

Report

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Evaluation of the effects of Militec-1® on the fuel consumption and exhaust emissions of a gasoline engine

by
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Contents

Summary.....	p. 1
1. Introduction.....	p. 1
2. Experimental Set-Up and Test Conditions.....	p. 1
3. Results and Discussion.....	p. 2
4. Conclusions.....	p. 3
Appendices.....	p. 10

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Summary

A Rover 1.4 litre, SI¹ gasoline engine with a carburettor fuel delivery system was used to evaluate the effects of the synthetic based metal conditioner marketed as Militec-1® on the engine fuel consumption and exhaust emissions. First, baseline tests without Militec-1® were carried out and values for fuel consumption, unburnt hydrocarbons, nitrogen oxides (NO_x), carbon monoxide (CO) and carbon dioxide (CO₂) were recorded. Militec-1® was then added to the oil reservoir and tests were carried out under the same operating conditions as the baseline tests. It was found that at different engine loads, Militec exhibited varying trends.

1. Introduction

Both SI and CI engines can be improved in terms of emissions, fuel consumption and performance with the use of after-market products. Examples of after-market products are oil-additives, fuel-additives, spark enhancers, air induction systems etc. Militec-1® is a product which is added to the oil reservoir and is marketed as a metal conditioner which protects metals with a synthetic molecular bond. It was of interest to investigate whether Militec-1® had an effect on emissions, fuel consumption or performance. Obviously, it is of benefit if emissions and fuel consumption are decreased and performance is improved.

2. Experimental Set-up and Test Conditions

For the testing purposes, a Rover engine was used that has a nominal 1.4 litre capacity and an 8 valve, single overhead cam (SOHC) configuration. The fuel is delivered to the cylinders via a carburettor. The basic engine specifications are given in Table 1. The relative air fuel ratio lambda (λ) was monitored through the use of a lambda sensor and adjusted through a screw-valve situated on the carburettor. Care was taken to maintain lambda equal to one (i.e. stoichiometric combustion). When lambda could not be maintained at stoichiometric, then care was taken to keep the lambda value the same for the comparison tests. The ignition timing was maintained at 0 CA deg ATDC (crank angle deg after top dead centre) for all tests. The throttle was used to control engine speed and a Froude Water Dynamometer was used to apply load.

Table 1. Engine Data.

Swept volume	1397 cm ³
Bore	75.0 mm
Stroke	79.0 mm
Compression Ratio	9.5:1
Fuel	Gasoline 95 RON
Oil Capacity	5 litres

A Signal 3000HM analyzer (flame ionisation detector, FID) was used to measure unburnt hydrocarbons and a Signal 4000VM analyzer (chemiluminescence) was used to measure NO_x emissions. These units use span gases with a known concentration of gas for calibration purposes and comparison checks. A Horiba Mexa 554J unit was used to measure CO, CO₂ and lambda. A 100cc burette was used to record the time taken to consume 100cc of fuel. Three fuel timing readings were taken and averaged out; the variation between sets of readings was a maximum of 1 second. Furthermore, since lambda is crucial to engine testing and consequent results, an air flowmeter was used to confirm the analyser lambda measurements. The lambda values readings of the Horiba Mexa analyser were checked against calculated lambda values obtained from the air and fuel flow rate measurements.

¹ A list of abbreviations is given in Appendix A.

The uncertainties of measurement are estimated to be up to 1.5%.

Nine different tests were undertaken, one at idle and eight at different speeds at low, mid and high loads without and with 10oz of Militec-1® added to the engine oil. Table 2 shows the different engine speed and loads used for testing. Figure 1 shows a schematic representation of the test rig.

Initially 3oz of Militec-1® were added to the engine oil and the engine was run-in for 15 hours. On further instruction an additional 7oz of Militec-1® was added and the engine was run-in for a further 6 hours before testing commenced. There was no oil change between testing.

Table 2. Engine test conditions (speeds and loads).

	Idle	Low Load			Mid Load			High Load	
Load (Nm)	0	15	15	15	30	30	30	45	45
Speed (rpm)		1000	2000	3000	1000	2000	3000	2000	3000

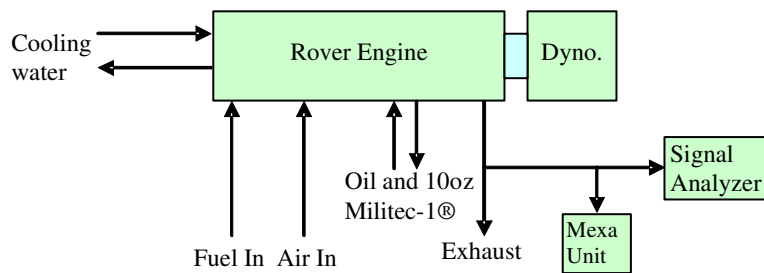


Figure 1. Schematic representation of the Rover engine test rig and test equipment.

