SAE International®

SURFACE VEHICLE STANDARD

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Engine Power Test Code - Spark Ignition and Compression Ignition - As Installed Net Power Rating

RATIONALE

This standard is intended to provide the industry with a repeatable means of determining the as installed net power and torque of an engine. The current revision has been made to reflect the changing specifications of fuels available in the market place and to clarify issues that experience has shown were unclear in the previous version of the standard.

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1. SCOPE

This standard is intended to provide a method to obtain repeatable measurements that accurately reflect true engine performance in customer service. Whenever there is an opportunity for interpretation of the standard, a good faith effort shall be made to obtain the engine's typical in-service performance and avoid finding the best possible performance under the best possible conditions. Intentional biasing of engine component or assembly tolerances to optimize performance for this test is prohibited.

1.1 Purpose of Standard

This SAE Standard has been adopted by SAE to specify:

a. A basis for net engine power and torque rating as installed in the final application

b. Reference inlet air and fuel supply test conditions

c. A method for correcting observed power and torque to reference conditions

d. A method for determining net full load engine power and torque with a dynamometer

e. A procedure to ensure that engine controls are operating in a manner consistent with customer operation.

1.2 Field of Application

This test code document is applicable to both spark ignition (SI) and compression ignition (CI) engines, naturally aspirated and pressure-charged, with and without charge air cooling. This document does not apply to aircraft or marine engines. The standard is applicable to the internal combustion engine used in a hybrid powertrain, but it does not comprehend the combined output of the hybrid powertrain.

1.2.1 This test code supersedes those portions of SAE J1349 JUN1995 dealing with net power rating. It can be used immediately, and it shall be used for testing after January 1, 2005.

1.2.2 Standard CI diesel fuel specifications are range mean values for Type 2-D EPA test fuel per Title 40, Code of Federal Regulations, Part 86.1313-2004 or most recent.

1.2.3 The corresponding test code for gross power and torque rating is SAE J1995.

1.2.4 The document for mapping engine performance is SAE J1312.

1.3 Relationship to ISO 1585

ISO 1585-1992 differs from SAE J1349 in several areas, among which the most important are:

a. This document is not limited to road vehicles.

b. This document requires inlet fuel temperature be controlled to 40 °C on CI engines.

c. This document includes a reference fuel specification and requires that engine power be corrected to that specification on all CI engines.

d. This document includes a different procedure for testing engines with a laboratory charge air cooler.

e. This document stipulates a 20% duty cycle limit on variable speed cooling fans in order to qualify for testing at the minimum power loss settings.

f. This document provides procedures for transient testing of light duty vehicles with the associated changes in control parameters and exhaust back pressure.

g. This document includes accessory losses if the accessories are standard on the vehicle application.

h. ISO 1585-1992 allows ±7% correction on SI and ±10% correction on CI engines.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1312 Procedure for Mapping Performance—Spark Ignition and Compression Ignition Engines

SAE J1995 Engine Power Test Code—Spark Ignition and Compression Ignition—Gross Power Rating

2.1.2 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 1585 Road vehicles—Engine test code—Net power

ISO 2288 Agricultural tractors and machines—Engine test code (bench test)—Net power

ISO 3046 Reciprocating internal combustion engines—Performance

ISO 4106 Motorcycles—Engine test code—Net power

ISO 9249 Earth-moving machinery—Engine test code—Net power

2.1.3 Federal Regulation

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-0000, www.gpoaccess.gov.

CFR 40 Part 86.1313-2004 or most recent

3. TERMS AND DEFINITIONS

This section contains the definitions of key terms used to describe the net power and torque test.

3.1 NET BRAKE POWER AND TORQUE

The power and torque produced by an engine at any speed when configured as a “fully equipped” engine (per 3.5), corrected to the reference atmospheric conditions and/or reference diesel fuel specifications per Section 5, and tested in accordance to the applicable procedures contained in this standard.

3.2 RATED NET POWER AND TORQUE

The net brake power and torque produced by the engine at the rated power speed and rated torque speed, respectively.

3.3 RATED POWER SPEED

The engine speed at which the Rated Brake Power is achieved. The rated power speed must be achievable in the application for which the engine is rated.

3.4 RATED TORQUE SPEED

The engine speed at which the Rated Brake Torque is achieved. The rated torque speed must be achievable in the application for which the engine is rated.

3.5 FULLY EQUIPPED ENGINE

A “fully equipped” engine is an engine equipped with only those accessories necessary to perform its intended service. Accessory components that are installed on all engines in the application, e.g., power steering pump, are also included on the engine for test. Table 1 in Section 6 lists the engine equipment and accessories required for the net power test.

3.6 REFERENCE TEST CONDITIONS

The standard (reference) engine inlet air supply and inlet fuel conditions to which all power corrections are made.

3.7 FRICTION POWER

The power required to drive the engine as equipped for the net power test. Friction power may be established by one of the following methods.

a. Preferred Method: Hot Motoring Friction—Record friction torque at wide-open throttle at each test speed run on the power test. All readings are to be taken at the same coolant and oil temperature as observed on the power test points ±3 °C, and variable engine devices should be at the as calibrated settings.

b. Alternative Method: If measured friction data are not available, it is permissible to assume 85% mechanical efficiency. When measured friction data are available, they must be used in computing mechanical efficiency. When this alternative method is used, it should be noted in the reported data that the results were corrected using an assumed mechanical efficiency of 85%.

3.8 INDICATED POWER

Indicated power is defined as the sum of the brake power and friction power for the purpose of this document.

4. SYMBOLS, UNITS, AND SUBSCRIPTS

4.1 Symbols and Units

SI units shall be used for all measurements unless otherwise specified.

TABLE 1 - SYMBOLS AND UNITS

Symbol	Term	Unit(s)
CA	Air correction factor	
CF	Fuel correction factor	
Fa	Atmospheric factor	
Fm	Engine factor	
Fd	Fuel density factor	
Fv	Fuel viscosity factor	
α	Pressure sensitivity exponent	
β	Temperature sensitivity exponent	
S	Viscosity sensitivity coefficient	
D	Engine displacement	L
Pa	Inlet air supply total pressure	kPa
t	Inlet air supply temperature	°C
T	Brake Torque*	N-m, lb-ft
Pm	Inlet manifold total pressure	kPa
R	Pressure ratio	
Q	Fuel delivery	mg/L cycle
Bp	Brake power*	kW, hp
Fp	Friction power*	kW, hp
Ip	Indicated power*	kW, hp
N	Engine speed	min^{-1}
F	Fuel flow	g/s
SG	Fuel density at 15 °C	kg/L
V	Fuel viscosity at 40 °C	mm^2/s

* Power and torque may be expressed as HP (0.746 kW) and lb-ft (1.356 N-m). This departure from metric standards is allowed due to the common use of English units in the advertising of power and torque to consumers.

