

§ 1065.601

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the filter to a PM-stabilization environment meeting the specifications of § 1065.190 for at least 30 minutes before weighing. If you expect a higher PM concentration or do not know what PM concentration to expect, expose the filter to the stabilization environment for at least 60 minutes before weighing. Note that 400 µg on sample media (e.g., filters) is an approximate net mass of 0.07 g/kW-hr for a hot-start test with compression-ignition engines tested according to 40 CFR part 86, subpart N, or 50 mg/mile for light-duty vehicles tested according to 40 CFR part 86, subpart B.

(f) Repeat the procedures in § 1065.590(f) through (i) to determine post-test mass of the sample media (e.g., filters).

(g) Subtract each buoyancy-corrected tare mass of the sample medium (e.g., filter) from its respective buoyancy-corrected mass. The result is the net PM mass, m_{PM} . Use m_{PM} in emission calculations in § 1065.650.

Subpart G—Calculations and Data Requirements

§ 1065.601 Overview.

(a) This subpart describes how to—
 (1) Use the signals recorded before, during, and after an emission test to calculate brake-specific emissions of each regulated constituent.

(2) Perform calculations for calibrations and performance checks.

(3) Determine statistical values.

(b) You may use data from multiple systems to calculate test results for a single emission test, consistent with good engineering judgment. You may not use test results from multiple emission tests to report emissions. We allow weighted means where appropriate. You may discard statistical outliers, but you must report all results.

(c) You may use any of the following calculations instead of the calculations specified in this subpart G:

(1) Mass-based emission calculations prescribed by the International Organization for Standardization (ISO), according to ISO 8178.

(2) Other calculations that you show are equivalent to within ±0.1% of the brake-specific emission results determined using the calculations specified in this subpart G.

EFFECTIVE DATE NOTE: At 73 FR 37324, June 30, 2008, § 1065.601 was amended by revising paragraph (c)(1), effective July 7, 2008. For the

convenience of the user, the revised text is set forth as follows:

§ 1065.601 Overview.

* * * * *

(c) * * *

(1) Mass-based emission calculations prescribed by the International Organization for Standardization (ISO), according to ISO 8178, except the following:

(i) ISO 8178-1 Section 14.4, NO_x Correction for Humidity and Temperature. See § 1065.670 for approved methods for humidity corrections.

(ii) ISO 8178-1 Section 15.1, Particulate Correction Factor for Humidity.

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§ 1065.602 Statistics.

(a) *Overview.* This section contains equations and example calculations for statistics that are specified in this part. In this section we use the letter “y” to denote a generic measured quantity, the superscript over-bar “ $\bar{}$ ” to denote an arithmetic mean, and the subscript “_{ref}” to denote the reference quantity being measured.

(b) *Arithmetic mean.* Calculate an arithmetic mean, \bar{y} , as follows:

$$\bar{y} = \frac{\sum_{i=1}^{10} y_i}{N} \quad \text{Eq. 1065.602-1}$$

Example:

$N = 3$
 $y_1 = 10.60$
 $y_2 = 11.91$
 $y_N = y_3 = 11.09$

$$\bar{y} = \frac{10.60 + 11.91 + 11.09}{3}$$

$\bar{y} = 11.20$

(c) *Standard deviation.* Calculate the standard deviation for a non-biased (e.g., $N-1$) sample, σ , as follows:

$$\sigma_y = \sqrt{\frac{\sum_{i=1}^N (y_i - \bar{y})^2}{(N-1)}} \quad \text{Eq. 1065.602-2}$$

Example:

$N = 3$
 $y_1 = 10.60$
 $y_2 = 11.91$

$$\begin{aligned} y_N = y_3 &= 11.09 \\ \bar{y} &= 11.20 \end{aligned}$$

$$\sigma_y = \sqrt{\frac{(10.60 - 11.2)^2 + (11.91 - 11.2)^2 + (11.09 - 11.2)^2}{2}}$$

$$\sigma_y = 0.6619$$

(d) *Root mean square.* Calculate a root mean square, rms_y , as follows:

$$rms_y = \sqrt{\frac{1}{N} \sum_{i=1}^N y_i^2} \quad \text{Eq. 1065.602-3}$$

Example:

$$\begin{aligned} N &= 3 \\ y_1 &= 10.60 \\ y_2 &= 11.91 \\ y_N = y_3 &= 11.09 \end{aligned}$$

$$rms_y = \sqrt{\frac{10.60^2 + 11.91^2 + 11.09^2}{3}}$$

$$rms_y = 11.21$$

(e) *Accuracy.* Calculate an accuracy, as follows, noting that the \bar{y}_i are arithmetic means, each determined by repeatedly measuring one sample of a single reference quantity, y_{ref} :

$$accuracy = |y_{ref} - \bar{y}| \quad \text{Eq. 1065.602-4}$$

Example:

$$\begin{aligned} y_{ref} &= 1800.0 \\ N &= 10 \end{aligned}$$

$$\bar{y} = \frac{\sum_{i=1}^{10} \bar{y}_i}{10} = 1802.5$$

$$\begin{aligned} accuracy &= |1800.0 - 1802.5| \\ accuracy &= 2.5 \end{aligned}$$

