0.1364	0.1363	0.1364	0.1363	0.1363	0.1364	0.1364	0.1363	0.1363	0.1364
2	0.1365	0.1364	0.1363	0.1363	0.1364	0.1363	0.1363	0.1364	0.1363	0.1363	0.1363
3	0.1365	0.1363	0.1363	0.1364	0.1363	0.1363	0.1363	0.1364	0.1363	0.1363	0.1363
Avg.	0.1365	0.1364	0.1363	0.1364	0.1363	0.1363	0.1363	0.1364	0.1363	0.1363	0.1363
Exhaust Valve											
No Wear Area (Top)											
1	0.1362	0.1363	0.1362	0.1363	0.1363	0.1362	0.1363	0.1363	0.1362	0.1362	0.1363
2	0.1363	0.1362	0.1363	0.1363	0.1363	0.1362	0.1361	0.1363	0.1363	0.1362	0.1362
3	0.1362	0.1362	0.1362	0.1363	0.1363	0.1363	0.1362	0.1363	0.1362	0.1363	0.1363
Avg.	0.1362	0.1362	0.1362	0.1363	0.1363	0.1362	0.1362	0.1363	0.1362	0.1362	0.1363
Wear Area (Middle)											
1	0.1362	0.1362	0.1363	0.1363	0.1364	0.1363	0.1363	0.1363	0.1363	0.1363	0.1364
2	0.1363	0.1362	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363
3	0.1362	0.1362	0.1362	0.1362	0.1363	0.1362	0.1363	0.1363	0.1363	0.1363	0.1364
Avg.	0.1362	0.1362	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363	0.1363	0.1364
Wear Area (Bottom)											
1	0.1363	0.1363	0.1363	0.1363	0.1364	0.1363	0.1363	0.1363	0.1363	0.1364	0.1363
2	0.1362	0.1362	0.1363	0.1362	0.1364	0.1364	0.1364	0.1364	0.1363	0.1365	0.1363
3	0.1363	0.1363	0.1363	0.1363	0.1364	0.1363	0.1363	0.1363	0.1363	0.1364	0.1363
Avg.	0.1363	0.1363	0.1363	0.1363	0.1364	0.1363	0.1363	0.1363	0.1363	0.1364	0.1363
Intake Valve Stem Guide											
Wear Area Top	0.1385	0.1390	0.1389	0.1389	0.1389	0.1384	0.1386	0.1388	0.1386	0.1385	0.1387
Wear Area Middle	0.1387	0.1386	0.1384	0.1387	0.1390	0.1388	0.1389	0.1390	0.1383	0.1380	0.1388
Wear Area Bottom	0.1383	0.1389	0.1386	0.1390	0.1385	0.1383	0.1386	0.1388	0.1384	0.1382	0.1385

Exhaust Valve Stem Guide											
Wear Area Top	0.1385	0.1379	0.1395	0.1387	0.1386	0.1383	0.1395	0.1387	0.1394	0.1389	0.1386
Wear Area Middle	0.1385	0.1383	0.1390	0.1384	0.1382	0.1385	0.1397	0.1385	0.1390	0.1386	0.1383
Wear Area Bottom	0.1388	0.1385	0.1392	0.1382	0.1388	0.1388	0.1394	0.1388	0.1395	0.1383	0.1387

