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TECHNICAL REPORT – THC/MHC/NMHC emission tests
CNG/gasoline bi-fuel vehicles carried out c/o JRC-ISPRA (EC)

1. INTRODUCTION

This test program has been set up in order to quantify the difference in THC emissions performance between OEM and retrofitted CNG-powered vehicles. With the introduction of the EURO 4 legislation, the limit of THC (0,1 gr/km) became difficult to be complied, namely for retrofitted CNG vehicles, equipped with original catalyst designed for gasoline. The OEM CNG vehicles have the advantage of being equipped with a catalyst designed to be used on CNG fuelled engine. Considering that the majority of HC emission from CNG vehicle consists of MHC (CH4), and that CH4 is non toxic, consequently in HC legislation outside Europe is not considered a pollutant, a proposal has been made for applying a factor to MHC emission limit for a retrofitted CNG vehicles, so in this way they can comply with legislation.

THC = K·MHC + NMHC

The factor K could be calculated as $K = \frac{1-\eta_{CNG}}{1-\eta_{GASOLINE}}$

where η_{CNG} is the HC conversion efficiency of CNG catalyst and $\eta_{GASOLINE}$ is the HC conversion efficiency of gasoline catalyst, but applied to CNG engine.

2. TEST PROGRAM

Two vehicles have been chosen belonging of the same car model:

- ◊ FIAT GRANDE PUNTO 1368CC-57KW-EURO 4

in two different versions:

1° version: OEM vehicle bi-fuel CNG/gasoline in production line equipped with CNG catalyst.

2° version: Retrofitted vehicle bi-fuel CNG/gasoline obtained by conversion of original gasoline vehicle to CNG, in workshop.

The tests of both vehicles have been carried out on rolling bench according the provisions of ECE-ONU R.83 as follows:

- Test cycle: NEDC (ECE + EUDC) – see Annex 1
- Fuel: CNG – G20 as reference fuel
- Adjustment period before each test: 3000 km
- OEM vehicle: 1° test with original CNG catalyst
  2° test with remplacing CNG catalyst with gasoline catalyst
- Retrofitted vehicle: 1° test with original gasoline catalyst
  2° test with remplacing gasoline with CNG catalyst

Every test for each vehicle has been repeated two times

3. RESULTS

The tests have been performed in the VELA2 laboratory at JRC-Ispra Joint Research Center EU in the rolling bench on the NEDC cycle according ECE-ONU R.83.
In the annexes 2, 3, 4, the detailed row data are reported, meanwhile in the fig. 1 a table with essential calculated data is shown.

The emissions of HC (as THC) in the ECE15 cycle and in the EUDC cycle have been measured as total amount collected in the bags (*), expressed in gr/test pre and post catalyst. Each emission amount is calculated as average of two tests. The NEDC total THC amounts have been obtained adding the THC amounts collected in ECE15 and in EUDC cycles. Then total THC amount in NEDC, pre and post, have been used to calculate the efficiency of CNG and gasoline catalyst as the ratio of $\frac{\text{pre HC amount} - \text{post HC amount}}{\text{pre HC amount}}$.

The efficiencies of the two catalysts related to THC conversion obtained from experimental data are:

1° Version OEM Vehicle bi-fuel: (see fig. 1 and fig. 2)

CNG catalyst: $\eta_{CNG} = 0{,}973$

GASOLINE catalyst: $\eta_{GASOLINE} = 0{,}924$

The "K" coefficient proposed in the documents GFV-02-05; GFV-05-03 (K = 0,42) and GFV-05-04 amended as K = 0,55, obtained from experimental data is:

$$K = \frac{1 - \eta_{CNG}}{1 - \eta_{GASOLINE}} = \frac{1 - 0{,}973}{1 - 0{,}924} = \mathbf{0{,}35}$$ (Related to THC conversion efficiencies)

(*) The samples of exhaust gaseous pre and post catalyst have been taken through two pumps at flow of 10 liter/min each and the HC amounts have been measured and calculated according the CVS procedure, in order to obtain the gr/test.

We could apply this coefficient "K" to THC in the formula in the par. 1, and not only to MHC. In the table in fig. 2 the emission data on NEDC are reported of OEM vehicle for details.