(f) *t-test.* Determine if your data passes a *t-test* by using the following equations and tables:

(1) For an unpaired *t-test*, calculate the *t* statistic and its number of degrees of freedom, *v*, as follows:

$$t = \frac{|\bar{y}_{ref} - \bar{y}|}{\sqrt{\frac{\sigma_{ref}^2}{N_{ref}} + \frac{\sigma_y^2}{N}}} \quad \text{Eq. 1065.602-5}$$

$$v = \frac{\left(\frac{\sigma_{ref}^2}{N_{ref}} + \frac{\sigma_y^2}{N}\right)^2}{\frac{(\sigma_{ref}^2/N_{ref})^2}{N_{ref}-1} + \frac{(\sigma_y^2/N)^2}{N-1}} \quad \text{Eq. 1065.602-6}$$

Example:

$$\begin{aligned} \bar{y}_{ref} &= 1205.3 \\ \bar{y} &= 1123.8 \\ \sigma_{ref} &= 9.399 \\ \sigma_y &= 10.583 \\ N_{ref} &= 11 \\ N &= 7 \end{aligned}$$

$$t = \frac{|1205.3 - 1123.8|}{\sqrt{\frac{9.399^2}{11} + \frac{10.583^2}{7}}}$$

$$\begin{aligned} t &= 16.63 \\ \sigma_{ref} &= 9.399 \\ \sigma_y &= 10.583 \\ N_{ref} &= 11 \\ N &= 7 \end{aligned}$$

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$$t = \frac{|1205.3 - 1123.8|}{\sqrt{\frac{9.399^2}{11} + \frac{10.583^2}{7}}}$$

v = 11.76

(2) For a paired *t*-test, calculate the *t* statistic and its number of degrees of freedom, *v*, as follows, noting that the ϵ_i are the errors (e.g., differences) between each pair of y_{refi} and y_i :

$$t = \frac{|\bar{\epsilon}| \cdot \sqrt{N}}{\sigma_{\epsilon}} \quad \text{Eq. 1065.602-7}$$

Example:

$\bar{\epsilon} = -0.12580$
 $N = 16$
 $\sigma_{\epsilon} = 0.04837$

$$t = \frac{|-0.12580| \cdot \sqrt{16}}{0.04837}$$

$t = 10.403$
 $v = N - 1$

Example:

$N = 16$
 $v = 16 - 1$
 $v = 15$

(3) Use Table 1 of this section to compare *t* to the t_{crit} values tabulated versus the number of degrees of freedom. If *t* is less than t_{crit} , then *t* passes the *t*-test.

TABLE 1 OF § 1065.602—CRITICAL *t* VALUES VERSUS NUMBER OF DEGREES OF FREEDOM, v^1

v	Confidence	
	90%	95%
1	6.314	12.706
2	2.920	4.303
3	2.353	3.182
4	2.132	2.776
5	2.015	2.571
6	1.943	2.447
7	1.895	2.365
8	1.860	2.306
9	1.833	2.262
10	1.812	2.228
11	1.796	2.201
12	1.782	2.179
13	1.771	2.160
14	1.761	2.145
15	1.753	2.131
16	1.746	2.120
18	1.734	2.101
20	1.725	2.086
22	1.717	2.074
24	1.711	2.064
26	1.706	2.056
28	1.701	2.048
30	1.697	2.042
35	1.690	2.030
40	1.684	2.021
50	1.676	2.009
70	1.667	1.994
100	1.660	1.984
1000+	1.645	1.960

¹Use linear interpolation to establish values not shown here.

(g) *F*-test. Calculate the *F* statistic as follows:

$$F_y = \frac{\sigma_y^2}{\sigma_{ref}^2} \quad \text{Eq. 1065.602-8}$$

Example:

$$\sigma_y = \sqrt{\frac{\sum_{i=1}^N (y_i - \bar{y})^2}{(N-1)}} = 10.583$$

$$\sigma_{ref} = \sqrt{\frac{\sum_{i=1}^{N_{ref}} (y_{refi} - \bar{y}_{ref})^2}{(N_{ref}-1)}} = 9.399$$

$$F = \frac{10.583^2}{9.399^2}$$

$F = 1.268$

(1) For a 90% confidence F -test, use Table 2 of this section to compare F to the $F_{\text{crit}90}$ values tabulated versus $(N-1)$ and $(N_{\text{ref}}-1)$. If F is less than $F_{\text{crit}90}$, then F passes the F -test at 90% confidence.