4.2 Subscripts

c = Refers to data corrected to reference inlet air and fuel supply conditions
o = Refers to data observed at the actual test conditions
d = Refers to the dry air portion of the total inlet air supply pressure
r = Refers to the reference test conditions per Section 5

5. REFERENCE TEST CONDITIONS AND CORRECTIONS

This section contains reference air and fuel supply test conditions and specifications, recommended test ranges, and applicability of the correction procedures.

5.1 Reference Atmospheric Conditions

Table 2 defines reference atmospheric conditions and test ranges for which correction factors are valid.

TABLE 2 - REFERENCE ATMOSPHERIC CONDITIONS

	Standard Condition	Test Range Limits
Inlet Air Supply Pressure (absolute)	100 kPa	—
Dry Air Pressure (absolute)	99 kPa	90 – 105 kPa
Inlet Air Supply Temperature	25 °C	15 – 35 °C

With the exception of humidity, no modification to the composition of intake air is permitted. Available laboratory equipment shall be set to minimize correction factors by controlling inlet air as close as possible to “reference atmospheric conditions”.

5.2 SI Gasoline Specifications

The ratings of SI engines tested under this standard must reflect the performance that a customer can obtain operating the engine on the manufacturer's recommended fuel. To achieve that, fuels used in testing must have energy content (defined as lower heating value) typical of that found in commercially available gasoline. The engine rating shall be for fuel octane values typical of commercially available fuels of the grade recommended by the manufacturer. No correction for power output is made due to fuel energy content.

Maximum allowable gasoline octane numbers for engine power rating have been determined corresponding to "regular", "mid-grade", and "premium" fuels from surveys of pump gasoline available throughout the United States in 2009. These values are listed in Table 3. . Nominal ethanol content of up to 10% is allowed in the test fuel to match the United States Environmental Protection Agency EPA) limit on ethanol content of pump gasoline. If the EPA limit for ethanol content in conventional gasoline (Except E85) is increased, the nominal ethanol content allowed under this standard shall be increased to match that limit provided that the ethanol content is within the manufacturer's recommended limit for the engine .

Many SI engines have electronic knock control systems that retard spark when knock is detected. If such a system is active when the engine is rated on the dynamometer, then the fuel used must be within the specified octane limits for the recommended fuel grade. An engine with a knock control system may be tested with higher octane fuel if the knock control system is disabled and the control settings are those that would be achieved when operating on customer-recommended fuel with active knock control. Vehicle test procedures for determining those control settings are specified in Section 9. Engines without knock control settings may be rated on any octane level fuel provided that the control settings are those used with customer-recommended fuel.

TABLE 3 - SI GASOLINE SPECIFICATIONS

Fuel Grade	Regular	Mid-Grade	Premium
Max. Research Octane No.:	94	96	99
Max. Motor Octane No.:	85	88	89
Max. Lower Heating Value:	43.5 MJ/kg	43.5MJ/kg	43.5 MJ/kg

The following table shall be used in determining the fuel to be used in testing SI engines:

TABLE 4 - FUEL TYPE SELECTION FOR SI ENGINE RATING

Manufacturer's Specification	Fuel to Use (per Table 3)	Comments
Absence of Declaration	Regular Fuel	
Minimum of 87 Octane	Regular Fuel	Assumed to be (R+M)/2 method.
Regular Fuel	Regular Fuel	
Premium Fuel Recommended	Premium Fuel	
Premium Fuel Required	Premium Fuel	
91+ Octane	Premium Fuel	Assumed to be (R+M)/2 method.
Premium Recommended When Towing	Regular Fuel	Towing is a small subset of customer usage. It is acceptable to have dual ratings.
Flex Fuel with Gasoline or E85	Recommended Gasoline E85 (conditional)	Always report the gasoline rating. If the E85 rating is more than 2% higher than the rating on gasoline, then a dual rating is permitted.
Mid-Grade Fuel Recommended	Mid-Grade Fuel	Premium not allowed.

5.3 Reference CI Fuel Specifications

Reference fuel specifications are defined by Title 40, Code of Federal Regulations, Part 86..307-82, and represent range mean values for Type 2-D diesel fuel. The reference fuel characteristics in Table 5 have been determined to affect engine test power, and are listed with the applicable test ranges for which correction factors are valid. Note that as indicated in 5.6.2, correction factors are not applied for engines where electronic controls adjust power and torque to compensate for fuel properties. Correction factors for engines using positive displacement injection systems are given in Appendix A.

TABLE 5 - REFERENCE CI FUEL SPECIFICATIONS

	Standard Condition	Test Range Limits
Fuel Density at 15 °C	0.850 kg/L	0.840 – 0.860 kg/L
Fuel Kinematic Viscosity at 40 °C	2.6 mm^2/s	2.0 – 3.2 mm^2/s
Fuel Inlet Temperature	40 °C	39 – 41 °C (pump/line/nozzles/common rail) or 37 – 43 °C (unit injectors)

5.4 Alternative Fuels

Reference values for alternative SI and CI fuels, both liquid and gaseous, are not presented in this document. Therefore, when alternative fuels are used for the net power engine test, no corrections to reference fuel conditions shall be made. Any reference to the rated power and torque for an engine rated on alternative fuel should specify the fuel used in rating the engine.

5.5 Power Correction Factor

The performance of SI and CI engines is affected by the density of the inlet combustion air as well as by the characteristics of the test fuel. Whenever possible, tests should be run at the standard conditions with reference fuels. When this is not possible, in order to provide a common basis of comparison, correction factors should be applied to the observed net power and torque to account for differences between reference air and fuel conditions and those at which the test data were acquired.

