2nd VegOil

Demonstration of 2nd Generation Vegetable Oil Fuels in Advanced Engines

Workpackage WP4

Engine Oil Development

Deliverable N° 4.6:

Conclusions from Engine Oil with Tier 4 Engines Publishable

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prepared by: Lubrizol Ltd.

Dr. Craig Jones

Lubrizol Limited
The Knowle, Hazelwood
GB Derbyshire DE 56 4AN
Tel.: +44 1332 842211
Fax.: +44 1773 551911
Email: craig.jones@lubrizol.com
Partner website : www.lubrizol.com
Project website : www.2ndVegOil.eu

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1 Results from Engine Oil with Tier 4 Engines

An ACEA E9 engine lubricant (ref: Deliverable 4.11a, Section 2) has been supplied to the relevant test facilities to enable them to conduct their field trial activities (ref: Deliverable 4.11a, Section 1). ACEA E9 engine lubricants are suitable for use in heavy duty vehicles fitted with DPF's according to the ACEA 2008 Engine Oil Sequences (ref: Deliverable 4.1, Appendix A).

Used engine lubricant samples have been supplied to Lubrizol by these test facilities.

Lubrizol has analysed these used engine lubricant samples using various industry standard used lubricant analysis techniques:

- Total Base Number (TBN by ASTM method D2896)
- Total Base Number (TBN by ASTM method D4739)
- Kinematic Viscosity (tested at 40^{o}C and 100^{o}C by ASTM method D7279)
- Total Acid Number (TAN by ASTM method D664)
- Wear metals and engine lubricant additive depletion, measured by Inductive Coupled Plasma (ICP)
- High Temperature High Shear viscosity (as measured by CEC Test method L-36-A-90)
- Percentage soot measured by Thermogravimetic Analysis (TGA)

The analytical data (ref: Table 1) from the used engine lubricant samples is detailed in Table 1 and shown graphically in Appendix B.

Table 1 Summary of Analytical Data from used Lubricant Samples

	Fresh Lubricant Code	OS240946	OS240946	OS240946	OS240946	OS240946
	Lubricant	ACEA E9	ACEA E9	ACEA E9	ACEA E9	ACEA E9
	Date Lubricant Sample Received	Fresh Oil Sample	Aug-09	Oct-09	Mar-10	Mar-10
	Tractor ID		613519	613519	613532	586574
	Tractor Owner		JDWM	JDWM	JD Seriel Washers	JDWM
	Tractor Operating Hours			355	397	1814
	Lubricant Operating Hours		246.3	259	250	
Test	**Test Method**					
TBN mg KOH/g	ASTM D2896	8.4	8.91	9.18	8.28	8.48
TBN-INFLECTION mg KOH/g	ASTM D4739	6.99	6.6	6.38	6.5	7
VISCOSITY @40 cSt	ASTM D7279	114.4	103	106	109.4	106.6
VISCOSITY @100 cSt	ASTM D7279	15.82	14.1	14.4	14.3	13.8
TAN BUFFER mg KOH/g	ASTM D664	2.47	2.55	2.45	3.51	2.29
Ca ppm	Inductive Coupled Plasma	2337	2449	2411	2292	2402
Cu ppm		0	4	5	2	7
Fe ppm		0	29	27	23	35
Mg ppm		0	7	6	6	7
Na ppm		0	0	4	0	13
P ppm		1098	1024	1040	1168	1055
Pb ppm		0	2	0	0	0
S ppm		3693	3701	3501	3352	3876
Si ppm		0	3	4	2	18
Zn ppm		1198	1186	1194	1167	1169
HTHSR cP	CEC L-36-A-90	4.43	4.2	4.25	4.2	
CARBON %wt	Thermogravimetric Analysis	0	0.511	0.476	0.21	0.174

Note:
Tractor operating hours = the total number of hours the tractor has been in operation
Lubricant operating hours = the number of hours the lubricant has been in operation in the tractor

Table 2 John Deere "Warning Limits" for Wear Metals and Other Elements

Table 2 contains the "warning limits" John Deere apply for wear metals and other elements based on used lubricant analysis when measured by ICP.

