1.0   PURPOSE

This Standard Test Procedure (STP) is to be used by investigators to determine the particulate index of a diesel engine.

2.0   SCOPE

This procedure applies to particulate index tests conducted on diesel engines to determine compliance with the requirements of 30 CFR 7.89: "Test to Determine the Particulate Index".

3.0   REFERENCES

3.1.   30 CFR Part 7, Subpart E, "Diesel Engines Intended for Use in Underground Coal Mines"

4.0   DEFINITIONS

4.1.   Brake Power – The observed power measured at the crankshaft or its equivalent when the engine is equipped only with standard auxiliaries necessary for its operation on the test bed.

4.2.   Category A Engines – Diesel engines intended for use in areas of underground coal mines where permissible electric equipment is required.

4.3.   Category B Engines – Diesel engines intended for use in areas of underground coal mines where nonpermissible electric equipment is allowed.

4.4.   Diesel Engine – Any compression ignition internal combustion engine using the basic diesel cycle where combustion results from the spraying of fuel into air heated by compression.

4.5.   Exhaust Emission – Any substance emitted to the atmosphere from the exhaust port of the combustion chamber of a diesel engine.

4.6.   Intermediate Speed – Maximum torque speed if it occurs between 60 percent and 75 percent of rated speed. If the maximum torque speed is less than 60 percent of rated speed, then the intermediate speed shall be 60 percent of the rated speed. If the maximum torque speed is greater than 75 percent of the rated speed, then the intermediate speed shall be 75 percent of rated speed.

4.7. Low Idle Speed – The minimum no load speed as specified by the engine manufacturer.

4.8. Maximum Torque Speed – The speed at which an engine develops maximum torque.

4.9. Operational Range – All speed and load (including percent loads) combinations from the rated speed to the minimum permitted engine speed at full load as specified by the engine manufacturer.

4.10. Particulates – Any material collected on a specified filter medium after diluting exhaust gases with clean, filtered air at a temperature of less than or equal to 125 °F (52 °C), as measured at a point immediately upstream of the primary filter. This is primarily carbon, condensed hydrocarbons, sulfates, and associated water.

4.11. Percent Load – The fraction of the maximum available torque at an engine speed.

4.12. Rated Horsepower – The nominal brake power output of a diesel engine as specified by the engine manufacturer with a specified production tolerance. For laboratory test purposes, the fuel pump calibration for the rated horsepower must be set between the nominal and the maximum fuel tolerance specification.

4.13. Rated Speed – Speed at which the rated power is delivered, as specified by the engine manufacturer.

4.14. Steady-State Condition – Diesel engine operating condition which is at a constant speed and load and at stabilized temperatures and pressures.

4.15. Total Oxides of Nitrogen – The sum total of the measured parts per millions (ppm) of nitric oxide (NO) plus the measured ppm of nitrogen dioxide (NO2).

5.0   TEST EQUIPMENT

5.1.1. Dynamometer stand/test cell to provide loading on the engine.

5.1.2. An apparatus for measuring torque that provides an accuracy of +/-2.0 percent based on the engine's maximum value.

5.1.3. An apparatus for measuring revolutions per minute (rpm) that provides an accuracy of +/-2.0 percent based on the engine's maximum value.

5.1.4. An apparatus for measuring temperature that provides an accuracy of +/-4 °F (2 °C) of the absolute value except for the exhaust gas temperature device that provides an accuracy of +/-27 °F (15 °C).

5.1.5. An apparatus for measuring intake and exhaust restriction pressures that provides an accuracy of +/-5 percent of maximum.

5.1.6. An apparatus for measuring atmospheric pressure that provides an accuracy of +/-0.5 percent of reading.

5.1.7. An apparatus for measuring fuel flow that provides an accuracy of +/-2 percent based on the engine's maximum value.

5.1.8. An apparatus for measuring the inlet air flow rate of the diesel engine that provides an accuracy of +/-2 percent based on the engine's maximum value.

5.1.9. For testing category A engines, an apparatus for metering in 1.0 +/-0.1 percent, by volume, of methane (CH_4) into the intake air system shall be provided.