5.5.1 All power and torque correction procedures for atmospheric air are based on the conditions of the engine inlet air supply immediately prior to the entrance into the engine air induction system. This may be ambient (atmospheric) air or a laboratory air plenum that maintains air supply conditions within the range limits defined per 5.1. Air supply systems that provide tuning or pressure charging in violation of the intent of this procedure are prohibited.

5.5.2 On any engine (CI or SI) where the power output is automatically controlled to compensate for changes in one or more of the listed inlet air and fuel supply test conditions, no correction for that test parameter shall be made. For example, boosted engines with absolute pressure controls shall not be corrected for ambient barometric pressure.

5.5.3 The magnitude of the power correction for tests run at non-standard conditions should not exceed 3% for inlet air or 3% for inlet fuel corrections. If the correction factor exceeds these values, it shall be noted as a nonstandard test in accordance with 8.1.

5.6 Correction Formulas

The applicable correction formulas for spark ignition and compression ignition engines are listed in this section. These correction formulas are designed for correction of net brake power at full throttle operation; however, for CI engines the formulas may also be used to correct partial load power for the purpose of determining specific fuel consumption. These correction formulas are not intended for altitude de-rating. This section includes all formulas necessary to correct observed engine power performance for deviations in inlet air and fuel supply conditions.

5.6.1 Spark-Ignition Engine Correction Formulas

These spark-ignition engine correction formulas are only applicable at full (WOT) throttle positions.

$$Bp_c = Ip_c - Fp_o \qquad \text{(Eq. 1)}$$

where:

$$Ip_c = CA \times Ip_o = CA \times (Bp_o + Fp_o) \qquad \text{(Eq. 2)}$$

and the atmospheric correction factor, CA, is defined as:

$$CA = \left(\frac{99}{Pa_{do}}\right)\left(\frac{t_o + 273}{298}\right)^{0.5} \qquad \text{(Eq. 3)}$$

If friction is measured then brake power can be calculated by combining Equations 1 and 2:

$$Bp_c = CA \times Bp_o + (CA - 1) \times Fp_o \qquad \text{(Eq. 4)}$$

If friction is **not** measured and 85% mechanical efficiency is assumed per 3.7 then:

$$Fp_o = \frac{(1 - ME) \times Bp_o}{ME} = \frac{(1 - 0.85) \times Bp_o}{0.85} = 0.176 \times Bp_o \qquad \text{(Eq. 5)}$$

Brake power assuming 85% mechanical efficiency can then be calculated by substituting Equation 5 into Equation 4:

$$Bp_c = (1.176 \times CA - 0.176) \times Bp_o \qquad \text{(Eq. 6)}$$

$$Bpc / Bp0 = 1 + 1.176 (CA-1) \qquad \text{(Eq. 7)}$$

From Equation 7, it is possible to derive the ISO correction factors for Bp using the exponential and logarithmic expressions:

Exponential Expansion –

$$a^x = 1 + x \ln(a) + (x \ln (a))^2/2! + (x \ln (a))^3/3! + \dots \quad \text{(Eq. 8)}$$

Logarithmic Expansion –

$$\ln(a) = (a-1) – ½(a-1)^2 + 1/3(a-1)^3 - \dots \quad \text{for } 2 \geq a > 0 \quad \text{(Eq. 9)}$$

Combining the two:

$$a^x = 1 + x(a-1) – ½ [(x^2 (a-1)^2)/2!] + \dots \quad \text{(Eq. 10)}$$

Eliminate for $0.9 \leq a \leq 1.1$

Let x=1.176 and a = CA

Then

$$Bp_c / Bp_0 \sim a^x \sim (CA)^{1.176} \sim (99.0/Pa_{do})^{1.176} * ((t_0+273)/298)^{0.588} \quad \text{(Eq. 11)}$$

$$Bp_c / Bp_0 = (99.0/Pa_{do})^{1.2} * ((t_0+273)/298)^{0.6} \quad \text{(Eq. 12)}$$

Equation 12 is the brake power correction factor used by ISO 1585.

NOTE: If a lab auxiliary charge air cooler is used in conjunction with the standard test method per 6.2.3, no inlet air temperature corrections shall be made. In this case, the temperature correction exponent becomes zero. Otherwise use Equation 3.

5.6.2 Compression Ignition Engine Correction Formulas

For turbocharged diesel engines using electronic injection systems, no correction factors shall be applied to engine output for changes in atmospheric density or fuel temperature when the control system will compensate for changes in fuel temperature and air density. For naturally-aspirated diesel engines or diesel engines with positive displacement injection systems, the correction factors given in Appendix A should be used as appropriate.

6. LABORATORY AND ENGINE EQUIPMENT

This section contains a list of laboratory and engine equipment used in the net power and torque test.

6.1 Engine Equipment

A “fully equipped” engine, as defined in 3.5, is required for the net power and torque test. Table 6 lists the engine accessories and control settings that are required for this test.

TABLE 6- ENGINE EQUIPMENT

System	Required	Comments
1. Air Induction System	Yes	The complete Air Induction System including all active or passive tuning and/or noise attenuation devices is required. The Air Induction System begins at the point where air enters from the atmosphere and ends at the entrance to the throttle body, inlet manifold, or turbocharger inlet, on engines as appropriate
Air Ducting	Yes	
Air Cleaner	Yes	
Air Preheat	No	
Active Tuning Device	Yes	
2. Pressure Charging System	Yes	
Boost Control Settings	Manufacturer's Specification	For all engines equipped with variable boost as a function of other engine parameters (speed/ load/fuel octane, etc.), the boost pressure controls must be set to reflect intended in-service operation.
3. Charge Air Cooling System	Yes	If applicable.
Charge Air Cooler	Yes	See 6.2.3 for laboratory auxiliary cooler provisions.
Cooling Pump or Fan	Conditional	Required if active at rated conditions.
4. Electrical System	Yes	
Ignition System	Yes	Timing set as described in 7.5
Starter	No	
Generator/Alternator	Conditional	Required if standard equipment in the application. A generator/alternator shall operate at a load level sufficient to power only the required components (i.e., fuel injectors, ignition system, electronic controller, electric fuel pump, cooling fans, coolant pumps). If an auxiliary power supply is used, the actual generator/alternator load for the required components must be determined and the generator/alternator input required to produce that power subtracted from the measured torque and power data. See 6.2.4 for laboratory equipment provisions.
Engine Control Unit	Yes	See 7.5.4 Laboratory controller may be used with correct settings.
5. Emissions Control System	Yes	All control settings or adjustments must be set to reflect intended in-service operation.
6. Fuel Supply System	Yes	See 6.2.2 for laboratory fuel supply system provisions.
Fuel Filters/Prefilters	No	
Fuel Supply Pump	Yes	Or equivalent electrical load if applicable.
Injection Pump/ Carburetor or Fuel Metering Control Settings	Manufacturer's Specification	Control settings must reflect intended in-service operation.
7. Engine Cooling System (Liquid)	Yes	
Cooling Pump	Yes	Generator load for electric pump shall be subtracted from engine output
EGR Cooling	Yes	If used on production application, EGR cooler should be used and output set to match in-vehicle performance.
Radiator	No	Functionally equivalent laboratory system recommended.
Thermostat	Yes	Production intent thermostat required. Blocked open thermostat is recommended.