Element	Warming Limit - maximum As measured by ICP (ppm)
Aluminium	20
Chromium	15
Copper	150 for 1st lubricant drain 20 for subsequent lubricant drains
Iron	125*
Lead	40
Nickel	10
Potassium	30
Tin	25
Silicon	30
Sodium	20

* John Deere warning limit is 0.5 ppm per hour. This per hour warning limit has been translated into a limit for 250 lubricant operating hours (due to the field trial tractors running for approximately 250 hours for each lubricant drain)

Review of the used lubricant samples shows

- Total Base Number (TBN by ASTM method D2896) and Total Base Number (TBN by ASTM method D4739)
  - Very little reduction in TBN is noted (<10%). This is considered to be a very small reduction in TBN. This highlights that the engine lubricant is effectively neutralising the acidic components caused by the combustion process.

- Kinematic Viscosity (tested at 40^{o}C and 100^{o}C by ASTM method D7279)
  - All used lubricant samples fall within the stay in grade specification for the ACEA E9 2008 specification (note: the stay in grade specifications for SAE 40 viscosity grade lubricants is between 12.5 to <16.3 mm^2/s according to SAE J300). The slight reduction in kinematic viscosity measured at 100^{o}C for all the used engine lubricant samples is considered to be normal as has been caused by the shearing of the viscosity modifier used in the engine lubricant.

- Total Acid Number (TAN by ASTM method D664)
  - Very little increase in TAN has been noted. This is combination with the small reduction in TBN confirms that the engine lubricant is effectively neutralising the acidic components caused by the combustion process.

- Wear metals and engine lubricant additive depletion, measured by Inductive Coupled Plasma (ICP)
  - Wear Metals
    - Copper (Cu), iron (Fe) and lead (Pb) are typical wear metals. Cu and Pb are usually found in specific engine parts (e.g. bearings), whilst Fe is contained in many engine parts. Measurement of excessively high levels of Cu, Fe or Pb in used engine lubricants usually indicate that a specific engine component is wearing and this may become a concern for long term engine durability. It should be noted however that some low level of wear will be experienced by all engines and therefore it is not unusual for Cu, Fe and Pb to be measured in used lubricant samples at low levels.
    - The maximum measured levels of Cu, Fe and Pb shown in Table 1 are considered to be very low and within normal operating levels for engines operating under the conditions of the field trial.

This is confirmed by the wear metals from each used lubricant sample being significantly below the John Deere warning limits shown in Table 2.

- The measured additive metals, calcium (Ca), phosphorus (P), sulphur (S) and zinc (Zn) highlight no change compared to the fresh oil.

- High Temperature High Shear viscosity (as measured by CEC Test method L-36-A-90)
  - Very little change in dynamic viscosity is noted between the fresh and used lubricant samples.

- Percentage soot measured by Thermogravimetic Analysis (TGA)
  - The soot levels in all the used lubricant samples are very low. This highlights that the combustion process is not producing a high level of soot species. The level of soot present in the engine lubricant are not expected to cause any problems in terms of soot handling capability of the engine lubricant.

2 Conclusions from Engine Oil with Tier 4 Engines

The analysis of the used lubricant samples highlighted in Section 1 confirms that the engine lubricant has not significantly changed compared to the fresh engine lubricant.

The ACEA E9 lubricant (OS240946) used in the evaluation of the Tier 4 engines is therefore considered suitable for this application (up to a drain oil interval of 250 hours). An assessment of engine lubricant performance beyond 250 hours in DPF fitted tractors is recommended.

Appendix A

List of Acronyms

ACEA – European Automobile Manufactures Association
E9 – An engine lubricant which meets the ACEA E9 engine lubricant specification
DPF – Diesel Particulate Filter