Blowers(P13-P24) measurement Data

Measurements	**E0**	**E0**	**E0**	**E10**	**E10**	**E10**	**E15**	**E15**	**E15**	**E20**	**E20**	**E20**
Piston	**Engine P14**	**Engine P16**	**Engine P22**	**Engine P13**	**Engine P19**	**Engine P24**	**Engine P17**	**Engine P20**	**Engine P23**	**Engine P18**	**Engine P21**	**Engine P15**
1	1.9655	1.9660	1.9662	1.9660	1.9660		1.9655	1.9657	1.9655	1.9655	1.9660	1.9660
2	1.9650	1.9655	1.9660	1.9660	1.9660		1.9658	1.9660	1.9659	1.9655	1.9661	1.9659
3	1.9655	1.9655	1.9660	1.9655	1.9661		1.9660	1.9655	1.9655	1.9660	1.9660	1.9655
Wear Area (Just under ring)	1.9653	1.9657	1.9661	1.9658	1.9660	0.0000	1.9658	1.9657	1.9656	1.9657	1.9660	1.9658
1	0.4730	0.4730	0.4730	0.4720	0.4730		0.4730	0.4730	0.4730	0.4730	0.4720	0.4730
2	0.4730	0.4730	0.4730	0.4720	0.4730		0.4730	0.4730	0.4730	0.4730	0.4720	0.4730
3	0.4725	0.4730	0.4730	0.4720	0.4730		0.4730	0.4730	0.4730	0.4730	0.4720	0.4730
Piston Wrist Pin Bore (L)	0.4728	0.4730	0.4730	0.4720	0.4730	0.0000	0.4730	0.4730	0.4730	0.4730	0.4720	0.4730
1	0.4720	0.4725	0.4730	0.4730	0.4730		0.4725	0.4730	0.4730	0.4725	0.4730	0.4730
2	0.4725	0.4730	0.4730	0.4730	0.4730		0.4725	0.4730	0.4730	0.4725	0.4730	0.4730
3	0.4725	0.4730	0.4730	0.4730	0.4730		0.4725	0.4730	0.4730	0.4725	0.4730	0.4730
Piston Wrist Pin Bore (R)	0.4723	0.4728	0.4730	0.4730	0.4730	0.0000	0.4725	0.4730	0.4730	0.4725	0.4730	0.4730
Connecting Rod												
Inner Diameter												
1	0.4740	0.4740	0.4740	0.4745	0.4740		0.4740	0.4730	0.4740	0.4730	0.4740	0.4740
2	0.4740	0.4740	0.4740	0.4740	0.4740		0.4735	0.4730	0.4740	0.4735	0.4740	0.4740
3	0.4735	0.4740	0.4740	0.4740	0.4740		0.4740	0.4735	0.4740	0.4740	0.4740	0.4740
Avg.	0.4738	0.4740	0.4740	0.4742	0.4740	0.0000	0.4738	0.4732	0.4740	0.4735	0.4740	0.4740
Wrist Pin												

Wear Area Outer (L)											
1	0.4720	0.4718	0.4720	0.4719	0.4710		0.4715	0.4710	0.4717	0.4715	0.4715	0.4715
2	0.4719	0.4720	0.4720	0.4720	0.4715		0.4715	0.4715	0.4715	0.4717	0.4715	0.4716
3	0.4717	0.4720	0.4720	0.4720	0.4715		0.4720	0.4718	0.4715	0.4720	0.4715	0.4715
Avg.	0.4719	0.4719	0.4720	0.4720	0.4713	0.0000	0.4717	0.4714	0.4716	0.4717	0.4715	0.4715
Wear Area Middle											
1	0.4720	0.4720	0.4720	0.4720	0.4710		0.4720	0.4710	0.4715	0.4715	0.4720	0.4720
2	0.4720	0.4720	0.4720	0.4720	0.4715		0.4720	0.4715	0.4720	0.4720	0.4720	0.4720
3	0.4720	0.4720	0.4720	0.4720	0.4715		0.4720	0.4715	0.4715	0.4720	0.4720	0.4715
Avg.	0.4720	0.4720	0.4720	0.4720	0.4713	0.0000	0.4720	0.4713	0.4717	0.4718	0.4720	0.4718
Wear Area Outer (R)											
1	0.4720	0.4715	0.4720	0.4720	0.4720		0.4720	0.4720	0.4715	0.4710	0.4715	0.4720
2	0.4715	0.4720	0.4720	0.4720	0.4715		0.4720	0.4715	0.4715	0.4715	0.4715	0.4715
3	0.4720	0.4720	0.4720	0.4720	0.4715		0.4715	0.4720	0.4715	0.4715	0.4715	0.4720
Avg.	0.4718	0.4718	0.4720	0.4720	0.4717	0.0000	0.4718	0.4718	0.4715	0.4713	0.4715	0.4718
Cylinder											
Wear Area Top											
1	1.9675	1.9675	1.9675	1.9675	1.9675		1.9675	1.9675	1.9675	1.9680	1.9675	1.9675
2												
3												
Avg.	1.9675	1.9675	1.9675	1.9675	1.9675	0.0000	1.9675	1.9675	1.9675	1.9680	1.9675	1.9675
Wear Area Middle											
1	1.9675	1.9675	1.9675	1.9680	1.9675		1.9680	1.9680	1.9680	1.9680	1.9675	1.9675
2												
3												
Avg.	1.9675	1.9675	1.9675	1.9680	1.9675	0.0000	1.9680	1.9680	1.9680	1.9680	1.9675	1.9675
Wear Area Bottom											
1	1.9680	1.9675	1.9680	1.9680	1.9675		1.9675	1.9680	1.9680	1.9685	1.9675	1.9675
2												
3												
Avg.	1.9680	1.9675	1.9680	1.9680	1.9675	0.0000	1.9675	1.9680	1.9680	1.9685	1.9675	1.9675
No Wear Area												

