



Designation: ~~D8108—20~~ D8108 – 21

## Standard Test Method for Determination of Particulate Matter Mass from Light Duty Mobile Sources (Gravimetric Method)<sup>1</sup>

This standard is issued under the fixed designation D8108; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

### 1. Scope

1.1 This test method covers a procedure for the gravimetric determination of particulate matter (PM) collected from diluted light duty vehicle exhaust. It is applicable to mass rates from 0.32 to 32 mg/km (0.2 to 20 mg/mile).

1.2 Diluted exhaust is passed through pre-weighed filter media which is re-weighed after ~~sampling~~ sampling. ~~The difference in weight is used to determine particulate mass emission rates.~~ mass, which is then used with other data to calculate the distance specific emissions.

1.3 The particulate materials that are measured using this test method are generated by a vehicle following the PM standard applicable portions of the United States Environmental Protection Agency (EPA) and California Air Resources Board (CARB) driving schedules and test procedures for determining the emissions of light duty vehicles. For other jurisdictions, consult regional regulations for applicability of these test procedures. These test procedures are referenced in **Annex A3** of this document.

1.4 The primary intent of this test method is to summarize the PM measurement test procedures as defined by the EPA and CARB (40 CFR Parts §1066, §1065, §86.101, and CARB test procedures for hybrid vehicle testing).

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NOTE 1—Some requirements are generalized from core references for simplicity and to provide guidance for users applying the principals in this standard to regions not governed by EPA and CARB regulation. For specific details, reference the regulated procedures.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee **D22** on Air Quality and is the direct responsibility of Subcommittee **D22.03** on Ambient Atmospheres and Source Emissions.

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## 2. Referenced Documents

### 2.1 *ASTM Standards:*<sup>2</sup>

[D1356 Terminology Relating to Sampling and Analysis of Atmospheres](#)

[E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods](#)

[E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method](#)

### 2.2 *ISO Standards:*<sup>3</sup>

[ISO 14644-1 Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration](#)

### 2.3 *Government Regulations:*

[CARB California Exhaust Emission Standards and Test Procedures for 2018 and Subsequent Model Zero-Emission Vehicles and Hybrid Electric Vehicles, in the Passenger Car, Light-Duty Truck and Medium-Duty Vehicle Classes – Sections F \(HEVs\) and G \(PHEVs\)](#)<sup>4</sup>

[EPA 40 CFR Part 86, Appendix I](#) <sup>5</sup>

[EPA 40 CFR Part 86.101](#) <sup>5</sup>

[EPA 40 CFR Part 1065](#) <sup>5</sup>

[EPA 40 CFR Part 1066](#) <sup>5</sup>

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.

<sup>4</sup> Available from California Air Resources Board (CARB), 1001 I Street, Sacramento, CA 95814, <https://ww2.arb.ca.gov>.

<sup>5</sup> Available from United States Environmental Protection Agency (EPA), William Jefferson Clinton Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, <http://www.epa.gov>.

### 3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology [D1356](#).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *driving schedule, n*—a series of vehicle speeds that a vehicle must follow during a test.

3.2.1.1 *Discussion*—

Driving schedules are specified in 40 CFR Part 86.

3.2.1.2 *Discussion*—

A driving schedule may consist of multiple test intervals or phases. For jurisdictions not governed by the CFR, please refer to local or regional requirements.

3.2.2 *duty cycle, n*—a set of weighting factors and the corresponding test cycles, where the weighting factors are used to combine the results of multiple test intervals into a composite result.

3.2.3 *federal test procedure (FTP), n*—one of the following:

3.2.3.1 The test cycle consisting of one urban dynamometer driving schedule (UDDS) as specified in paragraph (a) of Appendix I of 40 CFR Part 86, followed by a 10-minute soak with the engine off and repeat driving through the first 505 seconds of the UDDS. See 40 CFR 1066.801(c)(1).

3.2.3.2 The entire test procedure for measuring exhaust or evaporative emissions, or both, as described in 40 CFR 1066.801(c).

3.2.4 *light duty vehicles, n*—chassis certified vehicles under 6364 kg (14 000 pounds) gross vehicle weight rating (GVWR) as regulated under CARB LEV 3III and EPA Tier 3 standards.<sup>6</sup>

3.2.5 *particulate matter (PM), n*—material collected on the filter under EPA 40 CFR Parts 1065 and 1066 sampling conditions.

