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SURFACE VEHICLE STANDARD

SAE J1349 | REV. JAN90

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Submitted for recognition as an American National Standard

(R) ENGINE POWER TEST CODE - SPARK IGNITION AND COMPRESSION IGNITION - NET POWER RATING

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1. SCOPE:

This document has been adopted by SAE to specify:

1.1 A basis for net engine power rating.

1.2 Reference inlet air and fuel supply test conditions.

1.3 A method for correcting observed power to reference conditions.

1.4 A method for determining net full load engine power with a dynamometer.

2. FIELD OF APPLICATION:

This test code document is applicable to both four stroke and two stroke 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.

3. REFERENCES:

3.1 This test code supersedes those portions of SAE J1349 JUN85 dealing with net power rating.

3.2 Standard CI diesel fuel specifications are range mean values for Type 2-D EPA test fuel per Title 40, Code of Federal Regulations, Part 86.1313-87.

3.3 The corresponding test code for gross power rating is SAE J1995 JAN90.

3.4 The document for mapping engine performance is SAE J1312.

3.5 Relationship to ISO 1585 - ISO 1585 (DIS in 1989) 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 and certain SI engines.

d. This document includes a different procedure for testing engines with a laboratory charge air cooler (ISO method optional).

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.

3.6 Complete correlation has not been established with ISO 3046, ISO 2288, ISO 9249, or with ISO 4106. It is expected that these power test codes will eventually align with ISO 1585.

4. TERMS AND DEFINITIONS:

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

4.1 NET BRAKE POWER: The power of an engine when configured as a "fully equipped" engine as defined in 4.4 and 6.2, and tested and corrected in accordance with this document.

4.2 RATED NET POWER: Engine net power as declared by the manufacturer at "rated speed".

4.3 RATED SPEED: The speed determined by the manufacturer at which the engine power is rated.

4.4 FULLY EQUIPPED ENGINE: A "fully equipped" engine is an engine equipped with only those accessories necessary to perform its intended service. A fully equipped engine does not include components that are used to power auxiliary systems. If these components are integral with the engine or for any reason are included on the test engine, the power absorbed may be determined and added to the net brake power. Common "fully equipped" engine accessory examples are listed in Table 1.

4.5 REFERENCE TEST CONDITIONS: The standard or reference engine inlet air supply (atmospheric) and inlet fuel conditions to which all power corrections are made.

4.6 FRICTION POWER: The power required to drive the engine alone as equipped for the power test. Friction power may be established by one of the following methods (the value is needed for power correction of spark ignition engines):

a. Assume 85% mechanical efficiency.

b. 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.

4.7 INDICATED POWER: The power developed in the cylinders. It is defined as the sum of the brake power and friction power for the purpose of this document.

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: The following are reference atmospheric conditions and test ranges for which the correction procedures are valid:

	Standard Condition	Recommended 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 - 40°C

5.2 Reference SI Gasoline Specifications: Reference gasoline research and motor octane numbers have been determined corresponding to "regular" and "premium" test fuels. Reference gasoline is required for all SI engines equipped with knock sensors or other devices that control spark advance as a function of spark knock. Other SI engines may use any gasoline with an octane number sufficient to prevent knock.

	Regular Fuel	Premium Fuel
Research Octane No.:	92 ± 0.5	97 ± 0.5
Motor Octane No.:	83 ± 0.5	87 ± 0.5
Lower Heating Value:	43.3 MJ/kg ± 0.1	43.1 MJ/kg ± 0.1

5.3 Reference CI Fuel Specifications: Reference fuel specifications are per Title 40, Code of Federal Regulations, Part 86.1313-87, and represent range mean values for Type 2-D diesel fuel. The following reference fuel characteristics have been determined to affect engine test power, and are listed with the applicable test ranges for which the correction procedures are valid:

	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) or 37 - 43°C (unit injectors)

Observed engine power is also corrected for variations in lower heating value (LHV) based on an empirical relationship between LHV and fuel density per 9.4.2.

5.4 Alternate Fuels: Reference values for alternate SI and CI fuels, both liquid and gaseous, are not presented in this document. Therefore, when alternate fuels are used for the net power engine test, no corrections to reference fuel conditions shall be made.

