Appendix C

Fast Pass IM240 Standards Developed for Wisconsin

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Wisconsin requested EPA provide fast-pass cutpoints for final and intermediate standards. A method is outlined below. This was applied only to the Appendix. A fast-pass cutpoints but could be used on others also.

1) A scale factor for each pollutant at each second and needed standard is defined.

This was done to calculate the cutpoint at second i for each pollutant at each standard.

For Example:, HC Scale Factor for the 0.8 cutpoint

FPHC Scale Factor = [HC(0.8)Fast Pass Cutpoint at t= i] / [HC(0.8) Fast Pass Cutpoint at t=239]

2) The ratio of the Fast Pass cutpoint at t=239 to the distance traveled (1.973 mi) was found.

This was done so the new fast-pass cutpoints could be scaled to the new full 240 second standard

For HC(0.8g/mi)

FPHC 239 =	1.615	g
Distance =	1.973	mi
FPHC 239 g/mi =	0.81855	

% above 0.8 g/mi standard = (0.818-0.8)/0.8*100 = 2.2%

For New Standard HC(0.6 g/mi)

(FPHC 239 g/mi - 0.6)/0.6 * 100 = 2.2%

(This provides the same 2.2% overshoot as the phase-in fast-pass standards.)

FPHC 239 g/mi = 0.6132g/mi
FPHC 239 g = 1.2098

3) The new fast pass standards will then be calculated as

HC(0.6)FP = FP(0.6)239 * HCSF(0.8)i

t	HC(0.8) g	FPHC SF	HC(0.6) g
30	0.124	0.0768	0.0929
31	0.126	0.0780	0.0944
.....			
238	1.614	0.9994	1.2091
239	1.615	1.0000	1.2098

4) For Phase 2 Cutpoints Where Needed

Take the Old Std.

For Example FPHC Phase 2 = 0.5 g/mi

The Distance traveled from second 108 to second 239 is 1.359 mi

The Old FPHC 239 cutpoint is 0.716 g

In terms of g/mi this is 0.716/1.359 = 0.527 g/mi

The delta between this value and the actual standard is: (0.527-0.5) = 0.027 g/mi

The New FPHC 239 g/mi cutpoint is: 0.4 + 0.027 = 0.427 g/mi. In terms of g, this is FPHC 239 g/mi * 1.359 = 0.580 g

The scale factor is calculated as before for each second of the test, and the Phase 2 cutpoint at each second is calculated by multiplying this scale factor times the New FP cutpoint in g at 239. In this case that New FP cutpoint would be 0.580 * Scale Factor for each second.

	Hydrocarbon(g)						Carbon Monoxide (g)						Oxides of Nitrogen (g)		
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2	Composite	Composite	Composite
Sec	(0.6)	(0.4)	(0.8)	(0.5)	(1.1)	(0.7)	(10.0)	(0.8)	(15.0)	(12.0)	(20.0)	(16.0)	(1.5)	(2.0)	(2.5)
30	0.093	n/a	0.124	n/a	0.226	n/a	0.462	n/a	0.693	n/a	1.502	n/a	0.125	0.167	0.262
31	0.095	n/a	0.126	n/a	0.232	n/a	0.515	n/a	0.773	n/a	1.546	n/a	0.133	0.177	0.275
32	0.097	n/a	0.129	n/a	0.237	n/a	0.558	n/a	0.837	n/a	1.568	n/a	0.141	0.188	0.301
33	0.101	n/a	0.135	n/a	0.241	n/a	0.567	n/a	0.851	n/a	1.582	n/a	0.161	0.214	0.317
34	0.105	n/a	0.140	n/a	0.246	n/a	0.569	n/a	0.853	n/a	1.593	n/a	0.174	0.232	0.327
35	0.110	n/a	0.146	n/a	0.254	n/a	0.571	n/a	0.857	n/a	1.602	n/a	0.180	0.240	0.330
36	0.113	n/a	0.150	n/a	0.259	n/a	0.600	n/a	0.900	n/a	1.621	n/a	0.182	0.243	0.332
37	0.115	n/a	0.153	n/a	0.269	n/a	0.640	n/a	0.960	n/a	1.631	n/a	0.184	0.245	0.334
38	0.117	n/a	0.156	n/a	0.272	n/a	0.689	n/a	1.034	n/a	1.702	n/a	0.185	0.246	0.336
39	0.120	n/a	0.160	n/a	0.273	n/a	0.713	n/a	1.070	n/a	1.784	n/a	0.185	0.246	0.337
40	0.124	n/a	0.165	n/a	0.287	n/a	0.717	n/a	1.076	n/a	1.879	n/a	0.188	0.250	0.354
41	0.127	n/a	0.169	n/a	0.293	n/a	0.722	n/a	1.083	n/a	2.162	n/a	0.195	0.260	0.366
42	0.129	n/a	0.172	n/a	0.300	n/a	0.735	n/a	1.102	n/a	2.307	n/a	0.208	0.277	0.410
43	0.130	n/a	0.173	n/a	0.314	n/a	0.741	n/a	1.111	n/a	2.343	n/a	0.233	0.311	0.414
44	0.133	n/a	0.177	n/a	0.330	n/a	0.743	n/a	1.114	n/a	2.376	n/a	0.246	0.328	0.438
45	0.148	n/a	0.197	n/a	0.345	n/a	0.771	n/a	1.157	n/a	2.406	n/a	0.257	0.343	0.477
46	0.150	n/a	0.200	n/a	0.357	n/a	0.896	n/a	1.344	n/a	2.433	n/a	0.269	0.359	0.506
47	0.156	n/a	0.208	n/a	0.374	n/a	0.988	n/a	1.482	n/a	2.458	n/a	0.280	0.373	0.518
48	0.166	n/a	0.221	n/a	0.388	n/a	1.020	n/a	1.530	n/a	2.483	n/a	0.287	0.383	0.522
49	0.174	n/a	0.232	n/a	0.398	n/a	1.028	n/a	1.542	n/a	2.774	n/a	0.289	0.385	0.526
50	0.176	n/a	0.235	n/a	0.407	n/a	1.035	n/a	1.553	n/a	2.844	n/a	0.300	0.400	0.554
51	0.179	n/a	0.238	n/a	0.416	n/a	1.047	n/a	1.571	n/a	2.900	n/a	0.308	0.410	0.574
52	0.180	n/a	0.240	n/a	0.426	n/a	1.063	n/a	1.595	n/a	2.936	n/a	0.326	0.434	0.587
53	0.182	n/a	0.242	n/a	0.433	n/a	1.089	n/a	1.633	n/a	3.133	n/a	0.348	0.464	0.601
54	0.185	n/a	0.246	n/a	0.438	n/a	1.123	n/a	1.685	n/a	3.304	n/a	0.354	0.472	0.615
55	0.187	n/a	0.249	n/a	0.445	n/a	1.126	n/a	1.689	n/a	3.407	n/a	0.360	0.480	0.629
56	0.189	n/a	0.252	n/a	0.452	n/a	1.129	n/a	1.693	n/a	3.456	n/a	0.368	0.491	0.643
57	0.196	n/a	0.261	n/a	0.458	n/a	1.133	n/a	1.700	n/a	3.480	n/a	0.375	0.500	0.667
58	0.203	n/a	0.271	n/a	0.463	n/a	1.149	n/a	1.723	n/a	3.518	n/a	0.380	0.506	0.678
59	0.207	n/a	0.276	n/a	0.471	n/a	1.235	n/a	1.852	n/a	3.560	n/a	0.382	0.509	0.683
60	0.209	n/a	0.278	n/a	0.492	n/a	1.248	n/a	1.872	n/a	3.593	n/a	0.384	0.512	0.686
61	0.210	n/a	0.280	n/a	0.495	n/a	1.248	n/a	1.872	n/a	3.628	n/a	0.387	0.516	0.693
62	0.212	n/a	0.282	n/a	0.498	n/a	1.248	n/a	1.872	n/a	3.641	n/a	0.389	0.519	0.699
63	0.212	n/a	0.283	n/a	0.501	n/a	1.267	n/a	1.900	n/a	3.655	n/a	0.392	0.523	0.703
64	0.213	n/a	0.284	n/a	0.505	n/a	1.278	n/a	1.917	n/a	3.680	n/a	0.397	0.529	0.707
65	0.214	n/a	0.285	n/a	0.512	n/a	1.296	n/a	1.944	n/a	3.700	n/a	0.400	0.533	0.711
66	0.215	n/a	0.286	n/a	0.520	n/a	1.333	n/a	2.000	n/a	3.728	n/a	0.401	0.535	0.716
67	0.216	n/a	0.288	n/a	0.527	n/a	1.373	n/a	2.060	n/a	3.857	n/a	0.405	0.540	0.721
68	0.218	n/a	0.291	n/a	0.539	n/a	1.376	n/a	2.064	n/a	3.894	n/a	0.413	0.551	0.726
69	0.221	n/a	0.294	n/a	0.545	n/a	1.384	n/a	2.076	n/a	3.943	n/a	0.422	0.563	0.742
70	0.222	n/a	0.296	n/a	0.551	n/a	1.403	n/a	2.104	n/a	3.983	n/a	0.431	0.575	0.759
71	0.224	n/a	0.298	n/a	0.556	n/a	1.411	n/a	2.117	n/a	4.009	n/a	0.441	0.588	0.773
72	0.225	n/a	0.300	n/a	0.559	n/a	1.417	n/a	2.125	n/a	4.023	n/a	0.450	0.600	0.784
73	0.227	n/a	0.302	n/a	0.566	n/a	1.420	n/a	2.130	n/a	4.023	n/a	0.452	0.603	0.790
74	0.228	n/a	0.304	n/a	0.578	n/a	1.425	n/a	2.138	n/a	4.053	n/a	0.453	0.604	0.794
75	0.230	n/a	0.307	n/a	0.589	n/a	1.435	n/a	2.152	n/a	4.063	n/a	0.460	0.613	0.799
76	0.231	n/a	0.308	n/a	0.597	n/a	1.447	n/a	2.170	n/a	4.077	n/a	0.468	0.624	0.809
77	0.231	n/a	0.308	n/a	0.604	n/a	1.459	n/a	2.188	n/a	4.225	n/a	0.485	0.646	0.821