(2) For a 95% confidence F -test, use Table 3 of this section to compare F to the $F_{\text{crit}95}$ values tabulated versus $(N-1)$ and $(N_{\text{ref}}-1)$. If F is less than $F_{\text{crit}95}$, then F passes the F -test at 95% confidence.

Table 2 of § 1065.602--Critical F values, $F_{\text{crit}90}$ versus $N-1$ and $N_{\text{ref}}-1$ at 90 % confidence

$N-1$	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	1000+	
$N_{\text{ref}}-1$	1	39.86	49.50	53.59	55.83	57.24	58.50	59.43	59.85	60.19	60.70	61.22	61.74	62.00	62.26	62.52	62.79	63.06	63.32	
	2	8.526	9.000	9.162	9.243	9.293	9.326	9.349	9.367	9.381	9.392	9.408	9.425	9.441	9.450	9.458	9.466	9.475	9.483	9.491
	3	5.538	5.462	5.391	5.343	5.309	5.285	5.266	5.252	5.240	5.230	5.216	5.206	5.196	5.186	5.180	5.176	5.170	5.165	5.160
	4	4.545	4.325	4.191	4.107	4.051	4.010	3.979	3.955	3.936	3.920	3.896	3.870	3.844	3.831	3.817	3.804	3.790	3.775	3.761
	5	4.060	3.780	3.619	3.520	3.453	3.405	3.368	3.339	3.316	3.297	3.268	3.238	3.207	3.191	3.174	3.157	3.140	3.123	3.105
	6	3.776	3.463	3.289	3.181	3.108	3.055	3.014	2.983	2.958	2.937	2.905	2.871	2.836	2.818	2.800	2.781	2.762	2.742	2.722
	7	3.589	3.257	3.074	2.961	2.883	2.827	2.785	2.752	2.725	2.703	2.668	2.632	2.595	2.575	2.555	2.534	2.493	2.471	
	8	3.458	3.113	2.924	2.806	2.726	2.668	2.624	2.589	2.561	2.538	2.502	2.464	2.425	2.404	2.383	2.361	2.339	2.316	2.293
	9	3.360	3.006	2.813	2.693	2.611	2.551	2.505	2.469	2.440	2.416	2.379	2.340	2.298	2.277	2.255	2.232	2.208	2.184	2.159
	10	3.285	2.924	2.728	2.605	2.522	2.461	2.414	2.377	2.347	2.323	2.284	2.244	2.201	2.178	2.155	2.132	2.107	2.082	2.055
	11	3.225	2.860	2.660	2.536	2.451	2.389	2.342	2.304	2.274	2.248	2.209	2.167	2.123	2.100	2.076	2.052	2.026	2.000	1.972
	12	3.177	2.807	2.606	2.480	2.394	2.331	2.283	2.245	2.214	2.188	2.147	2.105	2.060	2.036	2.011	1.986	1.960	1.932	1.904
	13	3.136	2.763	2.560	2.434	2.347	2.283	2.234	2.195	2.164	2.138	2.097	2.053	2.007	1.983	1.958	1.931	1.904	1.876	1.846
	14	3.102	2.726	2.522	2.395	2.307	2.243	2.193	2.154	2.122	2.095	2.054	2.010	1.962	1.938	1.912	1.885	1.857	1.828	1.797
	15	3.073	2.695	2.490	2.361	2.273	2.208	2.158	2.119	2.086	2.059	2.017	1.972	1.924	1.899	1.873	1.845	1.817	1.787	1.755
