Evaluation of Emissions of a Stage V Telehandler with two fuels (diesel and Green D+) while performing routine work

Conclusions

- A method for comparing the performance of two fuels on one engine undertaking in-service operations has been developed involving sorting the data on the basis of lowest to highest energy outputs and taking tranches of 1000 seconds for inputs and outputs of the engine. This method relies principally on the gradient (the rate of change) of the variable for observing changes and trends.
- NOx values are too high for a Stage V engine and are not interpreted here.
- CO values are very low as would be expected for a Stage V engine.
- PN emissions are reduced between 46 to 96% with Green D+ relative to diesel.
- The data indicates a fuel efficiency improvement with 0.55% less fuel being consumed with Green D+ relative to diesel.
- The CO_2 emissions (a function of fuel consumption) was 6.5% lower with Green D+ and is consistent with a fuel efficiency improvement.
- The Greenhouse gas emission with Green D+ are lower by 92% relative to diesel B7.

Introduction

Emissions from a Stage V JCB 540-140 Telehandler (registration YT21SZO) were measured with Diesel on 21st September and with Green D+ on 13th October 2021. Measurements were conducted by Emissions Analytics.

The objective of the trial was to evaluate emissions of a Telehandler while running on retail diesel (B7) and on Green D+ while the vehicle is in-service conducting its regular duty. Testing was conducted at Hemins Place, Bicester. The diesel baseline was measured on 21st September and the Green D+ was measured on 13th October 2021.

Experimental Details

Equipment:

- A SEMTECH-LDV (Sensors Inc) analyser was used for measurement of tailpipe gases, CO, CO_2, NO and NO_2.
- Sensors Condensation Particle Number analyser was used for measurement of particulate number.
- Span and zero calibrations of the gaseous measurement equipment were performed at the start and the end of each test cycle. The zero calibration was performed with pure nitrogen, followed by the span calibration against gas bottles of known concentration (provided by Air Liquide).

Test method:

The mobile equipment was fitted onto the equipment, which then proceeded to carry out its daily duty. After the fuel change from diesel to Green D+, the vehicle was operated for 80 hours prior to the test measurements. The fuel filter was changed.

Results and Discussion.

- Basis for a valid comparison:

The difficulties of performing a comparison of emissions due to the fuel change are not insignificant when applied to emissions measured during in-service duty operations. The work and speed variations are completely random. The atmospheric conditions and conditions of the terrain were quite different during this study (temperature and humidity). The drivers were also not the same and the study was performed with a considerable time interval between the two.

The temperature – time profile for the two trial periods (Active and Idle) are shown in Figure 1 and 2 for the two fuels.

Figure 1: Temperature – time (seconds) profile for 'Active' mode

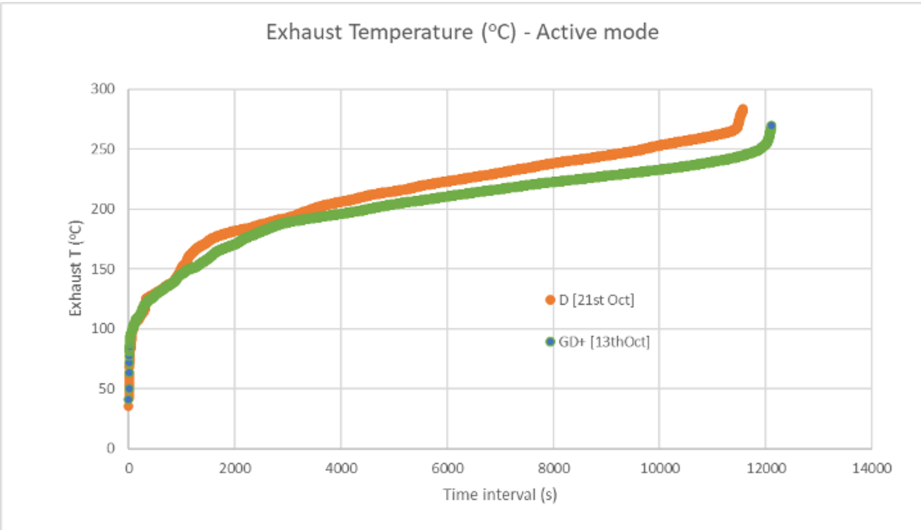
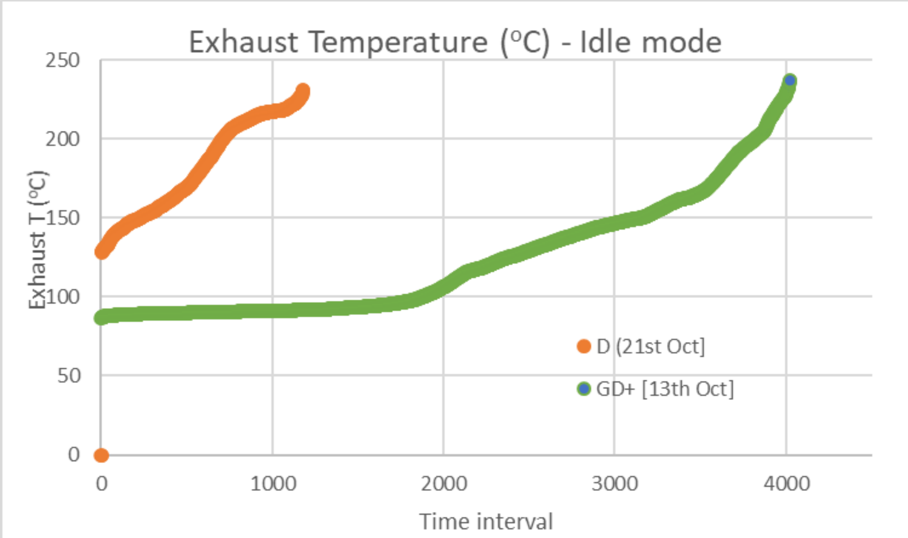