3.2.5.1 *Discussion*—

PM can include solid carbon, ash, semi-volatile organic material, semi-volatile inorganic material, etc.

3.2.6 *Phase 1, n*—relating to the first 505 seconds of the FTP cold-start test interval.

3.2.6.1 *Discussion*—

Note that the term Phase 1 may also apply to measurement of constituents that are not collected in a phase, such as PM and continuously measured total hydrocarbons (THC).

3.2.7 *Phase 2, n*—relating to the last 867 seconds of the FTP cold-start test interval.

3.2.8 *Phase 3, n*—relating to the first 505 seconds of the FTP hot-start test interval.

3.2.9 *Phase 4, n*—relating to the last 867 seconds of the FTP hot-start test interval, if run.

3.2.9.1 *Discussion*—

Note that Phase 2 data is generally used in place of running Phase 4 for a three-phase FTP.

3.2.10 *Reynolds number, n*—an experimental number which is the ratio of inertial forces to viscous forces.

3.2.10.1 *Discussion*—

For flow through a tube it is defined by the relationship:

$$\text{Re number} = 2v\rho r/\mu$$

where the parameters are:

$\mu$  = viscosity,

$\rho$  = density,

$v$  = velocity, and

<sup>6</sup> 40 CFR 1066.1

$r$  = radius.

3.2.10.2 *Discussion*—

Details on applying Reynolds number can be found in 40 CFR Parts 1065 and 1066; reference 40 CFR 1065.640(d) and 40 CFR 1066.110(b)(1)(viii).

3.2.11 *SC03, n*—the test cycle specified in Appendix I, paragraph (h), of 40 CFR Part 86.

3.2.12 *SFTP, n*—the collection of test cycles as given in 40 CFR 1066.801(c)(2).

3.2.13 *standard reference conditions, n*—the following:

3.2.13.1 Standard pressure is 101.325 kPa.

3.2.13.2 Standard temperature is 293.15 K.

3.2.14 *test interval, n*—a period over which a vehicle's emission rates are determined separately.

3.2.14.1 *Discussion*—

For many standards, compliance with the standard is based on a weighted average of the mass emissions from multiple test intervals. For example, 40 CFR Part 86 may specify a complete duty cycle as a cold-start test interval and a hot-start test interval. In cases where multiple test intervals occur over a duty cycle, the standard-setting part may specify additional calculations that weight and combine results to arrive at composite values for comparison against the applicable standards.

3.2.15 *test weight, n*—meaning given in 40 CFR 1066.410(h) or §1066.805.

3.2.16 *urban dynamometer driving schedule (UDDS), n*—the test cycle specified in Appendix I, paragraph (a), of 40 CFR Part 86.

3.2.17 *US06, n*—the test cycle specified in Appendix I, paragraph (g), of 40 CFR Part 86.

3.3 *Acronyms:*

3.3.1 *CFV, n*—critical flow venturi

3.3.2 *CH<sub>4</sub>, n*—methane

3.3.3 *CO, n*—carbon monoxide

3.3.4 *CO<sub>2</sub>, n*—carbon dioxide

3.3.5 *CVS, n*—constant volume sampler

3.3.6 *NMHC, n*—non-methane hydrocarbons

3.3.7 *PDP, n*—positive displacement pump

3.3.8 *PFSS, n*—partial flow sampling system

3.3.9 *SSV, n*—subsonic venturi

3.3.10 *THC, n*—total hydrocarbons

3.3.11  $V_{\text{mix}}$ , *n*—total diluted volume, corrected for any sample removed

#### 4. Summary of Test Method

4.1 To measure particulate matter emissions during exhaust emissions tests, a sample stream of raw or dilute exhaust is extracted for a measured period of time at a controlled flow rate. The volume of exhaust sample is measured and the particulate matter entrained in the exhaust sample is also measured by collection on a pre-weighed filter, which is then PM-stabilized and reweighed. The increase in filter mass is attributed to particulate matter collected from the sampled exhaust. The ratio of the mass of the particulate matter collected to the volume of exhaust sampled allows for the calculation of the exhaust particulate concentration. This concentration is used along with other recorded test signals to calculate the distance-specific emissions of particulate matter.

4.2 Valid measurements can be achieved only when:

4.2.1 Dilution air has been added to the raw exhaust such that the overall dilution factor of the extracted sample is within the range specified in [7.6.2](#).