3. Results and Discussion

All the measured and calculated values obtained from the tests are presented in Appendix B. Figures 2, 4 and 6 show the Brake Specific Fuel Consumption² (BSFC) plotted against engine speed for the three different tested engine loads. Figures 8 and 9 show BSFC values plotted on a Brake Mean Effective Pressure³ (BMEP) - speed map without and with Militec, respectively. It can be noticed that BSFC values are generally the same for tests with and without Militec. However, at the high load of 6.46 bar BMEP, it appears that BSFC values are lower when Militec is used. At 6.46 bar and 2000 rpm the BSFC value without the use of Militec is 343 g/kWh, whereas with Militec it falls to 330 g/kWh, i.e. an improvement of 3.8% as shown in Figure 6. Furthermore at 6.46 bar and 3000 rpm the BSFC value without the use of Militec is 310 g/kWh, whereas with Militec it falls to 303 g/kWh, i.e. an improvement of 2.3%. The BSFC value recorded at low load at 3000 rpm without Militec appears to be erroneous and for this reason a previously obtained value at 2800 rpm has been also included in the graph in Figure 2 to indicate the general BSFC trend (the tests without Militec could not be repeated following the addition of Militec).

On inspection of the Brake Specific Hydrocarbons (BSHC) values, shown in Figures 3, 5 and 7, it appears that values at low loads are lower with Militec addition compared to operation without Militec. For example at 1000, 2000 and 3000 rpm and 2.15 bar BMEP, the BSHC values without Militec are 5.2, 4.181 and 4.128 g/kWh, respectively, whereas with Militec the corresponding

² Rate of fuel consumption per unit power output.

³ Measure of engine work output.

values are 4.922, 3.989 and 3.148 g/kWh. This can be attributed to the higher exhaust gas temperatures⁴ (Appendix A) observed for operation with Militec. The higher exhaust temperatures indicate less unburned fuel around cylinder crevices and hence less HC production. BSHC values plotted on a BMEP-speed map are shown in Figures 10 and 11. At mid-load and high-load, it was the BSHC values with Militec were close to those measured without Militec.

On the other hand, as shown in Figures 3, 5 and 7, it appears that the higher exhaust temperatures occurring with Militec addition result in higher Brake Specific Nitrogen Oxides (BSNOx) values compared to baseline tests without Militec. BSNOx values plotted on a BMEP-speed map are shown in Figures 12 and 13. As it can be seen, BSNOx values are generally higher for testing with Militec compared to baseline testing. At 1000, 2000 and 3000 rpm and 2.15 bar BMEP, the BSNOx values achieved without Militec are 0.995, 1.699 and 5.599 g/kWh, respectively, while with Militec the corresponding values are 1.428, 1.731 and 6.031 g/kWh. NOx are formed in flames by three mechanisms: thermal, prompt and nitrous oxide. The higher combustion temperatures lead to higher NOx formation.

Brake Specific Carbon Monoxide (BSCO) values plotted against speed for the three tested engine loads are shown in Figures 2, 4 and 6. Figures 14 and 15 show BSCO values plotted on a BMEP-speed map. It appears that generally BSCO values are lower with Militec compared to operation without Militec. For example at 1000, 2000 and 3000 rpm and 4.31 bar BMEP, the BSCO values with Militec are 284.79, 255.63 and 202.06 g/kWh, respectively, whereas without Militec, the corresponding values are 319.76, 267.52 and 192.37 g/kWh. CO emissions are associated with oxidation reactions and in this case it appears that the higher in-cylinder temperatures with Militec (as deduced from the observed higher exhaust temperatures) aid the oxidation reactions and result in lower CO emissions.

On inspection of the BSCO values, it can be noticed that they are much higher compared to typical values for modern engines. This is due to the fact that the Rover engine that was used for the tests has a carburettor fuel delivery system rather than a port fuel injection (PFI) system. Fuel delivery with a carburettor causes locally rich air/fuel pockets which lead to high levels of CO while PFI systems allow a more homogeneous mixture of air and fuel leading to lower CO emissions. Nevertheless, a carburettor engine is still appropriate for the purposes of the current comparison tests with and without Militec.

Carbon Dioxide is a product of complete combustion that does not impair human health directly. Traditionally it has not been included in engine emission regulations but in recent years it has been started to be seen as an important pollution concern because it is a greenhouse gas associated with global warming. Thus, absolute CO₂ measurements (vol. % of exhaust gas) are given in Appendix B for completeness of the test results with and without addition of Militec.

4. Conclusions

At high load (6.46 bar BMEP) and speeds of 2000 and 3000 rpm, the addition of Militec resulted in improved (lower) fuel consumption, i.e. lower BSFC values. The BSFC decreased by 3.8% and 2.3% at 2000 and 3000 rpm, respectively, with addition of Militec. These operating conditions are similar to motorway driving. The BSFC values at low and mid-loads were generally the same for testing without and with Militec.

For tests using Militec, it was found that BSHC values (unburnt hydrocarbon emissions) were lower at low-loads. At mid-load and high-load, it was found that BSHC values with Militec were close to those measured without addition of Militec.

⁴ The in-cylinder temperature may be estimated from the exhaust gas temperature. Although the temperature readings obtained from thermocouples are average values, the general trend can still be used.

BSNO_x values (nitrogen oxides emissions) were higher for testing with Militec compared to baseline values without Militec. This is attributed to higher in-cylinder temperatures with Militec addition as deduced from the measured higher exhaust gas temperatures when Militec was used.

Carbon monoxide emissions were also investigated and it was found that, overall, Militec resulted in lower CO emissions. This indicates that the higher in-cylinder temperatures occurring with Militec aided the oxidation reactions leading to lower BSCO values.

Investigation of the chemical make-up of Militec was not undertaken; therefore it is not possible to comment on the molecular behaviour of Militec and its interaction with the engine surface. Furthermore, it is not possible to comment on why the exhaust temperatures were different between tests with and without addition of Militec.