	16	3.048	2.668	2.462	2.333	2.244	2.178	2.128	2.088	2.055	2.028	1.985	1.940	1.891	1.866	1.839	1.811	1.782	1.751	1.718
	17	3.026	2.645	2.437	2.308	2.218	2.152	2.102	2.061	2.028	2.001	1.958	1.912	1.862	1.836	1.809	1.781	1.751	1.719	1.686
	18	3.007	2.624	2.416	2.286	2.196	2.130	2.079	2.038	2.005	1.977	1.933	1.887	1.837	1.810	1.783	1.754	1.723	1.691	1.657
	19	2.990	2.606	2.397	2.266	2.176	2.109	2.058	2.017	1.984	1.956	1.912	1.865	1.814	1.787	1.759	1.730	1.699	1.666	1.631
	20	2.975	2.589	2.380	2.249	2.158	2.091	2.040	1.999	1.965	1.937	1.892	1.845	1.794	1.767	1.738	1.708	1.677	1.643	1.607
	21	2.961	2.575	2.365	2.233	2.142	2.075	2.023	1.982	1.948	1.920	1.875	1.827	1.776	1.748	1.719	1.689	1.657	1.623	1.586
	20	2.949	2.561	2.351	2.219	2.128	2.061	2.008	1.967	1.933	1.904	1.859	1.811	1.759	1.731	1.702	1.671	1.639	1.604	1.567
	23	2.937	2.549	2.339	2.207	2.115	2.047	1.995	1.953	1.919	1.890	1.845	1.796	1.744	1.716	1.686	1.655	1.622	1.587	1.549
	24	2.927	2.538	2.327	2.195	2.103	2.035	1.983	1.941	1.906	1.877	1.832	1.783	1.730	1.702	1.672	1.641	1.607	1.571	1.533
	25	2.918	2.528	2.317	2.184	2.092	2.024	1.971	1.929	1.895	1.866	1.820	1.771	1.718	1.689	1.659	1.627	1.593	1.557	1.518
	26	2.909	2.519	2.307	2.174	2.082	2.014	1.961	1.919	1.884	1.855	1.809	1.760	1.706	1.677	1.647	1.615	1.581	1.544	1.504
	27	2.901	2.511	2.299	2.165	2.073	2.005	1.952	1.909	1.874	1.845	1.799	1.749	1.695	1.666	1.636	1.603	1.569	1.531	1.491
	28	2.894	2.503	2.291	2.157	2.064	1.996	1.943	1.900	1.865	1.836	1.790	1.740	1.685	1.656	1.625	1.593	1.558	1.520	1.478
	29	2.887	2.495	2.283	2.149	2.057	1.988	1.935	1.892	1.857	1.827	1.781	1.731	1.676	1.647	1.616	1.583	1.547	1.509	1.467
	30	2.881	2.489	2.276	2.142	2.049	1.980	1.927	1.884	1.849	1.819	1.773	1.722	1.667	1.638	1.606	1.573	1.538	1.499	1.456
	40	2.835	2.440	2.226	2.091	1.997	1.927	1.873	1.829	1.793	1.763	1.715	1.662	1.605	1.574	1.541	1.506	1.467	1.425	1.377
	60	2.791	2.393	2.177	2.041	1.946	1.875	1.819	1.775	1.738	1.707	1.657	1.603	1.543	1.511	1.476	1.437	1.395	1.348	1.291
	120	2.748	2.347	2.130	1.992	1.896	1.824	1.767	1.722	1.684	1.652	1.601	1.545	1.482	1.447	1.409	1.368	1.320	1.265	1.193
1000+	2.706	2.303	2.084	1.945	1.847	1.774	1.717	1.670	1.632	1.599	1.546	1.487	1.421	1.383	1.342	1.295	1.240	1.169	1.000	