TABLE 6 - ENGINE EQUIPMENT (CONTINUED)

System	Required	Comments
Cooling Fan	Conditional	Cooling fans represent a significant parasitic load on an engine and must be considered in rating power and torque. A fan used in dynamometer testing shall be mounted behind a radiator with the same shrouding as in the application for which it is being rated. For applications in which the cooling fan runs less than 20% of the time during operation at the rated power conditions, the fan may be run in its minimum power setting. For all other applications, at each engine speed, a variable fan should be run at the minimum fan power required to provide steady-state cooling of the engine at maximum brake load when operated at reference atmospheric conditions. NOTE: If the fan is omitted for dynamometer testing, the minimum allowable fan power as described above should be determined and subtracted from the net brake power.
Engine Cooling System (Air)	Yes	
Blower	Yes	See previous comments same as liquid cooling fan.
8. Lubrication System	Yes	The fully equipped engine closed loop lubrication system is used. Oil fill shall be at manufacturer's full level as indicated on the dip stick. . For engines without dipsticks, the engine shall be filled with the maximum amount of oil specified by the manufacturer. Oil temperatures shall reflect in-service levels at reference test conditions. The production oil pan is mandatory.
9. Exhaust System	Yes	See 6.2.1 for exhaust system laboratory equipment provisions.
10. Engine Driven Auxiliary Devices	Conditional	Required if standard equipment**. It is permissible to run without a specific accessory and subtract the parasitic loss of the accessory from the engine brake output.**
Power Steering Pump	Conditional	Plumb fully operational pump for minimum parasitic loss at rated speed.
Air Conditioning Compressor	Conditional	Should be de-clutched
Vacuum Pumps	Conditional	Required only if needed to drive other required systems listed, and it functions in that capacity more than 20% of engine running time during intended in-service operation at rated power condition.
Air Compressors	Conditional	See previous comments - same as vacuum pumps.
Auxiliary Hydraulic Pump	Conditional	If required for engine operation or if standard equipment
11. Transmission	No	The correction of engine power or torque for transmission losses is not permitted.

6.2 Laboratory Equipment

The following provisions are made for use of standard laboratory test equipment for the net power test.

6.2.1 Exhaust System

A complete series production Exhaust System (including mufflers, active catalytic converters, resonators) or any laboratory system that provides equivalent restriction at the peak power engine speed. If a complete vehicle exhaust system is not used, the laboratory system must include the vehicle system at least through the first major restriction or reflection point for tuning (e.g., close-coupled catalytic converter.) It is strongly recommended that a full vehicle exhaust be used with engines having four-cylinders or less that are typically most sensitive to exhaust system tuning. Procedures for determining application-specific exhaust backpressure are given in Section 9. In order to run tests on the dynamometer, a catalytic converter with an inert substrate (lacking active catalyst material) may be used. It is also permissible to replace the converter substrate closest to the engine with a perforated plate serving as the first reflection point. Manufacturers who elect to use a perforated plate in place of an inert substrate must verify that the backpressure during dynamometer testing is equivalent to that observed in the production application.

6.2.2 Fuel Supply System

Any laboratory system that provides a supply of fuel to the fuel inlet of the fully equipped engine is acceptable. Fuel supply pressure should be controlled to application specific values. The fuel supply system must be capable of controlling fuel supply temperature to within the ranges specified in 7.5.13 for CI engines. The fuel supply system shall not exceed the manufacturer's maximum permissible restriction requirements, if applicable.

6.2.3 Charge Air Cooler

A Charge Air Cooler is recognized to have a significant impact on engine performance. For this reason, to obtain an accurate measure of rated engine power for all engines equipped with a Charge Air Cooler, the charge air temperature and pressure at the outlet of the Charge Air Cooler must be set to reflect in-service operation at standard inlet conditions. For charge-cooled engines, use of the production Charge Air Cooler is preferred, however, a laboratory auxiliary cooler may be employed for test purposes. The test methods required to control the auxiliary lab charge air cooler are defined in 7.5.5.

6.2.4 Auxiliary Power Supply

Even when an alternator/generator is installed, electrically driven engine components determined to be part of the basic engine may be operated via an external power supply. In such cases, the alternator/generator input power required to generate the electrical load must be determined and subtracted from the corrected net brake power.

7. LABORATORY TEST PROCEDURES

7.1 Instrumentation Accuracy

Critical measurements for the determination of engine power include: engine speed and torque; inlet air temperature, pressure and humidity; and the exhaust pressure. The following minimum test instrumentation accuracy is required for the critical measurements listed:

a. Torque—±0.5% of measured value

b. Speed—±0.2% of measured value

c. Inlet Air Temperature — ± 1.0 °C

d. Air Supply Pressure — ± 0.15 kPa

e. Inlet Air Humidity – ± 1.0 °C wet bulb

f. Exhaust Pressure—± 0.5 kPa

The following instrumentation accuracy is recommended for the additional measurements:

g. Fuel Flow—±1% of measured value

h. General Temperature measurements—±2 °C

i. Other Gas Pressures—±0.5 kPa

7.2 Measurement Requirements

7.2.1 Inlet Air Supply Pressure and Temperature

Pressure and temperature of the inlet air supply, used for the purpose of correcting engine power, shall be measured in a manner to obtain the total (stagnation) condition at the entrance to the engine air induction system. This measurement shall be made within 0.15 m of the entrance to the Air Induction System inlet duct. On those tests where the engine air supply is ambient air, this pressure is the barometric pressure; on those tests where the air supply is test cell ambient air, this pressure is the cell barometric pressure; on those tests where the inlet air supply is plumbed directly to the Air Induction System, the correction pressure is the pressure measured inside the lab plenum.