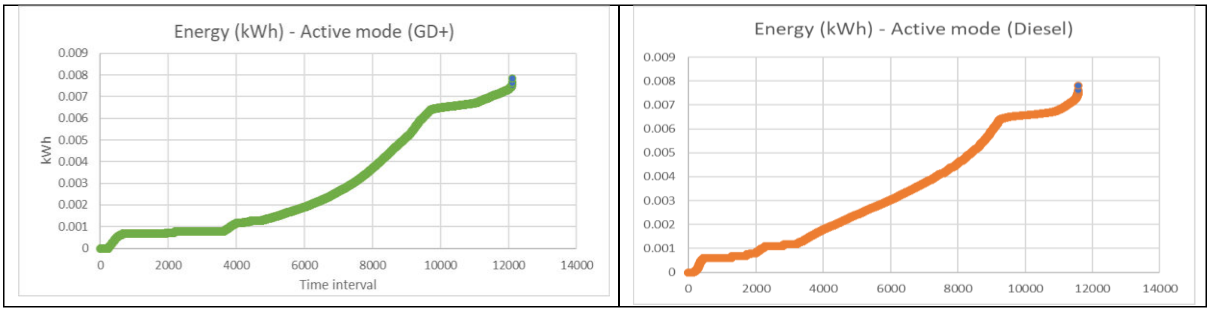
Figure 2: Temperature – time (seconds) profile for 'Idle' mode



The option of dividing the results into sequential tranches would not overcome the difficulty of comparing apples with pear. Graphs of the sequential CO_2 and power outputs indicate that the two days were very different therefore a random side by side comparison would not be appropriate.

The data were sorted in order of increasing Energy output. This provided similar profiles for both fuels. The Green D+ and Diesel profiles are shown in Figure 3.

Figure 3: Energy outputs (sorted in order of increasing energy)



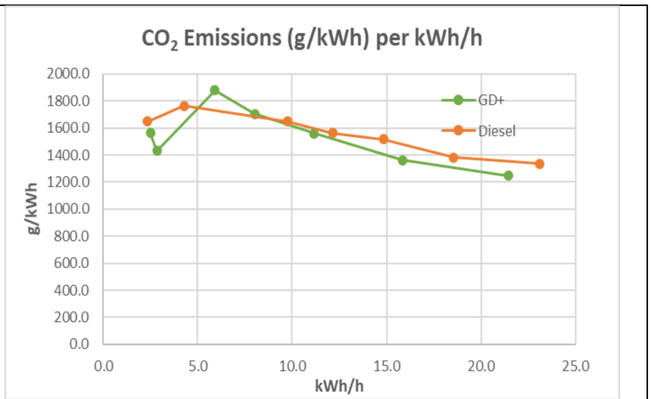
Seven 1000 second tranches of increasing energy output were the selected and the sum of the outputs (energy, fuel consumption, CO_2, CO NOx and PN) are shown in Table 1