4.2.2 A sample probe is used with a single opening oriented to face directly upstream.

4.2.3 The PM filter face velocity remains less than 140 cm/s.

4.2.4 The PM filter sample temperature as specified in [7.6.1](#).

4.2.5 The sampling train is designed and operated to avoid condensation and to be leak free;.

4.2.6 Good engineering judgment is used to ensure that selected procedures and equipment do not cause significant loss of PM from the sample.

#### 5. Significance and Use

5.1 This test method is used to demonstrate compliance with state, EPA as well as relevant international regulations for PM emissions from light-duty vehicles.

5.1.1 The EPA Tier 3 and CARB LEV III regulations specify FTP and SFTP PM emission standards for light-duty vehicles.

#### 6. Interferences and PM Background Correction

6.1 Background particulate matter mass in the dilution tunnel *may* result in a positive interference. The background PM mass in the dilution tunnel may be measured, and accounted for in the test results.<sup>7</sup>

6.1.1 PM background is not required to be measured during every test. PM background correction may be applied for a single site or multiple sites using a moving-average background value as long as the background PM sample media (for example, filters) were all made by the same manufacturer from the same material. Use good engineering judgment to determine how many background samples make up the moving average and how frequently to update those values. For example, one background sample per week may be collected and averaged along with previous background values, maintaining five observations for each calculated average value. Background sampling time should be representative of the duration of the test interval to which the background correction is applied.<sup>8</sup>

6.1.2 Background PM may be sampled from the dilution tunnel at any time before or after an emission test using the same sampling system used during the emission test. For this background sampling, the dilution tunnel blower must be turned on, the vehicle must be disconnected from the laboratory exhaust tubing, and the laboratory exhaust tubing must be capped. This PM blank test in combination with the dilute exhaust flow verification (propane check) may be performed as long as the exhaust tubing inlet to the CVS has a HEPA filter.<sup>9</sup>

6.1.3 The duration of the background sample may be different than that of the test cycle to which the background correction is to be applied, consistent with good engineering judgment.<sup>10</sup>

<sup>7</sup> 40 CFR 1066.110 (b)(2)(i) and §1066.605 (f)

<sup>8</sup> 40 CFR 1066.110 (b)(2)(i)(A)

<sup>9</sup> 40 CFR 1066.110 (b)(2)(i)(B)

<sup>10</sup> 40 CFR 1066.110 (b)(2)(i)(C)

6.1.4 PM background correction may not exceed 5 µg or 5 % of the net PM mass expected at the standard, whichever is greater.<sup>11</sup>

## 7. PM Sampling Apparatus

7.1 *Overview*—Vehicle PM mass is gravimetrically determined by operating the vehicle over a prescribed drive cycle inside an environmentally controlled emissions testing laboratory. The PM is collected either with a sample from the raw exhaust pipe (*partial flow* where the extracted sample is diluted) or from a full flow tunnel where the entire vehicle exhaust volume is diluted. A small sample of the vehicle’s diluted exhaust is proportionally extracted then flowed through a high efficiency fine mesh filter. The PM emissions are deposited on this filter. The amount of PM collected on the filter is then gravimetrically determined by subtracting the post-test (loaded) PM filter weight from tared or pre-test (clean) filter weight, both after buoyancy correction. This net mass is then proportionally increased to reflect the total PM mass emitted from the vehicle.

### DILUTED OR RAW EXHAUST PM SAMPLER

7.2 *Wetted Sample Materials*—It is recommend that heated sample transfer lines/enclosures are used to minimize temperature differences between transfer lines and exhaust constituents and prevent condensation or deposition. Use inert materials that are electrically conductive on the inside surfaces to collect PM such as 300 series stainless steel. Small amounts of inert polymers (for example, PTFE—polytetrafluoroethylene (PTFE)) are allowed for gaskets, valve seals, etc.<sup>12</sup> as well as short sections of flexible non-conductive tubing to connect to the vehicle’s tailpipe.<sup>13</sup>

7.3 *Sample Probe*—Extract a representative PM sample either from the CVS full flow “tunnel,” or from the vehicle raw exhaust pipe (partial flow sampling systems – PFSS).