Appendix B

Graphical Results from Engine Lubricant Analysis

Figure 1 Total Base Number by ASTM D2896

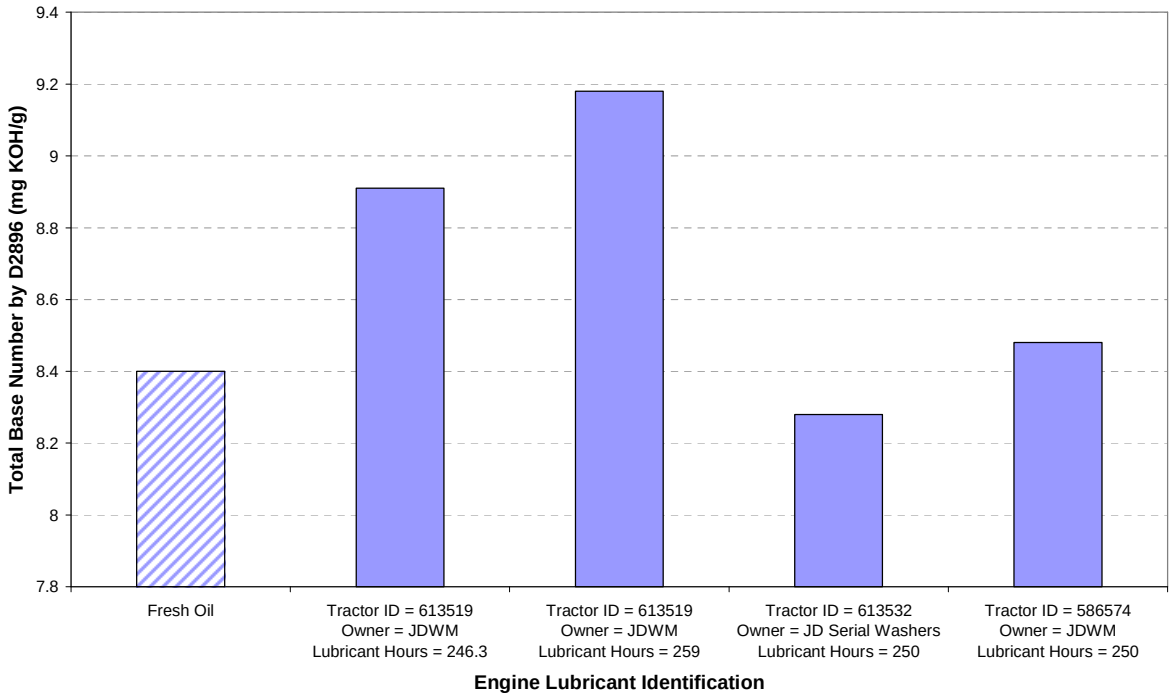