1	1.9670	1.9670	1.9670	1.9670	1.9670		1.9670	1.9670	1.9670	1.9670	1.9670	1.9670
2												
3												
Avg.	1.9670	1.9670	1.9670	1.9670	1.9670	0.0000	1.9670	1.9670	1.9670	1.9670	1.9670	1.9670
Piston Ring												
Ring to Land (Top Ring)												
1	0.0010	0.0010	0.0010	0.0010	0.0010		0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
2	0.0010	0.0010	0.0010	0.0010	0.0010		0.0015	0.0010	0.0015	0.0010	0.0010	0.0010
3	0.0015	0.0010	0.0010	0.0010	0.0010		0.0020	0.0010	0.0015	0.0015	0.0010	0.0010
Avg	0.0012	0.0010	0.0010	0.0010	0.0010	#DIV/0!	0.0015	0.0010	0.0013	0.0012	0.0010	0.0010
Ring to Land (Bottom Ring)												
1	0.0015	0.0010	0.0010	0.0010	0.0010		0.0010	0.0010	0.0010	0.0015	0.0010	0.0015
2	0.0010	0.0015	0.0010	0.0010	0.0010		0.0015	0.0010	0.0015	0.0015	0.0015	0.0010
3	0.0025	0.0015	0.0015	0.0010	0.0015		0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Avg	0.0017	0.0013	0.0012	0.0010	0.0012	#DIV/0!	0.0013	0.0012	0.0013	0.0015	0.0013	0.0013
Cam Shaft												
Lobe height												
1	1.1670	1.1520	1.1530	1.1550	1.1540		1.1540	1.1540	1.1535	1.1545	1.1535	1.1530
2												
3												
Avg.	1.1670	1.1520	1.1530	1.1550	1.1540	0.0000	1.1540	1.1540	1.1535	1.1545	1.1535	1.1530
Inner Diameter												
1	0.1995	0.2010	0.2020	0.2020	0.2005		0.2010	0.2000	0.2000	0.2025	0.2010	0.2030
2	0.2025	0.2020	0.2025	0.2020	0.2030		0.2025	0.2025	0.2025	0.2030	0.2030	0.2040
3	0.2005	0.2005	0.2015	0.2030	0.2020		0.2020	0.2010	0.2010	0.2010	0.2015	0.2020
Avg.	0.2008	0.2012	0.2020	0.2023	0.2018	0.0000	0.2018	0.2012	0.2012	0.2022	0.2018	0.2030
Lower Cam Case Shaft												
No Wear Area (Cover)												
1	0.1960	0.1960	0.1965	0.1965	0.1965		0.1960	0.1965	0.1965	0.1965	0.1960	0.1960
2	0.1960	0.1960	0.1965	0.1960	0.1965		0.1965	0.1965	0.1965	0.1965	0.1965	0.1965
3	0.1960	0.1960	0.1965	0.1960	0.1965		0.1965	0.1965	0.1965	0.1965	0.1965	0.1960

