

# **Assessing the Effect of Five Gasoline Properties on Exhaust Emissions from Light-Duty Vehicles certified to Tier-2 Standards**

## **Analysis of Data from EPA Phase 3**

**(EPAct/V2/E-89)**

### **Appendix I.1f**

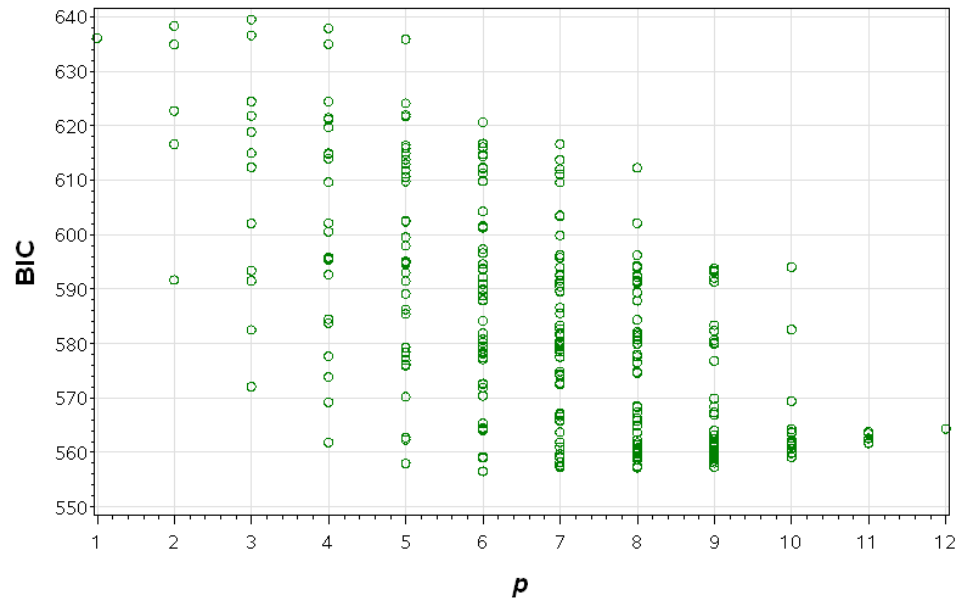
#### **Final Model Fitting**

#### **Total Hydrocarbons (THC) (Bag 3)**

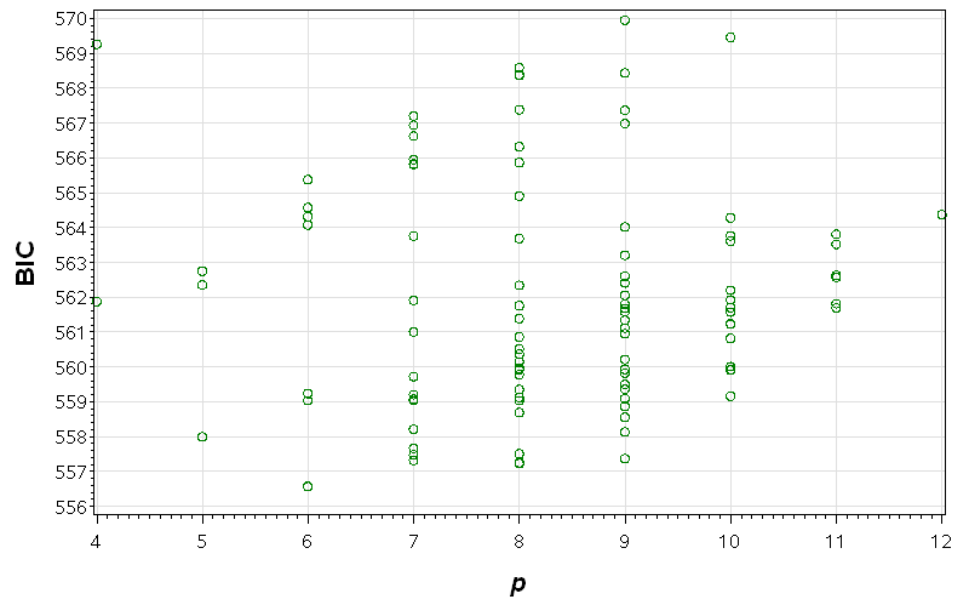
No. Observations:	956
No. Vehicles:	15
No. censored measurements:	2
No. missing measurements:	0
No. measurements removed:	0
Model Type:	Mixed model