For the cases of test results that do not indicate conclusively definite trends with Militec, the reasons may be related to the fact that following the addition of the 7oz of Militec-1® the engine running-in time was limited to 6 hours (initially the engine was run-in for 15 hours with only 3oz of Militec added).

The increased BSNO_x values with Militec would indicate that with addition of Militec in a diesel engine the smoke and particulate emissions would possibly decrease following the typical diesel engine smoke/NO_x trade-off. This indicates that it will be very useful to carry out a series of tests to investigate the effects of Militec on diesel engine fuel economy, exhaust emissions and performance.

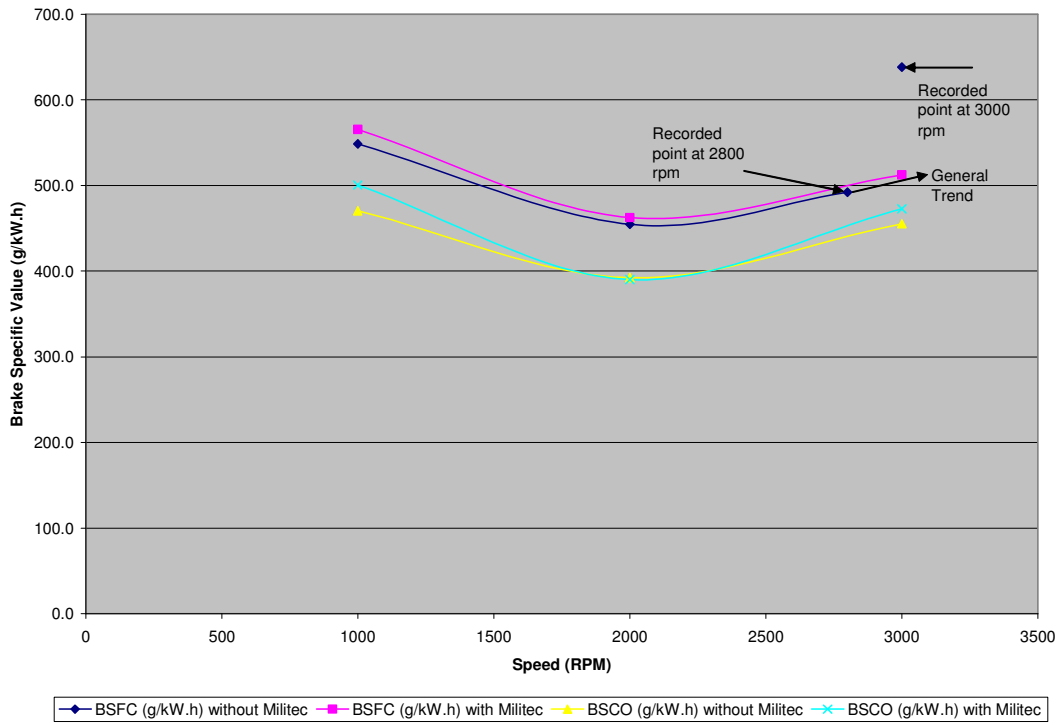


Figure 2. BSFC and BSCO values at low load (2.15 bar BMEP) without and with Militec.

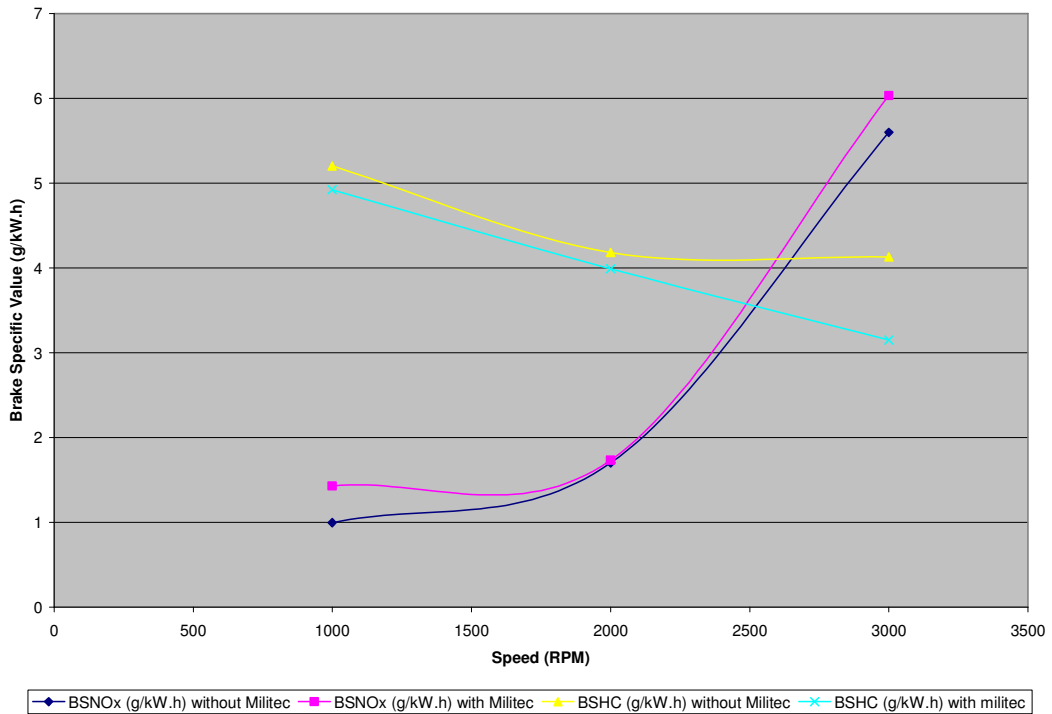


Figure 3. BSNOx and BSHC values at low load (2.15 bar BMEP) without and with Militec.