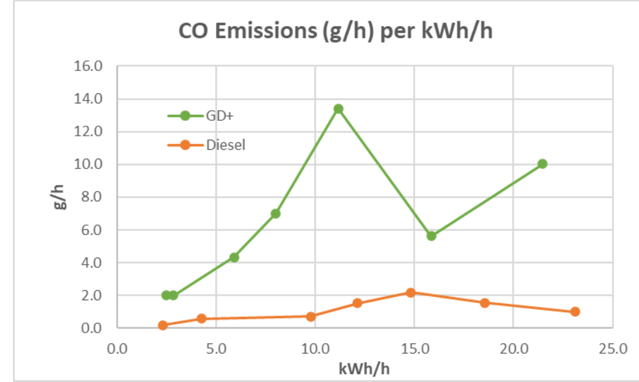
	GD+					
	Energy	Fuel	CO_2	CO	NOx	PN
per 1000s>	kWh	L	g	g	g	# x 10^{11}
1	0.6922	0.4429	1080.826	0.559	10.970	0.0203
2	0.7910	0.4640	1132.359	0.556	11.699	0.0116
3	1.6393	1.2581	3077.627	1.207	31.743	0.1787
4	2.2287	1.5532	3799.666	1.949	33.250	0.3467
5	3.1016	1.9775	4837.447	3.726	32.859	0.6795
6	4.4016	2.4474	5991.902	1.558	33.387	1.1518
7	5.9642	3.0390	7443.173	2.785	39.743	0.8305
per hour	kWh/h	L/h	g/h	g/h	g/h	# x 10^{11}/h
1	2.4921	1.5945	3890.974	2.011	39.493	0.0730
2	2.8476	1.6706	4076.491	2.003	42.116	0.0417
3	5.9014	4.5292	11079.459	4.344	114.275	0.6433
4	8.0233	5.5915	13678.799	7.018	119.699	1.2481
5	11.1659	7.1192	17414.808	13.413	118.291	2.4461
6	15.8459	8.8107	21570.848	5.608	120.192	4.1466
7	21.4712	10.9405	26795.422	10.025	143.074	2.9899
		L/kWh	g/kWh	g/kWh	g/kWh	# x10^{11}/kWh
1		0.6398	1561.337	0.807	15.848	0.0293
2		0.5867	1431.573	0.703	14.790	0.0146
3		0.7675	1877.442	0.736	19.364	0.1090
4		0.6969	1704.878	0.875	14.919	0.1556
5		0.6376	1559.643	1.201	10.594	0.2191
6		0.5560	1361.289	0.354	7.585	0.2617
7		0.5095	1247.968	0.467	6.664	0.1392

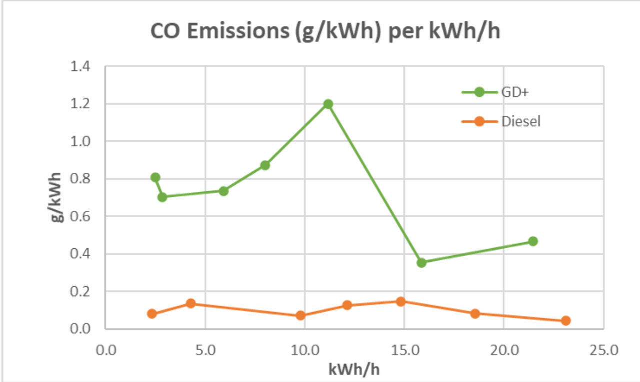
	Diesel					
	Energy	Fuel	CO_2	CO	NOx	PN
per 1000s>	kWh	L	g	g	g	# x 10^{11}
1	0.6493	0.4109	1071.351	0.052	10.417	0.2238
2	1.1862	0.8025	2092.051	0.162	25.326	0.3919
3	2.7176	1.7173	4476.783	0.194	26.345	1.2637
4	3.3732	2.0212	5268.527	0.424	27.066	1.3609
5	4.1215	2.3966	6246.824	0.604	28.118	1.8626
6	5.1515	2.7282	7111.620	0.428	31.225	2.4031
7	6.4142	3.2893	8574.315	0.281	37.589	2.3276
per hour	kWh/h	L/h	g/h	g/h	g/h	# x 10^{11}/h
1	2.3376	1.4791	3856.864	0.188	37.502	0.8058
2	4.2702	2.8889	7531.384	0.584	91.174	1.4108
3	9.7835	6.1822	16116.419	0.700	94.843	4.5493
4	12.1437	7.2762	18966.697	1.527	97.438	4.8993
5	14.8375	8.6276	22488.566	2.174	101.223	6.7054
6	18.5453	9.8214	25601.832	1.541	112.410	8.6513
7	23.0912	11.8416	30867.534	1.011	135.320	8.3793
		L/kWh	g/kWh	g/kWh	g/kWh	# x10^{11}/kWh
1		0.5935	1547.649	0.075	15.049	0.3234
2		1.0145	2644.855	0.205	32.018	0.4954
3		1.0476	2730.967	0.119	16.071	0.7709
4		0.9069	2363.943	0.190	12.144	0.6106
5		0.7727	2014.041	0.195	9.065	0.6005
6		0.6198	1615.676	0.097	7.094	0.5460
7		0.5515	1437.623	0.047	6.302	0.3903