### I.1f.1 Model fitting with respect to the 11-term design model.

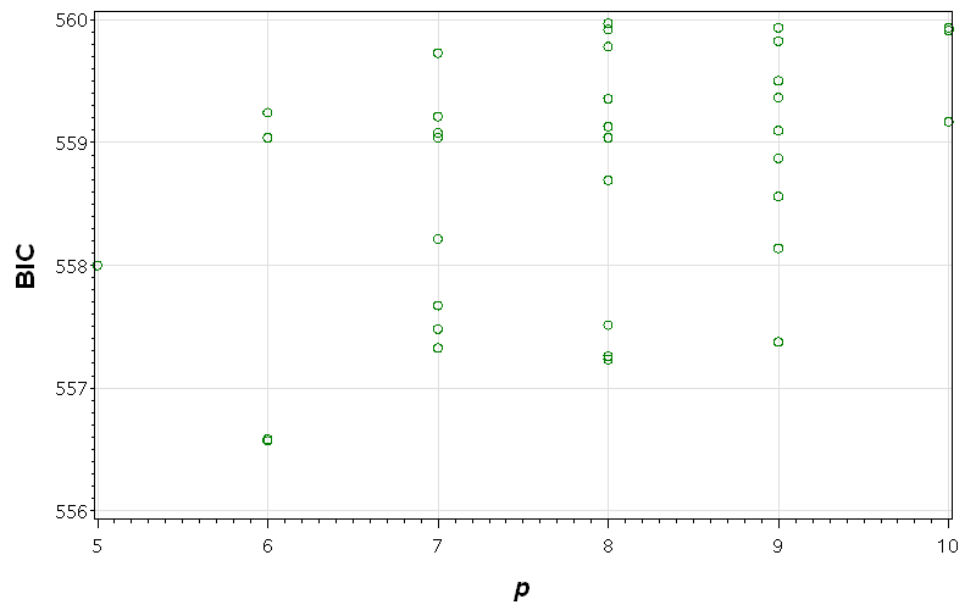
**Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy.**



**Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy (CLOSEUP of previous figure).**



**Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy (CLOSEUP of previous figure).**



**THC (Bag 3):** Number of terms ( $p$ ), Goodness-of-fit (BIC) and terms included in the 35 best-fitting candidate models (out of a total of 294 possible models with hierarchy). (Terms included in models ranked 1-9 comprise the “superset” for final model-fitting).

Rank	$p$	BIC	Design Terms									
			etOH	Arom	RVP	T50	T90	etOH $\times$ etOH	T50 $\times$ T50	etOH $\times$ Arom	etOH $\times$ RVP	etOH $\times$ T50
1	6	556.57	•	•		•	•				•	
2	6	556.58		•	•	•	•		•			
3	8	557.24	•	•	•	•	•			•	•	
4	8	557.26	•	•	•	•	•		•		•	
5	7	557.33	•	•	•	•	•				•	
6	9	557.38	•	•	•	•	•		•		•	
7	7	557.48	•	•		•	•		•		•	
8	8	557.52	•	•	•	•	•	•			•	
9	7	557.67	•	•		•	•	•			•	
10	5	558.00		•		•	•		•			
11	9	558.14	•	•	•	•	•	•		•	•	
12	7	558.22	•	•		•	•				•	•
13	9	558.56	•	•	•	•	•		•		•	•
14	8	558.70	•	•	•	•	•				•	•
15	9	558.87	•	•	•	•	•	•			•	•
16	6	559.04	•		•	•			•		•	
17	7	559.04	•	•	•	•			•			
18	7	559.04	•		•	•	•		•			
19	8	559.04	•	•	•	•	•		•			
20	7	559.08	•	•	•	•	•		•			
21	9	559.10	•	•	•	•	•				•	•
22	8	559.13	•	•		•	•		•		•	•
23	10	559.17	•	•	•	•	•		•		•	•
24	7	559.22	•	•		•	•			•		
25	6	559.25	•	•		•	•		•			
26	8	559.36	•	•		•	•	•			•	•
27	9	559.37	•	•	•	•	•	•		•		
28	9	559.51	•	•	•	•	•	•			•	
29	7	559.73	•	•		•	•	•	•			
30	8	559.78	•	•	•	•	•	•				
31	9	559.83	•	•	•	•	•		•		•	
32	10	559.92	•	•	•	•	•	•		•	•	
33	8	559.92	•	•		•	•	•			•	
34	10	559.94	•	•	•	•	•	•		•	•	•
35	9	559.94	•	•	•	•	•		•	•	•	