Figure 2 Total Base Number by ASTM D4739

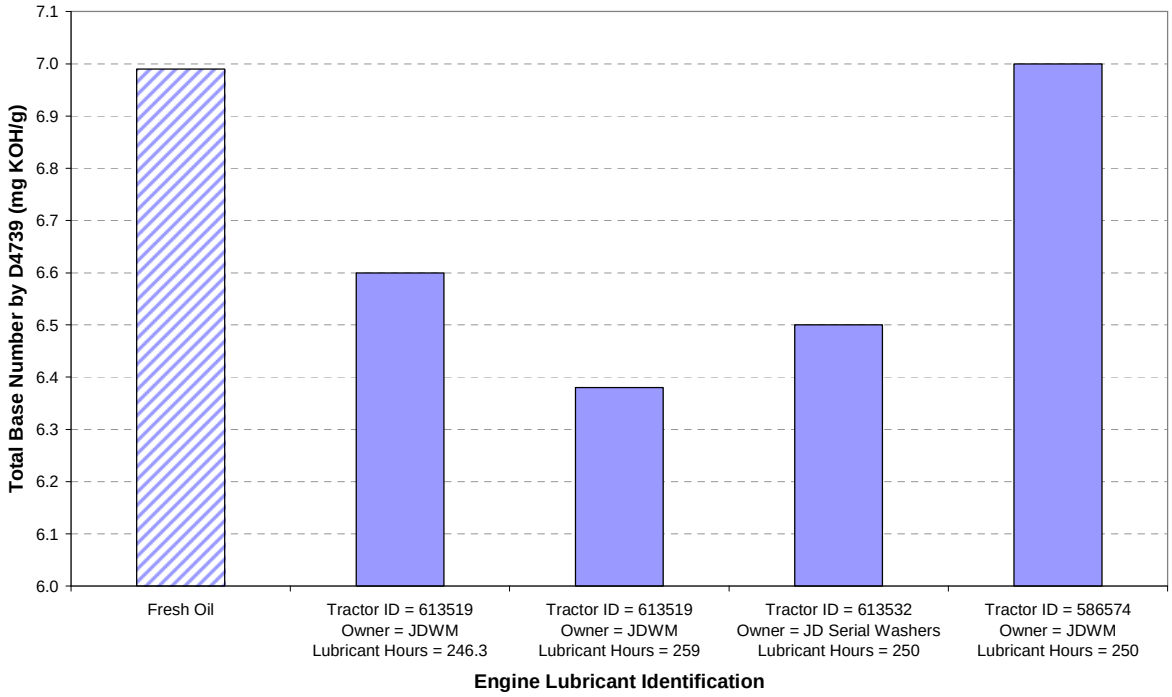

Figure 3 Kinematic Viscosity at 40°C by ASTM D7279

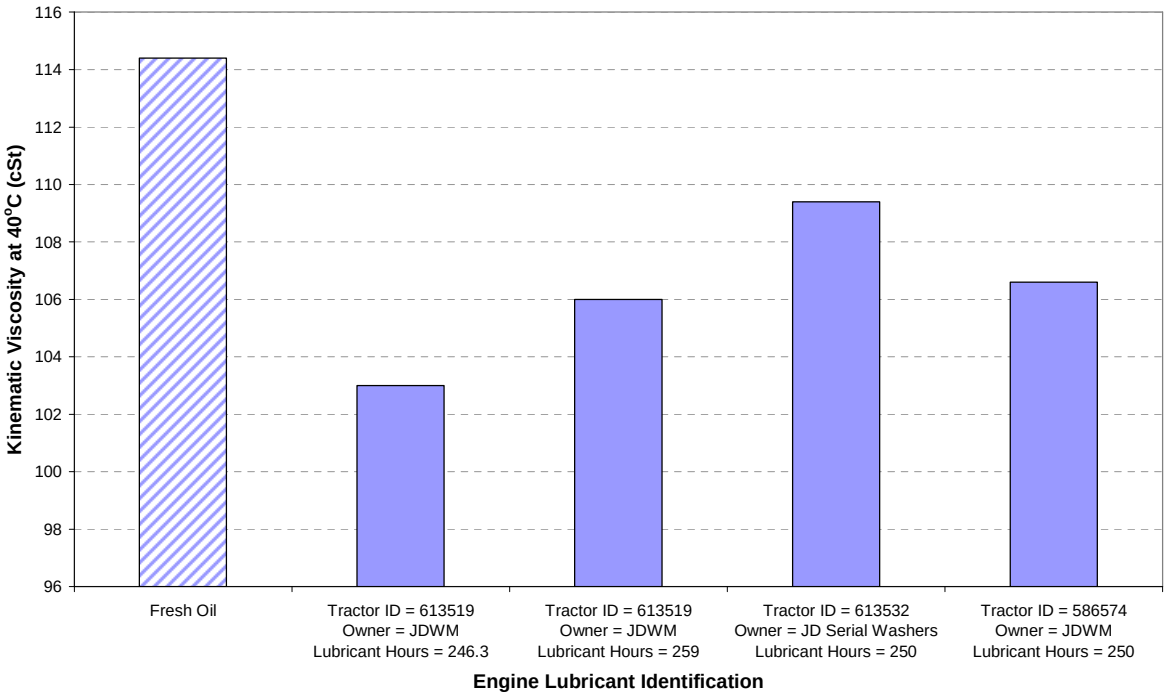