Avg.	0.1960	0.1960	0.1965	0.1962	0.1965	0.0000	0.1963	0.1965	0.1965	0.1965	0.1963	0.1962
Wear Area Middle (Cam)												
1	0.1960	0.1960	0.1960	0.1960	0.1960		0.1960	0.1960	0.1960	0.1960	0.1960	0.1960
2	0.1960	0.1965	0.1960	0.1960	0.1960		0.1960	0.1960	0.1960	0.1960	0.1960	0.1965
3	0.1965	0.1965	0.1960	0.1960	0.1960		0.1965	0.1960	0.1960	0.1960	0.1960	0.1960
Avg.	0.1962	0.1963	0.1960	0.1960	0.1960	0.0000	0.1962	0.1960	0.1960	0.1960	0.1960	0.1962
No Wear Area (Block)												
1	0.1965	0.1960	0.1965	0.1960	0.1965		0.1960	0.1965	0.1965	0.1965	0.1965	0.1960
2	0.1960	0.1960	0.1965	0.1960	0.1965		0.1965	0.1965	0.1965	0.1965	0.1965	0.1965
3	0.1960	0.1965	0.1965	0.1960	0.1965		0.1960	0.1965	0.1965	0.1965	0.1965	0.1965
Avg.	0.1962	0.1962	0.1965	0.1960	0.1965	0.0000	0.1962	0.1965	0.1965	0.1965	0.1965	0.1963
Upper Cam Case Shaft												
No Wear Area (Cover)												
1	0.1965	0.1960	0.1965	0.1960	0.1965		0.1965	0.1960	0.1965	0.1965	0.1965	0.1960
2	0.1965	0.1960	0.1965	0.1965	0.1965		0.1960	0.1965	0.1965	0.1965	0.1965	0.1960
3	0.1965	0.1960	0.1965	0.1960	0.1965		0.1960	0.1965	0.1965	0.1965	0.1965	0.1960
Avg.	0.1965	0.1960	0.1965	0.1962	0.1965	0.0000	0.1962	0.1963	0.1965	0.1965	0.1965	0.1960
Middle Wear Area (Follower)												
1	0.1960	0.1960	0.1965	0.1960	0.1965		0.1960	0.1961	0.1962	0.1960	0.1966	0.1960
2	0.1959	0.1960	0.1963	0.1960	0.1960		0.1962	0.1960	0.1960	0.1960	0.1963	0.1960
3	0.1960	0.1958	0.1965	0.1960	0.1960		0.1960	0.1960	0.1960	0.1960	0.1965	0.1960
Avg.	0.1960	0.1959	0.1964	0.1960	0.1962	0.0000	0.1961	0.1960	0.1961	0.1960	0.1965	0.1960
No Wear Area (Block)												
1	0.1960	0.1965	0.1965	0.1965	0.1965		0.1961	0.1965	0.1963	0.1965	0.1965	0.1965
2	0.1960	0.1960	0.1963	0.1960	0.1965		0.1959	0.1965	0.1965	0.1965	0.1964	0.1965
3	0.1960	0.1965	0.1964	0.1960	0.1964		0.1960	0.1965	0.1965	0.1965	0.1963	0.1965
Avg.	0.1960	0.1963	0.1964	0.1962	0.1965	0.0000	0.1960	0.1965	0.1964	0.1965	0.1964	0.1965
Intake Valve												
No Wear Area (Top)												
1	0.1365	0.1370	0.1365	0.1364	0.1367		0.1360	0.1365	0.1366	0.1366	0.1364	0.1365
2	0.1365	0.1370	0.1366	0.1365	0.1365		0.1362	0.1366	0.1365	0.1365	0.1365	0.1363