5.5 Power Corrections: 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. Therefore, in order to provide a common basis of comparison, it may be necessary to apply correction factors to the observed net power to account for differences between reference air and fuel conditions and those at which the test data were acquired.

5.5.1 All power correction procedures for atmospheric air are based on the conditions of the engine inlet air supply immediately prior to the entrance into the engine inlet 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.

5.5.2 On any engine 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.

5.5.3 The magnitude of the power correction should not exceed 5% for inlet air or 3% for inlet fuel corrections. If the correction factor exceeds these values, it shall be noted in accordance with 8.1.

5.6 Correction Formulas: The applicable correction formulas for spark ignition and compression ignition engines are listed in Section 9. 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 derating.

6. LABORATORY AND ENGINE EQUIPMENT:

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

6.1 Laboratory Equipment: The following standard laboratory test equipment is required for the net power test.

6.1.1 Inlet System: The intended service inlet system or any laboratory system that provides equivalent restriction at all speeds and loads. The inlet system begins at the point where air enters from the supply source (atmosphere or lab plenum) and ends at the entrance to the throttle body, inlet manifold, or turbocharger inlet, on engines as appropriate.

6.1.2 Exhaust System: A complete intended service exhaust system (including mufflers, catalytic converters, resonators, etc.) or any laboratory system that provides equivalent restriction at all speeds and loads. The exhaust system begins at the exhaust manifold outlet or at the turbine outlet on engines so equipped.

6.1.3 Fuel Supply System: Any laboratory system that provides a supply of fuel to the fuel inlet of the fully equipped engine. The fuel supply system must be capable of controlling fuel supply temperature to within the ranges specified in 5.3 for CI engines. The fuel supply system shall not exceed the manufacturer's maximum permissible restriction requirements, if applicable.

6.1.4 Charge Air Cooler: For charge cooled engines a laboratory auxiliary cooler may be employed for test purposes. If used, one of the following test methods is required and the appropriate correction procedure is applied per Section 9:

a. Standard Method: This is the preferred test method. The laboratory unit is set to simulate intended in-service charge air cooler restriction and inlet manifold temperatures as if the ambient and inlet supply air temperatures were 25°C.

b. Optional Method: The laboratory unit is set to duplicate the charge air cooler restriction and inlet manifold temperatures that would be obtained during intended service operation at the observed inlet air test conditions.

6.1.5 Auxiliary Power Supply: Electrically driven engine components determined to be part of the fully equipped engine may be operated via an external power supply. In such cases, the power required must be determined and subtracted from the corrected net brake power.

6.2 Engine Equipment: A fully equipped engine, as defined in 4.4, is used for the net power test. Table 1 lists fully equipped engine accessories and control settings required for the net power test.

7. TEST PROCEDURES:

This section contains the required test procedures for determining net engine power.

7.1 Instrumentation Accuracy: The following minimum test instrumentation accuracy is required:

1.	Torque	- ±0.5% of measured value
2.	Speed	- ±0.2% of measured value
3.	Fuel Flow	- ±1% of measured value
4.	Temperatures	- ±2°C
5.	Air Supply, Inlet and Exhaust Pressures	- ±0.1 kPa
6.	Other Gas Pressures	- ±0.5 kPa

TABLE 1 – Engine Equipment

System	Required	Comments
1. Inlet Air System	Yes	See 6.1.1.
Air Ducting	Yes	
Air Cleaner	Yes	
Air Preheat	No	
2. Pressure Charging System	Yes	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.
Boost Control Settings	Manufacturer's Specification	
3. Charge Air Cooling System	Yes	If applicable.
Charge Air Cooler	Yes	See 6.1.4 for auxiliary cooler options.
Cooling Pump or Fan	Conditional	Not required if it can be shown to be functioning less than 20% of running time during intended in-service operation at reference test conditions.
4. Electrical System	Yes	See 6.1.5.
Ignition System	Yes	
Starter	No	
Generator/Alternator	Conditional	Required only if needed to operate the fully equipped engine in a self sustained manner and an external power supply is not used. In this case, the generator shall operate at a load level only sufficient to power the required components (i.e., fuel injectors, electric fuel pump).
Ignition and Timing Control Settings	Manufacturer's Specification	For any engine equipped with electronic controls and/or knock sensors, the spark or timing advance must be adjusted to reflect intended in-service operation.
5. Emissions Control System	Yes	All control settings or adjustments must be set to reflect intended in-service operation.
6. RFI/EMI Controls (radio frequency or electromagnetic interference)	Manufacturer's Specification	Control settings must reflect intended in-service operation.

