

Table of Contents

1 Objectives and methodology	1
1.1 Introduction	2
1.2 Objective.....	2
1.3 Methodology.....	3
Chapter 1 bibliography	4
2 Introduction	5
2.1 Air pollution.....	6
2.2 Pollutants formation	15
2.2.1 Nitrogen oxides	15
2.2.2 Hydrocarbons	16
2.2.3 Carbon monoxide	17
2.3 Road emissions regulation	17
Chapter 2 bibliography	27
3 Methods and experimental	29
3.1 Introduction	30
3.2 Engine description.....	30
3.3 Test cell.....	32
3.4 Thermal management solutions description	39
3.4.1 Engine coolant management layout	39
3.4.2 Exhaust Gas Heat Recovery and WCAC coolant management layout	41

3.5	Driving cycles test procedure	44
3.6	Data analysis procedure	47
3.6.1	Pollutant emissions calculation	47
3.6.2	Test repeatability and experimental uncertainty	49
3.6.3	Error propagation	51
	Chapter 3 bibliography	57
4	Effect of low ambient temperature on engine performance	59
4.1	Introduction	60
4.2	NEDC and WLTC driving conditions	63
4.3	Results	65
4.3.1	Effect of low ambient temperature on air management	66
4.3.2	Engine out pollutants emissions and fuel consumption analysis	68
4.3.3	Comparison between NEDC and WLTC emissions ...	72
4.3.4	Emissions during engine warm-up	74
4.4	Conclusions	76
	Chapter 4 bibliography	81
5	Effect of low ambient temperature on DOC performance	83
5.1	Introduction	84
5.2	Catalysis temperature estimation	84
5.3	Results	87
5.3.1	WLTC	89
5.3.2	NEDC	94
5.4	Conclusions	98
	Chapter 5 bibliography	100
6	Analysis of thermal energy management solutions	101
6.1	Introduction	102
6.2	Baseline case	104

6.3	Coolant thermal management	105
6.3.1	Effect on pollutant emissions and fuel consumption . . .	106
6.3.1.1	Engine coolant management	106
6.3.1.2	WCAC coolant management	110
6.4	Exhaust gas heat recovery	111
6.4.1	Energy analysis	112
6.4.2	Effect on pollutant emissions and fuel consumption . . .	117
6.5	Effect of thermal management in intake air temperature	119
6.6	Conclusions	121
	Chapter 6 bibliography	124
7	Conclusions and future work	125
7.1	Introduction	126
7.2	Conclusions	126
7.3	Future work	128
	Chapter 7 bibliography	129