3	0.1365	0.1368	0.1365	0.1365	0.1365		0.1360	0.1366	0.1366	0.1365	0.1365	0.1365
Avg.	0.1365	0.1369	0.1365	0.1365	0.1366	0.0000	0.1361	0.1366	0.1366	0.1365	0.1365	0.1364
Wear Area (Middle)												
1	0.1362	0.1370	0.1361	0.1360	0.1361		0.1360	0.1360	0.1360	0.1362	0.1364	0.1365
2	0.1360	0.1365	0.1358	0.1360	0.1362		0.1360	0.1358	0.1365	0.1360	0.1365	0.1365
3	0.1360	0.1365	0.1360	0.1360	0.1360		0.1363	0.1355	0.1362	0.1360	0.1360	0.1365
Avg.	0.1361	0.1367	0.1360	0.1360	0.1361	0.0000	0.1361	0.1358	0.1362	0.1361	0.1363	0.1365
Wear Area (Bottom)												
1	0.1360	0.1365	0.1358	0.1365	0.1365		0.1360	0.1360	0.1363	0.1360	0.1360	0.1365
2	0.1360	0.1370	0.1360	0.1365	0.1363		0.1360	0.1365	0.1365	0.1365	0.1365	0.1363
3	0.1360	0.1370	0.1360	0.1360	0.1365		0.1362	0.1363	0.1360	0.1365	0.1365	0.1365
Avg.	0.1360	0.1368	0.1359	0.1363	0.1364	0.0000	0.1361	0.1363	0.1363	0.1363	0.1363	0.1364
Exhaust Valve No Wear Area (Top)												
1	0.1365	0.1365	0.1366	0.1365	0.1363		0.1365	0.1365	0.1365	0.1365	0.1364	0.1360
2	0.1365	0.1365	0.1365	0.1370	0.1365		0.1365	0.1363	0.1365	0.1365	0.1365	0.1365
3	0.1365	0.1365	0.1366	0.1365	0.1365		0.1365	0.1365	0.1365	0.1365	0.1365	0.1365
Avg.	0.1365	0.1365	0.1366	0.1367	0.1364	0.0000	0.1365	0.1364	0.1365	0.1365	0.1365	0.1363
Wear Area (Middle)												
1	0.1360	0.1359	0.1360	0.1360	0.1360		0.1360	0.1360	0.1362	0.1360	0.1361	0.1360
2	0.1360	0.1360	0.1358	0.1360	0.1362		0.1360	0.1358	0.1365	0.1361	0.1359	0.1362
3	0.1360	0.1360	0.1360	0.1362	0.1360		0.1360	0.1355	0.1360	0.1360	0.1360	0.1360
Avg.	0.1360	0.1360	0.1359	0.1361	0.1361	0.0000	0.1360	0.1358	0.1362	0.1360	0.1360	0.1361
Wear Area (Bottom)												
1	0.1360	0.1360	0.1361	0.1361	0.1362		0.1360	0.1360	0.1365	0.1360	0.1365	0.1365
2	0.1362	0.1365	0.1360	0.1360	0.1360		0.1360	0.1363	0.1363	0.1360	0.1360	0.1362
3	0.1360	0.1363	0.1359	0.1362	0.1365		0.1358	0.1361	0.1363	0.1360	0.1365	0.1360
Avg.	0.1361	0.1363	0.1360	0.1361	0.1362	0.0000	0.1359	0.1361	0.1364	0.1360	0.1363	0.1362
Intake Valve Stem Guide												
Wear Area Top	0.1380	0.1380	0.1375	0.1380	0.1382		0.1370	0.1380	0.1373	0.1370	0.1375	0.1370

Wear Area Middle	0.1385	0.1385	0.1380	0.1375	0.1380		0.1375	0.1383	0.1380	0.1370	0.1378	0.1385
Wear Area Bottom	0.1380	0.1390	0.1380	0.1382	0.1385		0.1370	0.1385	0.1380	0.1375	0.1380	0.1380

Appendix U-Blowers number of Pull start during Hot restart test

		Initial E0	Initial Blend	Midlife Blend	End Blend	End E0
P1	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	1	0	0	0	1
	# of No Choke Pulls	0	0	0	0	0
P2	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	1	0	0	1	1
	# of No Choke Pulls	0	0	0	0	0
P3	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	0	1	0	1	0
	# of No Choke Pulls	0	0	0	0	0
P4	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	0	0	0	0	1
	# of No Choke Pulls	0	0	0	0	0
P5	# of Full Choke Pulls	2	1	1	1	1
	# of Half Choke Pulls	0	0	0	1	1
	# of No Choke Pulls	0	0	0	0	0
P6	# of Full Choke Pulls	6	1	1	2	1
	# of Half Choke Pulls	1	0	0	0	1
	# of No Choke Pulls	0	0	0	0	0
P7	# of Full Choke Pulls	1	3	1	1	1
	# of Half Choke Pulls	1	2	0	1	1
	# of No Choke Pulls	0	0	0	0	0
P8	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	1	0	0	1	1
	# of No Choke Pulls	0	0	0	0	0
P9	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	0	0	0	0	0
	# of No Choke Pulls	0	0	0	0	0
P10	# of Full Choke Pulls	2	1	1	1	1
	# of Half Choke Pulls	0	1	0	1	1
	# of No Choke Pulls	0	0	0	0	0
P11	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	1	0	0	1	0
	# of No Choke Pulls	0	0	0	0	0
P12	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	1	0	0	1	0
	# of No Choke Pulls	0	0	0	0	0