78	0.231	n/a	0.308	n/a	0.611	n/a	1.467	n/a	2.200	n/a	4.243	n/a	0.488	0.651	0.833
79	0.236	n/a	0.314	n/a	0.620	n/a	1.475	n/a	2.212	n/a	4.260	n/a	0.494	0.659	0.839
80	0.240	n/a	0.320	n/a	0.624	n/a	1.475	n/a	2.212	n/a	4.282	n/a	0.505	0.673	0.844
81	0.243	n/a	0.324	n/a	0.628	n/a	1.481	n/a	2.221	n/a	4.322	n/a	0.522	0.696	0.857
82	0.245	n/a	0.327	n/a	0.632	n/a	1.481	n/a	2.222	n/a	4.398	n/a	0.530	0.706	0.870
83	0.247	n/a	0.329	n/a	0.636	n/a	1.485	n/a	2.227	n/a	4.482	n/a	0.536	0.715	0.883
84	0.250	n/a	0.333	n/a	0.642	n/a	1.491	n/a	2.236	n/a	4.515	n/a	0.543	0.724	0.894
85	0.252	n/a	0.336	n/a	0.646	n/a	1.495	n/a	2.243	n/a	4.518	n/a	0.553	0.737	0.902
86	0.254	n/a	0.339	n/a	0.650	n/a	1.508	n/a	2.262	n/a	4.520	n/a	0.560	0.747	0.907
87	0.257	n/a	0.343	n/a	0.654	n/a	1.514	n/a	2.271	n/a	4.522	n/a	0.561	0.748	0.910
88	0.260	n/a	0.347	n/a	0.657	n/a	1.523	n/a	2.284	n/a	4.522	n/a	0.561	0.748	0.912
89	0.263	n/a	0.350	n/a	0.661	n/a	1.533	n/a	2.299	n/a	4.523	n/a	0.561	0.748	0.913
90	0.267	n/a	0.356	n/a	0.664	n/a	1.539	n/a	2.308	n/a	4.526	n/a	0.561	0.748	0.914
91	0.269	n/a	0.358	n/a	0.666	n/a	1.551	n/a	2.326	n/a	4.527	n/a	0.561	0.748	0.915
92	0.270	n/a	0.360	n/a	0.668	n/a	1.553	n/a	2.330	n/a	4.527	n/a	0.561	0.748	0.916
93	0.272	n/a	0.363	n/a	0.670	n/a	1.554	n/a	2.331	n/a	4.528	n/a	0.561	0.748	0.917
94	0.275	n/a	0.367	n/a	0.673	n/a	1.563	n/a	2.344	n/a	4.528	n/a	0.561	0.748	0.918
95	0.278	n/a	0.370	n/a	0.678	n/a	1.565	n/a	2.347	n/a	4.528	n/a	0.561	0.748	0.919
96	0.279	n/a	0.372	n/a	0.686	n/a	1.570	n/a	2.355	n/a	4.529	n/a	0.561	0.748	0.920
97	0.282	n/a	0.376	n/a	0.696	n/a	1.597	n/a	2.395	n/a	4.575	n/a	0.561	0.748	0.921
98	0.291	n/a	0.388	n/a	0.707	n/a	1.634	n/a	2.451	n/a	4.703	n/a	0.561	0.748	0.922
99	0.297	n/a	0.396	n/a	0.718	n/a	1.672	n/a	2.508	n/a	4.805	n/a	0.563	0.751	0.924
100	0.304	n/a	0.405	n/a	0.727	n/a	1.727	n/a	2.590	n/a	4.886	n/a	0.573	0.764	0.929
101	0.308	n/a	0.410	n/a	0.743	n/a	1.773	n/a	2.660	n/a	4.957	n/a	0.592	0.789	0.941
102	0.308	n/a	0.411	n/a	0.754	n/a	1.833	n/a	2.749	n/a	5.104	n/a	0.617	0.822	0.970
103	0.309	n/a	0.412	n/a	0.766	n/a	1.942	n/a	2.913	n/a	5.340	n/a	0.650	0.867	1.027
104	0.310	n/a	0.413	n/a	0.782	n/a	2.108	n/a	3.162	n/a	5.496	n/a	0.679	0.905	1.093
105	0.316	n/a	0.421	n/a	0.798	n/a	2.113	n/a	3.170	n/a	5.625	n/a	0.694	0.925	1.155
106	0.321	n/a	0.428	n/a	0.813	n/a	2.131	n/a	3.197	n/a	5.815	n/a	0.716	0.955	1.234
107	0.323	n/a	0.430	n/a	0.824	n/a	2.192	n/a	3.288	n/a	6.473	n/a	0.739	0.985	1.275
108	0.341	n/a	0.455	n/a	0.853	n/a	2.279	n/a	3.419	n/a	7.037	n/a	0.745	0.993	1.305
109	0.344	0.012	0.459	0.015	0.868	0.037	2.391	0.115	3.587	0.168	7.419	0.246	0.746	0.995	1.320
110	0.347	0.014	0.462	0.017	0.877	0.044	2.397	0.119	3.595	0.173	7.643	0.257	0.747	0.996	1.332
111	0.348	0.017	0.464	0.021	0.885	0.049	2.427	0.163	3.640	0.237	7.759	0.286	0.758	1.010	1.346
112	0.350	0.019	0.466	0.024	0.890	0.052	2.493	0.183	3.740	0.266	7.824	0.379	0.771	1.028	1.358
113	0.351	0.019	0.468	0.024	0.896	0.057	2.579	0.192	3.868	0.280	7.889	0.425	0.776	1.034	1.378
114	0.353	0.020	0.471	0.025	0.901	0.060	2.585	0.200	3.877	0.291	7.960	0.457	0.783	1.044	1.406
115	0.366	0.021	0.488	0.026	0.919	0.067	2.623	0.216	3.934	0.314	8.024	0.477	0.794	1.059	1.426
116	0.385	0.023	0.513	0.029	0.944	0.076	2.677	0.227	4.015	0.331	8.076	0.494	0.806	1.075	1.438
117	0.404	0.026	0.538	0.032	0.954	0.077	2.707	0.237	4.061	0.345	8.111	0.504	0.810	1.080	1.448
118	0.421	0.028	0.561	0.035	0.963	0.078	2.709	0.240	4.063	0.350	8.130	0.512	0.810	1.080	1.460
119	0.433	0.028	0.577	0.035	0.964	0.086	2.719	0.245	4.079	0.356	8.148	0.519	0.811	1.081	1.462
120	0.435	0.029	0.580	0.036	0.967	0.088	2.760	0.252	4.140	0.367	8.211	0.529	0.818	1.091	1.467
121	0.440	0.031	0.586	0.038	0.973	0.091	2.790	0.267	4.185	0.388	8.478	0.529	0.822	1.096	1.476
122	0.446	0.032	0.594	0.040	0.982	0.094	2.799	0.280	4.199	0.407	8.548	0.530	0.833	1.111	1.494
123	0.452	0.033	0.603	0.041	0.991	0.096	2.803	0.318	4.205	0.463	8.561	0.531	0.842	1.122	1.505
124	0.458	0.034	0.610	0.042	1.000	0.099	2.808	0.330	4.212	0.480	8.568	0.532	0.851	1.135	1.517
125	0.461	0.034	0.615	0.042	1.010	0.101	2.821	0.348	4.232	0.506	8.572	0.533	0.854	1.138	1.546
126	0.468	0.034	0.624	0.042	1.018	0.103	2.865	0.356	4.298	0.518	8.584	0.548	0.854	1.139	1.569
127	0.471	0.036	0.628	0.045	1.023	0.105	2.896	0.359	4.344	0.522	8.592	0.610	0.854	1.139	1.586
128	0.474	0.037	0.632	0.046	1.028	0.107	2.907	0.361	4.361	0.525	8.596	0.614	0.854	1.139	1.596
129	0.478	0.037	0.637	0.046	1.031	0.109	2.911	0.363	4.366	0.528	8.597	0.622	0.854	1.139	1.603
130	0.481	0.040	0.641	0.049	1.034	0.111	2.913	0.364	4.369	0.530	8.601	0.631	0.854	1.139	1.605

131	**0.482**	**0.041**	**0.643**	**0.050**	**1.036**	**0.112**	**2.915**	**0.364**	**4.372**	**0.530**	**8.605**	**0.640**	**0.854**	**1.139**	**1.606**
132	**0.483**	**0.042**	**0.644**	**0.052**	**1.038**	**0.114**	**2.957**	**0.367**	**4.435**	**0.534**	**8.608**	**0.646**	**0.854**	**1.139**	**1.607**
133	**0.484**	**0.044**	**0.645**	**0.054**	**1.040**	**0.115**	**3.015**	**0.378**	**4.523**	**0.550**	**8.626**	**0.650**	**0.854**	**1.139**	**1.607**
134	**0.485**	**0.044**	**0.647**	**0.054**	**1.040**	**0.116**	**3.016**	**0.381**	**4.524**	**0.554**	**8.650**	**0.652**	**0.854**	**1.139**	**1.608**
135	**0.488**	**0.044**	**0.651**	**0.054**	**1.048**	**0.119**	**3.017**	**0.405**	**4.525**	**0.590**	**8.660**	**0.738**	**0.854**	**1.139**	**1.614**
136	**0.494**	**0.045**	**0.658**	**0.055**	**1.051**	**0.122**	**3.021**	**0.423**	**4.531**	**0.616**	**8.767**	**0.754**	**0.870**	**1.160**	**1.616**
137	**0.497**	**0.045**	**0.663**	**0.055**	**1.060**	**0.126**	**3.023**	**0.439**	**4.534**	**0.639**	**9.029**	**0.780**	**0.881**	**1.174**	**1.631**
138	**0.500**	**0.045**	**0.666**	**0.056**	**1.066**	**0.130**	**3.028**	**0.449**	**4.542**	**0.653**	**9.238**	**0.795**	**0.887**	**1.183**	**1.643**
139	**0.501**	**0.048**	**0.668**	**0.059**	**1.087**	**0.137**	**3.035**	**0.455**	**4.553**	**0.662**	**9.389**	**0.804**	**0.898**	**1.197**	**1.656**
140	**0.503**	**0.049**	**0.670**	**0.061**	**1.149**	**0.140**	**3.036**	**0.469**	**4.554**	**0.683**	**9.493**	**0.810**	**0.917**	**1.223**	**1.673**
141	**0.504**	**0.049**	**0.672**	**0.061**	**1.157**	**0.141**	**3.036**	**0.478**	**4.554**	**0.696**	**9.583**	**0.815**	**0.941**	**1.255**	**1.703**
142	**0.506**	**0.049**	**0.675**	**0.061**	**1.165**	**0.143**	**3.036**	**0.486**	**4.554**	**0.708**	**9.626**	**0.818**	**0.954**	**1.272**	**1.739**
143	**0.509**	**0.051**	**0.678**	**0.063**	**1.171**	**0.145**	**3.036**	**0.495**	**4.554**	**0.721**	**9.669**	**0.821**	**0.965**	**1.286**	**1.767**
144	**0.511**	**0.052**	**0.681**	**0.064**	**1.176**	**0.147**	**3.036**	**0.508**	**4.554**	**0.739**	**9.716**	**0.825**	**0.978**	**1.304**	**1.774**
145	**0.513**	**0.053**	**0.684**	**0.065**	**1.183**	**0.152**	**3.036**	**0.510**	**4.554**	**0.742**	**9.763**	**0.840**	**0.980**	**1.307**	**1.785**
146	**0.515**	**0.053**	**0.686**	**0.066**	**1.186**	**0.154**	**3.036**	**0.510**	**4.554**	**0.743**	**9.809**	**0.847**	**0.984**	**1.312**	**1.806**
147	**0.516**	**0.054**	**0.688**	**0.067**	**1.188**	**0.156**	**3.036**	**0.512**	**4.554**	**0.745**	**9.852**	**0.855**	**0.988**	**1.317**	**1.830**
148	**0.518**	**0.055**	**0.690**	**0.068**	**1.190**	**0.157**	**3.036**	**0.514**	**4.554**	**0.748**	**9.885**	**0.865**	**0.991**	**1.321**	**1.844**
149	**0.519**	**0.056**	**0.692**	**0.069**	**1.194**	**0.158**	**3.036**	**0.516**	**4.554**	**0.751**	**9.932**	**0.874**	**0.994**	**1.325**	**1.845**
150	**0.521**	**0.057**	**0.694**	**0.070**	**1.206**	**0.159**	**3.036**	**0.524**	**4.554**	**0.762**	**9.986**	**0.891**	**0.996**	**1.328**	**1.846**
151	**0.522**	**0.058**	**0.696**	**0.071**	**1.219**	**0.160**	**3.037**	**0.542**	**4.556**	**0.789**	**10.039**	**0.914**	**0.999**	**1.332**	**1.852**
152	**0.524**	**0.058**	**0.698**	**0.072**	**1.230**	**0.161**	**3.037**	**0.543**	**4.556**	**0.790**	**10.072**	**0.929**	**1.004**	**1.338**	**1.868**
153	**0.525**	**0.059**	**0.700**	**0.073**	**1.236**	**0.162**	**3.043**	**0.546**	**4.565**	**0.794**	**10.090**	**0.937**	**1.008**	**1.344**	**1.877**
154	**0.527**	**0.059**	**0.702**	**0.073**	**1.240**	**0.164**	**3.075**	**0.549**	**4.612**	**0.799**	**10.105**	**0.942**	**1.013**	**1.350**	**1.879**
155	**0.528**	**0.060**	**0.704**	**0.074**	**1.249**	**0.167**	**3.223**	**0.553**	**4.834**	**0.805**	**10.146**	**0.949**	**1.018**	**1.357**	**1.886**
156	**0.530**	**0.062**	**0.706**	**0.077**	**1.251**	**0.169**	**3.801**	**0.578**	**5.702**	**0.842**	**10.245**	**1.375**	**1.024**	**1.365**	**1.900**
157	**0.531**	**0.064**	**0.708**	**0.079**	**1.252**	**0.177**	**3.894**	**0.680**	**5.841**	**0.990**	**10.397**	**1.576**	**1.034**	**1.379**	**1.910**
158	**0.533**	**0.066**	**0.710**	**0.082**	**1.259**	**0.185**	**4.113**	**0.713**	**6.170**	**1.038**	**10.923**	**1.943**	**1.061**	**1.414**	**1.936**
159	**0.534**	**0.066**	**0.712**	**0.082**	**1.281**	**0.190**	**4.447**	**0.932**	**6.670**	**1.357**	**11.970**	**2.820**	**1.100**	**1.466**	**1.954**
160	**0.537**	**0.070**	**0.716**	**0.086**	**1.304**	**0.194**	**4.950**	**1.000**	**7.425**	**1.455**	**13.421**	**3.281**	**1.136**	**1.514**	**1.986**
161	**0.563**	**0.077**	**0.750**	**0.095**	**1.320**	**0.200**	**5.586**	**1.062**	**8.379**	**1.546**	**15.289**	**3.483**	**1.169**	**1.559**	**2.050**
162	**0.588**	**0.087**	**0.784**	**0.107**	**1.331**	**0.207**	**6.432**	**1.253**	**9.648**	**1.824**	**15.912**	**3.620**	**1.193**	**1.591**	**2.131**
163	**0.604**	**0.093**	**0.805**	**0.115**	**1.343**	**0.215**	**7.279**	**1.887**	**10.918**	**2.746**	**16.530**	**4.168**	**1.231**	**1.641**	**2.235**
164	**0.630**	**0.099**	**0.840**	**0.122**	**1.383**	**0.231**	**8.105**	**2.111**	**12.157**	**3.073**	**17.622**	**4.338**	**1.289**	**1.719**	**2.320**
165	**0.640**	**0.103**	**0.853**	**0.127**	**1.405**	**0.257**	**8.487**	**2.496**	**12.731**	**3.633**	**18.366**	**4.682**	**1.333**	**1.777**	**2.395**
166	**0.656**	**0.129**	**0.874**	**0.159**	**1.425**	**0.289**	**8.554**	**3.095**	**12.831**	**4.505**	**19.869**	**5.633**	**1.374**	**1.832**	**2.488**
167	**0.677**	**0.151**	**0.903**	**0.186**	**1.445**	**0.298**	**8.595**	**3.402**	**12.892**	**4.952**	**20.711**	**6.137**	**1.439**	**1.919**	**2.563**
168	**0.683**	**0.153**	**0.910**	**0.189**	**1.465**	**0.302**	**8.621**	**3.610**	**12.932**	**5.254**	**22.319**	**6.853**	**1.479**	**1.972**	**2.645**
169	**0.686**	**0.162**	**0.914**	**0.200**	**1.483**	**0.312**	**9.135**	**3.937**	**13.702**	**5.730**	**23.751**	**7.136**	**1.510**	**2.013**	**2.746**
170	**0.687**	**0.178**	**0.916**	**0.220**	**1.500**	**0.321**	**9.426**	**4.157**	**14.139**	**6.051**	**24.842**	**7.320**	**1.575**	**2.100**	**2.778**
171	**0.689**	**0.191**	**0.919**	**0.236**	**1.527**	**0.333**	**9.976**	**4.351**	**14.964**	**6.333**	**25.410**	**7.685**	**1.650**	**2.200**	**2.792**
172	**0.698**	**0.200**	**0.931**	**0.247**	**1.545**	**0.361**	**10.469**	**4.459**	**15.704**	**6.490**	**25.798**	**8.052**	**1.688**	**2.251**	**2.810**
173	**0.711**	**0.208**	**0.948**	**0.257**	**1.582**	**0.383**	**10.835**	**4.669**	**16.253**	**6.796**	**26.122**	**8.344**	**1.703**	**2.270**	**2.847**
174	**0.737**	**0.216**	**0.983**	**0.267**	**1.597**	**0.406**	**11.271**	**4.950**	**16.907**	**7.205**	**26.353**	**8.602**	**1.726**	**2.301**	**2.874**
175	**0.764**	**0.229**	**1.018**	**0.283**	**1.610**	**0.424**	**11.770**	**5.600**	**17.655**	**8.151**	**26.638**	**8.898**	**1.739**	**2.318**	**2.905**
176	**0.770**	**0.239**	**1.027**	**0.295**	**1.622**	**0.434**	**12.013**	**5.654**	**18.020**	**8.230**	**27.219**	**9.251**	**1.751**	**2.335**	**2.950**
177	**0.776**	**0.253**	**1.035**	**0.312**	**1.635**	**0.475**	**12.233**	**5.898**	**18.349**	**8.584**	**27.279**	**10.253**	**1.762**	**2.349**	**3.001**
178	**0.788**	**0.258**	**1.051**	**0.318**	**1.652**	**0.490**	**12.447**	**6.046**	**18.671**	**8.800**	**27.320**	**10.828**	**1.790**	**2.387**	**3.047**
179	**0.806**	**0.262**	**1.074**	**0.323**	**1.670**	**0.495**	**12.648**	**6.078**	**18.972**	**8.847**	**27.352**	**10.933**	**1.817**	**2.423**	**3.104**
180	**0.813**	**0.273**	**1.084**	**0.337**	**1.689**	**0.507**	**12.819**	**6.124**	**19.228**	**8.913**	**27.822**	**11.060**	**1.847**	**2.462**	**3.173**
181	**0.824**	**0.280**	**1.099**	**0.345**	**1.709**	**0.514**	**13.415**	**6.267**	**20.123**	**9.122**	**28.763**	**11.188**	**1.877**	**2.503**	**3.238**
182	**0.841**	**0.284**	**1.121**	**0.350**	**1.727**	**0.524**	**13.603**	**6.549**	**20.405**	**9.532**	**29.402**	**11.345**	**1.909**	**2.545**	**3.302**
183	**0.849**	**0.291**	**1.132**	**0.359**	**1.738**	**0.535**	**13.836**	**7.046**	**20.754**	**10.256**	**29.971**	**11.733**	**1.940**	**2.586**	**3.372**

