HDGAS

Heavy Duty Gas Engines integrated into Vehicles

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Project partners:

1 - AVL - AVL List GmbH - AT
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4 - DAI - Daimler AG - DE
5 - DINEX - Dinex Ecocat OY - DK
6 - FPT - FPT Industrial S.p.A. - IT
7 - IDIADA - Idiada Automotive Technology S.A.- ES
8 - IVECO - Iveco Espana SL - ES
9 - MAN - MAN Truck & Bus AG - DE
10 - POLIMI - Politecnico di Milano - IT
11 - RCD - Ricardo UK Limited - UK
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Executive summary

Experiments have been performed to assist in the specification of a series of aftertreatment solutions for 3 engines operating partially or fully on natural gas. The three engines on under investigation were a stoichiometric dedicated natural gas, lean operating natural gas and dual fuel Diesel and natural gas. The three engines have widely different aftertreatment requirements and hence different aftertreatment solutions.

Natural gas combustion has the added challenge of methane exhaust control. As already known methane does not oxidise at high efficiency until significantly above 400°C. For stoichiometric applications reaching above 400°C in the exhaust is achievable under normal lambda 1 operating conditions. However, for lean operating engine this is a significant challenge due to the lower exhaust temperatures for lambda > 1 applications. Therefore, the main challenge for the catalyst specification has been integrating methane control into the exhaust system.

For stoichiometric operation of a natural gas engine a modified three way catalyst was selected as the emissions control system. The Three way catalyst will simultaneously oxidise methane and carbon monoxide whilst reducing NOx emissions. The table below shows the three way catalyst specification required for emissions control from the 13 litre stoichiometric FPT engine. The significant difference compared to gasoline three way catalyst is the large amount of precious metal used. The large amount of precious metal is required for efficiency methane control.

Application	Partner	Engine L	Catalyst type	Substrate	Cells cpsi	Coating type Dinex	PGM Pt:Pd:Rh	PGM g/cft	Catalyst volume, L
Stoichiometric NG	FPT	13,0	TWC	Brazed EC	500	NG-TWC K5.7	0:16:1	200	13,3 x1 D334, L152

For the dedicated lean natural gas application the exhaust catalyst system need to control methane, carbon monoxide and NOx. Due to the lean operating nature of the engine, an SCR will be required for NOx control. The lean natural gas engine does not operate as lean as a standard Diesel engine hence will operate at higher temperatures and will therefore, require a more high temperature SCR formulation than many current Diesel applications. The high temperature operation is an advantage for methane control and will help reduce any fuel penalty required for exhaust thermal management. A significant amount of experimental and simulation work was undertaken to optimize methane control. During the fundamental studies at UEF it was found that combining different technologies significantly improved methane efficiency could be achieved. Also, due to the high temperature nature of the combustion, compared to Diesel operation a hybrid SCR system has been specified. The hybrid system will consist of an upfront Iron SCR catalyst followed by a downstream Cu-SCR catalyst. Due to the low PM/PN nature of the combustion process with natural gas it was assumed that a particulate filter was not required for the initial specification. The table below shows the exhaust aftertreatment specification for the 13 lite dedicated lean operating natural gas engine.

Application	Partner	Engine L	Catalyst type	Substrate	Cells cpsi	Coating type Dinex	PGM Pt:Pd:Rh	PGM g/cft	Catalyst volume, L
Lean Natural Gas	Ricardo	13,0	TWC	Brazed EC	500	NG-TWC K5.7	0:16:1	200	6,4 x 2 D334, L75
	Ricardo	13,0	MOC	Brazed EC	500	MOC- KGL4	1:0:4	200	6,4 x 2 D334, L75
	Ricardo	13,0	SCR	Brazed EC	500	Fe-SCR1	no	no	11,4 x 2 D309, L152
	Ricardo	13,0	SCR	Brazed EC	500	Cu-SCR1	no	no	11,4 x 2 D309, L152
	Ricardo	13,0	ASC	Brazed EC	500	Pt-ASC	1:0:0	5	~2-3 design later

For the dual fuel application, methane, hydrocarbons, carbon monoxide, NOx and PM/PN need to be controlled. The approached taken for this specification was to utilize the existing Diesel Euro VI OEM solution which would control HC, CO, NO_X and PM/PN and place a MOC upstream of the existing aftertreatment solution. Therefore, only the MOC needed to be specified. The table below shows the MOC specification for the 12.4 litre dual fuel application.

Application	**Partner**	**Engine L**	**Catalyst type**	**Substrate**	**Cells cpsi**	**Coating type Dinex**	**PGM Pt:Pd:Rh**	**PGM g/cft**	**Catalyst volume, L**
Dual- fuel	MAN IDIADA	12,4	MOC	Brazed EC	500	MOC- KGL4	1:4:0	200	11,4 x 1 D309, L152