Blowers number of Pull start during cold start test

		Initial E0	Initial Blend	Midlife Blend	End Blend	End E0
P1	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	0	0	0	0	0
	# of No Choke Pulls	0	0	0	0	0
P2	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	0	0	0	0	0
	# of No Choke Pulls	0	0	0	0	0
P3	# of Full Choke Pulls	2	1	1	1	1
	# of Half Choke Pulls	0	0	0	0	1
	# of No Choke Pulls	0	0	0	0	0
P4	# of Full Choke Pulls	1	2	1	1	1
	# of Half Choke Pulls	0	0	0	0	0
	# of No Choke Pulls	0	0	0	0	0
P5	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	1	0	0	0	0
	# of No Choke Pulls	0	0	0	0	0
P6	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	0	0	0	0	1
	# of No Choke Pulls	0	0	0	0	0
P7	# of Full Choke Pulls	2	1	1	1	1
	# of Half Choke Pulls	0	1	0	0	0
	# of No Choke Pulls	0	0	0	0	0
P8	# of Full Choke Pulls	2	1	1	1	1
	# of Half Choke Pulls	1	0	0	0	0
	# of No Choke Pulls	0	0	0	0	0
P9	# of Full Choke Pulls	1	1	2	1	1
	# of Half Choke Pulls	1	1	0	0	1
	# of No Choke Pulls	0	0	0	0	0
P10	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	0	0	0	0	1
	# of No Choke Pulls	0	0	0	0	0
P11	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	0	0	0	0	0
	# of No Choke Pulls	0	0	0	0	0
P12	# of Full Choke Pulls	1	1	1	1	1
	# of Half Choke Pulls	0	0	0	0	0
	# of No Choke Pulls	0	0	0	0	0

Appendix V- Trimmers number of Pull start during cold start test

		Initial E0	Initial Blend	Midlife Blend	End Blend	End E0
T1	# of Full Choke Pulls	3	5	5	5	5
	# of Half Choke Pulls	2	3	5	3	3
	# of No Choke Pulls	0	0	0	0	0
T2	# of Full Choke Pulls	3	5	5	5	5
	# of Half Choke Pulls	2	2	4	3	3
	# of No Choke Pulls	0	0	0	0	0
T3	# of Full Choke Pulls	2	2	5		
	# of Half Choke Pulls	1	1	3		
	# of No Choke Pulls	0	0	0		
T4	# of Full Choke Pulls	3	4	5	5	5
	# of Half Choke Pulls	2	1	3	3	3
	# of No Choke Pulls	0	0	0	0	0
T5	# of Full Choke Pulls	3	5	5		
	# of Half Choke Pulls	3	3	4		
	# of No Choke Pulls	0	0	0		
T6	# of Full Choke Pulls	3	5	3	5	5
	# of Half Choke Pulls	2	2	1	2	2
	# of No Choke Pulls	0	0	0	0	0
T7	# of Full Choke Pulls	3	5	5	5	5
	# of Half Choke Pulls	2	2	3	2	4
	# of No Choke Pulls	0	0	0	0	0
T8	# of Full Choke Pulls	3	2	5	5	3
	# of Half Choke Pulls	1	1	2	3	4
	# of No Choke Pulls	0	0	0	0	0
T9	# of Full Choke Pulls	2	5	5	5	5
	# of Half Choke Pulls	2	2	4	4	3
	# of No Choke Pulls	0	0	0	0	0
T10	# of Full Choke Pulls	3	5	5	5	5
	# of Half Choke Pulls	2	2	5	3	3
	# of No Choke Pulls	0	0	0	0	0
T11	# of Full Choke Pulls	3	7	5	5	5
	# of Half Choke Pulls	2	3	3	3	3
	# of No Choke Pulls	0	0	0	0	0
T12	# of Full Choke Pulls	5	5	5		
	# of Half Choke Pulls	2	4	4		
	# of No Choke Pulls	0	0	0		