Figure 4 Kinematic Viscosity at 100°C by ASTM D7279

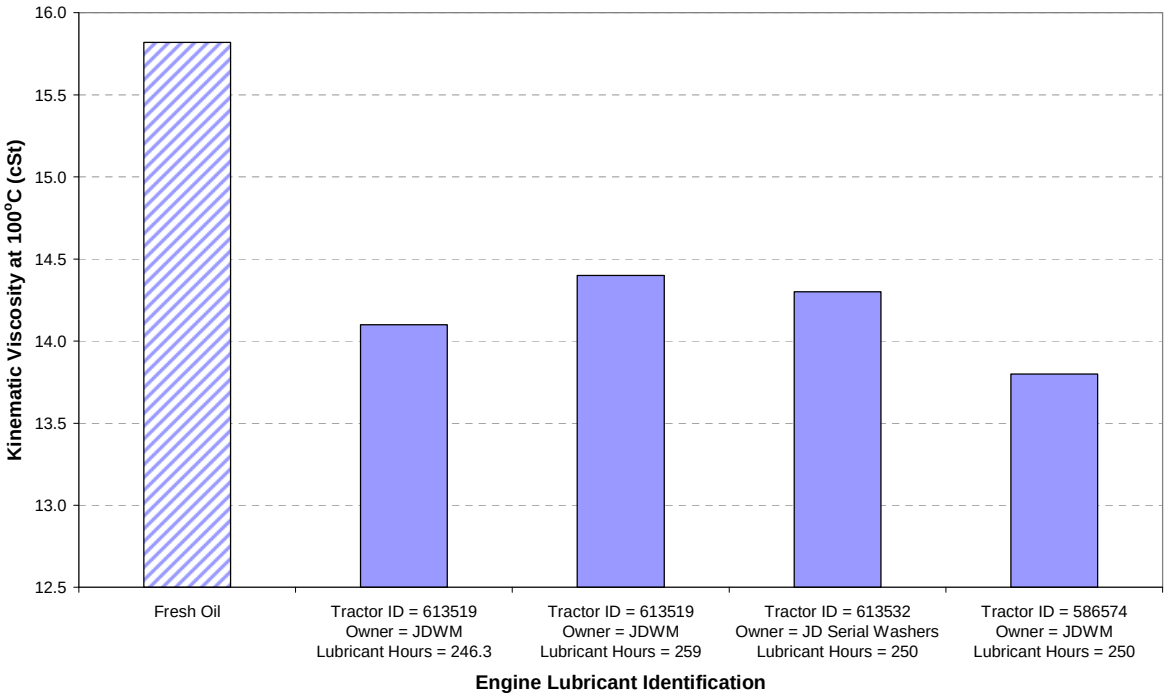

Figure 5 Total Acid Number by ASTM D664