Table 3 of §1065.602—Critical F values, F_{crit} , versus $N-1$ and $N_{\text{ref}}-1$ at 95 % confidence

$N-1$	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	1000+	
$N_{\text{ref}}-1$	1	161.4	199.5	215.7	224.5	230.1	233.9	236.7	238.8	240.5	241.8	243.9	245.9	248.0	249.0	250.1	251.1	252.2	253.2	254.3
	2	18.51	19.00	19.16	19.24	19.29	19.33	19.35	19.37	19.38	19.39	19.41	19.42	19.44	19.45	19.46	19.47	19.47	19.48	19.49
	3	10.12	9.552	9.277	9.117	9.014	8.941	8.887	8.845	8.812	8.786	8.745	8.703	8.660	8.639	8.617	8.594	8.572	8.549	8.526
	4	7.709	6.944	6.591	6.388	6.256	6.163	6.094	6.041	5.999	5.964	5.912	5.858	5.803	5.774	5.746	5.717	5.688	5.658	5.628
	5	6.608	5.786	5.410	5.192	5.050	4.950	4.876	4.818	4.773	4.735	4.678	4.619	4.538	4.527	4.496	4.464	4.431	4.399	4.365
	6	5.987	5.143	4.757	4.534	4.387	4.284	4.207	4.147	4.099	4.060	4.000	3.938	3.874	3.842	3.808	3.774	3.740	3.705	3.669
	7	5.591	4.737	4.347	4.120	3.972	3.866	3.787	3.726	3.677	3.637	3.575	3.511	3.445	3.411	3.376	3.340	3.304	3.267	3.230
	8	5.318	4.459	4.066	3.838	3.688	3.581	3.501	3.438	3.388	3.347	3.284	3.218	3.150	3.115	3.079	3.043	3.005	2.967	2.928
	9	5.117	4.257	3.863	3.633	3.482	3.374	3.293	3.230	3.179	3.137	3.073	3.006	2.937	2.901	2.864	2.826	2.787	2.748	2.707
	10	4.965	4.103	3.708	3.478	3.326	3.217	3.136	3.072	3.020	2.978	2.913	2.845	2.774	2.737	2.700	2.661	2.621	2.580	2.538
	11	4.844	3.982	3.587	3.357	3.204	3.095	3.012	2.948	2.896	2.854	2.788	2.719	2.646	2.609	2.571	2.531	2.490	2.448	2.405
	12	4.747	3.885	3.490	3.259	3.106	2.996	2.913	2.849	2.796	2.753	2.687	2.617	2.544	2.506	2.466	2.426	2.384	2.341	2.296
	13	4.667	3.806	3.411	3.179	3.025	2.915	2.832	2.767	2.714	2.671	2.604	2.533	2.459	2.420	2.380	2.339	2.297	2.252	2.206
	14	4.600	3.739	3.344	3.112	2.958	2.848	2.764	2.699	2.646	2.602	2.534	2.463	2.388	2.349	2.308	2.266	2.223	2.178	2.131
	15	4.543	3.682	3.287	3.056	2.901	2.791	2.707	2.641	2.588	2.544	2.475	2.403	2.328	2.288	2.247	2.204	2.160	2.114	2.066
	16	4.494	3.634	3.239	3.007	2.852	2.741	2.657	2.591	2.538	2.494	2.425	2.352	2.276	2.235	2.194	2.151	2.106	2.059	2.010
	17	4.451	3.592	3.197	2.965	2.810	2.699	2.614	2.548	2.494	2.450	2.381	2.308	2.230	2.189	2.148	2.104	2.058	2.011	1.960
	18	4.414	3.555	3.160	2.928	2.773	2.661	2.577	2.510	2.456	2.412	2.342	2.269	2.191	2.150	2.107	2.063	2.017	1.968	1.917
	19	4.381	3.522	3.127	2.895	2.740	2.628	2.544	2.477	2.423	2.378	2.308	2.234	2.156	2.114	2.071	2.026	1.980	1.930	1.878
	20	4.351	3.493	3.098	2.866	2.711	2.599	2.514	2.447	2.393	2.348	2.278	2.203	2.124	2.083	2.039	1.994	1.946	1.896	1.843
	21	4.325	3.467	3.073	2.840	2.685	2.573	2.488	2.421	2.366	2.321	2.250	2.176	2.096	2.054	2.010	1.965	1.917	1.866	1.812
	22	4.301	3.443	3.049	2.817	2.661	2.549	2.464	2.397	2.342	2.297	2.226	2.151	2.071	2.028	1.984	1.938	1.889	1.838	1.783
	23	4.279	3.422	3.028	2.796	2.640	2.528	2.442	2.375	2.320	2.275	2.204	2.128	2.048	2.005	1.961	1.914	1.865	1.813	1.757
	24	4.260	3.403	3.009	2.776	2.621	2.508	2.423	2.355	2.300	2.255	2.183	2.108	2.027	1.984	1.939	1.892	1.842	1.790	1.733
	25	4.242	3.385	2.991	2.759	2.603	2.490	2.405	2.337	2.282	2.237	2.165	2.089	2.008	1.964	1.919	1.872	1.822	1.768	1.711
	26	4.225	3.369	2.975	2.743	2.587	2.474	2.388	2.321	2.266	2.220	2.148	2.072	1.990	1.946	1.901	1.853	1.803	1.749	1.691
	27	4.210	3.354	2.960	2.728	2.572	2.459	2.373	2.305	2.250	2.204	2.132	2.056	1.974	1.930	1.884	1.836	1.785	1.731	1.672
	28	4.196	3.340	2.947	2.714	2.558	2.445	2.359	2.291	2.236	2.190	2.118	2.041	1.959	1.915	1.869	1.820	1.769	1.714	1.654
	29	4.183	3.328	2.934	2.701	2.545	2.432	2.346	2.278	2.223	2.177	2.105	2.028	1.945	1.901	1.854	1.806	1.754	1.698	1.638
	30	4.171	3.316	2.922	2.690	2.534	2.421	2.334	2.266	2.211	2.165	2.092	2.015	1.932	1.887	1.841	1.792	1.740	1.684	1.622
	40	4.085	3.232	2.839	2.606	2.450	2.336	2.249	2.180	2.124	2.077	2.004	1.925	1.839	1.793	1.744	1.693	1.637	1.577	1.509
	60	4.001	3.150	2.758	2.525	2.368	2.254	2.167	2.097	2.040	1.993	1.917	1.836	1.748	1.700	1.649	1.594	1.534	1.467	1.389
	120	3.920	3.072	2.680	2.447	2.290	2.175	2.087	2.016	1.959	1.911	1.834	1.751	1.659	1.608	1.554	1.495	1.429	1.352	1.254
1000+	3.842	2.996	2.605	2.372	2.214	2.099	2.010	1.938	1.880	1.831	1.752	1.666	1.571	1.517	1.459	1.394	1.318	1.221	1.100	