Trimmers number of Pull start during hot restart test

		Initial E0	Initial Blend	Midlife Blend	End Blend	End E0
T1	# of Full Choke Pulls	5	6	5	4	3
	# of Half Choke Pulls	6	6	4	5	3
	# of No Choke Pulls	0	0	0	0	0
T2	# of Full Choke Pulls	5	5	5	3	3
	# of Half Choke Pulls	4	4	4	3	3
	# of No Choke Pulls	0	0	0	0	0
T3	# of Full Choke Pulls	5	7			
	# of Half Choke Pulls	4	6			
	# of No Choke Pulls	0	0			
T4	# of Full Choke Pulls	5	6	3	5	5
	# of Half Choke Pulls	5	4	3	3	3
	# of No Choke Pulls	0	0	0	0	0
T5	# of Full Choke Pulls	5	5	5		
	# of Half Choke Pulls	5	4	4		
	# of No Choke Pulls	0	0			
T6	# of Full Choke Pulls	5	6	3	3	3
	# of Half Choke Pulls	4	4	3	3	2
	# of No Choke Pulls	0	0	0	0	0
T7	# of Full Choke Pulls	5	5	2	4	3
	# of Half Choke Pulls	4	2	3	4	2
	# of No Choke Pulls	0	0	0	0	0
T8	# of Full Choke Pulls	5	6	5	2	5
	# of Half Choke Pulls	3	3	3	2	2
	# of No Choke Pulls	0	0	0	0	0
T9	# of Full Choke Pulls	5	5	3	3	3
	# of Half Choke Pulls	6	5	3	4	3
	# of No Choke Pulls	0	0	0	0	0
T10	# of Full Choke Pulls	5	5	5	4	3
	# of Half Choke Pulls	4	4	4	4	3
	# of No Choke Pulls	0	0	0	0	0
T11	# of Full Choke Pulls	5	6	3	1	3
	# of Half Choke Pulls	8	6	3	2	4
	# of No Choke Pulls	0	0	0	0	0
T12	# of Full Choke Pulls	5	5	4		
	# of Half Choke Pulls	5	5	4		
	# of No Choke Pulls	0	0	0		

Appendix w – Trimmers (T13-T24) number of Pull start during cold start test

		Initial E0	Initial Blend	Midlife Blend	End Blend	End E0
T13	# of Full Choke Pulls	2	0	3	4	7
	# of Half Choke Pulls	1	2	2	3	5
	# of No Choke Pulls	0	2	0	0	0
T14	# of Full Choke Pulls	3	2	4		
	# of Half Choke Pulls	0	0	0		
	# of No Choke Pulls	0	0	0		
T15	# of Full Choke Pulls	3	3	3	9	10
	# of Half Choke Pulls	1	2	2	6	2
	# of No Choke Pulls	0	0	0	0	0
T16	# of Full Choke Pulls	3	4	1	3	4
	# of Half Choke Pulls	1	3	2	2	2
	# of No Choke Pulls	0	0	0	0	1
T17	# of Full Choke Pulls	2	2	3	3	2
	# of Half Choke Pulls	1	2	2	3	1
	# of No Choke Pulls	0	0	0	0	0
T18	# of Full Choke Pulls	3	5	3	7	7
	# of Half Choke Pulls	3	4	2	6	5
	# of No Choke Pulls	0	0	0	0	0
T19	# of Full Choke Pulls	2	2	3	1	4
	# of Half Choke Pulls	2	4	4	5	4
	# of No Choke Pulls	0	0	0	1	0
T20	# of Full Choke Pulls	2	3	2	3	2
	# of Half Choke Pulls	1	2	1	2	1
	# of No Choke Pulls	0	0	0	0	0
T21	# of Full Choke Pulls	4	4	3	3	8
	# of Half Choke Pulls	2	3	2	2	4
	# of No Choke Pulls	0	0	0	0	0
T22	# of Full Choke Pulls	3	4	4	3	3
	# of Half Choke Pulls	2	3	4	4	2
	# of No Choke Pulls	0	0	0	0	0
T23	# of Full Choke Pulls	4	4	4	8	10
	# of Half Choke Pulls	3	2	3	7	7
	# of No Choke Pulls	0	0	0	2	1
T24	# of Full Choke Pulls	3	5	2	6	5
	# of Half Choke Pulls	2	2	1	4	4
	# of No Choke Pulls	0	0	0	0	0