7.2.2 Intake Manifold Pressure and Temperature

Intake manifold pressure and temperature shall be measured as static values with probes located in a section common to several cylinders. In such installations, dynamic pressure is assumed zero.

7.2.3 Charge Air Cooler Pressure and Temperature

For engines equipped with a charge air cooler, instrument the engine with thermocouples and pressure probes midstream at the air inlet and outlet of the Charge Air Cooler. On charge air-cooled engines in which a laboratory cooler is employed for testing, pre-cooler charge air pressure must also be measured for the purpose of setting in-service restrictions per 7.5.5. Pre-cooler pressure must be measured upstream of the auxiliary unit in a manner to obtain the total (stagnation) value. Auxiliary cooler restriction is the difference between the pre-cooler and intake manifold pressures.

7.2.4 Coolant Temperature

Coolant temperature in liquid-cooled engines shall be measured at the inlet and outlet of the engine, in air-cooled engines at points specified by the manufacturer.

7.2.5 Oil Pressure and Temperature

Oil pressure shall be measured at the entrance to the main oil gallery. Oil temperature can be measured at the same location or inside the oil sump.

7.2.6 Fuel Temperature and Pressure

Fuel temperature and pressure shall be measured at the inlet to the carburetor or fuel injector rail for SI engines, and at the inlet to the high-pressure injection pump or unit injector rail for CI engines, and at the outlet of the volumetric flow meter for gaseous-fueled engines. Fuel temperature must also be measured at the entrance to the fuel flow meter for the purposes of density correction in the mass fuel flow calculation.

7.2.7 Exhaust System Pressure and Temperature

Exhaust system pressure shall be measured to obtain the total (stagnation) pressure downstream of the exhaust runner collector(s). Exhaust System temperature shall be measured in approximately the same location as the pressure measurement. In the event that the engine is equipped with close-coupled catalysts, the pressure probe can be located downstream of the catalysts. For applications that use laboratory exhaust equipment to mimic backpressure in service (steady state or transient), the pressure probes must be installed in the same location for both the vehicle test and the dynamometer net power test.

7.2.8 Air/Fuel Ratio

The air/fuel ratio shall be measured for the purpose of ensuring that the air/fuel run on the dynamometer is the same as that run in the application.

7.3 Adjustments and Run-In

7.3.1 Adjustments

No component, assembly, or calibration adjustments are allowed during the test.

7.3.2 Run-In

The engine shall be run-in according to the manufacturer's recommendation. If no such recommendation is available, the engine shall be run-in until friction has stabilized as determined by brake torque readings that are repeatable within 1%.

7.4 Test Operating Conditions

There are two alternative methods for determining the engine control settings and operating conditions used in rating engine power and torque; steady-state and transient. See Table 7 for differences in test set-up between these methods.

7.4.1 Steady-State

Steady-state procedures have historically been used for all engine rating. They are still appropriate for engines that usually operate at constant speed and load such as industrial engines, generator sets, small hand-held engines, utility, lawn and garden engines, off-highway vehicles and medium or heavy duty on-highway vehicles. It is acceptable to use steady-state procedures and operating conditions for rating of any engine.

7.4.2 Transient

Power achieved during transient maneuvers such as acceleration from a stop or passing on the highway can be more meaningful to consumers of light duty vehicles than steady-state power. The widespread application of sophisticated electronic controls has provided engine manufacturers with the opportunity to regulate engine operation as a function of time as well as environmental conditions and fuel type. Examples of engine control parameters that may vary with time are variable valve actuation, active intake manifolds, electronic spark control, catalyst protection algorithms, active exhaust controls, variable boost control, electronic throttle control, knock control, traction and vehicle stability control, variable compression ratio, injection timing and pressure. It is the intent of this procedure to rate engine power and torque with these controls set as they would be for the customer in the most likely operating condition.

The method for determining test conditions used for rating engines from light duty vehicles is to obtain and record time synchronized data on all engine control parameters from an engine installed in a vehicle during a transient maneuver and then to duplicate these control settings during steady state engine operation on a dynamometer. The procedure for obtaining these data can be found in Section 9.

7.4.3

TABLE 7 - ENGINE SET-UP

	Steady-State		***Transient***	*Reference*
Applicability	non-road engines (ex. stationary, lawn equipment, generator, industrial)	on-road vehicle applications only	Light duty passenger vehicle applications only	section 9 (introduction)
Charge Air Cooler (CAC) Outlet Conditions	Use production CAC.	Use production CAC or lab CAC with equivalent pressure restriction. Measure CAC outlet temperature and pressure during steady-state testing in the application environment at each engine speed and match on dyno test stand.	Use production CAC or lab CAC with equivalent pressure restriction. Measure CAC outlet temperature and pressure during transient fixed gear vehicle testing. Match temperature and pressure on dyno test stand to vehicle values at each engine speed. All vehicle data must come from same fixed gear run.	section 7.5.5 section 6.2.3 section 9.1.4
Exhaust Back Pressure	Use full exhaust system in dynamometer test room.	Use full exhaust system in dynamometer test room or match back pressure after first reflective point based on data from steady-state vehicle testing with vehicle held at constant rpm for at least 2 min. Vehicle gear can vary by engine speed.	Match backpressure in dynamometer test room to value measured at peak power speed during transient vehicle acceleration maneuver. Any gear may be used, but all data must come from this same transient maneuver.	section 7.2.7 section 7.5.15 section 9.1.3
ECU Control Settings (fuel inj. timing, ignition timing, valve timing, EGR, tuning valve position, etc.)	Engine control unit (ECU) fully enabled and automatically controlling engine electronics (if applicable).	(1) Engine control unit (ECU) fully enabled and automatically controlling engine electronics OR (2) match ECU parameter settings according to values measured from vehicle testing with vehicle held at constant rpm for at least 2 min.	Measure parameter during transient fixed gear vehicle testing. Match value on dyno test stand to vehicle values at each engine speed. All vehicle data must come from same fixed gear run. Use same method of measurement in vehicle and on dyno stand.	section 7.5.4 section 9.3
Boost	Allow boost to stabilize according to engine control settings.	Allow boost to stabilize according to engine control settings.	Match manifold absolute pressure measured during transient vehicle acceleration maneuver.	section 7.5.6
Data Acquisition	Torque (±1%), engine speed (±1%), and all temperatures (±2°C) stabilized for at least 1 minute.	Torque (±1%), engine speed (±1%), and all temperatures (±2°C) stabilized for at least 1 minute.	(1) Torque (±1%), engine speed (±1%), and all temperatures (±2°C) stabilized for at least 1 minute, OR (2) torque and engine speed stabilized for 5 sec. then take 10 Hz data for 10 seconds.	section 7.5.3