(h) *Slope*. Calculate a least-squares regression slope, a_{1y} , as follows:

$$a_{1y} = \frac{\sum_{i=1}^N (y_i - \bar{y}) \cdot (y_{\text{ref}i} - \bar{y}_{\text{ref}})}{\sum_{i=1}^N (y_{\text{ref}i} - \bar{y}_{\text{ref}})^2} \quad \text{Eq. 1065.602-9}$$

Example:
 $N = 6000$
 $y_1 = 2045.8$

$\bar{y} = 1051.1$
 $y_{\text{ref}1} = 2045.0$
 $\bar{y}_{\text{ref}} = 1055.3$

$$a_{1y} = \frac{(2045.8 - 1050.1) \cdot (2045.0 - 1055.3) + \dots + (y_{6000} - 1050.1) \cdot (y_{\text{ref}6000} - 1055.3)}{(2045.0 - 1055.3)^2 + \dots + (y_{\text{ref}6000} - 1055.3)^2}$$

$a_{1y} = 1.0110$

(i) *Intercept.* Calculate a least-squares regression intercept, a_{0y} , as follows:

$$a_{0y} = \bar{y} - (a_{1y} \cdot \bar{y}_{\text{ref}}) \quad \text{Eq. 1065.602-10}$$

Example:

$\bar{y} = 1050.1$
 $a_{1y} = 1.0110$
 $\bar{y}_{\text{ref}} = 1055.3$
 $a_{0y} = 1050.1 - (1.0110 \cdot 1055.3)$

$a_{0y} = -16.8083$

(j) *Standard estimate of error.* Calculate a standard estimate of error, *SEE*, as follows:

$$SEE_y = \sqrt{\frac{\sum_{i=1}^N [y_i - a_{0y} - (a_{1y} \cdot y_{\text{ref}i})]^2}{N - 2}} \quad \text{Eq. 1065.602-11}$$

Example:

$N = 6000$
 $y_1 = 2045.8$

$a_{0y} = -16.8083$
 $a_{1y} = 1.0110$
 $y_{\text{ref}1} = 2045.0$

$$SEE_y = \sqrt{\frac{[2045.8 - (-16.8083) - (1.0110 \cdot 2045.0)]^2 + \dots + [y_{6000} - (-16.8083) - (1.0110 \cdot y_{\text{ref}6000})]^2}{6000 - 2}}$$

$SEE_y = 5.348$

(k) *Coefficient of determination.* Calculate a coefficient of determination, r^2 , as follows:

$$r_y^2 = 1 - \frac{\sum_{i=1}^N [y_i - a_{0y} - (a_{1y} \cdot y_{refi})]^2}{\sum_{i=1}^N [y_i - \bar{y}]^2} \quad \text{Eq. 1065.602-12}$$

Example:
 N = 6000
 y_i = 2045.8

a_{0y} = -16.8083
 a_{1y} = 1.0110
 y_{refi} = 2045.0
 ȳ = 1480.5

$$r_y^2 = 1 - \frac{[2045.8 - (-16.8083) - (1.0110 \times 2045.0)]^2 + \dots + [y_{6000} - (-16.8083) - (1.0110 \cdot y_{ref6000})]^2}{[2045.8 - 1480.5]^2 + \dots + [y_{6000} - 1480.5]^2}$$

$$r_y^2 = 0.9859$$

(l) *Flow-weighted mean concentration.* In some sections of this part, you may need to calculate a flow-weighted mean concentration to determine the applicability of certain provisions. A flow-weighted mean is the mean of a quantity after it is weighted proportional to a corresponding flow rate. For example, if a gas concentration is measured continuously from the raw exhaust of an engine, its flow-weighted mean concentration is the sum of the products of each recorded concentration times its respective exhaust molar flow rate, divided by the sum of the recorded flow rate values. As another example, the bag concentration from a CVS system is the same as the flow-weighted mean concentration because the CVS system itself flow-weights the bag concentration. You might already expect a certain flow-weighted mean concentration of an emission at its standard based on previous testing with similar engines or testing with similar equipment and instruments. If you need to estimate your expected flow-weighted mean concentration of an emission at its standard, we recommend using the following examples as a guide for how to estimate the flow-weighted mean concentration expected at the standard. Note that these examples are not exact and that they contain assumptions that are not always valid. Use good en-

gineering judgement to determine if you can use similar assumptions.