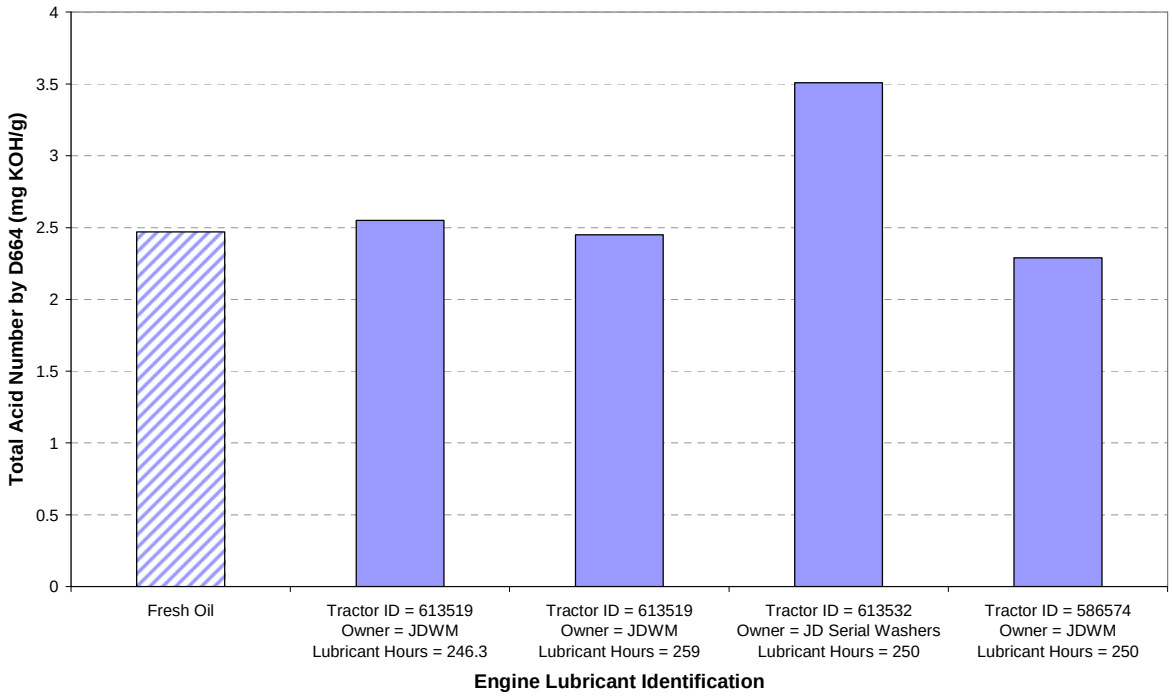

Figure 6 Wear Metals by ICP

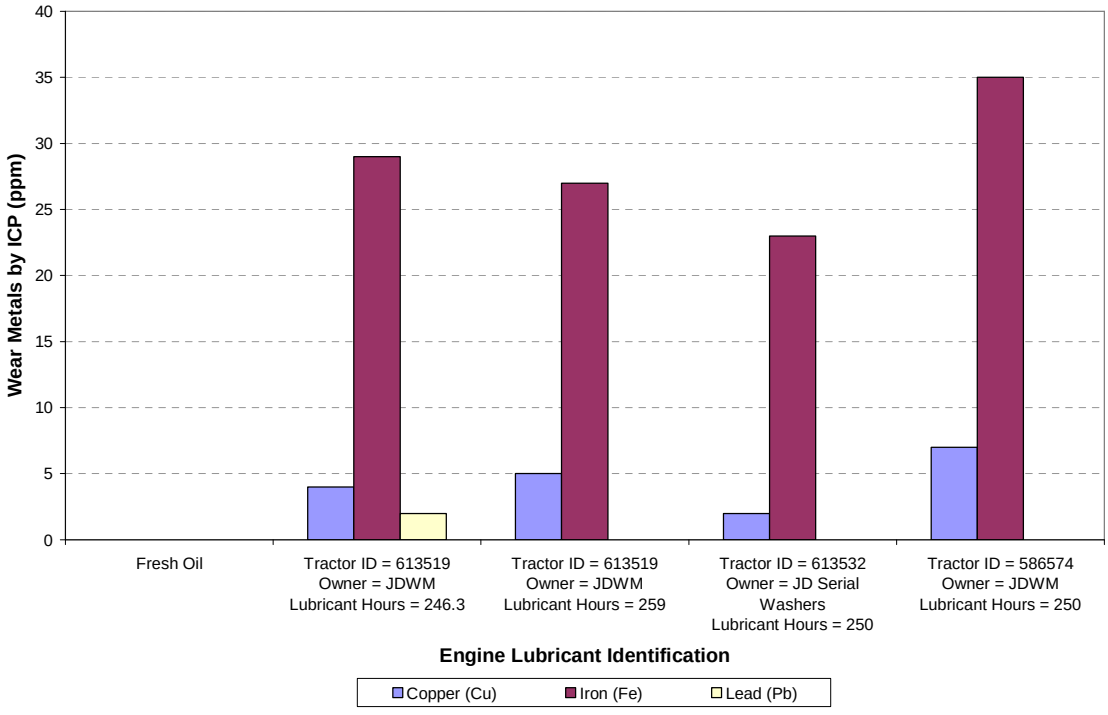

Figure 7 Additive Metals by ICP

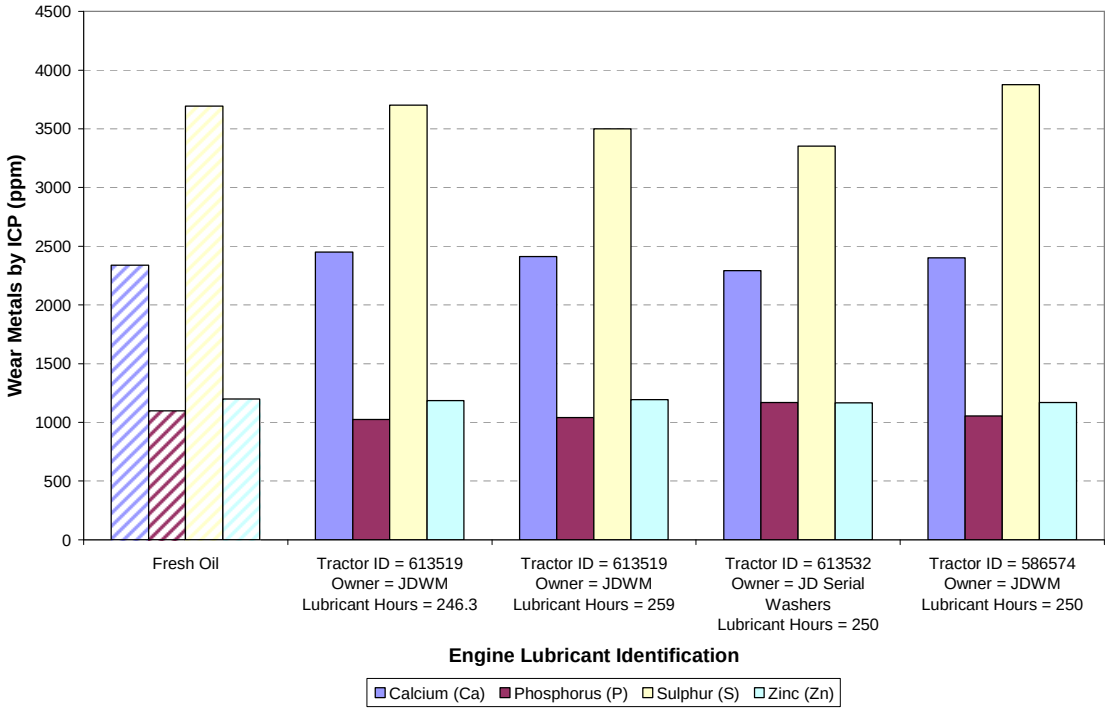

