CERTIFICATE OF TESTING

Technology Group

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ISSUED TO:	**Mr. David Abbott (M.D.)**	PAGE:	**1 of 5**

Title:	Comparative fuel consumption tests diesel vs LPG mix on a SCANIA R420 tractor unit with a GSPK diesel-gas system
Test standard(s):	LTC and GSPK defined procedures
Test piece description:	SCANIA R420 (Euro3) 4x2 tractor unit

OBJECTIVES:

1. To determine the likely fuel cost savings on typical long-haul distribution work for a SCANIA tractor unit with a GSPK LPG system with an optimised LPG control map.
2. To quantify the increase in engine torque and maximum power (if any) with the optimised LPG control map (compared with the diesel baseline)

CONCLUSIONS:

1. During simulated motorway running at RSL speed (nominally at 56mph) with the engine developing 170kW power at the wheels, this vehicle showed a 12% fuel cost saving when running on LPG mix with the optimised control map (MAP3) when compared with the diesel baseline (see Fig.1, mode 1 results).
2. The 8-mode test, which simulated running at motorway speed (56mph RSL) and at 80km/h for A-roads and dual-carriageways, shows the % fuel cost savings at typical engine load conditions for this vehicle (Fig.1). By applying weighting factors to those mode results based on typical operating patterns for this vehicle, an overall fuel cost saving of 14.5% was predicted (Fig.2). Over the same 8-mode test the previously installed LPG control map (MAP1) predicted much lower fuel cost savings of 6%. However, as the vehicles in this fleet are returning significant fuel cost savings in service with the current LPG map (MAP1), there is a high level of confidence that fuel cost savings will improve further when running with the newly optimised LPG map (MAP3).

Certified that the specimens detailed hereon have been subjected to the tests as required by the contract/order unless otherwise stated above.

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CONCLUSIONS: (continued)

3. When running on diesel/LPG mix with the optimised MAP3 installed there was virtually no increase in the maximum torque or power of the engine (as measured at the road wheels) when compared with the diesel baseline for this vehicle. There was a small increase in torque and power at 1200 rpm only, which will enhance the driveability of the vehicle slightly.
4. There was a small increase in exhaust gas temperature with LPG (MAP3) when compared to the diesel baseline but only at low engine speeds under full load conditions. The maximum exhaust gas temp. on the diesel full load power curve was 560 deg.C at 900 rpm and the maximum temp. on the LPG full load power curve was 600 deg.C at 900 and 1000 rpm. The increase in exhaust temperature was less than 20 deg.C (in 500) over the main engine full load power curve (1200 to 1900 rpm).

   During the 8-mode test, at lower engine load levels which reflect typical engine operating conditions, the exhaust gas temperatures were slightly lower on LPG than on diesel only (within 10 deg.C)

TEST METHOD:

The vehicle was installed on the SAC dyno. (rolling road) at LTC and tested under precisely controlled engine speed and load conditions.

The vehicle's baseline power curve was measured in 9th gear on diesel only prior to the LPG map optimisation (see Fig.3) and then measured again on diesel/LPG mix with the optimised MAP3 installed (see Fig.4). Engine speed, road speed, tractive effort, inlet manifold (boost) pressure and exhaust gas temperature were measured and power at the wheels was calculated from road speed and tractive effort. The tractive effort curve equates with the engine torque curve.

Diesel and LPG consumption rates were then determined during steady state running at the required conditions with the optimised MAP3 installed.

Back to back tests were carried out simulating motorway running at 56mph (RSL setting) using typical road load values for a laden 38/40 tonne tractor/trailer combination.

Back to back tests were then carried out using an 8-mode test with 2 speeds (56mph and 50mph) and 4 engine load levels based on a statistical analysis of engine speed and load data from typical truck journeys with this type of vehicle. (see Fig.1)

From these results a prediction of fuel cost savings in service operation was made by applying weighting factors to each mode, based on an analysis by GSPK of a sample of typical journeys with a similar truck. (see Fig.2)

RESULTS:

8-mode test at 2 engine speeds corresponding to 56mph and 50mph in top gear.