7.5 Power and Torque Determination

7.5.1 Test Procedure

This section defines the actual dynamometer test procedure used in obtaining Rated Net Power and Torque. The test shall consist of a run at full throttle for spark-ignited engines and at a fixed full-load fuel injection pump setting for CI engines. The following test controls and operating conditions must be adhered to meet the requirements of this standard:

7.5.2 Test Points

Measurements shall be taken at increments of no more than 500 rpm in sequence from the lowest to the highest engine speeds recommended by the manufacturer. The operating speeds shall include those for peak power and peak torque. Data at 100 rpm increments around peak torque and peak power are recommended to accurately distinguish their respective rated speeds. Engine speed shall not deviate from the nominal set speed by more than ±1% or 5 rpm, whichever is greater.

7.5.3 Logging of Measurements

No data shall be taken until torque and speed measurements have remained stable within 1% and controlled temperatures have remained stable within ±2 °C for at least 1 min. The recorded measurements shall be the average of readings over a span of 1 min. Alternatively, data can be taken by stabilizing the torque and speed for 5 s and then acquiring data at a minimum 10 Hz rate for at least 10 s. If this alternative procedure is used, the entire speed sweep shall be repeated at least three times. The results are considered valid if the repeatability of at least three measurements is within 1% of the mean.

7.5.4 Engine Calibration Controls

The engine calibration settings (including spark advance and air/fuel ratio) shall be representative of the in-service controls. For light duty vehicles, the engine control settings can be set to values equivalent to those recorded during the vehicle transient test described in Section 9. Replication of transient control settings used during the steady state power test on dynamometer must include any time-based delays that would occur in the transient vehicle test. Engines equipped with active knock control are required to run at the spark advance established with the fuel grade specified in Table 4.

7.5.5 Charge Air Cooler Settings

For any engine equipped with a Charge Air Cooler, the air temperature at the outlet of the Charge Air Cooler must be set to reflect the conditions exhibited during in-service operation. For light duty vehicles, the transient vehicle test procedure described in Section 9 can be used to derive the Charge Air Cooler outlet air temperature and pressure at all engine speeds. For all other engine applications, the Charge Air Cooler outlet temperatures and pressures should be set to replicate the values exhibited during fully warmed up, steady-state operation. For either of these tests, the Charge Air Cooler temperature shall be maintained within a tolerance of ±2 °C at all engine speeds tested. If no testing was performed to determine the Charge Air Cooler outlet temperature, a fixed charge air cooler outlet temperature of 80 °C can be used.

7.5.6 Boosted Engine Settings

For engines equipped with variable boost as a function of charge or inlet air temperature, octane rating, and/or engine speed, the boost pressure shall be set to replicate the in-service conditions established with the fuel grade specified in Table 4.

7.5.7 Ambient Temperature

Ambient test cell temperature control is not required by this standard.

7.5.8 Inlet Air Conditions

The pressure, temperature, and humidity of the engine's inlet air supply shall be controlled as close to the standard reference conditions per 5.1 as possible to minimize the correction factor. The inlet air pressure temperature and humidity shall not deviate from the controlled set points by more than 3% for the entire test. If a laboratory plenum is plumbed to the engine for the purpose of controlling inlet air supply conditions, the exhaust backpressure should be referenced to the laboratory plenum pressure rather than the cell ambient pressure.

7.5.9 Coolant Temperature

Coolant temperature, measured at the thermostat location for a liquid-cooled engine, shall be controlled to within ±3 °C of the nominal thermostat control temperature specified by the manufacturer. If no temperature is specified, the coolant temperature shall be controlled to 90 °C ± 3 °C. Cooling air supply temperature for an air-cooled engine is regulated to 25 °C ± 10 °C.

7.5.10 Coolant Type

For liquid cooled engines, the type of coolant and water-mix ratio shall match the engine coolant used in series production by the manufacturer.

7.5.11 Oil Temperature

Although oil temperature control is not an expressed requirement of this standard, the oil temperatures run in the dynamometer rating test must be representative of the temperatures exhibited in service with a fully warmed up engine. The temperature must be controlled to a value no greater than the maximum limits specified by the manufacturer.

7.5.12 Oil Type

The type of engine oil used for the test shall match the SAE designated oil type recommended by the manufacture for the application.

7.5.13 Fuel Temperature

Fuel inlet temperature for diesel fuel injection shall be controlled to 40 °C ± 3 °C for unit injector systems, and 40 °C ± 1 °C for pump/line/nozzle systems. Test fuel temperature control is not required on SI engine power tests or on CI engines with electronic controls that compensate for fuel temperature changes.

7.5.14 Fuel Pressure

The fuel pressure shall be controlled to match the operating pressure specified by the manufacture in series production.

7.5.15 Exhaust Backpressure

As indicated in 7.4, for light duty vehicles, the exhaust backpressure can be set to replicate the values measured in a vehicle transient maneuver. For all other applications, if a laboratory exhaust system is used, the exhaust backpressure must be set to replicate the values measured under the steady state conditions exhibited in service. The exhaust backpressure setting used at peak power must match the exact value recorded during in service conditions within ±1.5 kPa. The exhaust backpressure should be referenced to the engine induction system inlet pressure.

8. PRESENTATION OF RESULTS

This section contains a listing of test data to be recorded and procedures for presenting results.