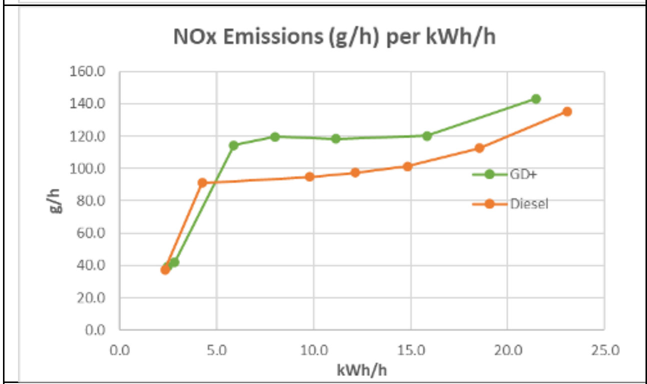
From these data it is apparent that the NOx emissions are far too high for a Stage V engine ranging from 6 to 32 g/kWh (the limit for this engine is 0.4g/kWh). It would suggest either that the NOx abatement system was not functioning correctly, or that the instrument was inaccurate for this emission. The results in Table 1 are shown in Figure 4.

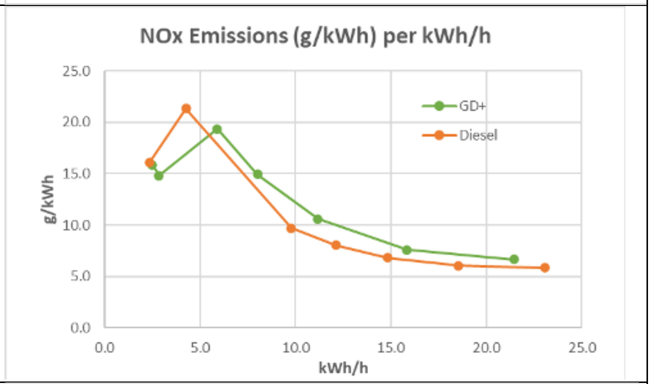
Figure 4: Results for CO_2, CO, NOx, PN and Fuel consumption in g/h and g/kWh versus kWh/h