4 demand levels (engine load) based on GSPK analysis of sample of typical journeys

Fig.1 Fuel cost savings with optimised map (MAP3) on 8-mode test

Mode	Fuel / MAP	Engine speed rpm	GSPK Demand actual	Power at wheels kW	Total diesel litres	Total LPG litres	LPG % by volume	% Diesel reduc'n	Total fuel cost £	% saving c/w diesel
1	Diesel	1385	51	171.4	1.60	0.00	0.0	0.0	1.33	0
	MAP3	1385	45	171.4	1.19	0.60	33.5	25.6	1.17	**12.1%**
2	Diesel	1385	33	126.1	1.21	0.01	0.0	0.0	1.01	0
	MAP3	1385	28	127.3	0.81	0.66	44.9	33.1	0.87	**13.6%**
3	Diesel	1385	21	97.5	0.96	0.01	0.0	0.0	0.80	0
	MAP3	1385	20	97.5	0.62	0.63	50.4	35.4	0.70	**12.0%**
4	Diesel	1385	0	39.9	0.52	0.01	0.0	0.0	0.43	0
	MAP3	1385	0	39.9	0.52	0.01	1.9	0.0	0.43	0.0%
5	Diesel	1282	50	170.0	1.57	0.01	0.0	0.0	1.31	0
	MAP3	1282	44	170.4	1.11	0.51	31.5	29.3	1.07	**17.7%**
6	Diesel	1282	30	130.8	1.20	0.01	0.0	0.0	1.00	0
	MAP3	1282	28	130.6	0.80	0.50	38.5	33.3	0.81	**18.5%**
7	Diesel	1282	21	102.2	0.97	0.01	0.0	0.0	0.81	0
	MAP3	1282	21	101.7	0.59	0.46	43.8	39.2	0.63	**22.3%**
8	Diesel	1282	0	35.9	0.47	0.00	0.0	0.0	0.39	0
	MAP3	1282	0	35.9	0.47	0.00	0.0	0.0	0.39	0.0%
Modes 1 to 4 at RSL (87 km/h) and modes 5 to 8 at 80 km/h										

Weighting factors were applied to the results of these 8-modes also based on GSPK analysis of sample journeys with a similar vehicle and operation to provide a prediction of expected fuel cost savings on long haul distribution work.

Fig.2 Predicted fuel cost savings in service based on results from 8-mode test

Mode	Weighting factor %	Diesel used (weighted)	LPG used (weighted)	Diesel only cost (gas off)	Diesel cost (gas on)	LPG cost (gas on)	Total cost (gas on)	%age cost savings	Diesel reduction	% LPG	Total fuel Increase
1	5	8.00	0.00	**6.64**							
	5	5.95	3.00		4.94	0.90	**5.84**	**12.1%**	25.6%	33.5%	11.9%
2	20	24.20	0.20	**20.09**							
	20	16.20	13.20		13.45	3.96	**17.41**	**13.3%**	33.1%	44.9%	21.5%
3	40	38.40	0.40	**31.87**							
	40	24.80	25.20		20.58	7.56	**28.14**	**11.7%**	35.4%	50.4%	30.2%
4	5	2.60	0.05	**2.16**							
	5	2.60	0.05		2.16	0.01	**2.17**	**-0.7%**	0.0%	1.9%	1.9%
5	1	1.57	0.01	**1.30**							
	1	1.11	0.51		0.92	0.15	**1.07**	**17.6%**	29.3%	31.5%	3.2%
6	9	10.80	0.09	**8.96**							
	9	7.20	4.50		5.98	1.35	**7.33**	**18.3%**	33.3%	38.5%	8.3%
7	20	19.40	0.20	**16.10**							
	20	11.80	9.20		9.79	2.76	**12.55**	**22.0%**	39.2%	43.8%	8.2%
8	0	0.00	0.00	**0.00**							
	0	0.00	0.00		0.00	0.00	**0.00**	**0.0%**	0.0%	0.0%	0.0%
	100%			**87.13**	58.48	16.85	**74.52**	**14.5%**	83p/ltr	30p/ltr	