8.1 Reporting Requirements

All reported engine test data shall carry the notation: "Performance obtained and corrected in accordance with SAE J1349 Revised JAN2011. Any deviation from this document, its procedures, or limits shall be noted (e.g., Correction factors used exceed valid range defined in the SAE J1349 Procedure Revised JAN2011, Correction factors determined using assumed mechanical efficiency of 85% rather than actual test data). The following information is to be provided in the engine power rating report:

8.1.1 General Test Information

a. Date of test

b. Engine serial number

c. Test/run number

d. Test location and test cell number

e. Additional engine equipment listed per 6.1

8.1.2 Engine Description

a. Engine Displacement

b. Bore and stroke

c. Number and configuration of cylinders

d. Ignition type (Spark, Compression)

e. Combustion cycle (2-Stroke, 4-Stroke)

f. Fuel system (Carburetion, Throttle Body Injection, Multi-port injection, etc.)

g. Valve train (Push Rod - 2 Valve, Dual Overhead Cam - 4 Valve, Electro-Mechanical, etc.)

h. Pressure charging (naturally aspirated, turbocharged, supercharged)

i. Charge air cooling (if applicable)

j. Fan system (Electric, Clutch Driven, Hydraulic, etc.)

k. Knock control system (if applicable)

l. Manufacturer's recommended minimum fuel octane number

8.1.3 Liquid Fuel - Spark Ignition Engine

a. Fuel type and/or blend

b. Research and motor octane numbers

c. H:C Ratio

d. Fuel density/specific gravity at 15 °C

e. Lower heating value

8.1.4 Gaseous Fuel - Spark Ignition Engine

a. Fuel type or grade

b. Composition

c. Density at 15 °C and 101 kPa

d. Lower heating value

8.1.5 Diesel Fuels

a. ASTM or other fuel grade

b. Density at 15 °C

c. Viscosity at 40 °C

d. Lower heating value (optional)

8.1.6 Lubricating Oil

a. API engine service classification

b. SAE viscosity grade

c. Manufacturer and brand name

8.1.7 Engine Coolant

a. Coolant type

b. Coolant/Water Mix

c. Manufacture and brand name

8.1.8 Test Cell Measurements and Calibrations

a. Test cell venting pressure for exhaust system

b. Load cell calibration

c. Pressure transducer calibrations

d. Thermocouple and/or Resistance Temperature Detector/Platinum Resistance Thermometer calibrations

e. Fuel flow meter calibration

8.2 Test Data Requirements

All reported or advertised test data bearing the SAE J1349 notation shall include a minimum of the following parameter measurements and calculations at each test point:

TABLE 8 - TEST DATA PARAMETERS

Measurements
Engine Speed (may be obtained from engine controller)
Observed Brake Torque
Friction Torque
Air/Fuel Ratio
Spark Advance / Ignition Timing (may be obtained from the engine controller)
Ambient Temperature and Pressure
Inlet Air Temperature and Pressure
Inlet Air Water Vapor Pressure
Intake Manifold Air Temperature and Pressure (may be obtained from engine controller)
Temperature of Fuel at Fuel Flow Meter
Fuel Rail Temperature and Pressure
Engine Coolant Inlet and Outlet Temperature (water cooled engines only)
Oil Sump Temperature and Oil Gallery Pressure
Exhaust Gas Temperature at the manifold outlet (Left & Right)
Exhaust Pressure at the manifold outlet (Left & Right)
Smoke (optional—CI engines only)
Calculations
Corrected Torque (nearest whole number above 25 lb-ft, below 25 lb-ft, it is permissible to rate to the nearest 0.1 unit)
Observed BMEP
Corrected BMEP
Observed Brake Power
Corrected Brake Power (nearest whole number above 25 hp, below 25 hp it is permissible to rate to the nearest 0.1 unit)
SAE J1349 Correction Factor (reported to four significant digits)
Mass Air flow (May be measured directly or calculated from fuel flow and A/F Ratio measurements)
Volumetric Fuel Flow
Mass Fuel Flow
Brake Specific Fuel Consumption
Boosted Engine Parameters
Boost Pressure
Intercooler Inlet and Outlet Air Temperature and Pressure
Compressor Inlet and Outlet Temperature and Pressure
Turbine Inlet and Outlet Temperature and Pressure
Charge Air Cooler Efficiency
Engine Controller Parameters (If Available)
Manifold Absolute Pressure (MAP) or Total Mass Airflow (as applicable)
Spark Advance/Ignition Timing
Injection timing (Diesel and direct-injection gasoline engines)
Desired/Commanded Air/Fuel Ratio

9. TRANSIENT VEHICLE TESTING

Steady-state engine control settings, exhaust system backpressure, and charge air cooler efficiency may apply to all engines if so chosen, but must be used for engines installed in on-road vehicles over 8500 lb GVW (medium-duty or heavy-duty truck engines), and engines that usually operate at constant speed and load such as (but not limited to) industrial engines, generator sets, small hand-held engines, utility, lawn and garden engines, and engines used in off-highway vehicles.

Any engine may be tested using the steady-state conditions defined above. It is simpler and requires less equipment, time and testing. But it should be understood that engines which operate at continuously varying speeds and loads (i.e., light duty vehicles) create many transient effects related to heat transfer and the properties of various materials at different temperatures. These transient effects may permit the creation of control algorithms that temporarily increase brake horsepower and are representative of the power the end-user would obtain under similar, transient conditions. The traditional, steady-state test condition may yield lower net brake horsepower and torque for the same engine.

For some applications, an engine's exhaust backpressure and time dependent control settings that occur during transient maneuvers can be used in testing to provide a more representative measure of the engine performance that the customer will receive in service. The transient vehicle test specifications and procedures described in the following sub-sections can be applied to all engines used to propel vehicles below medium-duty trucks, the dividing line being 8500 lb GVW. This group includes but is not limited to: snowmobile engines, passenger car engines, light truck engines, and all terrain vehicle engines.

9.1 Transient Vehicle Test Specifications

9.1.1 Vehicle Equipment

The test must be conducted with a vehicle matching as closely as possible the intended design for series production. Exhaust system and charge air cooler design and engine mass flow must match production intent. Slight deviations are allowable as are typical of pre-production parts.

9.1.2 Vehicle Weight

Empty vehicle weight plus full tank of the fuel recommended by the manufacturer for customer use, driver, and test equipment.