Figure 8 High Temperature High Shear Viscosity by CEC L-36-A-90

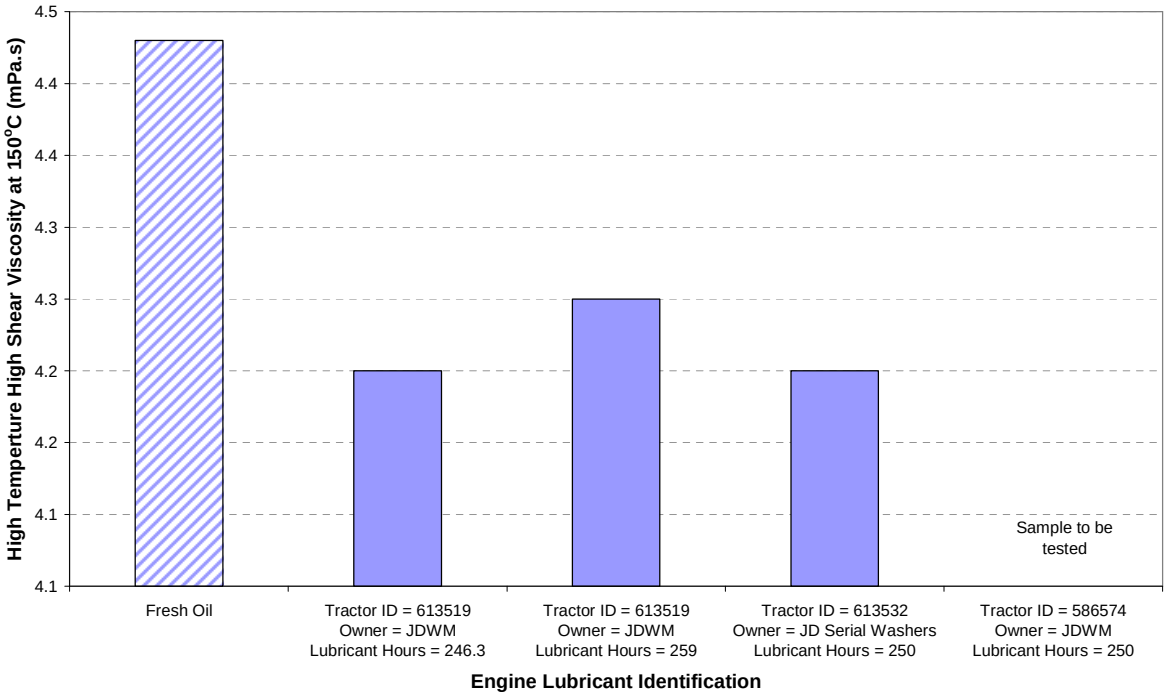

Figure 9 Percent Soot Measured by TGA