FUEL	**F2 CNG G20**			
CATALYST	***GASOLINE***		***CNG***	
Each test = average of 2 tests	**1° TEST**	**2° TEST**	**1° TEST**	**2° TEST**
ECE 15				
THC [gr] PRE	11,820	10,090	10,510	10,240
THC [gr] POST	0,820	0,870	0,380	0,340
CATALYST η	93,100	91,370	96,420	96,710
EUDC				
THC [gr] PRE	3,310	3,560	3,230	2,840
THC [gr] POST	0,210	0,260	0,000	0,000
CATALYST η	93,550	92,560	99,900	99,910
NEDC (ECE+EUDC)				
THC [gr] PRE	15,130	13,650	13,74	13,08
THC [gr] POST	1,030	1,130	0,380	0,340
CATALYST η	93,19	91,72	97,23	97,40
AVERAGE efficiencies η	**92,455**		**97,315**	

Fig. 1 - VEHICLE: FIAT G. PUNTO Natural Power 1368cc (57kw – EURO 4)
OEM CNG Fuelled
Pre/Post Catalyst emissions measurements

FUEL	**F2 CNG G20**			
CATALYST	***GASOLINE***		***CNG***	
Each test = average of 2 tests	**1° TEST**	**2° TEST**	**1° TEST**	**2° TEST**
THC (EURO 4) [0,1] gr/km	0,077		0,047	
MHC gr/km	0,058		0,032	
NMHC (Euro 4) [0,068] gr/km	0,019		0,015	

Fig. 2 - VEHICLE: FIAT G. PUNTO Natural Power 1368cc (57kw – EURO 4)
OEM CNG Fuelled
Emission data on NEDC

2° Version Retrofitted Vehicle bi-fuel: (see fig. 3 and fig. 4)

CNG catalyst: $\eta_{CNG} = 0,9706$

GASOLINE catalyst: $\eta_{GASOLINE} = 0,9031$

The "K" coefficient proposed in the documents GFV-02-05; GFV-05-03 (K = 0,42) and GFV-05-04 amended as K = 0,55, obtained from experimental data is:

$$K = \frac{1-\eta_{CNG}}{1-\eta_{GASOLINE}} = \frac{1-0,9706}{1-0,9031} = 0,303$$ (Related to THC conversion efficiencies)

According these results, we could apply this coefficient "K" to THC in the formula in the par. 1, and not only to MHC, as proposed in the amendment GFV-05-04.

FUEL	**F2 CNG G20**			
CATALYST	***GASOLINE***		***CNG***	
Each test = average of 2 tests	**1° TEST**	**2° TEST**	**1° TEST**	**2° TEST**
ECE 15				
THC [gr] PRE	10,33	5,91	12,38	10,56
THC [gr] POST	0,66	0,63	0,37	0,45
CATALYST η	93,63	89,41	97,04	95,73
EUDC				
THC [gr] PRE	3,74	0,34	4,08	3,98
THC [gr] POST	0,20	0,20	0,07	0,02
CATALYST η	94,61	40,55	98,23	99,60
NEDC (ECE+EUDC)				
THC [gr] PRE	14,08	6,26 (*)	16,45	14,54
THC [gr] POST	0,86	0,83	0,44	0,47
CATALYST η	93,89	86,73	97,34	96,79
AVERAGE efficiencies η	**90,31**		**97,06**	

Fig. 3 - VEHICLE: FIAT G. PUNTO 1368cc (57kw – EURO 4)
OEM Gasoline fuelled – Retrofit CNG
Pre/Post Catalyst emissions measurements

(*) The 2° test has been performed with a different calibration of electronic control unit respect the 1° test. The conversion efficiency of catalyst can be taken as right, anyway.

FUEL	F2 CNG G20			
CATALYST	*GASOLINE*		*CNG*	
Each test = average of 2 tests	**1° TEST**	**2° TEST**	**1° TEST**	**2° TEST**
THC (EURO 4) [0,1] gr/km	0,077		0,039	
MHC gr/km	0,042		0,009	
NMHC (Euro 4) [0,068] gr/km	0,035		0,030	

Fig. 4 - VEHICLE: FIAT G. PUNTO Natural Power 1368cc (57kw – EURO 4)
OEM Gasoline fuelled – Retrofit CNG
Emission data on NEDC

4. CONCLUSIONS

- Two vehicles have been tested on NEDC cycle:
  - FIAT G.PUNTO OEM (bifuel CNG/Gasoline)
  - FIAT G.PUNTO RETROFIT (bifuel CNG/Gasoline)
- Two Catalytic converters have been applied to both vehicles:
  - CNG designed catalyst
  - Gasoline design catalyst
- The value of "K" factor in the formula $K = \frac{1-\eta_{CNG}}{1-\eta_{GASOLINE}}$ has been determined as THC reduction efficiency pre/post sampling:

  $K_{OEM\ vehicle} = 0,350$
  $K_{retrofit\ vehicle} = 0,303$