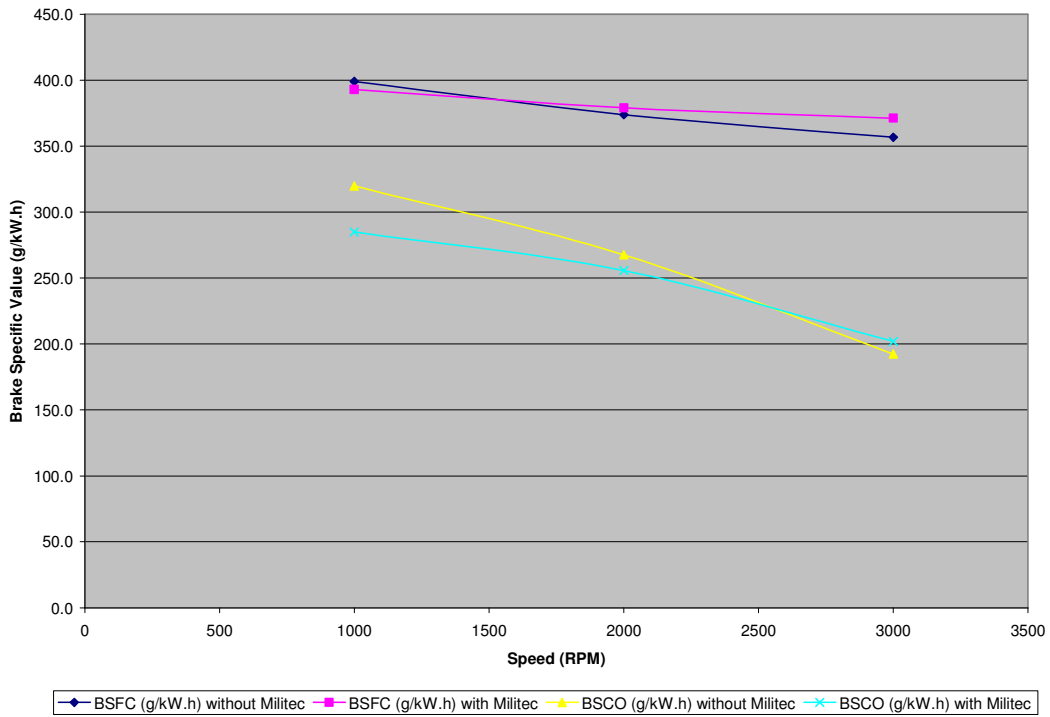


Figure 4. BSFC and BSCO values at mid load (4.31 bar BMEP) without and with Militec.

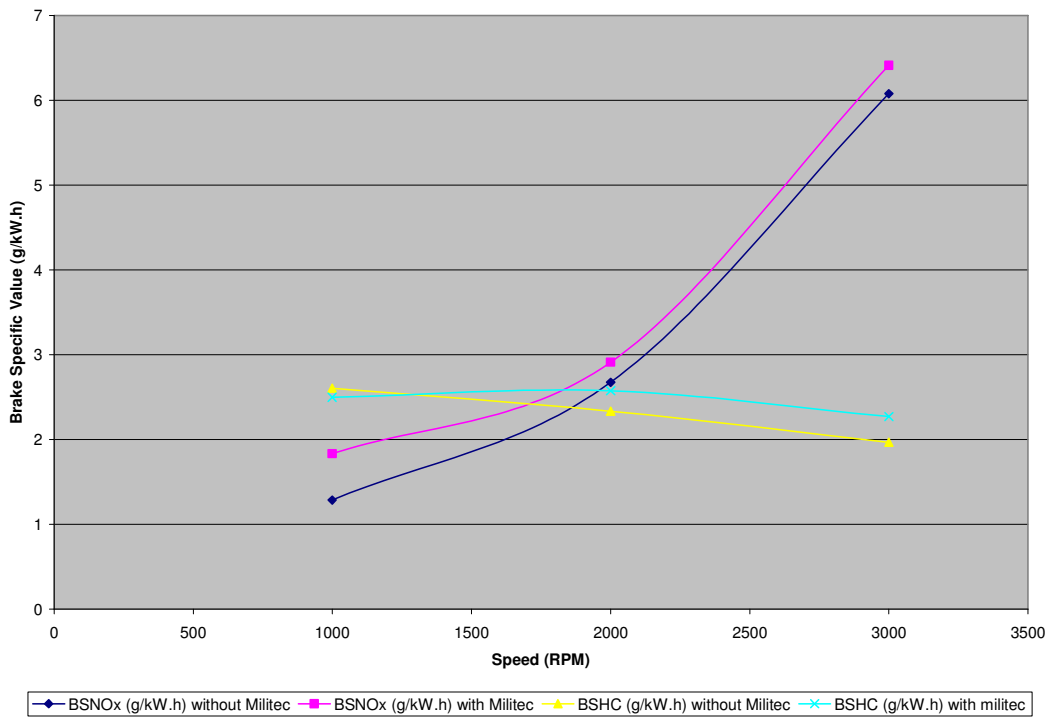


Figure 5. BSNOx and BSHC values at mid load (4.31 bar BMEP) without and with Militec.