5.1.10. Particulate sampling system.

5.1.11. Diesel fuel meeting the specifications in 30 CFR Part 7.86(a)(2) Table E-1.

6.0   TEST SAMPLES

N/A

7.0   PROCEDURES

7.1. The test shall be performed in the order listed in Table E-3.

7.2. Couple the diesel engine to the dynamometer and attach the sampling and measurement devices as specified in section 5.0 above.

7.3. A minimum time of 10 minutes is required for each measuring point.

7.4. Prior to testing, condition and weigh the particulate filters as follows:

7.4.1. At least 1 hour before the test, each filter (pair) shall be placed in a closed, but unsealed, petri dish and placed in a weighing chamber (room) for stabilization.

7.4.2. At the end of the stabilization period, each filter (pair) shall be weighed. The reading is the tare weight.

7.4.3. The filter (pair) shall then be stored in a closed petri dish or a filter holder, both of which shall remain in the weighing chamber (room) until needed for testing.

7.4.4. The filter (pair) must be re-weighed if not used within 8 hours of its removal from the weighing chamber (room).

7.5. Run the engine.

7.5.1. The parameter for fa shall be calculated in accordance with Sec.7.87(a)(3).

7.5.2. The air inlet and exhaust backpressure restrictions on the engine shall be set as specified in Sec. 7.87(a)(3) (iii) and (iv).

7.5.3. The dilution air shall be set to obtain a maximum filter face temperature of 125 deg. F (52 deg. C) or less at each test mode.

7.5.4. The total dilution ratio shall not be less than 4.

7.6. The engine shall be at a steady state condition before starting the test modes.

7.6.1. The engine speed and torque shall be measured and recorded at   each test mode.

7.6.2. The data required for use in the particulate index calculation specified in paragraph (a)(9) of this section shall be measured and recorded at each test mode.

7.7. A 1.0 ± 0.1 percent CH_4, by volume shall be injected into the engine's intake air for category A engines.

7.8. Operate the engine at each rated speed and horsepower rating requested by the applicant according to Table E-3 to collect particulate on the primary filter.

7.8.1.   One pair of single filters shall be collected or eight multiple filter pairs shall be collected.

7.8.2.   Particulate sampling shall be started after the engine has reached a steady-state condition.

7.8.3.   The sampling time required per mode shall be either a minimum of 20 seconds for the single filter method or a minimum of 60 seconds for the multiple filter method.

7.8.4.   The minimum particulate loading specified in Sec. 7.86 (c)(18) (iii) or (iv) shall be done.

Table E-3.--Particulate Test Modes

Speed	Rated Speed				Intermediate Speed			Low-idle Speed
% Torque	100	75	50	10	100	75	50	0
Weighting Factor	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15

7.8.5.   Test speeds shall be maintained within ± percent of rated speed or ± 3 RPM, which ever is greater, except for low idle which shall be within the tolerances set by the manufacturer.

7.8.6.   The specified torque shall be held so that the average over the period during which the measurements are being taken is within ± 2 percent of the maximum torque at the test speed.

7.8.7.   The modal weighting factors (WF) given in Table E-3 shall be applied to the multiple filter method during the calculations as shown in paragraph 7.9.3.2. of this section.

7.8.8.   For the single filter method, the modal WF shall be taken into account during sampling by taking a sample proportional to the exhaust mass flow for each mode of the cycle.

7.9.   After completion of the test, condition and weigh the particulate filters in the weighing chamber (room) as follows:

7.9.1.   Condition the filters for at least 1 hour, but not more than 80 hours.

7.9.2. At the end of the stabilization period, weigh each filter. The reading is the gross weight.

7.9.3. The particulate mass of each filter is its gross weight minus its tare weight.

7.9.4. The particulate mass (Pf for the single filter method; Pf, i for the multiple filter method) is the sum of the particulate masses collected on the primary and back-up filters.