7.3.1 For any pair of flow rates, use recorded sample and total flow rates, where total flow rate means the raw exhaust flow rate for raw exhaust sampling and the dilute exhaust flow rate for CVS sampling, or their 1 Hz means with the statistical calculations as for example described in 40 CFR 1065.602. Determine the standard error of the estimate, SEE, of the sample flow rate versus the total flow rate. For each test interval, demonstrate that SEE was less than or equal to 3.5 % of the mean sample flow rate.<sup>14</sup>

7.3.1.1 Maintain sample proportionality to the total flow of diluted exhaust or raw exhaust. For any pair of flow rates, use recorded sample and total flow rates, where total flow rate means the raw exhaust flow rate for raw exhaust sampling and the dilute exhaust flow rate for CVS sampling, or their 1 Hz means to demonstrate that each flow rate was constant within ±2.5 % of its respective mean or target flow rate.<sup>15</sup>

7.3.1.2 Pressure control, maintain static pressure at the location where raw exhaust is introduced into the tunnel within ±1.2 kPa of atmospheric pressure.<sup>16</sup>

7.3.2 Use PM probes with a single opening at the end.<sup>17</sup>

7.3.3 Orient PM probes to face directly upstream and be radially centered.<sup>18</sup>

7.3.4 Shielding a PM probe’s opening with either a PM pre-classifier such as a hat, or utilizing a pre-classifier further downstream is allowed, but not both.<sup>19</sup>

7.3.5 It is recommend that the inside diameter of PM probes is sized to approximate isokinetic sampling at the expected mean flow rate.<sup>20</sup>

7.4 *Direct Vehicle Exhaust (DVE)*—For PFSS, utilize a direct vehicle exhaust volume measurement to maintain PM sample

<sup>11</sup> 40 CFR 1066.110 (b)(2)(i)(D)

<sup>12</sup> 40 CFR 1065.145(d)(2)

<sup>13</sup> 40 CFR 1066.110(b)(1)(iv)

<sup>14</sup> 40 CFR 1065.545(a) and 1066.425(g)(1)

<sup>15</sup> 40 CFR 1065.545(b) and 1066.425(g)(1)

<sup>16</sup> 40 CFR 1065.140(c)(2)

<sup>17</sup> 40 CFR 1065.145(c)(3)

<sup>18</sup> 40 CFR 1065.145(c)(3)

<sup>19</sup> 40 CFR 1065.145(c)(3)

<sup>20</sup> 40 CFR 1065.145(c)(3)

proportionality and for calculating total exhaust volume to determine vehicle PM emissions. It is recommended that high accuracy ultrasonic technology with a frequency response of at least 5 hertz for this measurement is used to match the PFSS data recording and control minimum frequencies.<sup>21</sup>

#### 7.5 Exhaust Dilution Gas for PM Measurement:

7.5.1 Exhaust gases must be diluted at least once (primary) before sampling onto the PM filter. (See 7.6.2.) For full flow dilution, the sample extracted from the CVS tunnel can be diluted a second time (secondary) as needed.<sup>22</sup>

7.5.2 Dilution gas may be ambient air, purified air, or nitrogen.<sup>23</sup>

7.5.3 It is recommended to filter all dilution gas sources with high-efficiency particulate (HEPA) filters with an initial minimum collection efficiency specification of 99.97 %.<sup>24</sup>

7.5.4 In addition to the allowances in 40 CFR 1065.140(c)(6), heating the dilution air as described in paragraph 40 CFR 1066.110(b)(2)(iii)(A) to prevent or limit aqueous condensation is allowed. Dilution gas may be conditioned (dehumidified or heated) before diluting the PM sample to avoid aqueous condensation.<sup>25</sup>

7.5.5 Control dilution gas temperature to 15 – 52 °C.<sup>26</sup>

#### 7.6 Operational Parameters:

7.6.1 Control sample temperature to  $47 \pm 5$  °C tolerance, as measured anywhere within 20 cm upstream or downstream of the PM filter.<sup>27</sup>

7.6.2 The total time weighted dilution factor is required to be 7:1 – 20:1. The maximum DF of 20:1 is generally not applicable to hybrid electric vehicle or plug-in hybrid electric vehicles (HEV/PHEVs) emissions since the dilution factor is infinite when the engine is off; however it is strongly recommend to stay under the specified maximum dilution factor limit when the engine is running. To determine the overall dilution factor for PM samples utilizing secondary dilution gas, multiply the dilution factor from the CVS by the dilution ratio of secondary dilution gas to primary diluted exhaust.<sup>28</sup>

7.6.3 Secondary dilution may be used as needed to meet total dilution factor. It may also be used to control the sample temperature prior to the filter media.