184	0.864	0.314	1.152	0.387	1.755	0.547	14.456	7.463	21.684	10.862	30.276	12.598	1.970	2.627	3.452
185	0.871	0.322	1.161	0.398	1.778	0.560	14.637	7.555	21.955	10.996	30.988	12.953	2.005	2.673	3.545
186	0.876	0.324	1.168	0.400	1.795	0.574	15.100	7.699	22.650	11.206	31.095	13.213	2.062	2.749	3.648
187	0.881	0.326	1.175	0.402	1.808	0.585	15.326	7.911	22.989	11.514	31.314	14.131	2.103	2.804	3.701
188	0.886	0.328	1.181	0.405	1.820	0.589	15.690	8.172	23.535	11.894	31.833	14.839	2.138	2.851	3.759
189	0.891	0.339	1.188	0.418	1.825	0.589	15.917	8.258	23.876	12.019	32.239	15.137	2.171	2.894	3.821
190	0.902	0.348	1.203	0.429	1.827	0.598	16.012	8.361	24.018	12.170	32.547	15.138	2.198	2.931	3.870
191	0.914	0.358	1.219	0.442	1.829	0.607	16.309	8.600	24.464	12.517	32.855	15.141	2.228	2.971	3.892
192	0.925	0.370	1.233	0.457	1.834	0.617	16.457	8.655	24.685	12.598	33.153	15.595	2.265	3.020	3.914
193	0.938	0.383	1.251	0.473	1.847	0.621	16.621	8.674	24.931	12.625	33.444	15.658	2.308	3.077	3.955
194	0.941	0.395	1.255	0.487	1.862	0.629	16.792	8.693	25.188	12.653	33.482	15.704	2.349	3.132	3.997
195	0.944	0.406	1.258	0.501	1.876	0.638	16.979	8.778	25.468	12.777	33.516	15.729	2.389	3.185	4.035
196	0.949	0.413	1.265	0.510	1.891	0.649	17.085	8.867	25.627	12.906	33.549	16.058	2.414	3.219	4.089
197	0.960	0.415	1.280	0.512	1.906	0.664	17.164	8.924	25.746	12.989	33.653	16.987	2.451	3.268	4.146
198	0.970	0.416	1.293	0.514	1.920	0.679	17.233	8.973	25.850	13.060	33.973	17.064	2.474	3.299	4.206
199	0.976	0.418	1.301	0.516	1.933	0.693	17.316	9.045	25.974	13.165	34.159	17.073	2.513	3.350	4.243
200	0.985	0.420	1.313	0.518	1.945	0.706	17.427	9.098	26.141	13.242	34.191	17.153	2.555	3.406	4.295
201	0.993	0.427	1.324	0.527	1.953	0.719	17.483	9.215	26.225	13.412	34.250	17.332	2.600	3.466	4.351
202	0.999	0.438	1.332	0.540	1.959	0.726	17.559	9.386	26.338	13.662	34.469	17.406	2.623	3.497	4.398
203	1.006	0.443	1.341	0.547	1.977	0.737	17.698	9.463	26.547	13.773	34.716	17.641	2.636	3.514	4.410
204	1.018	0.448	1.357	0.553	1.991	0.745	17.879	9.579	26.818	13.942	34.969	17.922	2.638	3.517	4.419
205	1.031	0.453	1.375	0.559	2.011	0.752	18.035	9.680	27.052	14.090	35.144	18.484	2.639	3.519	4.426
206	1.044	0.456	1.392	0.563	2.037	0.800	18.262	9.773	27.393	14.224	35.418	18.553	2.642	3.523	4.429
207	1.056	0.459	1.408	0.567	2.058	0.805	18.334	9.911	27.501	14.426	35.766	18.658	2.659	3.545	4.453
208	1.067	0.463	1.422	0.571	2.079	0.817	18.421	9.961	27.632	14.498	35.949	18.953	2.678	3.570	4.486
209	1.075	0.466	1.433	0.575	2.089	0.836	18.535	10.152	27.803	14.776	36.010	19.266	2.700	3.600	4.542
210	1.082	0.469	1.443	0.579	2.097	0.839	18.635	10.242	27.953	14.907	36.548	19.309	2.714	3.619	4.598
211	1.090	0.482	1.453	0.595	2.109	0.846	18.803	10.248	28.205	14.916	37.179	19.731	2.729	3.639	4.638
212	1.097	0.490	1.463	0.605	2.123	0.866	19.029	10.315	28.543	15.014	37.651	19.902	2.765	3.686	4.715
213	1.101	0.497	1.468	0.614	2.138	0.879	19.331	10.458	28.997	15.221	38.041	20.012	2.799	3.732	4.774
214	1.103	0.504	1.470	0.622	2.150	0.882	19.333	10.630	29.000	15.472	38.591	20.260	2.843	3.791	4.829
215	1.106	0.508	1.474	0.627	2.158	0.891	19.337	10.687	29.005	15.555	38.852	20.739	2.875	3.833	4.872
216	1.109	0.517	1.478	0.638	2.165	0.905	19.387	10.754	29.081	15.652	38.861	21.346	2.918	3.890	4.931
217	1.111	0.521	1.481	0.643	2.171	0.917	19.521	10.971	29.281	15.969	38.926	21.810	2.949	3.932	4.960
218	1.113	0.521	1.484	0.643	2.178	0.918	19.655	11.012	29.483	16.028	39.194	22.001	2.970	3.960	4.963
219	1.115	0.523	1.487	0.645	2.185	0.919	19.823	11.250	29.734	16.375	39.474	22.290	2.998	3.997	4.965
220	1.118	0.527	1.490	0.651	2.192	0.941	19.869	11.327	29.803	16.487	39.668	22.324	3.010	4.013	4.968
221	1.120	0.531	1.493	0.655	2.195	0.952	19.881	11.353	29.821	16.524	39.781	22.343	3.026	4.035	4.971
222	1.128	0.537	1.504	0.663	2.200	0.957	19.898	11.390	29.847	16.578	39.890	22.522	3.029	4.038	4.974
223	1.142	0.544	1.522	0.671	2.205	0.963	19.908	11.463	29.862	16.684	39.954	22.661	3.038	4.050	4.977
224	1.160	0.547	1.547	0.675	2.208	0.970	19.915	11.511	29.873	16.755	39.984	22.666	3.050	4.066	4.979
225	1.162	0.554	1.549	0.684	2.212	0.975	20.005	11.522	30.008	16.770	39.989	22.667	3.053	4.070	4.980
226	1.172	0.562	1.562	0.694	2.214	0.979	20.084	11.546	30.126	16.805	39.990	22.668	3.054	4.072	4.981
227	1.181	0.568	1.574	0.701	2.216	0.985	20.085	11.587	30.127	16.865	39.990	22.669	3.054	4.072	4.982
228	1.184	0.569	1.579	0.702	2.217	0.988	20.085	11.652	30.127	16.960	39.990	22.670	3.055	4.073	4.983
229	1.188	0.574	1.584	0.708	2.218	0.992	20.139	11.652	30.208	16.960	39.991	22.671	3.055	4.073	4.984
230	1.192	0.574	1.589	0.708	2.219	0.995	20.209	11.654	30.314	16.962	40.012	22.671	3.055	4.073	4.985
231	1.193	0.574	1.590	0.709	2.221	0.996	20.215	11.672	30.323	16.988	40.061	22.672	3.055	4.073	4.986
232	1.197	0.575	1.596	0.710	2.223	0.996	20.217	11.729	30.325	17.072	40.116	22.673	3.056	4.074	4.987
233	1.199	0.575	1.598	0.710	2.225	0.996	20.245	11.744	30.368	17.094	40.249	22.673	3.056	4.074	4.988
234	1.203	0.576	1.604	0.711	2.227	0.997	20.274	11.806	30.411	17.184	40.253	22.673	3.056	4.075	4.989
235	1.208	0.577	1.610	0.712	2.228	0.997	20.277	11.808	30.416	17.187	40.290	22.674	3.056	4.075	4.990
236	1.209	0.577	1.612	0.712	2.228	0.999	20.285	11.809	30.428	17.188	40.385	22.675	3.057	4.076	4.991

237	**1.210**	**0.577**	**1.613**	**0.712**	**2.229**	**1.001**	**20.287**	**11.810**	**30.430**	**17.189**	**40.488**	**22.675**	**3.057**	**4.076**	**4.992**
238	**1.211**	**0.578**	**1.614**	**0.713**	**2.230**	**1.004**	**20.301**	**11.845**	**30.452**	**17.241**	**40.720**	**22.675**	**3.057**	**4.076**	**4.993**
239	**1.211**	**0.580**	**1.615**	**0.716**	**2.231**	**1.007**	**20.325**	**11.934**	**30.488**	**17.370**	**40.763**	**22.677**	**3.057**	**4.076**	**4.994**

Appendix D

Fast Pass IM240 Standards: Modal Regression Technique

Developed by Sierra Research
Contract 68-C4-0056 Work Assignment 2-04

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Development of Fast-Pass Standards

This method differs from those presented in Appendices A, B, and C in that second-by-second standards are not used, rather the second-by-second emissions are used to project a final IM240 score which is then compared to the appropriate IM240 standard as listed on pages 1-4 of this document. A sample of the regression coefficients used to project the full IM240 scores are presented in the appendix. The complete set of coefficients can be downloaded from the EPA web site.

Full-duration, second-by-second IM240 data collected in the Arizona I/M program were used for this analysis. Nearly 110,000 individual tests were in the database used in the analysis, which is comprised of all full-duration IM240 tests conducted in Arizona from April 1995 through April. Regression coefficients were generated separately for light-duty gasoline vehicles (i.e., passenger cars) and light-duty trucks for the following model year groups listed below.

- 1981 to 1984,
- 1985 to 1989, and
- 1990 and later.

Regression coefficients were developed for HC, CO, and NOx and for both the composite IM240 and for Phase 2 of the IM240 after dividing the IM240 drive trace into 24 separate modes. The Phase 2 regressions used mode 11 as the first mode and continued through mode 23. The composite IM240 regressions used modes 1 through 23. (Although the trace was divided into 24 modes, if a fast-pass decision is not made by mode 23, then the vehicle would run the full IM240. At that point, a pass/fail decision should be made on the actual IM240 score, not the predicted score.) Finally, it is recommended that the first mode at which a pass/fail decision should be made is mode 4 (which ends at second 32 of the IM240) for a composite IM240 prediction, or mode 13 (which ends at second 113 of the IM240) for a Phase 2 prediction.

The regression coefficients for a 0.8 g/mi HC composite IM240 cutpoint are given in this appendix, along with the coefficients for a 0.5 g/mi HC Phase 2 IM240 cutpoint. The full series of regression coefficients developed in this effort were provided to EPA electronically, and are available on the OMS web page.

Using the 2% Random Sample from the Arizona program (which consists of 26,000 records), pass/fail rates were calculated with the modal regression procedures outlined above as well as the current fast-pass cutpoint tables. This analysis was performed using the final IM240 HC, CO, and NOx standards, and the results are presented in Table D1.

As observed in Table D1, the revised fast-pass methodology results in a lower fraction of false passes than the current method, particularly for older cars. However, this improvement in failing vehicle identification is offset by a longer average test time for passing vehicles in the older model year groups. For newer vehicles (i.e., 1990 and later), the revised methodology results in significant improvements in average test time, without a significant increase in the fraction of false passes.