(1) To estimate the flow-weighted mean raw exhaust NO_x concentration from a turbocharged heavy-duty compression-ignition engine at a NO_x standard of 2.5 g/(kW·hr), you may do the following:

(i) Based on your engine design, approximate a map of maximum torque versus speed and use it with the applicable normalized duty cycle in the standard-setting part to generate a reference duty cycle as described in §1065.610. Calculate the total reference work, W_{ref}, as described in §1065.650. Divide the reference work by the duty cycle's time interval, Δt_{dutycycle}, to determine mean reference power, P̄_{ref}.

(ii) Based on your engine design, estimate maximum power, P_{max}, the design speed at maximum power, f_{max}, the design maximum intake manifold boost pressure, P_{inmax}, and temperature, T_{inmax}. Also, estimate a mean fraction of power that is lost due to friction and pumping, P̄_{frict}. Use this information along with the engine displacement volume, V_{disp}, an approximate volumetric efficiency, η_v, and the number of engine strokes per power stroke (2-stroke or 4-stroke), N_{stroke} to estimate the maximum raw exhaust molar flow rate, n_{exhmax}.

(iii) Use your estimated values as described in the following example calculation:

$$\bar{x}_{\text{exp}} = \frac{e_{\text{std}} \cdot W_{\text{ref}}}{M \cdot \dot{n}_{\text{exhmax}} \cdot \Delta t_{\text{duty cycle}} \cdot \left(\frac{\bar{P}_{\text{ref}} + (\bar{P}_{\text{frict}} \cdot P_{\text{max}})}{P_{\text{max}}} \right)} \quad \text{Eq. 1065.602-13}$$

$$\dot{n}_{\text{exhmax}} = \frac{P_{\text{max}} \cdot V_{\text{disp}} \cdot f_{\text{nmax}} \cdot \frac{2}{N_{\text{stroke}}} \cdot \eta_v}{R \cdot T_{\text{max}}} \quad \text{Eq. 1065.602-14}$$

Example:

$e_{\text{NOx}} = 2.5 \text{ g}/(\text{kW} \cdot \text{hr})$
 $W_{\text{ref}} = 11.883 \text{ kW} \cdot \text{hr}$
 $M_{\text{NOx}} = 46.0055 \text{ g/mol} = 46.0055 \cdot 10^{-6} \text{ g}/\mu\text{mol}$
 $\Delta t_{\text{duty cycle}} = 20 \text{ min} = 1200 \text{ s}$
 $\bar{P}_{\text{ref}} = 35.65 \text{ kW}$
 $\bar{P}_{\text{frict}} = 15\%$
 $P_{\text{max}} = 125 \text{ kW}$
 $P_{\text{max}} = 300 \text{ kPa} = 300000 \text{ Pa}$
 $V_{\text{disp}} = 3.011 = 0.0030 \text{ m}^3$
 $f_{\text{nmax}} = 2800 \text{ rev/min} = 46.67 \text{ rev/s}$

$N_{\text{stroke}} = 4 \text{ l/rev}$
 $\eta_v = 0.9$
 $R = 8.314472 \text{ J}/(\text{mol} \cdot \text{K})$
 $T_{\text{max}} = 348.15 \text{ K}$

$$\dot{n}_{\text{exhmax}} = \frac{300 \cdot 3.0 \cdot 46.67 \cdot \frac{2}{4} \cdot 0.9}{8.314472 \cdot 348.15}$$

$\dot{n}_{\text{exhmax}} = 6.53 \text{ mol/s}$

$$\bar{x}_{\text{exp}} = \frac{2.5 \cdot 11.883}{46.0055 \cdot 10^{-6} \cdot 6.53 \cdot 1200 \cdot \left(\frac{35.65 + (0.15 \cdot 125)}{125} \right)}$$

$\bar{x}_{\text{exp}} = 189.4 \mu\text{mol/mol}$

(2) To estimate the flow-weighted mean NMHC concentration in a CVS from a naturally aspirated nonroad spark-ignition engine at an NMHC standard of 0.5 g/(kW·hr), you may do the following:

(i) Based on your engine design, approximate a map of maximum torque versus speed and use it with the applicable normalized duty cycle in the

standard-setting part to generate a reference duty cycle as described in §1065.610. Calculate the total reference work, W_{ref} , as described in §1065.650.

(ii) Multiply your CVS total molar flow rate by the time interval of the duty cycle, $\Delta t_{\text{duty cycle}}$. The result is the total diluted exhaust flow of the \dot{n}_{dexh} .