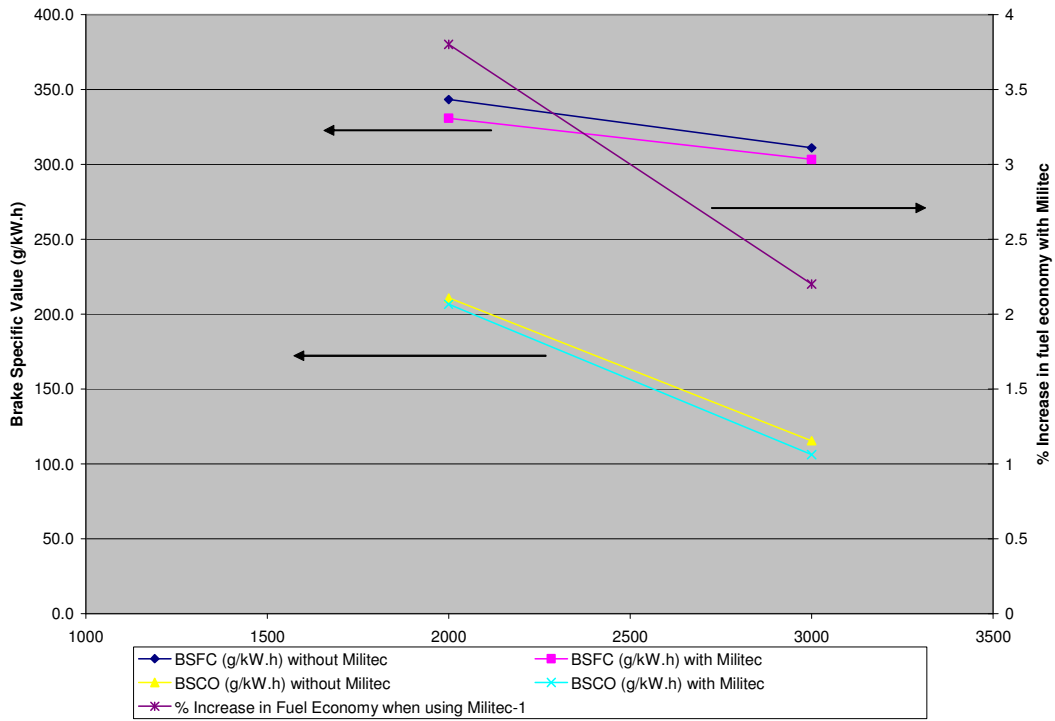


Figure 6. BSFC and BSCO values at high load (6.46 bar BMEP) without and with Militec.

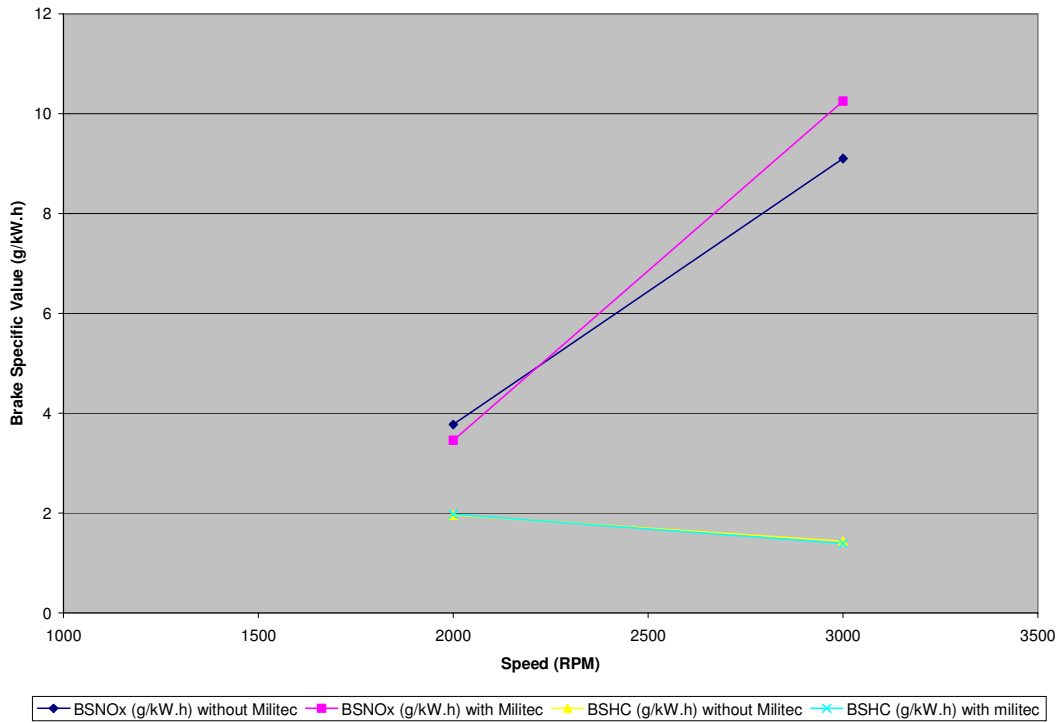


Figure 7. BSNOx and BSHC values at high load (6.46 bar BMEP) without and with Militec.