Table D1
Comparison of Current and Revised Fast-Pass Methodologies Under the Final IM240 Standards
(26,000 Vehicle Sample)

Vehicle Class	Model Year Group	"True" Failure Rate[a]	Current Fast-Pass		Revised Fast-Pass	
			Failure Rate	Pass Time (seconds)	Failure Rate	Pass Time (seconds)
LDV	81 - 84	79%	76%	125	78%	157
	85 - 89	45%	41%	130	43%	121
	1990+	8%	7%	88	7%	57
LDT	81 - 84	62%	51%	71	60%	113
	85 - 89	42%	35%	70	40%	93
	1990+	9%	7%	60	7%	57

[a] The "true" failure rate is based on full-duration IM240 test scores.

Composite IM240 HC Regression Coefficients Developed from Modal IM240 Data Analysis
1981-1984 Model Year Light-Duty Gasoline Vehicles
0.8 g/mi Cutpoint

			Regression Coefficients																						
Mode	RMS Error	Const	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
M1	0.301	0.566	5.043	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M2	0.253	0.378	0.187	2.802	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M3	0.247	0.371	-0.383	2.022	2.586	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M4	0.232	0.337	-0.363	0.828	0.771	3.854	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M5	0.228	0.325	-0.454	1.046	-0.497	2.884	3.156	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M6	0.214	0.286	0.371	0.566	0.327	-0.040	1.592	4.850	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M7	0.202	0.274	0.697	0.468	0.136	-0.077	1.315	2.032	2.632	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M8	0.194	0.260	0.489	0.715	-0.044	-0.411	1.211	2.268	0.853	2.410	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M9	0.189	0.247	0.452	0.747	0.049	-0.370	1.228	2.028	0.757	0.664	2.993	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M10	0.185	0.242	0.163	0.947	-0.410	-0.223	0.801	1.855	0.909	0.463	2.017	2.189	.	.	.	.	.	.	.	.	.	.	.	.	.
M11	0.182	0.236	-0.613	1.036	-0.076	-0.458	0.652	1.882	0.997	0.312	1.900	1.397	4.130	.	.	.	.	.	.	.	.	.	.	.	.
M12	0.160	0.179	0.127	0.496	0.458	-0.049	0.861	0.657	0.532	0.742	0.756	1.363	1.119	2.786	.	.	.	.	.	.	.	.	.	.	.
M13	0.151	0.160	0.257	0.519	0.463	-0.050	0.494	0.783	0.574	0.498	0.793	1.013	1.266	2.081	2.388	.	.	.	.	.	.	.	.	.	.
M14	0.149	0.156	0.285	0.535	0.377	0.080	0.324	0.741	0.578	0.480	0.878	0.729	1.310	2.069	1.748	1.228	.	.	.	.	.	.	.	.	.
M15	0.146	0.152	0.397	0.612	0.326	-0.091	0.754	0.525	0.543	0.420	0.631	0.591	0.768	1.894	1.505	0.562	2.644	.	.	.	.	.	.	.	.
M16	0.144	0.150	0.428	0.652	0.276	-0.140	0.404	0.656	0.668	0.406	0.658	0.454	-0.393	1.833	1.390	0.498	1.810	1.915	.	.	.	.	.	.	.
M17	0.140	0.142	0.463	0.579	0.511	-0.148	0.619	0.189	0.756	0.455	0.462	0.632	-0.086	1.551	1.247	0.516	0.846	1.432	2.815	.	.	.	.	.	.
M18	0.138	0.140	0.505	0.566	0.462	-0.015	0.443	0.386	0.676	0.317	0.386	0.622	-0.033	1.600	1.086	0.435	0.399	1.133	1.908	1.738	.	.	.	.	.
M19	0.134	0.128	0.506	0.528	0.820	-0.205	0.294	0.539	0.735	0.259	0.147	1.098	-0.693	1.478	0.929	0.550	0.693	0.252	1.463	1.566	1.476	.	.	.	.
M20	0.102	0.058	0.441	0.520	0.567	0.283	0.334	0.275	0.678	0.396	0.600	1.082	0.232	0.525	0.815	0.244	0.831	1.083	0.721	1.244	0.809	0.931	.	.	.
M21	0.068	0.032	0.507	0.551	0.501	0.508	0.307	0.466	0.393	0.487	0.542	1.195	0.446	0.329	0.563	0.546	0.500	0.690	0.700	0.763	0.805	0.426	1.089	.	.
M22	0.041	0.013	0.518	0.516	0.564	0.503	0.329	0.622	0.398	0.508	0.395	1.055	0.557	0.394	0.483	0.526	0.715	0.469	0.615	0.618	0.444	0.540	0.430	1.148	.
M23	0.030	0.007	0.517	0.526	0.512	0.515	0.448	0.487	0.455	0.519	0.429	0.938	0.682	0.389	0.577	0.509	0.500	0.654	0.403	0.575	0.458	0.517	0.386	0.681	0.819

NOTE: Results for only 23 modes are shown here because if the 24th mode is completed the actual IM240 score would then be used rather than the predicted score.

Phase 2 IM240 HC Regression Coefficients Developed from Modal IM240 Data Analysis
1981-1984 Model Year Light-Duty Gasoline Vehicles
0.5 g/mi Cutpoint

			Regression Coefficients												
Mode Number	RMS Error	Reg. Const.	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
P11	0.179	0.346	8.141	.	.	.	.	.	.	.	.	.	.	.	.
P12	0.145	0.219	2.349	3.104	.	.	.	.	.	.	.	.	.	.	.
P13	0.136	0.198	1.727	2.209	2.823	.	.	.	.	.	.	.	.	.	.
P14	0.134	0.192	1.330	2.210	2.034	1.470	.	.	.	.	.	.	.	.	.
P15	0.131	0.188	0.571	1.862	1.732	0.807	2.665	.	.	.	.	.	.	.	.
P16	0.129	0.184	-0.983	1.887	1.610	0.588	1.883	2.208	.	.	.	.	.	.	.
P17	0.125	0.171	-0.505	1.456	1.415	0.728	0.712	1.820	3.193	.	.	.	.	.	.
P18	0.122	0.168	-0.516	1.481	1.215	0.533	0.276	1.426	2.227	1.985	.	.	.	.	.
P19	0.118	0.154	-0.904	1.381	1.041	0.803	0.703	0.602	1.573	1.758	1.711	.	.	.	.
P20	0.086	0.076	0.344	0.701	0.965	0.539	1.035	1.357	0.881	1.678	0.988	1.091	.	.	.
P21	0.061	0.041	0.994	0.508	0.691	0.796	0.735	1.173	0.792	1.146	0.925	0.640	1.372	.	.
P22	0.039	0.016	1.142	0.562	0.700	0.745	1.010	0.779	0.752	0.874	0.560	0.732	0.647	1.544	.
P23	0.029	0.007	1.198	0.561	0.777	0.755	0.770	1.005	0.484	0.833	0.607	0.715	0.560	0.975	1.098

NOTE: Results for only modes are presented only for modes 11 through 23. Mode 11 is the first mode of Phase 2 and if the 24th mode is completed the actual IM240 full or composite score would be used rather than the predicted score.

Composite IM240 HC Regression Coefficients Developed from Modal IM240 Data Analysis
1985-1989 Model Year Light-Duty Gasoline Vehicles
0.8 g/mi Cutpoint

			Regression Coefficients																						
Mode	RMS Error	Const	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
M1	0.301	0.430	5.602	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M2	0.248	0.259	0.159	3.044	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M3	0.242	0.255	-0.183	2.108	2.824	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M4	0.224	0.223	0.012	1.015	0.555	3.864	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M5	0.219	0.212	-0.084	1.168	-0.763	2.919	3.395	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M6	0.207	0.189	0.424	0.758	-0.026	0.591	1.742	4.092	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M7	0.194	0.181	0.649	0.668	-0.372	0.443	1.314	1.053	3.066	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M8	0.184	0.169	0.369	0.880	-0.438	0.037	1.302	1.440	0.797	2.830	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M9	0.174	0.157	0.342	0.927	-0.266	-0.055	1.335	1.391	0.656	0.035	4.534	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M10	0.171	0.154	0.180	1.101	-0.631	0.068	0.949	1.233	0.822	-0.082	3.332	2.217	.	.	.	.	.	.	.	.	.	.	.	.	.
M11	0.167	0.150	-0.536	1.168	-0.318	-0.082	0.705	1.264	0.846	-0.127	3.103	1.373	4.334	.	.	.	.	.	.	.	.	.	.	.	.
M12	0.144	0.106	0.170	0.593	0.221	0.266	0.883	0.515	0.448	0.428	1.462	1.314	1.001	2.829	.	.	.	.	.	.	.	.	.	.	.
M13	0.137	0.095	0.153	0.601	0.146	0.360	0.542	0.548	0.519	0.277	1.402	1.109	1.248	2.159	2.122	.	.	.	.	.	.	.	.	.	.
M14	0.135	0.091	0.169	0.583	0.126	0.499	0.226	0.547	0.530	0.265	1.482	0.760	1.225	2.183	1.358	1.490	.	.	.	.	.	.	.	.	.
M15	0.131	0.089	0.272	0.609	0.139	0.358	0.572	0.388	0.544	0.195	1.174	0.605	0.985	1.914	1.217	0.696	2.684	.	.	.	.	.	.	.	.
M16	0.129	0.087	0.278	0.683	0.092	0.322	0.166	0.487	0.671	0.212	1.115	0.457	-0.039	1.831	1.143	0.626	1.714	2.124	.	.	.	.	.	.	.
M17	0.125	0.081	0.348	0.641	0.274	0.241	0.418	0.209	0.775	0.207	0.887	0.657	0.145	1.602	0.944	0.500	0.969	1.584	2.648	.	.	.	.	.	.
M18	0.122	0.080	0.348	0.651	0.147	0.387	0.291	0.439	0.622	0.115	0.812	0.631	0.217	1.651	0.809	0.246	0.548	1.358	1.605	1.837	.	.	.	.	.
M19	0.116	0.070	0.355	0.591	0.583	0.180	0.199	0.559	0.697	0.082	0.426	1.018	-0.368	1.511	0.738	0.346	0.826	0.523	1.293	1.374	1.818	.	.	.	.
M20	0.085	0.029	0.432	0.465	0.545	0.443	0.311	0.226	0.677	0.359	0.604	1.148	0.387	0.555	0.731	0.187	1.034	0.908	0.755	1.211	0.916	0.953	.	.	.
M21	0.055	0.018	0.542	0.524	0.385	0.537	0.398	0.546	0.373	0.556	0.462	1.214	0.466	0.368	0.484	0.520	0.679	0.708	0.564	0.703	0.808	0.426	1.126	.	.
M22	0.035	0.009	0.575	0.503	0.544	0.511	0.339	0.596	0.434	0.512	0.371	1.085	0.490	0.400	0.498	0.500	0.819	0.484	0.555	0.610	0.493	0.533	0.467	1.096	.
M23	0.024	0.004	0.574	0.499	0.516	0.525	0.455	0.493	0.482	0.528	0.353	0.981	0.668	0.420	0.558	0.534	0.542	0.577	0.422	0.576	0.522	0.504	0.427	0.599	0.842

NOTE: Results for only 23 modes are shown here because if the 24th mode is completed the actual IM240 score would then be used rather than the predicted score.

Phase 2 IM240 HC Regression Coefficients Developed from Modal IM240 Data Analysis
1985-1989 Model Year Light-Duty Gasoline Vehicles
0.5 g/mi Cutpoint

			Regression Coefficients												
Mode Number	RMS Error	Reg. Const.	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
P11	0.177	0.259	9.328	.	.	.	.	.	.	.	.	.	.	.	.
P12	0.140	0.150	2.179	3.452	.	.	.	.	.	.	.	.	.	.	.
P13	0.132	0.131	1.779	2.527	2.741	.	.	.	.	.	.	.	.	.	.
P14	0.129	0.125	1.374	2.545	1.628	1.888	.	.	.	.	.	.	.	.	.
P15	0.125	0.121	0.861	2.070	1.387	1.001	2.991	.	.	.	.	.	.	.	.
P16	0.123	0.119	-0.368	2.053	1.269	0.818	2.160	2.195	.	.	.	.	.	.	.
P17	0.118	0.109	0.059	1.736	1.014	0.823	1.032	1.762	3.119	.	.	.	.	.	.
P18	0.115	0.107	-0.009	1.760	0.833	0.559	0.556	1.401	2.128	2.030	.	.	.	.	.
P19	0.109	0.094	-0.526	1.622	0.698	0.823	0.762	0.636	1.569	1.573	2.175	.	.	.	.
P20	0.077	0.041	0.637	0.716	0.900	0.635	1.081	1.205	1.005	1.455	1.267	1.123	.	.	.
P21	0.057	0.025	0.945	0.562	0.700	0.868	0.834	1.063	0.867	0.971	1.063	0.658	1.363	.	.
P22	0.037	0.013	0.917	0.590	0.738	0.748	1.105	0.785	0.740	0.839	0.583	0.740	0.631	1.554	.
P23	0.027	0.006	1.052	0.609	0.774	0.810	0.757	0.906	0.536	0.802	0.675	0.711	0.575	0.903	1.137

NOTE: Results for only modes are presented only for modes 11 through 23. Mode 11 is the first mode of Phase 2 and if the 24th mode is completed the actual IM240 full or composite score would be used rather than the predicted score.