(iii) Use your estimated values as described in the following example calculation:

$$\bar{x}_{\text{NMHC}} = \frac{e_{\text{std}} \cdot W_{\text{ref}}}{M \cdot \dot{n}_{\text{dexh}} \cdot \Delta t_{\text{duty cycle}}} \quad \text{Eq. 1065.602-15}$$

Example:

$e_{\text{NMHC}} = 1.5 \text{ g}/(\text{kW} \cdot \text{hr})$
 $W_{\text{ref}} = 5.389 \text{ kW} \cdot \text{hr}$
 $M_{\text{NMHC}} = 13.875389 \text{ g/mol} = 13.875389 \cdot 10^{-6} \text{ g}/\mu\text{mol}$
 $\dot{n}_{\text{dexh}} = 6.021 \text{ mol/s}$
 $\Delta t_{\text{duty cycle}} = 30 \text{ min} = 1800 \text{ s}$

$$\bar{x}_{\text{NMHC}} = \frac{1.5 \cdot 5.389}{13.875389 \cdot 10^{-6} \cdot 6.021 \cdot 1800}$$

$\bar{x}_{\text{NMHC}} = 53.8 \mu\text{mol/mol}$

EFFECTIVE DATE NOTE: At 73 FR 37324, June 30, 2008, §1065.602 was amended by revising

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§ 1065.610

paragraphs (f)(3) before the table, and (l) introductory text, effective July 7, 2008. For the convenience of the user, the revised text is set forth as follows:

§ 1065.602 Statistics.

* * * * *

(f) * * *

(3) Use Table 1 of this section to compare t to the t_{crit} values tabulated versus the number of degrees of freedom. If t is less than t_{crit} , then t passes the t -test. The Microsoft Excel software package contains a TINV function that returns results equivalent to §1065.602 Table 1 and may be used in place of Table 1.

* * * * *

(l) *Flow-weighted mean concentration.* In some sections of this part, you may need to calculate a flow-weighted mean concentration to determine the applicability of certain provisions. A flow-weighted mean is the mean of a quantity after it is weighted proportional to a corresponding flow rate. For example, if a gas concentration is measured continuously from the raw exhaust of an engine, its flow-weighted mean concentration is the sum of the products of each recorded concentration times its respective exhaust molar flow rate, divided by the sum of the recorded flow rate values. As another example, the bag concentration from a CVS system is the same as the flow-weighted mean concentration because the CVS system itself flow-weights the bag concentration. You might already expect a certain flow-weighted mean concentration of an emission at its standard based on previous testing with similar engines or testing with similar equipment and instruments. If you need to estimate your expected flow-weighted mean concentration of an emission at its standard, we recommend using the following examples as a guide for how to estimate the flow-weighted mean concentration expected at the standard. Note that these examples are not exact and that they contain assumptions that are not always valid. Use good engineering judgment to determine if you can use similar assumptions.

* * * * *

$$f_{ntest} = f_{ni} \text{ at the maximum of } (f_{nnormi}^2 + P_{normi}^2) \quad \text{Eq. 1065.610-1}$$

Where:

f_{ntest} = maximum test speed.
 i = an indexing variable that represents one recorded value of an engine map.

§ 1065.610 Duty cycle generation.

This section describes how to generate duty cycles that are specific to your engine, based on the normalized duty cycles in the standard-setting part. During an emission test, use a duty cycle that is specific to your engine to command engine speed, torque, and power, as applicable, using an engine dynamometer and an engine operator demand. Paragraph (a) of this section describes how to “normalize” your engine’s map to determine the maximum test speed and torque for your engine. The rest of this section describes how to use these values to “denormalize” the duty cycles in the standard-setting parts, which are all published on a normalized basis. Thus, the term “normalized” in paragraph (a) of this section refers to different values than it does in the rest of the section.

(a) *Maximum test speed, f_{ntest} .* This section generally applies to duty cycles for variable-speed engines. For constant-speed engines subject to duty cycles that specify normalized speed commands, use the no-load governed speed as the measured f_{ntest} . This is the highest engine speed where an engine outputs zero torque. For variable-speed engines, determine the measured f_{ntest} from the power-versus-speed map, generated according to §1065.510, as follows:

(1) Based on the map, determine maximum power, P_{max} , and the speed at which maximum power occurred, f_{nPmax} . Divide every recorded power by P_{max} and divide every recorded speed by f_{nPmax} . The result is a normalized power-versus-speed map. Your measured f_{ntest} is the speed at which the sum of the squares of normalized speed and power is maximum, as follows:

f_{nnormi} = an engine speed normalized by dividing it by f_{nPmax} .
 P_{normi} = an engine power normalized by dividing it by P_{max} .