TABLE 1
(Continued)

System	Required	Comments
7. Fuel Supply System	Yes	
Fuel Filters/Prefilters	Optional	See 6.1.3.
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.
8. Engine Cooling System (liquid)	Yes	
Cooling Pump	Yes	
Radiator	Optional	Functionally equivalent laboratory system recommended.
Thermostat	Optional	If not used, then coolant temperature and flow shall be regulated to intended in-service levels.
Cooling Fan	Yes	On variable speed units the fan may be run at minimum power consumption levels if it can be shown to be functioning less than 20% of engine running time during intended in-service operation at reference test conditions. NOTE: If for any reason the fan is omitted, the minimum allowable fan power should be determined and subtracted from the net brake power. If run at full output, the fan power absorbed should be calculated and the difference between it and the minimum allowable fan power shall be added to the net brake power.
Engine Cooling System (Air)	Yes	
Blower	Yes	See above comments - same as liquid cooling fan.
9. Lubrication System	Yes	The fully equipped engine closed loop lubrication system is used. Oil fill shall be at manufacturer's full level. Oil temperatures shall reflect in-service levels at reference test conditions.
10. Exhaust System	Yes	See 6.1.2.
11. Auxiliary Drives		
Power Steering Pump	No	
Freon Compressor	No	
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.
Air Compressors	Conditional	See above comments - same as vacuum pumps.

7.2 Adjustments and Run-in:

7.2.1 Adjustments shall be made before the test in accordance with the manufacturer's instructions. No changes or adjustments shall be made during the test.

7.2.2 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 corrected brake power is repeatable within 1% over an 8 h period.

7.3 Pressure and Temperature Measurement:

7.3.1 Pressure and temperature of the inlet air supply, used for the purpose of engine power corrections, shall be measured in a manner to obtain the total (stagnation) condition at the entrance to the engine inlet system. 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.

7.3.2 Inlet air pressure, used for the purpose of determining inlet system restriction, shall be measured in a manner to obtain the total (stagnation) pressure immediately prior to the end of the inlet system as defined in 6.1.1.

7.3.3 Inlet 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.

7.3.4 On charge air cooled engines in which a laboratory cooler is employed for testing, precooler charge air pressure must also be measured for the purpose of setting in-service restrictions per 6.1.4. Precooler 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 precooler and inlet manifold pressures.

7.3.5 Coolant temperatures 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.

7.3.6 Oil pressure and temperature shall be measured at the entrance to the main oil gallery.

7.3.7 Fuel temperature 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.

7.3.8 Exhaust pressure shall be measured in a manner to obtain the total (stagnation) pressure in a straight section of piping not less than three nor more than six diameters downstream of the entrance to the exhaust system as defined in 6.1.2.

7.4 Test Operating Conditions:

7.4.1 The engine must be started and warmed up in accordance with manufacturer's specifications. No data shall be taken until torque and speed have been maintained within 1% and temperatures have been maintained within ±2°C for at least 1 min.

7.4.2 Engine speed shall not deviate from the nominal speed by more than ±1% or ±10 min^{-1}, whichever is greater.

7.4.3 Coolant outlet temperature for a liquid cooled engine shall be controlled to within ±3°C of the nominal thermostat value specified by the manufacturer. Coolant inlet air temperature for an air cooled engine is regulated to 35°C ± 5.

7.4.4 Fuel inlet temperature for diesel fuel injection shall be controlled to 40°C ± 3 for unit injector systems, and 40°C ± 1 for pump/line/nozzle systems. Test fuel temperature control is not required on SI engine power tests.

7.4.5 The exhaust gas must be vented to a reservoir having a total pressure within 0.75 kPa of the inlet air supply pressure.

7.5 Test Points: Record full throttle data for at least five approximately evenly spaced operating points to define the power curve between 600 rpm (or the lowest stable speed) and the maximum engine speed recommended by the manufacturer. One of the operating speeds shall be the rated speed, one shall be the peak torque speed.