Composite IM240 HC Regression Coefficients Developed from Modal IM240 Data Analysis
1990+ Model Year Light-Duty Gasoline Vehicles
0.8 g/mi Cutpoint

			Regression Coefficients																						
Mode	RMS Error	Const.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
M1	0.368	0.162	10.855	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M2	0.271	0.028	0.252	4.621	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M3	0.253	0.036	0.096	2.693	4.788	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M4	0.230	0.031	0.720	0.868	1.740	4.997	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M5	0.221	0.026	0.391	1.110	0.060	3.325	5.174	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M6	0.207	0.021	0.862	0.623	1.005	0.397	2.743	5.132	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M7	0.192	0.025	1.279	0.372	0.699	0.393	2.028	1.127	3.732	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M8	0.175	0.030	1.076	0.515	0.477	0.150	1.178	1.750	0.608	3.725	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M9	0.162	0.032	1.111	0.490	0.510	0.142	1.351	1.370	0.587	0.494	5.180	.	.	.	.	.	.	.	.	.	.	.	.	.	.
M10	0.155	0.034	0.742	0.835	-0.133	0.470	0.754	0.829	0.980	0.287	3.033	3.511	.	.	.	.	.	.	.	.	.	.	.	.	.
M11	0.149	0.037	-0.292	0.916	0.270	0.141	0.342	0.923	1.049	0.326	2.661	2.172	5.629	.	.	.	.	.	.	.	.	.	.	.	.
M12	0.123	0.028	0.433	0.321	0.650	0.528	0.818	-0.003	0.245	1.037	0.672	2.127	1.234	3.583	.	.	.	.	.	.	.	.	.	.	.
M13	0.115	0.025	0.578	0.296	0.562	0.394	0.374	0.234	0.492	0.715	0.629	1.553	1.271	2.743	2.839	.	.	.	.	.	.	.	.	.	.
M14	0.113	0.025	0.618	0.262	0.555	0.503	-0.034	0.227	0.569	0.714	0.776	1.121	1.069	2.758	1.607	2.069	.	.	.	.	.	.	.	.	.
M15	0.107	0.027	0.747	0.284	0.574	0.244	0.529	0.033	0.676	0.571	0.487	1.011	0.912	2.369	1.258	0.591	3.362	.	.	.	.	.	.	.	.
M16	0.102	0.027	0.719	0.462	0.356	0.136	0.065	0.303	0.778	0.668	0.345	0.659	-0.008	2.189	1.033	0.401	2.153	2.766	.	.	.	.	.	.	.
M17	0.098	0.026	0.794	0.426	0.518	0.062	0.242	0.168	0.786	0.737	0.079	0.882	0.127	1.928	0.726	0.488	1.245	1.994	2.960	.	.	.	.	.	.
M18	0.095	0.026	0.769	0.455	0.367	0.197	0.174	0.420	0.710	0.561	0.016	0.870	0.128	2.015	0.442	0.256	0.759	1.521	1.733	2.083	.	.	.	.	.
M19	0.090	0.023	0.816	0.385	0.654	0.080	0.083	0.642	0.717	0.557	-0.358	1.269	-0.488	1.916	0.340	0.282	0.819	0.888	1.357	1.477	1.846	.	.	.	.
M20	0.068	0.009	0.575	0.360	0.539	0.382	0.257	0.458	0.639	0.556	0.034	1.205	0.514	0.804	0.472	0.255	0.693	1.266	0.881	1.203	0.837	1.073	.	.	.
M21	0.041	0.007	0.544	0.483	0.489	0.528	0.539	0.520	0.388	0.588	0.284	1.157	0.523	0.367	0.461	0.575	0.548	0.853	0.677	0.674	0.583	0.370	1.309	.	.
M22	0.027	0.003	0.559	0.500	0.535	0.538	0.444	0.602	0.406	0.514	0.284	0.992	0.497	0.407	0.518	0.526	0.656	0.637	0.661	0.573	0.470	0.497	0.525	1.112	.
M23	0.019	0.002	0.553	0.496	0.515	0.537	0.525	0.518	0.438	0.535	0.349	0.870	0.650	0.429	0.549	0.567	0.521	0.624	0.554	0.536	0.443	0.510	0.387	0.654	0.853

NOTE: Results for only 23 modes are shown here because if the 24th mode is completed the actual IM240 score would then be used rather than the predicted score.

Phase 2 IM240 HC Regression Coefficients Developed from Modal IM240 Data Analysis
1990+ Model Year Light-Duty Gasoline Vehicles
0.5 g/mi Cutpoint

			Regression Coefficients												
Mode Number	RMS Error	Reg. Const.	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
P11	0.153	0.098	13.195	.	.	.	.	.	.	.	.	.	.	.	.
P12	0.114	0.048	3.112	4.074	.	.	.	.	.	.	.	.	.	.	.
P13	0.102	0.041	1.873	2.680	3.765	.	.	.	.	.	.	.	.	.	.
P14	0.099	0.039	1.406	2.668	2.167	2.454	.	.	.	.	.	.	.	.	.
P15	0.095	0.040	1.107	2.141	1.738	1.122	3.342	.	.	.	.	.	.	.	.
P16	0.091	0.040	-0.030	2.065	1.365	0.858	2.119	3.157	.	.	.	.	.	.	.
P17	0.088	0.038	0.165	1.791	1.043	0.931	1.028	2.401	3.357	.	.	.	.	.	.
P18	0.085	0.038	0.093	1.843	0.719	0.663	0.610	1.854	2.189	2.206	.	.	.	.	.
P19	0.081	0.035	-0.272	1.779	0.514	0.829	0.678	1.356	1.669	1.515	1.952	.	.	.	.
P20	0.057	0.016	0.581	0.846	0.727	0.616	0.627	1.840	1.313	1.345	0.856	1.195	.	.	.
P21	0.040	0.010	0.817	0.585	0.723	0.936	0.588	1.434	1.014	0.886	0.731	0.623	1.512	.	.
P22	0.028	0.005	0.823	0.606	0.751	0.837	0.740	1.015	0.843	0.855	0.581	0.717	0.749	1.426	.
P23	0.020	0.003	0.909	0.612	0.790	0.837	0.609	0.957	0.714	0.775	0.632	0.719	0.591	0.868	1.158

NOTE: Results for only modes are presented only for modes 11 through 23. Mode 11 is the first mode of Phase 2 and if the 24th mode is completed the actual IM240 full or composite score would be used rather than the predicted score.

Appendix E

Calculation of Raw Emission Scores from Dilute Measurements

Calculation of Raw Emission Scores from Dilute Measurements

The constant volume sampling technique, which has been part of the FTP for the exhaust emissions testing of passenger cars and light-duty trucks since the 1972 model year, involves the collection of a sample of exhaust gas after it has been diluted to a known, constant volume. Using this procedure, a device called a "constant volume sampler" dilutes the vehicle exhaust and then samples a constant volume fraction of the dilute mixture. In a typical test facility, the dilution is achieved by drawing "background" air from the room where the vehicle is being driven on a chassis dynamometer. A slipstream from the diluted exhaust is pumped into a series of sample bags during the test. Three sample bags are used for dilute exhaust samples: the first represents the "cold start" phase of the test, the second represents "stabilized" operation, and the third represents the "hot start" phase of the test. Samples of background air are simultaneously collected in three additional bags. At the end of the test, measurement of the concentration of pollutants in the sample bags and calculation of the total flow of the dilute mixture during each phase allows the mass of emissions emitted during each phase of the test to be calculated. Division of the calculated mass by the associated driving distance provides the mass emissions rate (normally expressed in grams per mile).

A variation of the FTP test procedure is used in CVS-based I/M testing. Instead of filling sample bags with dilute mixture during separate phases of the test, the concentrations of pollutants in the dilute exhaust stream are continuously monitored. Mass emissions per mile of travel are calculated from integration of the continuous measurements divided by the distance driven during the test. (This technique facilitates the use of "fast pass" and "fast fail" algorithms for shortening the test in cases where a vehicle is extremely clean or extremely dirty during the early portion of the test.)

In CVS-based testing, the volume of background (dilution) air in the sample substantially exceeds the volume of exhaust gas, usually by a factor of ten or more. As a result, the extent to which the dilution air is contaminated with pollutants can significantly affect the calculated mass emissions. To eliminate this interference, the extent to which the vehicle exhaust has been diluted must be known. The FTP specifies that the ratio of total volume to exhaust volume ("dilution factor") be calculated using the following equation:

$$[1]\ DF_{EPA} = \frac{13.4}{CO_{2e} + CO_e + HC_e}$$

where: CO_{2e}, CO_e, and HC_e are the concentrations measured in the dilute sample expressed as percent volume.

In the above equation, the DF calculated in accordance with the FTP is specified as "DF_{EPA}" to distinguish it from an improved formulation of the DF discussed below. As noted above, DF_{EPA} is used in the FTP to correct the emissions concentration in the sample bag for pollutants in the dilution (background) air. Although not required by the FTP, the average DF can also be used to calculate the average concentration of the undiluted tailpipe emissions emitted while the sample bag was being filled. If there were no pollutants in the dilution air, the tailpipe concentrations could be calculated simply by multiplying the dilute measurement by the DF:

[2] $Ctp = Cconc * DF$

where: Ctp is the actual raw tailpipe concentration, and Cconc is the concentration of a pollutant in the dilute sample defined as:

[3] $$C_{conc} = C_e - C_d \left(1 - \frac{1}{DF}\right)$$

where Ce is the pollutant dilute concentration and Cd is the pollutant background concentration.

Substituting [3] into [2] yields:

[4] $$Ctp = \left[Ce - Cd\left(1 - \frac{1}{DF}\right)\right]DF$$

As noted above, the CVS technique used to measure emissions in I/M programs involves calculating mass emissions by integrating the continuously monitored dilute sample. An average dilution factor can still be calculated from the integrated average of the dilute emissions. The DF can also be calculated continuously and used to calculate the undiluted tailpipe concentration at any point in time. This capability makes it possible to use the CVS emissions measurement system to determine whether a vehicle meets emissions standards that are based on tailpipe concentrations. If, for example, a CO concentration of 0.1% is measured in the dilute exhaust stream, and if the calculated DF is 10, then the tailpipe emission concentration would be calculated to be 1.0% CO (assuming background concentrations were zero).

Although there are several advantages associated with the use of the reverse dilution calculation method, some error is introduced in the calculation of the tailpipe concentration due to the discrepancies that can exist between actual test conditions and the assumptions on which the standard DF calculation is based. As described in detail in a previously referenced technical paper (SAE paper 980678), the DF equation contained in the FTP is based on three assumptions:

1. Exhaust emissions of vehicles are the product of a chemically balanced (i.e., stoichiometric) ratio of air and fuel;
2. The concentrations of pollutants in the background air have an insignificant effect on the calculation of the DF; and
3. No water vapor has been removed from the sample.

Each of these assumptions is problematic when the reverse dilution technique is used to calculate the concentration of pollutants in a vehicle tailpipe that would otherwise be measured directly in an I/M program. First, although most vehicles run very close to a stoichiometric air-fuel ratio, this is not always the case. Second, in the environment of an I/M test lane, pollution in the background air can be significant. Third, analyzers routinely used for raw exhaust measurement remove a substantial amount of water from the sample.[3]

A more complicated expression of the DF is required to address the limitations of the DF equation contained in the FTP. The recommended equation is as follows:[4]

$$DF = \frac{100 - K_1\left(CO_{2d}\right) - K_2\left(CO_d\right) - K_3(HC_d)}{K_1(CO_{2e} - CO_{2d}) + K_2\left(CO_e - CO_d\right) + K_3(HC_e - HC_d)}$$

where: K_1, K_2, and K_3 are constants that depend on the fuel type (see below);
CO_{2d} is the concentration of CO_2 in the background air;
CO_d is the concentration of CO in the background air;
HC_d is the concentration of HC in the background air;
CO_{2e} is the concentration of CO_2 in the dilute sample;
CO_e is the concentration of CO in the dilute sample; and
HC_e is the concentration of HC in the dilute sample.

All of the concentrations in the above equation are expressed in volume percent. The HC values are expressed in hexane equivalent. The values of K_1, K_2, and K_3 depend on the type of fuel and whether the calculated pollutant concentrations are on a wet or dry basis. When attempting to match measurements that would be made by typical systems for raw exhaust measurement, the values for dry exhaust should be used. For gasoline fuel with pollutant concentrations measured on a wet basis, such as in IM240 set-ups, the value of K_1 is 6.5431, the value for K_2 is 4.6561, and the value of K_3 is 57.0945.

Dilution Correction of Tailpipe Measurements

As noted earlier, one of the problems associated with I/M standards based on maximum allowable tailpipe concentrations is that certain causes of dilution (e.g., air injection,[5] exhaust leaks, or inadequate sample probe insertion

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[3] So-called "BAR90" analyzers actually use a condensate removal system to dispose of the water that condenses when raw exhaust is drawn through the sample probe; however, the efficiency of water removal depends on the temperature of the exhaust sample because no temperature control is provided by the analyzer.

[4] The DF equation in the previously referenced SAE paper is based on the simplifying assumption that there is no residual oxygen in the exhaust of stoichiometric or richer air-fuel mixtures. This assumption holds unless there is substantial misfire. In the case of misfire, the exhaust may contain oxygen that dilutes the concentration of other constituents. Equation 4 is a refinement of the equation contained in the SAE paper that accounts for misfire.

[5] Air injection can reduce mass emissions by facilitating more complete combustion in either the exhaust manifold or the catalytic converter. However, the dilution associated with air injection causes the measured concentration to be

depth) may cause measured concentrations to be substantially lower than for another vehicle with identical mass emissions. Because of this problem, EPA guidance for concentration measurement during simple I/M tests specifies that the sum of CO plus CO_2 emissions should be at least 6% in order for the test to be considered valid. Although the basis for the recommendation is not documented, it appears to represent the maximum level of exhaust dilution that might be expected with a relatively high output air injection system installed on a relatively small engine. As a result, it allows the exhaust concentration to be reduced by more than 50% due to various sources of dilution.[6] It is therefore a relatively ineffective means of preventing exhaust dilution from affecting the results of an I/M test.