9.1.3 Exhaust Pressure Measurement

Instrument the vehicle with pressure probe(s) installed downstream of the exhaust runner collector for each exhaust manifold. The same method and location of exhaust pressure measurement used in the vehicle must be used in the subsequent dynamometer net power test to set exhaust backpressure. For turbocharged engines, backpressure must be measured downstream of the turbine.

9.1.4 Charge Air Cooler (if applicable)

For engines equipped with a Charge Air Cooler, instrument the engine with thermocouples and pressure probes midstream at the air inlet and outlet of the Charge Air Cooler.

9.1.5 Method of Data Acquisition

Instrument the vehicle with any suitable data acquisition system to record all engine controller parameters that will be required to replicate the engine's time-based variable controls on the dynamometer net power test. This may include, but is not limited to: rpm, MAP, mass airflow, spark advance, A/F ratio, cam timing, fuel injector timing and pulse width, EGR (exhaust gas recirculation) valve and throttle position, coolant and oil temperature.

9.1.6 Ambient Conditions

The test must be conducted at the following ambient conditions:

a. Air Temperature: 25 °C ± 10 °C

b. Barometric Pressure: 90 to 105 kPa

c. Humidity: ≤70% relative humidity

NOTE: The purpose of this specification is to prohibit testing at humidity levels high enough to suppress knock such that the spark advance settings determined from the vehicle test would be unrepresentative of the spark advance which a customer would see at standard conditions.

d. Wind speed: less than 7 m/s (15 mph)

e. Road Surface: A closed course, with dry, flat, level hard-paved surface.

9.2 Transient Vehicle Test Procedures

9.2.1 Engine Warm-Up

The engine must be fully warmed up. Run the vehicle at a moderate speed (90 to 100 km/h for road vehicles) The engine is fully warmed up when the coolant outlet temperature has stabilized within +/-3C for a minimum of 5 minutes. When the vehicle is stopped following warmup, the acceleration run for determining control parameters and backpressure shall be started within 4 minutes of the time the vehicle comes to rest.

9.2.2 Data Acquisition Rate

All data recorded by the data acquisition system must be recorded at 10 Hz or faster sample rate.

9.2.3 Vehicle Acceleration Test Procedures

For measuring exhaust back-pressure, charge air cooler parameters (when applicable), and time-dependent engine control parameters, the vehicle shall be locked in a fixed gear and accelerated at full load from the lowest stable engine speed in that gear to the engine maximum speed.

Evaporative cooling of charge air coolers is prohibited unless offered by the manufacturer as standard equipment on the engine in the application being rated. If evaporative cooling is used, the evaporative cooling fluid must be as recommended by the manufacturer.

9.2.4 Vehicle Data Averaging

The acceleration test should be repeated at least once and the results averaged for application to the dynamometer net power test.

9.3 Application of Vehicle Transient Data to Net Power Test

The exhaust backpressure, charge air cooler parameters, and engine control parameters shall be determined by averaging the transient vehicle test data for all test runs. The dynamometer net power test shall be controlled at each speed set point to the averaged parameters recorded during the vehicle test. The exhaust backpressure applied to the dynamometer net power test can be set with a valve or orifice plate sized and located to match the average vehicle transient backpressure at the engine's peak power speed.

For charge-air-cooled engines, the charge air cooler outlet temperature shall be adjusted for the ambient temperature recorded during the vehicle tests by increasing or decreasing the charge air cooler outlet temperature by the same amount that the ambient conditions for the vehicle test varied from the standard temperature.

10. NOTES

10.1 Marginal Indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE POWER TEST CODE COMMITTEE

APPENDIX A

These CI engine correction formulas are applicable at all speed and load levels.

$$Bp_c = (CA \times CF) \times Bp_o \quad \text{(Eq. A1)}$$

A.1 Calculation of Atmospheric Correction Factor, CA

$$CA = (Fa)^{Fm} \quad \text{(Eq. A2)}$$

where:

$$fa = \left(\frac{Pa_{dr}}{Pa_{do}}\right)^{\alpha} \left(\frac{t_o + 273}{t_r + 273}\right)^{\beta} = \left(\frac{99}{Pa_{do}}\right)^{\alpha} \left(\frac{t_o + 273}{298}\right)^{\beta} \quad \text{(Eq. A3)}$$

and values for α and β, are summarized in Table A1:

TABLE A1 - ATMOSPHERIC CORRECTION FACTOR EXPONENTS

Pressure Charging System	Charge Air Cooling System	α	β
Naturally Aspirated	None	1.0	0.7
Mechanically Supercharged	All	1.0	0.7
Turbocharged	None	0.7	1.2
Turbocharged	Air-to-Air	0.7	1.2
Turbocharged	Jacket Water	0.7	0.7
Turbocharged	Lab Auxiliary (Standard)	0.7	0.4
Turbocharged	Lab Auxiliary (Optional)	0.7	1.2

Where “standard” and “optional” refer to the lab auxiliary cooler test method described in 6.2.3.

A.2 The value of the engine factor fm is determined from Table A2:

TABLE A2 - ENGINE FACTOR CALCULATION

	FM
$\frac{Q}{R} < 37.2$	0.2
$37.2 > \frac{Q}{R} < 65$	$\left(0.036 \times \frac{q}{r}\right) - 1.14$
$65 > \frac{Q}{R}$	1.2

where:

- Q = 120 000 x F/(D x N) for four-stroke engines
- Q = 60 000 x F/(D x N) for two-stroke engines
- R = Pm_o/Pa_o for all engines (R = 1 if naturally aspirated)

A.3 Calculation of Fuel Correction Factor, CF

$$CF = Fd \times Fv \tag{Eq. A4}$$

where:

$$fd = 1 + 0.70\left(\frac{SG_r - SG_o}{SG_o}\right) = 1 + 0.70\left(\frac{0.850 - SG_o}{SG_o}\right) \tag{Eq. A5}$$

and:

$$Fv = \frac{1 + S/V_o}{1 + S/V_r} = \frac{1 + S/V_o}{1 + S/2.6} \tag{Eq. A6}$$

NOTE: The previous equations correct observed power to reference fuel density and viscosity levels. A correction coefficient of 0.70 in the previous density factor equation is added to account for typical changes in lower heating value at differing density levels, based on an empirical LHV-SG relationship.