**Models fit for THC (Bag 3): (all models include an intercept term).**

Model Term	Notation	Model				
		Superset	SM2 <sup>1</sup>	SM4		SM5 <sup>2</sup>
etOH	$Z_e$	•	•	•		×
Arom	$Z_a$	•	•	•		•
RVP	$Z_r$	•	•	×		•
T50	$Z_5$	•	•	•		•
T90	$Z_9$	•	•	•		•
etOH × etOH	$ZZ_{ee}$	•	×			
T50 × T50	$ZZ_{55}$	•	×			
etOH × Arom	$ZZ_{ea}$	---	---	---		---
etOH × RVP	$ZZ_{er}$	•	•	×		×
etOH × T50	$ZZ_{e5}$	•	•	•		×
etOH × T90	$ZZ_{e9}$	---	---	---		---

<sup>1</sup> Represents “Superset minus 2,” etc.

<sup>2</sup> Not nested within SM4; test with respect to SM2.

**THC (Bag 3): Model fitting history, starting with the 10-term superset model.**

Fit Parameters				<i>Test with respect to Previous Model</i>		
Model	$p$	$-2\ln L$	BIC <sup>1</sup>	Dev.	$d$	$\Pr > \chi^2$
Superset	10	527.403	559.900			
SM2 <sup>2</sup>	8	530.138	557.218	2.735	2	0.255
SM4	6	556.555	534.890	4.753	2	0.0929
SM5	5	562.345	543.388	13.250	3	0.00413

<sup>1</sup> A lower value indicates a better fit.

<sup>2</sup> Best fit with respect to the 11-term design model.

<sup>3</sup> Not nested within SM4; test with respect to SM2.

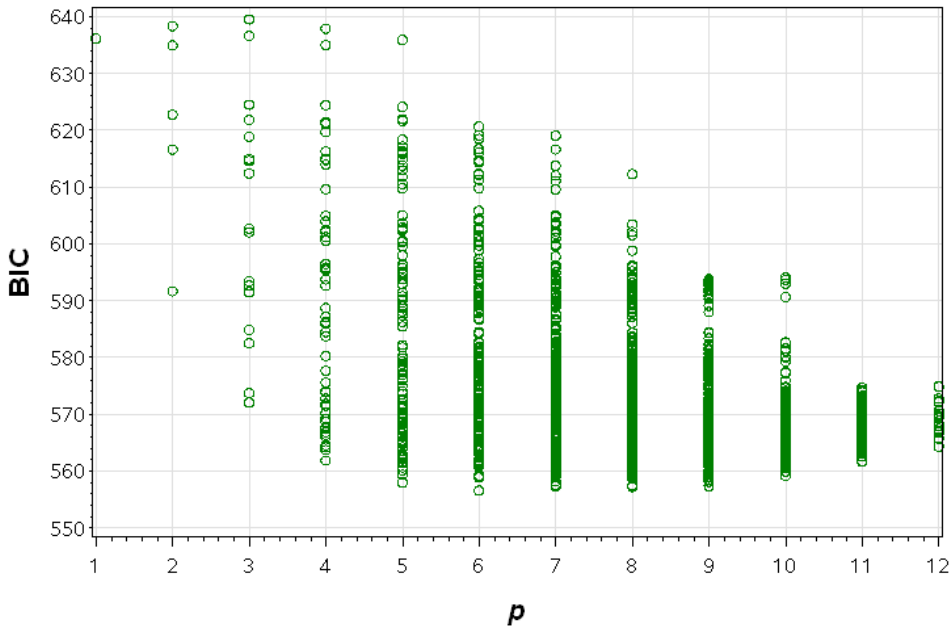
THC (Bag 3): Coefficients and Tests of Effect for the Superset and Reduced Models, with respect to the 11-term design model.