7.6.4 Filter face flow velocity shall be no more than 140 cm/second.<sup>29</sup>

7.6.5 Net filter PM mass gain shall be no more than 400 µg.<sup>30</sup>

7.6.6 PM sample residence time from 1st dilution point up to the filter is 1.0 – 5.5 seconds, with a residence time of at least 0.50 s from the final dilution point to the filter.<sup>31</sup> If PM is collected on a single filter for either a 3 phase or 4 phase FTP, the overall residence time of 5.5 s may be exceeded for sample flow rates below the highest expected flow rate.<sup>32</sup>

7.6.7 All PM sampler flowrates, sample flowrate, dilution air flowrate, and filter flow rate must be set to meet all the requirements of the EPA test method.

<sup>21</sup> 40 CFR 1066.125 Table 1

<sup>22</sup> 40 CFR 1065.140(a)

<sup>23</sup> 40 CFR 1065.140(a)

<sup>24</sup> 40 CFR 1065.140(b)(3)

<sup>25</sup> 40 CFR 1065.140(b)

<sup>26</sup> 40 CFR 1066.110(b)(2)(iii)(A)

<sup>27</sup> 40 CFR 1065.140(e)(4)

<sup>28</sup> 40 CFR 1066.110(b)(2)(iii)(B)

<sup>29</sup> 40 CFR 1066.110(b)(2)(iii)(C)

<sup>30</sup> 40 CFR 1065.170(a)(2)

<sup>31</sup> 40 CFR 1065.140(e)(3)

<sup>32</sup> 40 CFR 1066.815(b)