Trimmers(T13-T24) number of Pull start during hot restart test

		Initial E0	Initial Blend	Midlife Blend	End Blend	End E0
T13	# of Full Choke Pulls					
	# of Half Choke Pulls	4	4	3	4	6
	# of No Choke Pulls					
T14	# of Full Choke Pulls					
	# of Half Choke Pulls	6	3	3	0	0
	# of No Choke Pulls					
T15	# of Full Choke Pulls					
	# of Half Choke Pulls	6	2	2	5	6
	# of No Choke Pulls					
T16	# of Full Choke Pulls					
	# of Half Choke Pulls	8	6	8	5	10
	# of No Choke Pulls					
T17	# of Full Choke Pulls					
	# of Half Choke Pulls	8	5	1	7	2
	# of No Choke Pulls					
T18	# of Full Choke Pulls					
	# of Half Choke Pulls	10	2	2	7	3
	# of No Choke Pulls					
T19	# of Full Choke Pulls					
	# of Half Choke Pulls	3	8	1	4	3
	# of No Choke Pulls					
T20	# of Full Choke Pulls					
	# of Half Choke Pulls	2	3	1	7	5
	# of No Choke Pulls					
T21	# of Full Choke Pulls					
	# of Half Choke Pulls	2	3	1	3	3
	# of No Choke Pulls					
T22	# of Full Choke Pulls					
	# of Half Choke Pulls	3	3	2	3	5
	# of No Choke Pulls					
T23	# of Full Choke Pulls					
	# of Half Choke Pulls	3	5	3	4	2
	# of No Choke Pulls					
T24	# of Full Choke Pulls					
	# of Half Choke Pulls	4	4	1	5	3
	# of No Choke Pulls					

Appendix X – Trimmer performance test data

Engine	Time period	position	condition	WOT/IDLE
T2	Initial blend	Inverted down	Died	idle
T2	midlife	Roll to right	Died	idle
T3	midlife blend	horizontal normal	Died	idle
T6	Initial blend	all the positions	Hesitate	idle/wot
T6	midlife blend	all the positions	Hesitate	idle/wot
T7	end of life blend	nose down	Died	idle
T7	end of life blend	Inverted down	Died	idle
T8	Initial blend	all the positions	Hesitate	wot
T9	Initial blend	Roll to right	Hesitate	wot
T9	Initial blend	nose down	Hesitate	wot
T9	Initial blend	Inverted down	Hesitate	wot
T9	midlife blend	horizontal normal	Died	wot
T9	end of life blend	all position	Hesitate	idle/wot
T11	Initial blend	all position	Hesitate	wot
T12	Initial E0	nose down	Died	idle
T12	midlife blend	all the positions	Hesitate	wot
T12	end of life blend	all the positions	Hesitate	wot
T13	Initial blend	Roll to right	Died	wot
T13	end of life E0	Roll to right	Died	idle
T14	Initial E0	Roll to right	Hesitate	wot
T14	Initial blend	all the positions	Hesitate	wot
T15	Initial blend	Inverted down	Hesitate	wot
T16	Initial E0	Roll to right	Hesitate	wot
T17	end of life blend	Roll to right	slow	wot
T18	midlife blend	Roll to right	Hesitate	wot
T19	initial E0	all the positions	Hesitate	wot
T21	end of life blend	all the positions	Died	idle
T22	midlife blend	all the positions	slow	wot
T23	initial E0	all the positions	Hesitate	wot