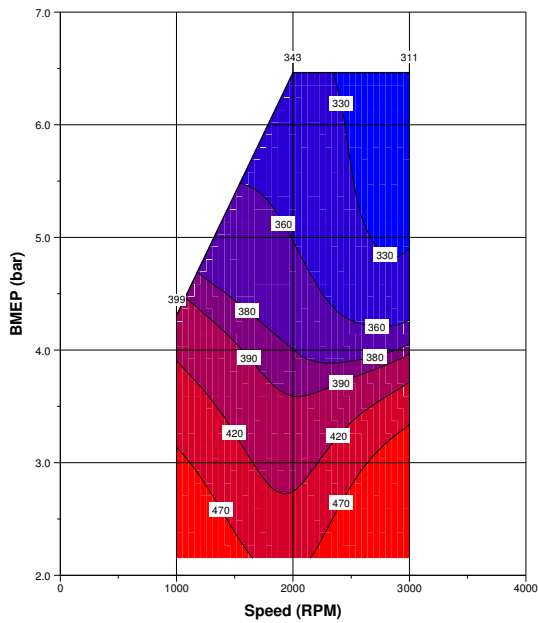


Figure 8. BSFC map values without Militec.

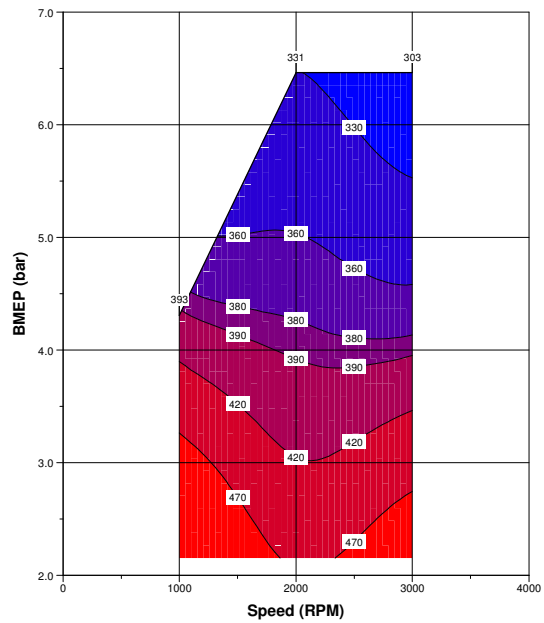


Figure 9. BSFC map values with Militec.

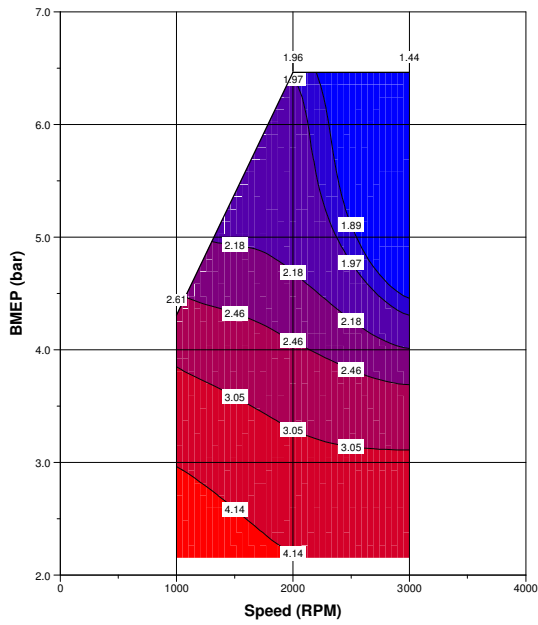


Figure 10. BSHC map values without Militec.

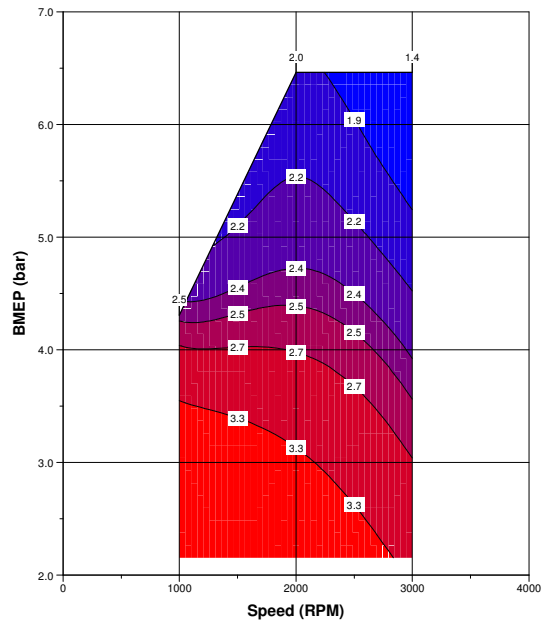


Figure 11. BSHC map values with Militec.

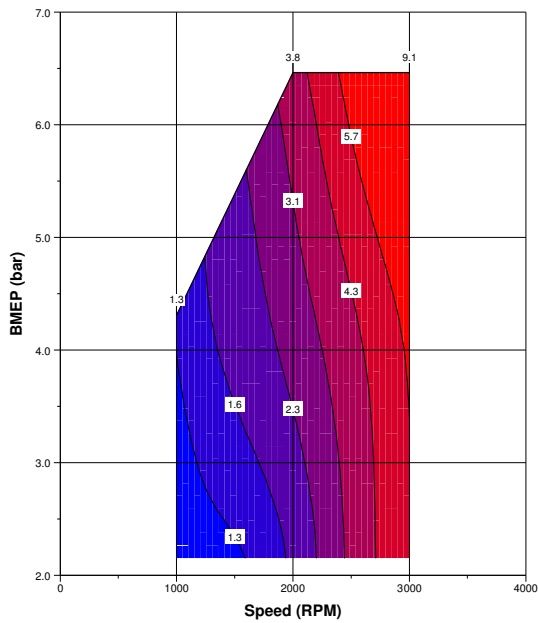


Figure 12. BSNOx map values without Militec.