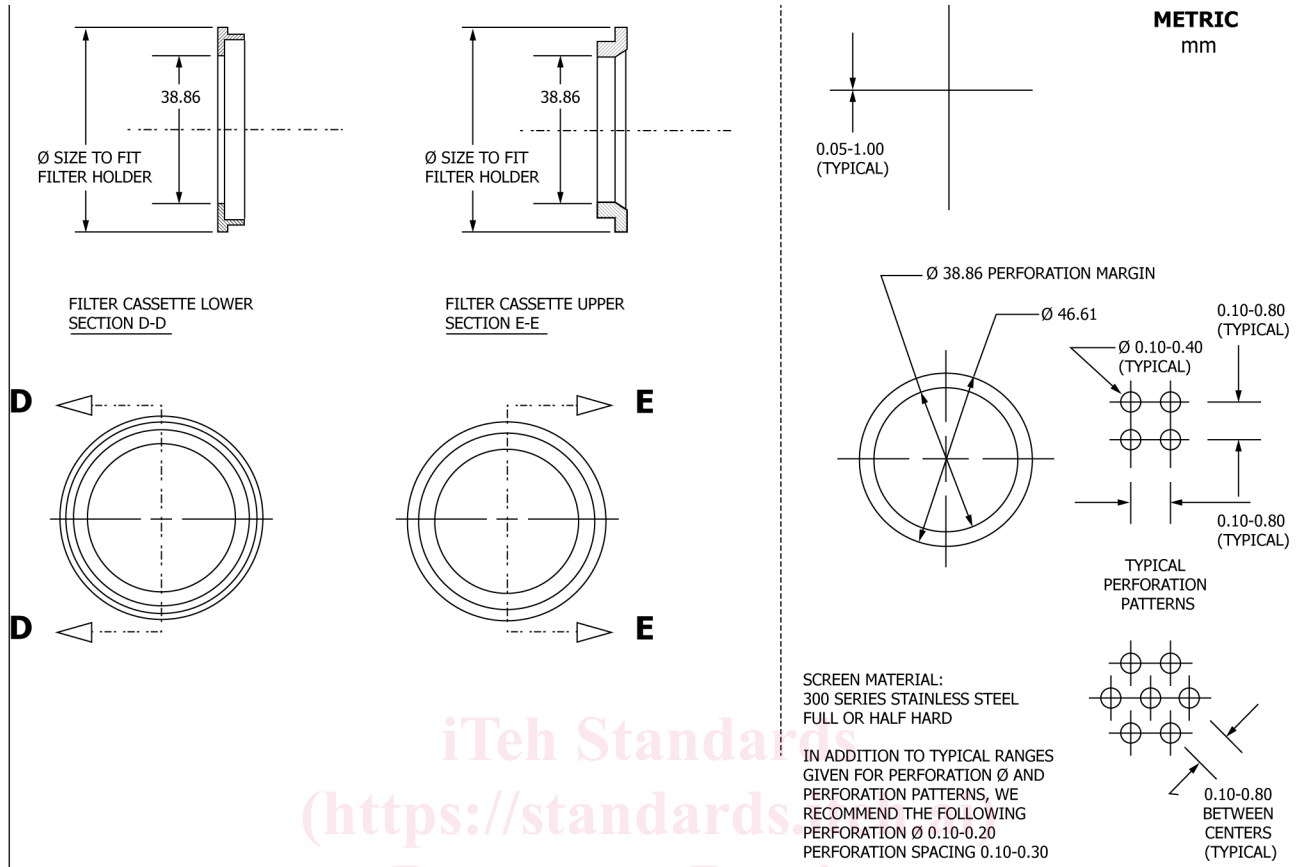


FIG. 1 PM Filter Cassette Specifications

7.7 *Filter Holder*—Use a filter holder with a 12.5° (from center) divergent cone angle to transition from the transfer-line inside diameter to the exposed diameter of the filter face.<sup>33</sup>

7.8 *Pre-Classifier:*

7.8.1 An inertial impactor or a cyclonic separator is used to remove at least 50 % of PM at an aerodynamic diameter of 10 µm and no more than 1 % of PM at an aerodynamic diameter of 1 µm over the range of flow rates used. Install the pre-classifier in the dilution system downstream of the last dilution stage. Locate PM sample media within 75 cm downstream of the pre-classifier's exit.<sup>34</sup>

7.9 *Transporting PM Filters*—Transfer the PM filters/cassette from the test site to a weigh room in an individual container that is covered or sealed to prevent communication of semi-volatile matter from one filter to another.<sup>35</sup>

7.10 *Filter Cassette and Backing Screen*—Use a clean cassette and a fine mesh supporting screen designed to the specifications of Figure 1 of 40 CFR 1065.170. The cassette must be made of one of the following materials: acetal, 300 series stainless steel, polycarbonate, acrylonitrile-butadiene-styrene (ABS) resin, or conductive polypropylene.<sup>36</sup>

7.11 See Fig. 1.<sup>37</sup>

<sup>33</sup> 40 CFR 1065.170(c)(1)(v)

<sup>34</sup> 40 CFR 1065.145(f)(1)

<sup>35</sup> 40 CFR 1065.170(c)(1)(viii)

<sup>36</sup> 40 CFR 1065.170(c)(1)(vii)

<sup>37</sup> 40 CFR 1065.170 Figure 1



7.12 *Background PM Sampler:*

7.12.1 Collecting and measuring background (tunnel) PM concentrations under the same conditions diluted exhaust PM is collected and measured is recommended or measure them in a way that does not affect compliance with applicable standards. For example, the following simplifications for background sampling may be used.<sup>38</sup>

7.12.1.1 Proportional sampling requirements may be disregarded.

7.12.1.2 Unheated PM sampling systems may be used.

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<sup>38</sup> 40 CFR 1065.140(b)(2)

### 7.13 *PM Filters:*

7.13.1 The filter must be circular, with an overall diameter of  $46.50 \pm 0.6$  mm and an exposed surface diameter of at least 38 mm.<sup>39</sup>

7.13.2 The filter must have a minimum initial collection efficiency of 99.7 %.<sup>40</sup>

7.13.3 It is highly recommended that a pure PTFE filter material that does not have any flow-through support bonded to the back and has an overall thickness of  $40 \pm 20$   $\mu\text{m}$  be used. An inert polymer ring may be bonded to the periphery of the filter material for support and for sealing between the filter cassette parts. Polymethylpentene (PMP) and PTFE are inert materials commonly used as a support ring, but other inert materials may be used. The use of PTFE-coated glass fiber filter material is permitted, as long as this filter media selection does not affect the ability to demonstrate compliance with the applicable standards.<sup>41</sup>

### 7.14 *Exhaust Collection System:*

7.14.1 It is important to minimize the lengths of exhaust tubing used in this test method. No more than 4 m total length of exhaust tubing without heat or insulation may be used. A total length of laboratory exhaust tubing up to 10 m may be used provided that insulation or heating, or both, of the tubing is performed to minimize the temperature difference between the exhaust gas and the tubing wall over the course of the emission test. The laboratory exhaust tubing length is defined as starting at the end of the vehicle's tailpipe and ends at the first sample point or the first dilution point. The laboratory exhaust tubing may include flexible sections, but it is recommended that it be limited to the shortest length of flexible tubing practicable. For multiple-tailpipe configurations where the tailpipes combine into a single flow path for emission sampling, the start of the laboratory exhaust tubing may be taken at the last joint where the exhaust flow first becomes a single, combined flow.<sup>42</sup>