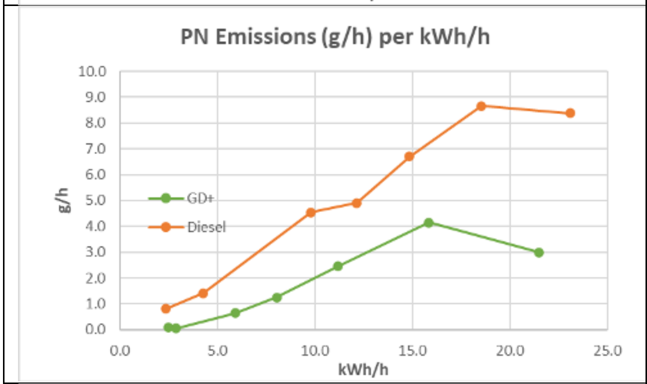


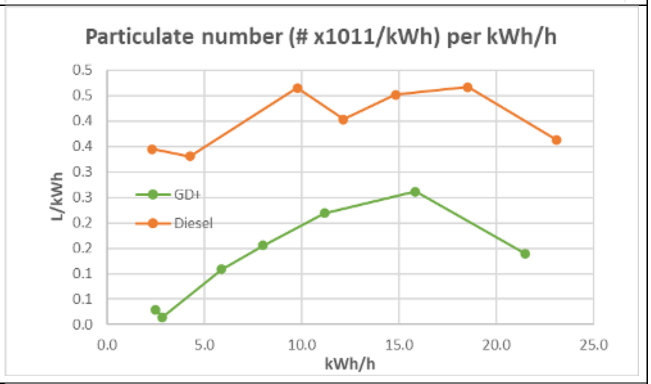


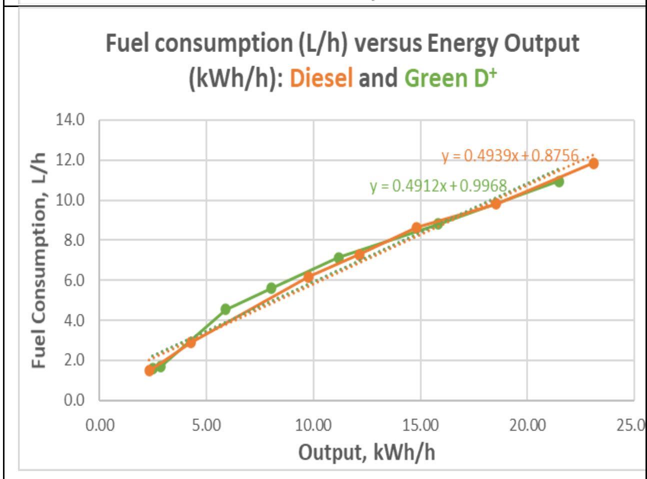


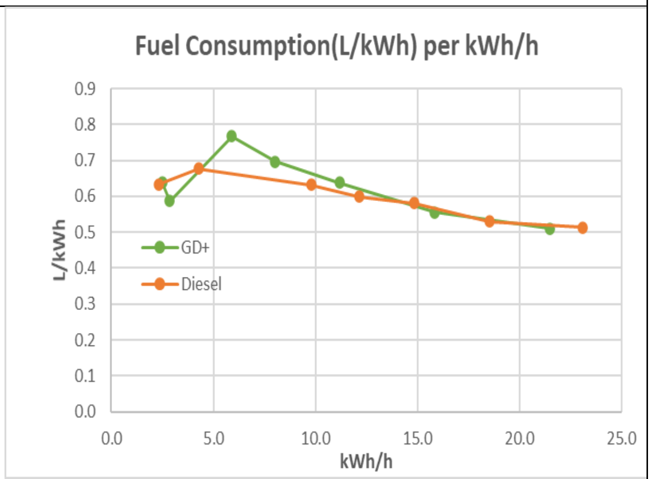












- The CO emissions are very low. The NOx emissions are high. In a Stage V engine both these pollutants would be removed by the after-treatment system.

- PN shows the expected reduction with Green D+, a reduction of 44% to 96% across the output range.
- The fuel consumption and CO_2 emissions show similar profiles for both fuels. The CO_2 emission appears to be fractionally lower with Green D+. The fuel consumptions graphs are virtually superimposable. The linear equations fitted to the data for the two fuels indicate the following Specific fuel consumption and CO_2 emissions values:

Table 2: Gradients of quasi-linear graphs of Specific fuel consumption and CO_2 (mass) emissions

	Specific FC	Specific CO_2 emission
Green D+	0.4912 L/kWh	1203.8 g/kWh
Diesel	0.4939 L/kWh	1287.4 g/kWh

Fuel consumption is 0.55% lower with Green D+.
CO_2 emission is 6.5% lower with Green D+

Theoretical calculations predict that substitution of Green D+ with diesel will result in a volumetric increase in fuel consumption of 4.71% and a decrease of 4.2% CO_2 in the exhaust stream. This calculation is based on an assumption of equal fuel efficiency.

- The greenhouse gas, CO_2e, emissions associated with Green D+ is 249g CO_2e/L. The corresponding value for diesel is 3122g CO_2e/L. The GHG emission is lowered by 92% with Green D+. [source: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021].

Conclusions

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[Note: The data were collated by Emissions Analytics for Green Biofuels Limited. The analysis and interpretation of the data are the sole property of GBF Ltd.]

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