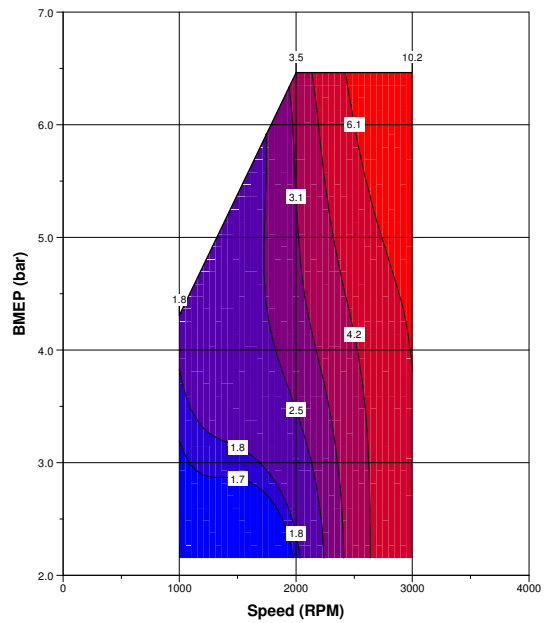


Figure 13. BSNOx map values with Militec.

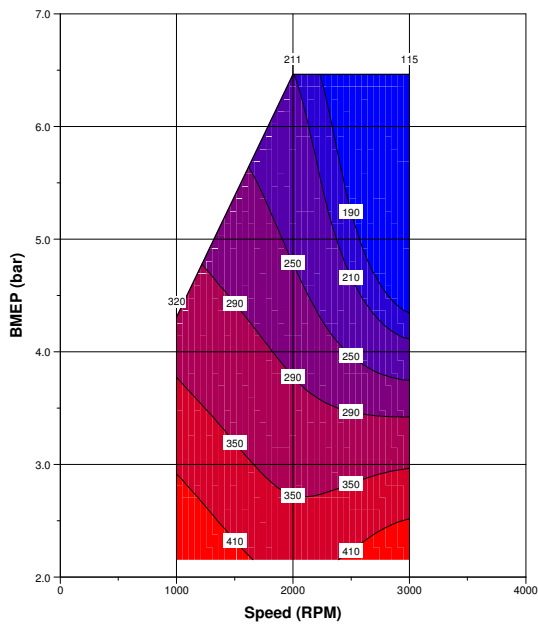


Figure 14. BSCO map values without Militec.

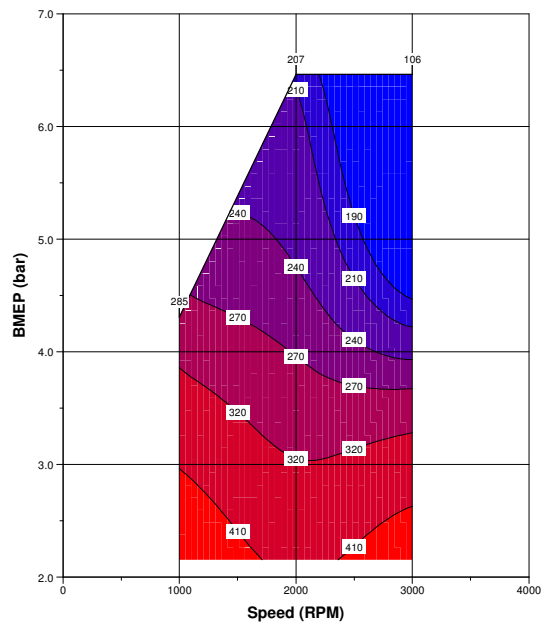


Figure 15. BSCO map values with Militec.

Appendixes

Appendix A

List of abbreviations

AFR	Air Fuel Ratio
ATDC	After Top Dead Centre
BMEP	Brake Mean Effective Pressure (used to indicate engine load)
BSFC	Brake Specific Fuel Consumption
BSCO	Brake Specific Carbon Monoxide Emissions
BSHC	Brake Specific Hydrocarbon Emissions
BSNO _x	Brake Specific Nitrogen Oxides Emissions
CA	Crank Angle
CI	Compression Ignition
Lambda (λ)	Relative air fuel ratio (ratio of air fuel ratio over stoichiometric combustion air fuel ratio)
SI	Spark Ignition
SOHC	Single Overhead Camshaft

Appendix B

Test conditions, fuel consumption and measured temperatures

Without Militec

Torque (Nm)	0	23.94851	23.94851	23.94851	47.89701	47.89701	47.89701	71.84552	71.84552
Power (kW)	0	2.50661	5.013221	7.519831	5.314014	10.02644	15.03966	15.03966	22.55949
BMEP (bar)	0	2.153137	2.153137	2.153137	4.306274	4.306274	4.306274	6.459411	6.459411
Fuel Time (s) to consume									
100 cc of fuel	211	199	120	57	129	73	51	53	39
Fuel mass flow rate (g/h)	1296.682	1374.874	2280	4800	2120.93	3747.945	5364.706	5162.264	7015.385
Fuel mass flow rate (kg/s)	0.00036	0.000382	0.000633	0.001333	0.000589	0.001041	0.00149	0.001434	0.001949
BSFC (g/kW.h)		548.4994	454.7974	638.3122	399.1202	373.8061	356.7039	343.2434	310.9726
AFR	12.2	14.8	15.1	14.9	14.6	14.6	15.3	15.1	15.7
Lambda	0.84	1.01	1.04	1.02	1	1	1.05	1.03	1.07
Water Temperature (oC)	89	88	86	84	90	87	87	89	89
Exhaust Temperature (oC)	337	223	353	435	325	441	540	515	609
Oil Temperature (oC)	104	89	98	105	99	106	114	111	118
Air Temperature (oC)	41	30	33	33	39	34	34	35	34
Oil Temp Sump (oC)	110	87	100	107	102	106	115	113	119
Coolant Return (oC)	73	67	61	58	65	60	59	61	63
Load (lb)	0	15	15	15	30	30	30	45	45
Speed (rpm)	1000	1000	2000	3000	1000	2000	3000	2000	3000