7.9.5. The test is void and must be rerun if the sample on the filter contacts the petri dish or any other surface.

7.10. The particulate index for the mass particulate shall be calculated from the equations listed below—

7.10.1. The following abbreviations shall be:

cfm--Cubic feet per min (ft\3\ min)
PT--Particulate (gr/hr)
m mix--Diluted exhaust gas mass flow rate on wet basis (kg/hr)
m sample--Mass of the diluted exhaust sample passed through the particulate sampling filters (kg)
P_f--Particulate sample mass collected on a filter (mg) at each test mode as determined in Table E-3.
K_p--Humidity correction factor for particulate
WF--Weighting factor
i-Subscript denoting an individual mode, i=1, . . . n
PI--Particulate Index (cfm)

7.10.2. When calculating ambient humidity correction for the particulate concentration (Pf part), the equation shall be:

$P_f$corr=$(P_f)(K_p)$
K_p=1/(1+0.0133 * (H-10.71))

Where:

H_a=humidity of the intake air, g water per kg dry air

$H_a = (6.220 * R_a * p_a)/(p_B - p_a - R_a * 10_{-2})$
R_a = relative humidity of the intake air, %
p_a = saturation vapor pressure of the intake air, kPa
p_B = total barometric pressure, kPa

7.10.3.　When the multiple filter method is used, the following equations shall be used.

7.10.3.1.　Mass of particulate emitted is calculated as follows:

$$\text{PT gr / hr}_i = \frac{(\mathbf{P_{fcorr}mg_i})(\mathbf{m\ mix\ kg/hr_i})}{(\mathbf{m\ sample\ kg_i})(\mathbf{1000\ mg / gr})}$$

7.10.3.2.　Determination of weighted particulate average is calculated as follows:

$$\text{PT gr/hr}_i = \sum_{i=1}^{i=n} (\text{PT gr/ hr}_i)(\text{WF}_i)$$

7.10.3.3.　Determination of particulate index for the mass particulate from the average of the test modes shall be calculated as follows:

$$\text{PI} = \frac{(\mathbf{PT\ gr / hr})(\mathbf{1000\ mg / gr})(\mathbf{1\ hr / 60min})(\mathbf{35.31\ ft^3 /m^3})}{(\mathbf{1 / 1\ mg /m^3})}$$

7.10.4.　When the single filter method is used, the following equations shall be used.

7.10.4.1.　Mass of particulate emitted:

$$PT \text{ gr / hr} = \frac{(P_{fcorr}\text{mg})(\text{m mix kg/hr})\text{avg.}}{(\text{m sample kg})(1000 \text{ mg / gr})}$$

$$(\text{m sample kg}) = \sum_{i=1}^{i=n} (\text{m sample kg}_i)$$

Where:

7.10.4.2. Determination of particulate index for the mass particulate from the average of the test modes shall be as follows:

$$PI = \frac{(PT \text{ gr / hr})(1000 \text{ mg / gr})(1 \text{ hr / 60min})(35.31 \text{ ft}^3 / \text{m}^3)}{(1 / 1 \text{ mg} / \text{m}^3)}$$

7.10.5. When the effective weighting factor, WFE , i, for each mode is calculated for the single filter method, the following shall apply.

$$WF_{E,i} \quad \frac{(\text{m sample kg}_i)(\text{m mix kg /hr avg.})}{(\text{m sample kg}_i)(\text{m mix kg /hr}_i)}$$

7.10.5.1. The value of the effective weighting factors shall be within ± 0.005 (absolute value) of the weighting factors listed in Table E-3.

7.11. A particulate index for each requested rated speed and horsepower shall be the value determined in paragraph 7.9.3.3. of this section for the multiple filter method or paragraph 7.9.4.2. of this section for the single filter method.

7.11.1. Particulate indices less than 20,000 cfm shall be rounded up to the next 500 cfm. Example: 10,432 cfm shall be listed 10,500 cfm.

7.11.2. Particulate indices greater than 20,000 cfm shall be rounded up to the nearest thousand 1,000 cfm. Example: 26,382 cfm shall be listed 27,000 cfm.

8.0   TEST DATA

8.1. Refer to Sec. 7.4 (a).

9.0   PASS/FAIL CRITERIA

N/A