Effect	<i>Full Model (superset)</i>				
	Estimate	Std. Err.	d.f.	t-value	Pr>t
Intercept	-4.2293	0.2433	15	-17.4	0.00000
$Z_{\varepsilon}$	0.002753	0.01466	941	0.188	0.85
$Z_{\alpha}$	-0.06119	0.01026	941	-5.965	0.00000
$Z_{\gamma}$	-0.01863	0.01165	941	-1.599	0.11
$Z_{\beta}$	0.02938	0.01478	941	1.987	0.047
$Z_{\vartheta}$	0.04874	0.01015	941	4.803	0.00000
$ZZ_{\varepsilon\varepsilon}$	-0.008040	0.01953	941	-0.412	0.68
$ZZ_{\beta\beta}$	0.01427	0.01477	941	0.966	0.33
$ZZ_{\varepsilon\alpha}$	---	---	---	---	---
$ZZ_{\varepsilon\gamma}$	0.01530	0.01009	941	1.517	0.13
$ZZ_{\varepsilon\beta}$	-0.03094	0.02103	941	-1.471	0.14
$ZZ_{\varepsilon\vartheta}$	---	---	---	---	---
$\sigma_{veh}^2$	0.8865				
$\sigma_{\tau}^2$	0.09191				

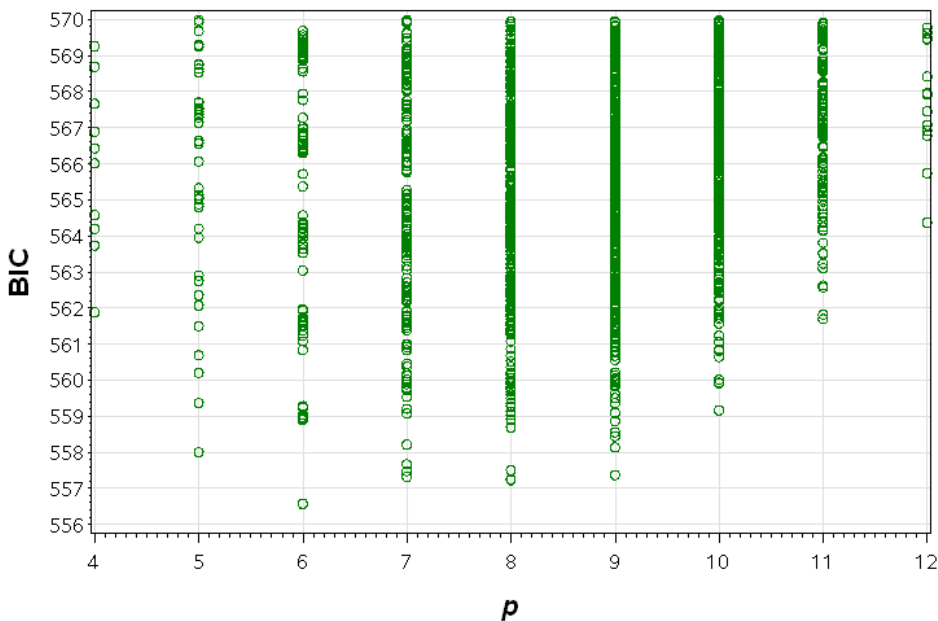
<i>Reduced Model (SM2)</i>				
Estimate	Std. Err.	d.f.	t-value	Pr>t
-4.2300	0.2432	15	-17.4	0.00000
0.0079	0.01301	941	0.606	0.54
-0.0612	0.01024	941	-5.98	0.00000
-0.0142	0.01134	941	-1.25	0.21
0.0360	0.01385	941	2.60	0.0096
0.0490	0.01015	941	4.83	0.00000
---	---	---	---	---
---	---	---	---	---
0.0167	0.0099	941	1.67	0.094
-0.0313	0.0103	941	-3.05	0.0024
---	---	---	---	---
$\sigma_{veh}^2$	0.8860			
$\sigma_{\tau}^2$	0.09218			