With Militec

Torque (Nm)	0	23.94851	23.94851	23.94851	47.89701	47.89701	47.89701	71.84552	71.84552
Power (kW)	0	2.50661	5.013221	7.519831	5.314014	10.02644	15.03966	15.03966	22.55949
BMEP (bar)	0	2.153137	2.153137	2.153137	4.306274	4.306274	4.306274	6.459411	6.459411
Fuel Time (s) to consume									
100 cc of fuel	213	193	118	71	131	72	49	55	40
Fuel mass flow rate (g/h)	1284.507	1417.617	2318.644	3853.521	2088.55	3800	5583.673	4974.545	6840
Fuel mass flow rate (kg/s)	0.000357	0.000394	0.000644	0.00107	0.00058	0.001056	0.001551	0.001382	0.0019
BSFC (g/kW.h)		565.5512	462.5059	512.4478	393.0267	378.9979	371.2632	330.7618	303.1983
AFR	11.9	14.8	15.1	14.9	14.6	14.6	15.3	15.1	15.7
Lambda	0.81	1.01	1.04	1.02	1	1	1.05	1.03	1.07
Water Temperature (oC)	85	88	86	86	88	88	87	90	88
Exhaust Temperature (oC)	205	263	386	471	352	470	563	526	625
Oil Temperature (oC)	91	95	101	110	104	106	114	109	117
Air Temperature (oC)	36	35	35	34	38	33	32	34	33
Oil Temp Sump (oC)	91	97	104	109	107	107	114	112	118
Coolant Return (oC)	68	70	62	60	67	60	59	61	62
Load (lb)	0	15	15	15	30	30	30	45	45
Speed (rpm)	1000	1000	2000	3000	1000	2000	3000	2000	3000

Exhaust Emissions

Without Militec

Speed (rpm)	Brake Torque (Nm)	BMEP (bar)	Fuel flow rate, m_f (kg/s)	Fuel flow rate, v_f (s/100cc)	CO ₂ (%)	CO (%)	O ₂ (%)	uHC (ppm)	NOx (ppm)	bsfc	bsno	bshc	bsco
1000	0	0.00	0.000360	211	3.18	8.87	6.8	11500	29.14				
1000	23.94	2.15	0.000382	199	7.98	6.04	3.04	1028	104.8	548.5	0.995	5.2	470.4
2000	23.94	2.15	0.000633	120	7.74	5.92	4	974	211	454.8	1.699	4.181	392.47
3000	23.94	2.15	0.001333	57	9.08	5.05	3.4	704	509	638.3	5.599	4.128	455.34
1000	47.89	4.31	0.000589	129	8.5	5.7	3.46	714	188	399.1	1.287	2.606	319.76
2000	47.89	4.31	0.001041	73	9.18	5.13	3.14	687	420	373.8	2.676	2.333	267.52
3000	47.89	4.31	0.001490	51	10.14	3.75	3.08	591	973	356.7	6.078	1.968	192.37
2000	71.84	6.46	0.001434	53	9.64	4.28	3.22	614	629	343.2	3.773	1.963	210.79
3000	71.84	6.46	0.001949	39	11.22	2.56	2.74	497	1658	311.0	9.101	1.437	115.49

With Militec

Speed (rpm)	Brake Torque (Nm)	BMEP (bar)	Fuel flow rate, m_f (kg/s)	Fuel flow rate, v_f (s/100cc)	CO ₂ (%)	CO (%)	O ₂ (%)	uHC (ppm)	NOx (ppm)	bsfc	bsno	bshc	bsco
1000	0	0.00	0.000357	213	4.3	10	4.89	8526	23				
1000	23.94	2.15	0.000394	193	7.68	6.14	3.14	931	144	565.6	1.428	4.922	500.591
2000	23.94	2.15	0.000644	118	7.82	5.75	4.78	908	210	462.5	1.731	3.989	390.24
3000	23.94	2.15	0.001070	71	7.44	6.39	3.18	656	670	512.4	6.031	3.148	472.8
1000	47.89	4.31	0.000580	131	9.16	5.22	3.5	703	275	393.0	1.834	2.499	284.794
2000	47.89	4.31	0.001056	72	9.4	4.8	3.36	743	448	379.0	2.912	2.575	255.635
3000	47.89	4.31	0.001551	49	10.14	3.8	3.22	658	990	371.3	6.412	2.272	202.067
2000	71.84	6.46	0.001382	55	9.78	4.45	3.22	655	610	330.8	3.457	1.979	206.545
3000	71.84	6.46	0.001900	40	11.4	2.42	2.82	488	1920	303.2	10.249	1.389	106.146