Recently, the California Bureau of Automotive Repair (BAR) devised an improved procedure for eliminating the effects of exhaust dilution. BAR's procedure uses equations developed from basic combustion chemistry to determine the extent to which an exhaust sample must have been diluted before a concentration measurement was made. The measured concentrations are adjusted to what they would be under stoichiometric conditions with no dilution air from any source (including leaner than stoichiometric operation). BAR's exhaust dilution correction essentially involves the application of a dilution factor to the concentrations measured at the tailpipe. As described in Sierra's SAE paper, BAR's method is more sophisticated than the DF calculation incorporated into the FTP because it accounts for variations in air-fuel ratio. However, the BAR procedure ignores the effects of background air, which is not a factor during tailpipe measurements. As the SAE paper illustrates, Sierra's recommended DF equation incorporates the same basic dilution correction used by BAR in combination with a correction for pollutants in the background air. When correcting tailpipe concentrations for dilution, where no background air is involved, Sierra's DF calculation and BAR's dilution adjustment produce the same result.

Recognizing the advantages of BAR's new dilution correction procedure, EPA has incorporated it in Guidance to states on Acceleration Simulation Mode (ASM) testing. Although BAR's procedure is equally applicable to other tests that rely on concentration measurement, it has not yet been incorporated into revised guidance for idle, 2500 rpm, and other steady-state tests. However, when CVS testing is used in combination with Sierra's recommended reverse dilution calculation procedure, the effect is similar to using BAR's dilution correction.

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reduced by more than the true reduction in mass emissions.

[6] With measurement systems that remove water, and for an engine running a stoichiometric, a 6% sum of CO and CO_2 represents each part exhaust being diluted with 1.5 parts air.

Appendix F

Modal Analysis of Second-by-Second Data Preconditioning Guidelines

Developed by Sierra Research
Contract 68-C4-0056 Work Assignment 2-04

Modal Analysis of Second-by-Second Data Preconditioning Guidelines

Developed by Sierra Research
Contract 68-C4-0056 Work Assignment 2-04

Using the replicate IM240 data collected by Gordon-Darby, it was possible, through trial and error, to identify criteria to determine whether a vehicle failing an initial IM240 is inadequately preconditioned and should be tested again. This analysis was performed for each pollutant individually, and then for all pollutants combined. The analysis included 283 LDVs and 83 LDTs. The evaluation followed a step-wise progression in which the aim was to maximize the identification of vehicles that could benefit from a second test, while minimizing testing of vehicles likely to fail a second test. Recommendations for passenger cars are summarized below. A similar set of conditions was also developed for light-duty trucks, which are subject to different IM240 standards than passenger cars.

IM240 Retest Criteria for Passenger Cars

HC Failures **-** If PPmHC209-214 is less than 1,500, a retest is recommended if any of the following occur:

1. Phase 2 HC < 0. 8 g/mi; or
2. $\text{massHC}_{175\text{-}199} < 0.2$ g; or
3. $(\text{ppmHC}_{75\text{-}80}/\text{ppmHC}_{214}) > 4.0$

For vehicles failing only HC, the following additional constraints are required for a vehicle to be retested:

1. Mass $\text{HC}_{175\text{-}199}<0.3$g and $(\text{ppmHC}_{75\text{-}80}/\text{ppmHC}_{209\text{-}214})>1.5$;or
2. Mass $\text{HC}_{175\text{-}199} < 0.3$g and Phase 2 HC < 1.0 g/mi

CO Failures **-** For CO failures, the above criteria for HC are recommended. In addition, the following constraints are recommended:

1. do not retest if Phase 2 CO > 20 g/mi and (Phase 1 CO/Phase 2 CO) <2; and
2. if the vehicle fails both HC and CO, retest if Mass $\text{HC}_{175\text{-}199} <0.3$ g and mass $\text{CO}_{175\text{-}199} < 5.0$ g.

If the vehicle is a CO-only failure, then a vehicle would benefit from a retest if:

1. Mass $\text{CO}_{175\text{-}199} < 6.0$ g; or
2. $(\text{ppmCO}_{75\text{-}80}/\text{ppmCO}_{209\text{-}214}) > 4.0$; or
3. Mass $\text{CO}_{175.199} < 10$ g and (Phase I CO > 0.75 x Phase 2 CO).

NOx Failures **-** For vehicles failing HC or CO and NOx, a retest is recommended if the following condition occurs:

1. Mass $\text{NOx}_{175\text{-}199} = 1.0$g

For NOx Only failures, retest is recommended if the following criteria are met:

1. Mass $\text{NOx}_{175199}<9$; or
2. Mass $\text{NOx}_{175\text{-}199}<1.l$ and$(\text{ppmNOx}_{40\text{-}45}/\text{ppmNOx}_{209\text{-}215})>1.5$;or
3. IM240 $\text{NOx}<2.2$ and $(\text{ppmNOx}_{40\text{-}45}/\text{ppmNOx}_{209\text{-}215})> 1.0$

Multiple Pollutants **-** For multiple pollutant failures, a retest is eliminated under the following conditions:

1. the vehicle fails for all pollutants; or
2. the vehicle fails HC and CO and (Phase 2 CO > 20 g/mi and mass $\text{CO}_{175\text{-}199} >6.0$ g); or
3. the vehicle fails HC and NOx and $(\text{ppmHC}_{209\text{-}214} >1{,}200)$ or $(\text{ppmNOx}_{209\text{-}214} > 1{,}200$

IM240 Retest Criteria for Light-Duty Trucks

Because they are subject to different numerical IM240 emission standards, a different set of retest criteria were developed for light-duty trucks. These criteria are similar to those established for passenger cars, with adjustments to account for standards differences.

HC Failures **-** For 1981 to 1983 model year vehicles, if $\text{ppmHC}_{209\text{-}214} < 2{,}000$ and any of the following conditions exist, then a retest is recommended:

1. Phase 2 HC < 3.0 g/mi; or
2. Mass $\text{HC}_{175\text{-}199} < 0.8$ g; or
3. $(\text{ppmHC}_{75\text{-}80}/\text{ppmHC}_{209\text{-}214})>4.0$

In addition, if the full IM240 is less than 3.5 g/mi HC (regardless of the value of $\text{ppmHC}_{209\text{-}214}$), then a retest is recommended.

For 1984 and later model year vehicles, if $\text{ppmHC}_{209\text{-}214}<1{,}500$ and any of the following conditions exist a retest is recommended:

1. Phase 2 HC< 2.0 g/mi; or
2. $\text{MassHC}_{175\text{-}199} < 0.4$ g; or
3. $(\text{ppmHC}_{75\text{-}80}/\text{ppmHC}_{209\text{-}214})>4.0$

In addition, if $0.4<\text{Mass HC}_{175\text{-}199}<0.8$ and $(\text{ppmHC}_{75\text{-}80}/\text{ppmHC}_{209\text{-}214})>2.0$ (regardless of the value of $\text{ppmHC}_{209\text{-}214}$) then a retest is recommended.

A retest is not recommended if Phase 2 HC > 3.2 g/mi.

CO Failures **-** For CO failures, the above criteria outlined for HC were also used. In addition, the following conditions were also imposed to cut down on the number of vehicles incorrectly identified as needing a retest:

1. If 1981 to 1983 model year and Mass CO$_{175-199}$>36g then do not retest.
2. If 1984 or later model year and Mass CO$_{175-199}$>18g then do not retest.
3. If Phase 2 CO>40 and Phase 2 CO > Phase I CO then do not retest.

NOx Failures **-** If the vehicle failed NOx and either HC or CO, the above criteria were used to determine the need for a retest. For LDT1&2s, if the vehicle failed only NOx. then a retest is recommended if Mass NOx$_{l75-199}$ < 1.4 g. For 1988 and later LDT3&4s, a retest is recommended only if Mass NOx$_{175-199}$ < 2.5 g.

Appendix G

Full and Fast-Pass IM240 Positive Kinetic Energy Speed Variation Limits

Developed by Sierra Research
Contract 68-C4-0056

Full and Fast-Pass IM240 Positive Kinetic Energy Speed Variation Limits

Developed by Sierra Research
Contract 68-C4-0056

Evaluation of Alternative Statistical Measures

Based upon similar work conducted by the New York Automotive Emissions Laboratory (AEL,)[7] two easily determined, alternative statistical metrics were evaluated for their ability to identify and quantify IM240 speed variations that significantly affect emissions:

(1). DPWRSUM **-** the sum of absolute changes in specific power; and

(2). Positive Kinetic Energy (PKE) **-** the sum of positive differences in kinetic energy per unit distance.

Each of these metrics are explained in more detail below.

DPWRSUM **-** Specific power is defined as power per unit mass, which can be restated as follows:

$$\text{Specific Power} = \frac{\text{power}}{\text{mass}} = \frac{\text{work}}{\text{mass} \times \Delta\text{time}} = \frac{\Delta\text{kinetic energy}}{\text{mass} \times \Delta\text{time}} = \frac{\frac{1}{2} \times \text{mass} \times \Delta V^2}{\text{mass} \times \Delta\text{time}}$$

Over a transient driving cycle of second-by-second speeds, EPA defines the specific power P at any time t (and dropping the factor of ½) as:

$$P_t = V_t^2 - V_{t-1}^2$$

The absolute difference in specific power at time t can then be written as:

$$DP_t = \left| P_t - P_{t-1} \right| = \left| V_t^2 - 2 \; V_{t-1}^2 + V_{t-2}^2 \right|$$

The DPWRSUM statistic then is defined over a cycle of N seconds as:

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[7] W. J. Webster and C. Shih, "A Statistically Derived Metric to Monitor Time-Speed Variability in Practical Emissions Testing," New York State Department of Environmental Conservation, presented at the 6th CRC On-Road Vehicle Emissions Workshop, March 18-20, 1996.

$$DPWRSUM = \sum_{t=0}^{N} DP_t = \sum_{t=0}^{N} \left| V_t^2 - 2\,V_{t-1}^2 + V_{t-2}^2 \right|$$

PKE - Positive Kinetic Energy has been defined mathematically as:

$$PKE = \frac{\sum_{t=0}^{N} PP_t}{\int_0^x dx}$$

over a traveled driving cycle of distance x where PP is the positive specific power and is given by the following expression when $V_t > V_{t-1}$, and is zero when $V_t \leq V_{t-1}$.

$$PP_t = V_t^2 - V_{t-1}^2$$

Each of these metrics can be easily computed from the second-by-second speed measurements collected in IM240 testing. In comparing their relative ability to identify speed variations that produce high emissions, it is helpful to consider which speed variations contribute to the value of each metric (similar to the earlier examination of the SE statistic) over an IM240 test.

Note that although both DPWRSUM and PKE are affected by differences in specific power or squared speeds over "adjacent" seconds of an IM240 trace, the value of DPWRSUM is increased during decelerations as well as accelerations. PKE on the other hand, is only increased during acceleration periods.

IM240 REFERENCE DATA			PKE VARIATION CUTPOINTS (miles/hr2)				
		CUM PKE	"BASE"	MULT.	VARYING	CUMULATIVE PKE	
TIME	SPEED	(miles/hr2)	DELTA	FACTOR	DELTA	LOW	HIGH
0	0.0	0.0	.	.	.	.	.
1	0.0	0.0	.	.	.	.	.
2	0.0	0.0	.	.	.	.	.
3	0.0	0.0	.	.	.	.	.
4	0.0	0.0	.	.	.	.	.
5	3.0	10,800.0	.	.	.	.	.
6	5.9	14,080.4	.	.	.	.	.
7	8.6	15,214.6	.	.	.	.	.
8	11.5	16,417.2	.	.	.	.	.
9	14.3	17,001.5	.	.	.	.	.
10	16.9	17,079.7	.	.	.	.	.
11	17.3	13,902.5	.	.	.	.	.
12	18.1	12,336.8	.	.	.	.	.
13	20.7	13,263.7	.	.	.	.	.
14	21.7	12,284.1	.	.	.	.	.
15	22.4	11,261.4	.	.	.	.	.
16	22.5	9,964.5	.	.	.	.	.
17	22.1	8,890.2	.	.	.	.	.
18	21.5	8,046.4	.	.	.	.	.
19	20.9	7,366.6	.	.	.	.	.
20	20.4	6,805.5	.	.	.	.	.
21	19.8	6,336.9	.	.	.	.	.
22	17.0	5,983.3	.	.	.	.	.
23	14.9	5,704.2	.	.	.	.	.
24	14.9	5,450.1	.	.	.	.	.
25	15.2	5,306.1	.	.	.	.	.
26	15.5	5,171.6	.	.	.	.	.
27	16.0	5,103.3	.	.	.	.	.
28	17.1	5,213.3	.	.	.	.	.
29	19.1	5,599.3	.	.	.	.	.
30	21.1	5,990.0	342.3	4.000	1,369.3	4,621	7,359
31	22.7	6,242.3	356.7	3.986	1,421.8	4,820	7,664
32	22.9	6,014.8	343.7	3.971	1,365.1	4,650	7,380
33	22.7	5,745.3	328.3	3.957	1,299.3	4,446	7,045
34	22.6	5,500.0	314.3	3.943	1,239.3	4,261	6,739
35	21.3	5,287.2	302.2	3.929	1,187.0	4,100	6,474
36	19.0	5,110.8	292.1	3.914	1,143.3	3,968	6,254
37	17.1	4,961.9	283.6	3.900	1,105.9	3,856	6,068