### 1.1f.2 Model Fitting with respect to the 16-term extended Model.

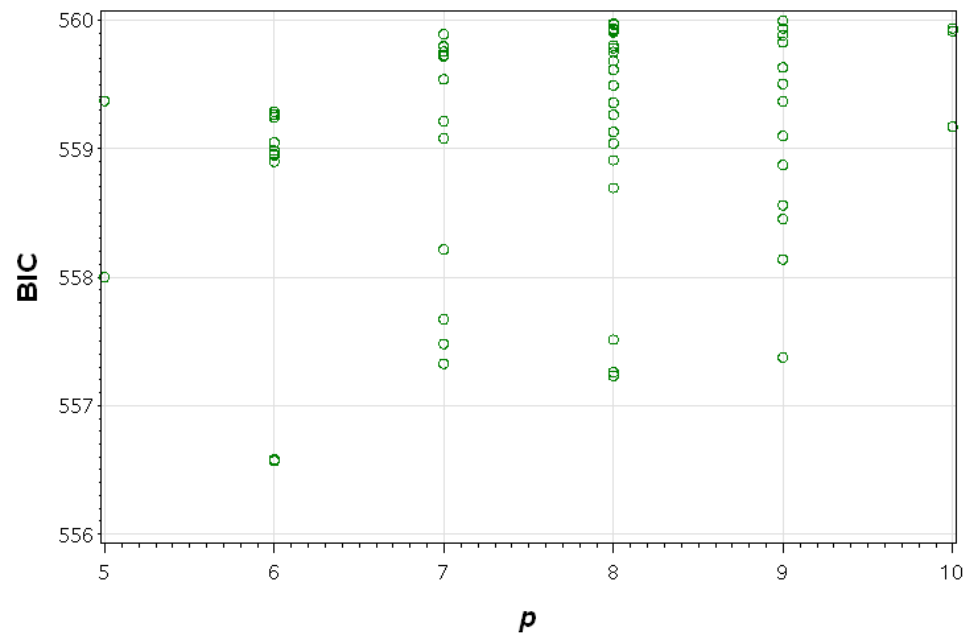
Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy.



Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for subset of models respecting hierarchy (CLOSEUP of previous figure).



**Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for subset of models respecting hierarchy (CLOSEUP of previous figure).**





**THC (Bag 3):** Number of terms ( $p$ ), Goodness-of-fit (BIC) and terms included in the 35 best-fitting candidate models (out of a total of 2,964 possible models with hierarchy). (Terms included in models ranked 1-9 comprise the “superset” for final model-fitting).

Rank	$p$	BIC	Design Terms										Extended Terms					
			etOH	Arom	RVP	T50	T90	etOH $\times$ etOH	T50 $\times$ T50	etOH $\times$ Arom	etOH $\times$ RVP	etOH $\times$ T50	etOH $\times$ T90	Arom $\times$ RVP	Arom $\times$ T50	Arom $\times$ T90	T50 $\times$ T90	RVP $\times$ T90
1	6	556.57	•	•		•	•					•						
2	6	556.58		•	•	•	•		•									
3	8	557.24	•	•	•	•	•				•	•						
4	8	557.26	•	•	•	•	•		•			•						
5	7	557.33	•	•	•	•	•					•						
6	9	557.38	•	•	•	•	•		•		•	•						
7	7	557.48	•	•		•	•		•			•						
8	8	557.52	•	•	•	•	•	•				•						
9	7	557.67	•	•		•	•	•				•						
10	5	558.00		•		•	•		•									
11	9	558.14	•	•	•	•	•	•			•	•						
12	7	558.22	•	•		•	•					•	•					
13	10	558.45	•	•	•	•	•		•		•	•		•				
14	9	558.56	•	•	•	•	•		•			•	•					
15	8	558.70	•	•	•	•	•					•	•					
16	9	558.87	•	•	•	•	•	•				•	•					
17	7	558.90	•	•		•	•					•			•			
18	9	558.91	•	•	•	•	•		•			•		•				
19	7	558.95	•	•		•	•					•				•		
20	7	558.96		•	•	•	•		•							•		
21	7	558.99		•	•	•	•		•								•	
22	8	559.04	•	•	•	•	•		•		•							
23	7	559.05		•	•	•	•		•						•			
24	7	559.08	•	•	•	•	•		•									
25	9	559.10	•	•	•	•	•				•	•	•					
26	8	559.13	•	•		•	•		•			•	•					
27	10	559.17	•	•	•	•	•		•		•	•	•					
28	7	559.22	•	•		•	•			•		•						
29	6	559.25	•	•		•	•		•									
30	9	559.26	•	•	•	•	•				•	•		•				
31	7	559.27		•	•	•	•		•									
32	7	559.27	•	•		•	•					•						
33	7	559.29		•	•	•	•		•						•			
34	8	559.36	•	•		•	•	•				•	•					
35	9	559.37	•	•	•	•	•	•	•		•							

NOTE: Model fitting for 16-term extended model has results identical to that for the 11-term design model, as presented above.