7.14.2 Insulation or heating any laboratory exhaust tubing is permitted.<sup>43</sup>

7.14.3 Use laboratory exhaust tubing materials that are smooth-walled and not chemically reactive with exhaust gases and particles. Nominally smooth spiral-style and accordion-style flexible tubing are considered to be smooth-walled. Materials must also be electrically conductive. Series 300 stainless steel is an acceptable material for testing. Short sections of nonconductive flexible tubing may be used to connect a PM sampling system to the vehicle's tailpipe; use good engineering judgment to limit the amount of nonconductive surface area exposed to the vehicle's exhaust.<sup>44</sup>

7.14.4 It is recommend that laboratory exhaust tubing that has either a wall thickness of less than 2 mm or is air gap-insulated to minimize temperature differences between the wall and the exhaust is used.<sup>45</sup>

7.14.5 Electrically ground the entire exhaust system, with the exception of nonconductive flexible tubing.<sup>46</sup>

7.14.6 For vehicles with multiple tailpipes, route the exhaust into a single flow and ensure proper mixing.<sup>47</sup>

7.14.7 A remote mix tee, which dilutes the exhaust closer to the tailpipe may be used.<sup>48</sup>

7.14.8 Route the exhaust gases to a dilution tunnel.<sup>49</sup>

7.14.9 Whether sampling PM emissions from the raw exhaust pipe (PFSS) or from the tunnel, ensure mixing of raw exhaust gases in the transfer tube before sampling (PFSS), and likewise in the tunnel and with dilution gas.<sup>50</sup>

<sup>39</sup> 40 CFR 1065.170(c)(1)(ii)

<sup>40</sup> 40 CFR 1065.170(c)(1)(i)

<sup>41</sup> 40 CFR 1065.170(c)(1)(iii)

<sup>42</sup> 40 CFR 1066.110(b)(1)(i)

<sup>43</sup> 40 CFR 1066.110(b)(1)(iii)

<sup>44</sup> 40 CFR 1066.110(b)(1)(iv)

<sup>45</sup> 40 CFR 1066.110(b)(1)(v)

<sup>46</sup> 40 CFR 1066.110(b)(1)(vii)

<sup>47</sup> 40 CFR 1066.110(b)(1)(viii)

<sup>48</sup> 40 CFR 1066.110(b)(2)(v)

<sup>49</sup> 40 CFR 1065.140(c)

<sup>50</sup> 40 CFR 1066.110(b)(1)(viii)

**TABLE 1 Summary of Equipment Specifications That Apply for Chassis Testing<sup>A</sup>**

40 CFR Part 1065 References	Applicability for Chassis Testing Under This Part
40 CFR 1065.140	Use all except as noted: <ul style="list-style-type: none"> <li>• 40 CFR 1065.140(b) applies as described in Section 7.</li> <li>• Use 40 CFR 1065.140(c)(6), with the additional allowance described in Section 7.</li> <li>• Do not use 40 CFR 1065.140(d)(2)(iv).</li> <li>• Use 40 CFR 1065.140(e)(1) as described in this section.</li> <li>• Do not use 40 CFR 1065.140(e)(2).</li> </ul>
40 CFR 1065.145	Use all except 40 CFR 1065.145(b).
40 CFR 1065.150	Use all.
40 CFR 1065.170	Use all except as noted: <ul style="list-style-type: none"> <li>• Use 40 CFR 1065.170(c)(1)(vi) as described in Section 7.</li> </ul>
40 CFR 1065.190	Use all.

<sup>A</sup> 40 CFR 1066.110 Table 1

7.14.10 It is recommended that the diluted or raw exhaust stream *at the first sampling point* has a Reynolds number,  $Re\#$ , > 4000, where  $Re\#$  is based on the inside diameter of the tunnel or the raw exhaust transfer tube, as appropriate.<sup>51</sup>

7.14.11 Summary of applicable 40 CFR Part 1065 equipment specifications.<sup>52</sup> (See Table 1.)

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<sup>51</sup> 40 CFR 1065.140(c)(3)

<sup>52</sup> 40 CFR 1066.110(e)