Fig.3 Baseline engine power curve – diesel only

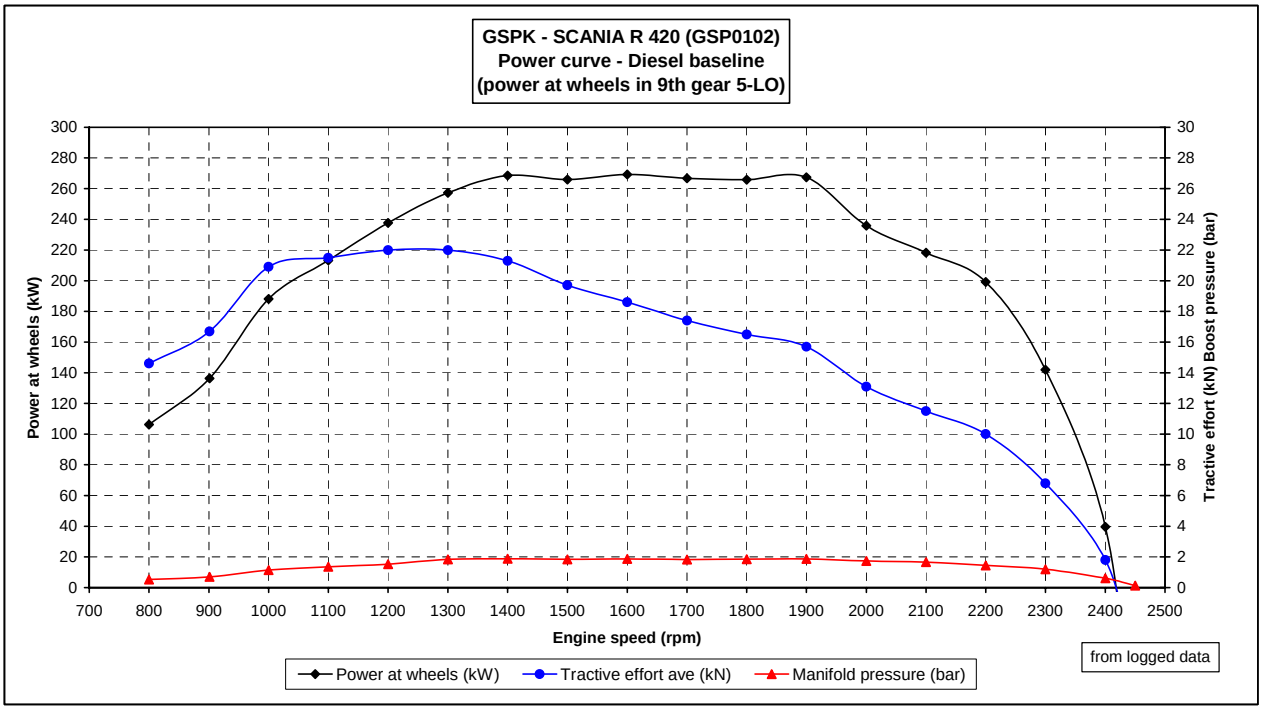
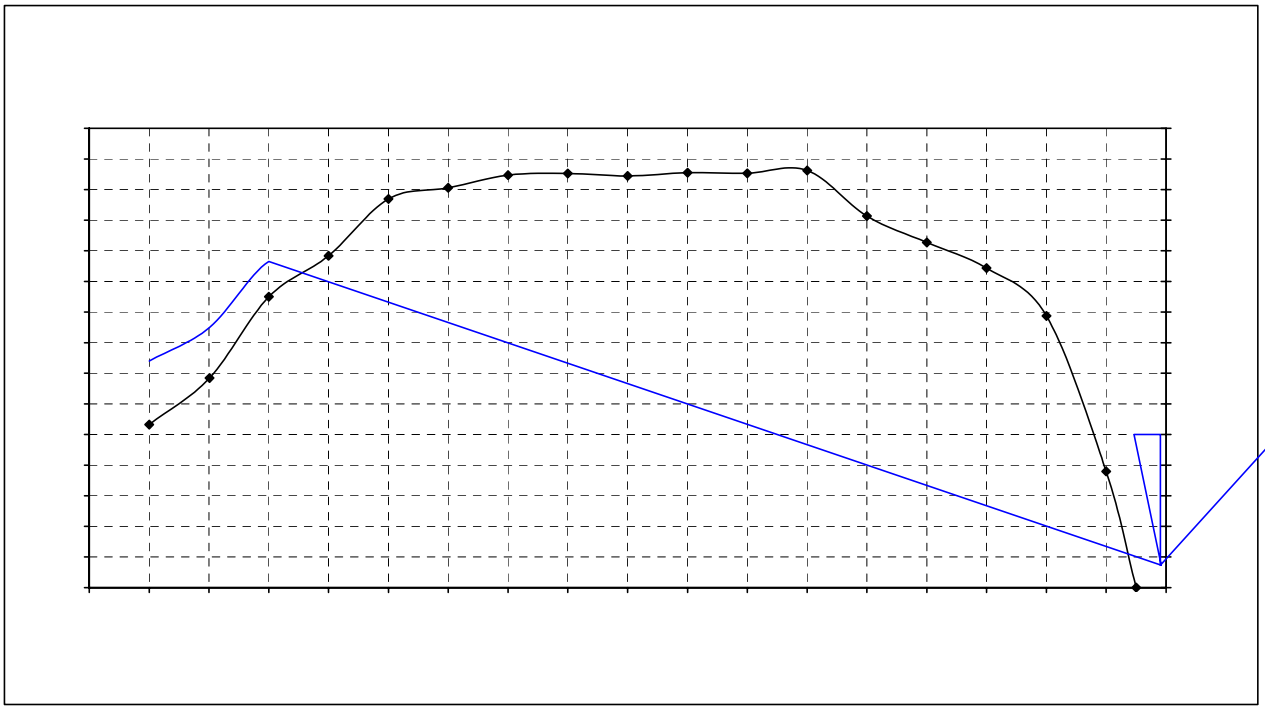