38	15.8	4,831.8	276.1	3.886	1,072.9	3,759	5,905
39	15.8	4,708.3	269.1	3.871	1,041.7	3,667	5,750
40	17.7	4,937.5	282.2	3.857	1,088.4	3,849	6,026
41	19.8	5,220.8	298.4	3.843	1,146.5	4,074	6,367
42	21.6	5,450.3	311.5	3.829	1,192.5	4,258	6,643
43	23.2	5,638.2	322.2	3.814	1,229.0	4,409	6,867
44	24.2	5,685.3	324.9	3.800	1,234.6	4,451	6,920
45	24.6	5,592.5	319.6	3.786	1,209.9	4,383	6,802
46	24.9	5,481.7	313.3	3.771	1,181.5	4,300	6,663
47	25.0	5,332.7	304.8	3.757	1,145.0	4,188	6,478
48	25.7	5,321.5	304.1	3.743	1,138.2	4,183	6,460
49	26.1	5,245.9	299.8	3.729	1,117.8	4,128	6,364
50	26.7	5,216.3	298.1	3.714	1,107.2	4,109	6,323
51	27.5	5,230.2	298.9	3.700	1,105.9	4,124	6,336
52	28.6	5,307.9	303.3	3.686	1,118.0	4,190	6,426
53	29.3	5,298.0	302.8	3.671	1,111.6	4,186	6,410
54	29.8	5,246.1	299.8	3.657	1,096.4	4,150	6,343
55	30.1	5,155.0	294.6	3.643	1,073.2	4,082	6,228
56	30.4	5,068.3	289.6	3.629	1,051.0	4,017	6,119
57	30.7	4,985.6	284.9	3.614	1,029.8	3,956	6,015
58	30.7	4,848.3	277.1	3.600	997.5	3,851	5,846
59	30.5	4,719.2	269.7	3.586	967.0	3,752	5,686
60	30.4	4,597.2	262.7	3.571	938.3	3,659	5,535
61	30.3	4,481.7	256.1	3.557	911.1	3,571	5,393
62	30.4	4,389.2	250.8	3.543	888.7	3,501	5,278
63	30.8	4,352.1	248.7	3.529	877.6	3,474	5,230
64	30.4	4,250.1	242.9	3.514	853.6	3,397	5,104
65	29.9	4,154.4	237.4	3.500	831.0	3,323	4,985
66	29.5	4,064.1	232.3	3.486	809.6	3,255	4,874
67	29.8	4,022.9	229.9	3.471	798.1	3,225	4,821
68	30.3	4,013.3	229.3	3.457	792.9	3,220	4,806
69	30.7	3,988.8	228.0	3.443	784.8	3,204	4,774
70	30.9	3,935.5	224.9	3.429	771.1	3,164	4,707
71	31.0	3,869.4	221.1	3.414	755.0	3,114	4,624
72	30.9	3,791.8	216.7	3.400	736.8	3,055	4,529
73	30.4	3,718.5	212.5	3.386	719.5	2,999	4,438
74	29.8	3,649.2	208.5	3.371	703.1	2,946	4,352
75	29.9	3,595.5	205.5	3.357	689.8	2,906	4,285
76	30.2	3,569.2	204.0	3.343	681.9	2,887	4,251
77	30.7	3,569.2	204.0	3.329	678.9	2,890	4,248
78	31.2	3,569.3	204.0	3.314	676.0	2,893	4,245
79	31.8	3,582.2	204.7	3.300	675.6	2,907	4,258
80	32.2	3,569.2	204.0	3.286	670.2	2,899	4,239

81	**32.4**	**3,531.2**	**201.8**	**3.271**	**660.2**	**2,871**	**4,191**
82	**32.2**	**3,469.8**	**198.3**	**3.257**	**645.9**	**2,824**	**4,116**
83	**31.7**	**3,411.4**	**195.0**	**3.243**	**632.2**	**2,779**	**4,044**
84	**28.6**	**3,360.3**	**192.0**	**3.229**	**620.0**	**2,740**	**3,980**
85	**25.1**	**3,316.8**	**189.5**	**3.214**	**609.3**	**2,708**	**3,926**
86	**21.6**	**3,280.2**	**187.5**	**3.200**	**599.9**	**2,680**	**3,880**
87	**18.1**	**3,250.2**	**185.7**	**3.186**	**591.7**	**2,658**	**3,842**
88	**14.6**	**3,226.3**	**184.4**	**3.171**	**584.7**	**2,642**	**3,811**
89	**11.1**	**3,208.4**	**183.4**	**3.157**	**578.9**	**2,630**	**3,787**
90	**7.6**	**3,196.3**	**182.7**	**3.143**	**574.1**	**2,622**	**3,770**
91	**4.1**	**3,189.8**	**182.3**	**3.129**	**570.3**	**2,619**	**3,760**
92	**0.6**	**3,188.9**	**182.2**	**3.114**	**567.5**	**2,621**	**3,756**
93	**0.0**	**3,188.9**	**182.2**	**3.100**	**564.9**	**2,624**	**3,754**
94	**0.0**	**3,188.9**	**182.2**	**3.086**	**562.3**	**2,627**	**3,751**
95	**0.0**	**3,188.9**	**182.2**	**3.071**	**559.7**	**2,629**	**3,749**
96	**0.0**	**3,188.9**	**182.2**	**3.057**	**557.1**	**2,632**	**3,746**
97	**0.0**	**3,188.9**	**182.2**	**3.043**	**554.5**	**2,634**	**3,743**
98	**3.3**	**3,203.1**	**183.0**	**3.029**	**554.4**	**2,649**	**3,757**
99	**6.6**	**3,250.7**	**185.8**	**3.014**	**560.0**	**2,691**	**3,811**
100	**9.9**	**3,331.3**	**190.4**	**3.000**	**571.1**	**2,760**	**3,902**
101	**13.2**	**3,443.8**	**196.8**	**2.986**	**587.6**	**2,856**	**4,031**
102	**16.5**	**3,587.2**	**205.0**	**2.971**	**609.1**	**2,978**	**4,196**
103	**19.8**	**3,760.1**	**214.9**	**2.957**	**635.4**	**3,125**	**4,396**
104	**22.2**	**3,892.7**	**222.5**	**2.943**	**654.7**	**3,238**	**4,547**
105	**24.3**	**4,013.3**	**229.4**	**2.929**	**671.7**	**3,342**	**4,685**
106	**25.8**	**4,090.8**	**233.8**	**2.914**	**681.3**	**3,409**	**4,772**
107	**26.4**	**4,093.0**	**233.9**	**2.900**	**678.3**	**3,415**	**4,771**
108	**25.7**	**4,045.3**	**231.2**	**2.886**	**667.1**	**3,378**	**4,712**
109	**25.1**	**3,999.9**	**228.6**	**2.871**	**656.4**	**3,344**	**4,656**
110	**24.7**	**3,956.1**	**226.1**	**2.857**	**646.0**	**3,310**	**4,602**
111	**25.2**	**3,951.8**	**225.8**	**2.843**	**642.0**	**3,310**	**4,594**
112	**25.4**	**3,924.1**	**224.3**	**2.829**	**634.3**	**3,290**	**4,558**
113	**27.2**	**4,024.3**	**230.0**	**2.814**	**647.2**	**3,377**	**4,672**
114	**26.5**	**3,979.2**	**227.4**	**2.800**	**636.7**	**3,342**	**4,616**
115	**24.0**	**3,939.2**	**225.1**	**2.786**	**627.1**	**3,312**	**4,566**
116	**22.7**	**3,902.0**	**223.0**	**2.771**	**618.0**	**3,284**	**4,520**
117	**19.4**	**3,870.9**	**221.2**	**2.757**	**609.9**	**3,261**	**4,481**
118	**17.7**	**3,842.9**	**219.6**	**2.743**	**602.4**	**3,241**	**4,445**
119	**17.2**	**3,816.0**	**218.1**	**2.729**	**595.0**	**3,221**	**4,411**
120	**18.1**	**3,834.3**	**219.1**	**2.714**	**594.8**	**3,240**	**4,429**
121	**18.6**	**3,832.2**	**219.0**	**2.700**	**591.3**	**3,241**	**4,423**
122	**20.0**	**3,879.0**	**221.7**	**2.686**	**595.4**	**3,284**	**4,474**
123	**20.7**	**3,887.7**	**222.2**	**2.671**	**593.5**	**3,294**	**4,481**

124	**21.7**	**3,914.4**	**223.7**	**2.657**	**594.4**	**3,320**	**4,509**
125	**22.4**	**3,923.5**	**224.2**	**2.643**	**592.6**	**3,331**	**4,516**
126	**22.5**	**3,895.8**	**222.6**	**2.629**	**585.2**	**3,311**	**4,481**
127	**22.1**	**3,863.1**	**220.8**	**2.614**	**577.1**	**3,286**	**4,440**
128	**21.5**	**3,831.7**	**219.0**	**2.600**	**569.3**	**3,262**	**4,401**
129	**20.9**	**3,801.8**	**217.3**	**2.586**	**561.8**	**3,240**	**4,364**
130	**20.4**	**3,772.9**	**215.6**	**2.571**	**554.4**	**3,219**	**4,327**
131	**19.8**	**3,745.4**	**214.0**	**2.557**	**547.3**	**3,198**	**4,293**
132	**17.0**	**3,722.1**	**212.7**	**2.543**	**540.9**	**3,181**	**4,263**
133	**17.1**	**3,703.4**	**211.6**	**2.529**	**535.1**	**3,168**	**4,239**
134	**15.8**	**3,682.2**	**210.4**	**2.514**	**529.1**	**3,153**	**4,211**
135	**15.8**	**3,661.2**	**209.2**	**2.500**	**523.1**	**3,138**	**4,184**
136	**17.7**	**3,720.0**	**212.6**	**2.486**	**528.4**	**3,192**	**4,248**
137	**19.8**	**3,794.6**	**216.9**	**2.471**	**535.9**	**3,259**	**4,330**
138	**21.6**	**3,860.2**	**220.6**	**2.457**	**542.1**	**3,318**	**4,402**
139	**22.2**	**3,863.3**	**220.8**	**2.443**	**539.3**	**3,324**	**4,403**
140	**24.5**	**3,964.6**	**226.6**	**2.429**	**550.2**	**3,414**	**4,515**
141	**24.7**	**3,943.1**	**225.3**	**2.414**	**544.0**	**3,399**	**4,487**
142	**24.8**	**3,915.9**	**223.8**	**2.400**	**537.1**	**3,379**	**4,453**
143	**24.7**	**3,883.2**	**221.9**	**2.386**	**529.4**	**3,354**	**4,413**
144	**24.6**	**3,851.1**	**220.1**	**2.371**	**521.9**	**3,329**	**4,373**
145	**24.6**	**3,819.6**	**218.3**	**2.357**	**514.5**	**3,305**	**4,334**
146	**25.1**	**3,817.5**	**218.2**	**2.343**	**511.1**	**3,306**	**4,329**
147	**25.6**	**3,815.4**	**218.0**	**2.329**	**507.7**	**3,308**	**4,323**
148	**25.7**	**3,789.6**	**216.6**	**2.314**	**501.2**	**3,288**	**4,291**
149	**25.4**	**3,758.6**	**214.8**	**2.300**	**494.0**	**3,265**	**4,253**
150	**24.9**	**3,728.8**	**213.1**	**2.286**	**487.1**	**3,242**	**4,216**
151	**25.0**	**3,704.9**	**211.7**	**2.271**	**480.9**	**3,224**	**4,186**
152	**25.4**	**3,698.2**	**211.3**	**2.257**	**477.0**	**3,221**	**4,175**
153	**26.0**	**3,702.8**	**211.6**	**2.243**	**474.6**	**3,228**	**4,177**
154	**26.0**	**3,673.1**	**209.9**	**2.229**	**467.8**	**3,205**	**4,141**
155	**25.7**	**3,644.1**	**208.3**	**2.214**	**461.1**	**3,183**	**4,105**
156	**26.1**	**3,637.9**	**207.9**	**2.200**	**457.4**	**3,181**	**4,095**
157	**26.7**	**3,643.0**	**208.2**	**2.186**	**455.0**	**3,188**	**4,098**
158	**27.3**	**3,648.1**	**208.5**	**2.171**	**452.7**	**3,195**	**4,101**
159	**30.5**	**3,812.6**	**217.9**	**2.157**	**470.0**	**3,343**	**4,283**
160	**33.5**	**3,978.0**	**227.3**	**2.143**	**487.1**	**3,491**	**4,465**
161	**36.2**	**4,133.0**	**236.2**	**2.129**	**502.8**	**3,630**	**4,636**
162	**37.3**	**4,172.3**	**238.4**	**2.114**	**504.1**	**3,668**	**4,676**
163	**39.3**	**4,282.5**	**244.7**	**2.100**	**513.9**	**3,769**	**4,796**
164	**40.5**	**4,330.6**	**247.5**	**2.086**	**516.2**	**3,814**	**4,847**
165	**42.1**	**4,412.1**	**252.1**	**2.071**	**522.3**	**3,890**	**4,934**
166	**43.5**	**4,477.8**	**255.9**	**2.057**	**526.4**	**3,951**	**5,004**