Fig.4 Engine power curve with optimised LPG MAP3



TEST EQUIPMENT:

Results were obtained using a programmable data logger to record the following:

Dyno (road) speed and tractive effort (power at wheels was calculated from these)

Engine speed, manifold (boost) pressure, diesel used total, LPG (liquid) used total, LPG vapour pressure, exhaust gas temperature (plus engine water outlet, fuel inlet, drive axle oil and ambient temperatures for monitoring and control purposes)

Cumulative fuel used (litres) was displayed continuously on the data logger for both diesel and LPG and the fuel consumption rates were calculated by recording change in total fuel used over a fixed time interval (3 minutes for the 8-mode test).

Diesel consumption was measured with a JPS FM10 positive displacement fuel meter (5cc resolution) and the LPG consumption (liquid) was measured using GSPK's Endress and Hauser Coriolis mass flow rate measurement system (1cc resolution).

DISCUSSION:

It was not possible to verify the accuracy of the new LPG Coriolis device at the time of testing, but cross-checks between the amount of LPG (litres) used to refuel the vehicle and that recorded by the E & H device indicated an uncertainty (error band) of +/- 5%. It is more likely that the Coriolis device is over-reading slightly, so the fuel cost savings indicated are more likely to be pessimistic / conservative and the fuel cost savings should therefore be slightly better than indicated.

There is a lack of devices or systems available "off the shelf" at present for precision measurement of LPG liquid mass flow at low flow rates and this Coriolis system is believed to be the best currently available for the purpose. The level of uncertainty with this device will reduce with further testing and calibration experience.

As there was no significant increase in the maximum torque or power of the engine with the GSPK optimised LPG map installed, this should allay the usual concerns over the durability of the driveline (clutch, transmission, drive axle) with the increased engine power developed by some LPG fumigation systems.

When running the vehicle against the RSL (road speed limiter) on the dyno. the vehicle indicated speed (tachograph) was nominally 3 km/h (2 mph) higher than the actual dyno. road speed (i.e. dyno. speed 87 km/h for vehicle indicated speed of 90 km/h / 56 mph). This is because there is inherently more tyre slip on the steel dyno. rollers than when running on highway and also because there is a tolerance on the calibration accuracy of the vehicle speedo/tachograph, which varies with load and tyre wear/tread depth.

These results are an extract from a larger program of work carried out at LTC to optimise the LPG mapping and conduct comparative fuel consumption tests which are reported in full in the mi-Technology report GSP.0102/1 prepared by the author (June 2006).