167	**45.1**	**4,561.4**	**260.7**	**2.043**	**532.5**	**4,029**	**5,094**
168	**46.0**	**4,584.2**	**262.0**	**2.029**	**531.4**	**4,053**	**5,116**
169	**46.8**	**4,598.2**	**262.8**	**2.014**	**529.3**	**4,069**	**5,127**
170	**47.5**	**4,603.2**	**263.1**	**2.000**	**526.1**	**4,077**	**5,129**
171	**47.5**	**4,546.8**	**259.8**	**1.986**	**516.0**	**4,031**	**5,063**
172	**47.3**	**4,492.0**	**256.7**	**1.971**	**506.1**	**3,986**	**4,998**
173	**47.2**	**4,438.6**	**253.7**	**1.957**	**496.4**	**3,942**	**4,935**
174	**47.2**	**4,386.5**	**250.7**	**1.943**	**487.0**	**3,899**	**4,874**
175	**47.4**	**4,352.1**	**248.7**	**1.929**	**479.7**	**3,872**	**4,832**
176	**47.9**	**4,343.2**	**248.2**	**1.914**	**475.1**	**3,868**	**4,818**
177	**48.5**	**4,342.6**	**248.2**	**1.900**	**471.5**	**3,871**	**4,814**
178	**49.1**	**4,342.0**	**248.1**	**1.886**	**467.9**	**3,874**	**4,810**
179	**49.5**	**4,324.9**	**247.2**	**1.871**	**462.5**	**3,862**	**4,787**
180	**50.0**	**4,316.3**	**246.7**	**1.857**	**458.1**	**3,858**	**4,774**
181	**50.6**	**4,316.0**	**246.7**	**1.843**	**454.5**	**3,861**	**4,771**
182	**51.0**	**4,299.3**	**245.7**	**1.829**	**449.3**	**3,850**	**4,749**
183	**51.5**	**4,291.0**	**245.2**	**1.814**	**444.9**	**3,846**	**4,736**
184	**52.2**	**4,299.3**	**245.7**	**1.800**	**442.3**	**3,857**	**4,742**
185	**53.2**	**4,332.3**	**247.6**	**1.786**	**442.1**	**3,890**	**4,774**
186	**54.1**	**4,356.8**	**249.0**	**1.771**	**441.0**	**3,916**	**4,798**
187	**54.6**	**4,347.7**	**248.5**	**1.757**	**436.6**	**3,911**	**4,784**
188	**54.9**	**4,322.3**	**247.0**	**1.743**	**430.5**	**3,892**	**4,753**
189	**55.0**	**4,280.9**	**244.6**	**1.729**	**422.9**	**3,858**	**4,704**
190	**54.9**	**4,232.4**	**241.9**	**1.714**	**414.6**	**3,818**	**4,647**
191	**54.6**	**4,185.2**	**239.2**	**1.700**	**406.6**	**3,779**	**4,592**
192	**54.6**	**4,139.1**	**236.5**	**1.686**	**398.7**	**3,740**	**4,538**
193	**54.8**	**4,109.5**	**234.9**	**1.671**	**392.5**	**3,717**	**4,502**
194	**55.1**	**4,088.2**	**233.6**	**1.657**	**387.2**	**3,701**	**4,475**
195	**55.5**	**4,075.0**	**232.9**	**1.643**	**382.6**	**3,692**	**4,458**
196	**55.7**	**4,046.6**	**231.3**	**1.629**	**376.6**	**3,670**	**4,423**
197	**56.1**	**4,034.0**	**230.5**	**1.614**	**372.1**	**3,662**	**4,406**
198	**56.3**	**4,006.4**	**229.0**	**1.600**	**366.3**	**3,640**	**4,373**
199	**56.6**	**3,986.7**	**227.8**	**1.586**	**361.3**	**3,625**	**4,348**
200	**56.7**	**3,952.4**	**225.9**	**1.571**	**354.9**	**3,597**	**4,307**
201	**56.7**	**3,911.4**	**223.5**	**1.557**	**348.1**	**3,563**	**4,259**
202	**56.3**	**3,871.4**	**221.2**	**1.543**	**341.3**	**3,530**	**4,213**
203	**56.0**	**3,832.5**	**219.0**	**1.529**	**334.8**	**3,498**	**4,167**
204	**55.0**	**3,795.0**	**216.9**	**1.514**	**328.4**	**3,467**	**4,123**
205	**53.4**	**3,759.3**	**214.8**	**1.500**	**322.3**	**3,437**	**4,082**
206	**51.6**	**3,725.4**	**212.9**	**1.486**	**316.3**	**3,409**	**4,042**
207	**51.8**	**3,704.9**	**211.7**	**1.471**	**311.5**	**3,393**	**4,016**
208	**52.1**	**3,691.1**	**210.9**	**1.457**	**307.4**	**3,384**	**3,998**
209	**52.5**	**3,683.7**	**210.5**	**1.443**	**303.7**	**3,380**	**3,987**

210	**53.0**	**3,682.8**	**210.5**	**1.429**	**300.7**	**3,382**	**3,984**
211	**53.5**	**3,682.0**	**210.4**	**1.414**	**297.6**	**3,384**	**3,980**
212	**54.0**	**3,681.1**	**210.4**	**1.400**	**294.5**	**3,387**	**3,976**
213	**54.9**	**3,705.8**	**211.8**	**1.386**	**293.5**	**3,412**	**3,999**
214	**55.4**	**3,704.7**	**211.7**	**1.371**	**290.4**	**3,414**	**3,995**
215	**55.6**	**3,684.4**	**210.6**	**1.357**	**285.8**	**3,399**	**3,970**
216	**56.0**	**3,677.1**	**210.1**	**1.343**	**282.2**	**3,395**	**3,959**
217	**56.0**	**3,644.6**	**208.3**	**1.329**	**276.7**	**3,368**	**3,921**
218	**55.8**	**3,612.7**	**206.5**	**1.314**	**271.3**	**3,341**	**3,884**
219	**55.2**	**3,581.7**	**204.7**	**1.300**	**266.1**	**3,316**	**3,848**
220	**54.5**	**3,551.6**	**203.0**	**1.286**	**261.0**	**3,291**	**3,813**
221	**53.6**	**3,522.5**	**201.3**	**1.271**	**255.9**	**3,267**	**3,778**
222	**52.5**	**3,494.5**	**199.7**	**1.257**	**251.1**	**3,243**	**3,746**
223	**51.5**	**3,467.4**	**198.2**	**1.243**	**246.3**	**3,221**	**3,714**
224	**50.5**	**3,441.2**	**196.7**	**1.229**	**241.6**	**3,200**	**3,683**
225	**48.0**	**3,416.8**	**195.3**	**1.214**	**237.1**	**3,180**	**3,654**
226	**44.5**	**3,394.4**	**194.0**	**1.200**	**232.8**	**3,162**	**3,627**
227	**41.0**	**3,374.0**	**192.8**	**1.186**	**228.6**	**3,145**	**3,603**
228	**37.5**	**3,355.6**	**191.8**	**1.171**	**224.6**	**3,131**	**3,580**
229	**34.0**	**3,339.0**	**190.8**	**1.157**	**220.8**	**3,118**	**3,560**
230	**30.5**	**3,324.3**	**190.0**	**1.143**	**217.1**	**3,107**	**3,541**
231	**27.0**	**3,311.4**	**189.2**	**1.129**	**213.6**	**3,098**	**3,525**
232	**23.5**	**3,300.3**	**188.6**	**1.114**	**210.2**	**3,090**	**3,510**
233	**20.0**	**3,290.9**	**188.1**	**1.100**	**206.9**	**3,084**	**3,498**
234	**16.5**	**3,283.1**	**187.6**	**1.086**	**203.7**	**3,079**	**3,487**
235	**13.0**	**3,277.1**	**187.3**	**1.071**	**200.7**	**3,076**	**3,478**
236	**9.5**	**3,272.7**	**187.0**	**1.057**	**197.7**	**3,075**	**3,470**
237	**6.0**	**3,269.9**	**186.9**	**1.043**	**194.9**	**3,075**	**3,465**
238	**2.5**	**3,268.7**	**186.8**	**1.029**	**192.1**	**3,077**	**3,461**
239	**0.0**	**3,268.7**	**186.8**	**1.014**	**189.5**	**3,079**	**3,458**
Cycle Sums		**3,268.7**				**3,079**	**3,458**

Appendix H

Derivation of TRLHP Coefficients

Derivation of TRLHP Coefficients

(a) Road Load Equation

(1) Vehicle Loading. Road load is defined by the following equation relating track road load horsepower and vehicle velocity.

$$TRLHP_{@\ Obmph} = (A_V * Obmph) + (B_V * Obmph^2) + (C_V * Obmph^3)$$

Where: TRLHP = Track Road Load Horsepower.

A_V, B_V, C_V = Coefficients relating TRLHP and velocity.

Obmph = Observed velocity in mph.

(2) Coefficients. A_V, B_V, and C_V are horsepower coefficients from EPA vehicle certification data or EPA default values. Coefficients shall be calculated to a minimum of five significant digits by the following equations. Power fractions determined from track coast-down data shall be calculated to a minimum of two significant digits. In the absence of new car certification coefficients, the default power fractions shall be used.

(A) $$A_v = \frac{A_vPF}{50} * (TRLHP_{@50mph}) \quad hp/mph$$

(B) $$B_v = \frac{B_vPF}{2500} * (TRLHP_{@50mph}) \quad hp/mph^2$$

(C) $$C_v = \frac{C_vPF}{125{,}000} * (TRLHP_{@50mph}) \quad hp/mph^3$$

Where: A_V, B_V, C_V = Coefficients relating TRLHP and velocity.

A_VPF, B_VPF, and C_VPF are power fractions, and indicate the fraction of the total power at 50 mph contributed by each of the A_V*50, B_V*2500, and C_V*125,000 terms.

$TRLHP_{@50mph}$ = Track Road Load Horsepower at 50mph.

(D) $A_VPF + B_VPF + C_VPF = 1$

Derivation of A_VPF, B_VPF, and C_VPF from known track coastdown curves shall be computed as follows:

(E) $$A_vPF = \frac{A_v * 50}{\left(A_v * 50\right) + \left(B_v * 2500\right) + \left(C_v * 125{,}000\right)}$$

(F) $$B_vPF = \frac{B_v * 2500}{\left(A_v * 50\right) + \left(B_v * 2500\right) + \left(C_v * 125{,}000\right)}$$

(G) $$C_vPF = \frac{C_v * 125{,}000}{\left(A_v * 50\right) + \left(B_v * 2500\right) + \left(C_v * 125{,}000\right)}$$

Default values:

A_VPF = 0.35

B_VPF = 0.10

C_VPF = 0.55

(3) TRLHP@50mph. In absence of new vehicle certification data, the 50 mph TRLHP shall be selected from the EPA I/M Look-up Table. It is based on the following equation:

$$TRLHP = \frac{\left(0.5 * ETW \big/ 32.2\right) * (V_1^2 - V_2^2)}{550 * ET}$$

Where: ET = Elapsed time for the vehicle on the road to coast down from 55 to 45 mph

ETW = Equivalent Test Weight in pounds

V_1 = Initial velocity in feet/second

V_2 = Final velocity in feet/second

Appendix I

Derivation of GTRL Coefficients

Derivation of Dynamometer Tire/Roll Interface Losses

(a) Generic Tire Roll Loss

(1) Tire/Roll Interface Losses. Tire/roll losses include vehicle drive train losses and may be determined on a vehicle and dynamometer specific basis, or using the default values presented below.

Tire losses shall be characterized by the following equation:

$$GTRL_{@\ Obmph} = (A_t * Obmph) + (B_t * Obmph^2) + (C_t * Obmph^3)$$

Where: GTRL = Generic tire/roll interface losses.

A_t, B_t, and C_t are curve coefficients relating tire/roll interface losses and velocity.

Obmph is the observed velocity in mph.

(A) $$A_t = \frac{A_t PF}{50} * (GTRL_{@50mph}) \quad hp/mph$$

(B) $$B_t = \frac{B_t PF}{2500} * (GTRL_{@50mph}) \quad hp/mph^2$$

(C) $$C_t = \frac{C_t PF}{125{,}000} * (GTRL_{@50mph}) \quad hp/mph^3$$

(D) $$A_{t8} = \frac{0.76}{50} * (GTRL_{@50mph}) \quad hp/mph$$

(E) $$B_{t8} = \frac{0.33}{2500} * (GTRL_{@50mph}) \quad hp/mph^2$$

(F) $$C_{t8} = \frac{-0.09}{125{,}000} * (GTRL_{@50mph}) \quad hp/mph^3$$

(G) $$A_{t20} = \frac{0.65}{50} * (GTRL_{@50mph}) \quad hp/mph$$

(H) $$B_{t20} = \frac{0.48}{2500} * (GTRL_{@50mph}) \quad hp/mph^2$$

(I) $$C_{t20} = \frac{-0.13}{125{,}000} * (GTRL_{@50mph}) \quad hp/mph^3$$

Where: A_t, B_t, and C_t are curve coefficients necessary to properly characterize the tire/roll interface losses for any roll size.

A_tPF, B_tPF, and C_tPF are power fractions of the total tire loss power at 50 mph.

$A_t PF + B_t PF + C_t PF = 1$

$GTRL_{@50mph}$ = Generic tire/roll interface losses.

A_{t8}, B_{t8}, and C_{t8} are curve coefficients for twin 8.65 inch diameter rolls using default values for A_tPF, B_tPF, and C_tPF.

A_{t20}, B_{t20}, and C_{t20} are curve coefficients for twin 20.0 inch diameter rolls using default values for A_tPF, B_tPF, and C_tPF.

Derivation of A_tPF, B_tPF, and C_tPF from vehicle and dynamometer specific data shall be computed as follows:

(J) $$A_t PF = \frac{A_t * 50}{(A_t * 50) + (B_t * 2500) + (C_t * 125{,}000)}$$

(K) $$B_t PF = \frac{B_t * 2500}{(A_t * 50) + (B_t * 2500) + (C_t * 125{,}000)}$$

(L) $$C_t PF = \frac{C_t * 125{,}000}{(A_t * 50) + (B_t * 2500) + (C_t * 125{,}000)}$$

Default values:

$A_{t8}PF = 0.76$

$B_{t8}PF = 0.33$

$C_{t8}PF = -0.09$

$A_{t20}PF = 0.65$

$B_{t20}PF = 0.48$

$C_{t20}PF = -0.13$

(2) Look-up Table. The vehicle specific values for GTRL at 50 mph using the default values for A_{t8}PF, B_{t8}PF, C_{t8}PF, and A_{t20}PF, B_{t20}PF, and C_{t20}PF, are contained in the latest version of the EPA I/M Look-up Table.