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 JAN90". Any deviation from this document, its procedures, or limits shall be noted. All reported or advertised test data bearing the SAE J1349 notation shall include a minimum of the following information at each test point:

a. Engine speed
b. Corrected net brake power (or torque)

8.2 Recorded Test Conditions: Record the following ambient air, fuel, and lubricating oil test conditions and specifications.

8.2.1 Inlet Air Supply Conditions:

a. Air supply pressure
b. Air supply vapor pressure
c. Air supply temperature

8.2.2 Spark Ignition Engine Fuel - Liquid:

a. Fuel type and/or blend
b. Research and motor octane numbers
c. Lower heating value

8.2.3 Spark Ignition Engine Fuel - Gaseous:

a. Fuel type or grade
b. Composition
c. Density at 15°C and 101 kPa
d. Lower heating value

8.2.4 Diesel Fuels:

a. ASTM or other fuel grade
b. Density at 15°C
c. Viscosity at 40°C
d. Lower heating value (optional)

8.2.5 Lubricating Oil:

a. API engine service classification
b. SAE - viscosity grade
c. Manufacturer and brand name

8.3 Recorded Test Data: Record the following minimum information at each data test point:

a. Brake torque
b. Friction torque (if measured)
c. Engine speed
d. Fuel flow rate
e. Fuel supply pressure and temperature
f. Ignition and/or injection timing
g. Oil pressure and temperature
h. Coolant temperature
i. Inlet manifold air temperature and pressure
j. Total pressure drop across the inlet air system
k. Total pressure drop across the auxiliary cooler (if applicable)
l. Total pressure drop across the exhaust system
m. Smoke (optional - CI engines only)

8.4 Engine Equipment: Record all engine equipment listed per 6.2. Additionally, record engine manufacturer, displacement, bore and stroke, number and configuration of cylinders, carburetion or injection system type, plus type of pressure charging system, if applicable. If a laboratory charge air cooler is used, record the test method per 6.1.4.

For SI engines equipped with knock sensors, the engine should be designated as a "regular" or "premium" fuel engine. For those SI engines without knock sensors, the minimum octane number for which knock does not occur shall be recorded as stated by the engine manufacturer.

8.5 Additional Recorded Information: Record any other pertinent test data as determined by the manufacturer. This may include, but is not limited to: test date, engine serial number, test number, test location, etc.

9. CORRECTION FORMULAS:

This section includes all formulas necessary to correct observed engine power for deviations in inlet air and fuel supply conditions.

9.1 Symbols and Units:

SYMBOLS	TERM	UNITS
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	
ß	Temperature sensitivity exponent	
S	Viscosity sensitivity coefficient	
D	Engine displacement	l
B	Inlet air supply total pressure	kPa
t	Inlet air supply temperature	°C
P	Inlet manifold total pressure	kPa
r	Pressure ratio	
q	Fuel delivery	mg/L cycle
bp	Brake power	kW
fp	Friction power	kW
ip	Indicated power	kW
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

9.2 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.

9.3 Spark Ignition Correction Formulas: These spark ignition engine correction formulas are only applicable at full (WOT) throttle positions.

$$bp_c = CA \times bp_o \qquad \text{(Eq.1)}$$

Calculation of atmospheric correction factor, CA. If 85% mechanical efficiency is assumed:

$$CA = 1.18 \left[\left(\frac{99}{B_{do}} \right) \left(\frac{t_o + 273}{298} \right)^{.5} \right] - 0.18 \qquad \text{(Eq.2)}$$

9.3 (Continued)

If friction power is measured:

$$bp_C = ip_C - fp_O \qquad \text{(Eq.3)}$$

where:

$$ip_C = ip_O \left(\frac{99}{B_{do}}\right)\left(\frac{t+273}{298}\right)^{.5}$$

and:

$$ip_O = fp_O + bp_O$$

NOTE: If a lab auxiliary charge air cooler is used in conjunction with the standard test method per 6.1.4, no inlet air temperature corrections shall be made. In this case, the temperature correction exponent becomes zero. Otherwise use the above formula.

9.4 Compression Ignition Engine Correction Formulas: These CI engine correction formulas are applicable at all speed and load levels.

$$bp_C = (CA \times CF)\, bp_O \qquad \text{(Eq.4)}$$

9.4.1 Calculation of Atmospheric Correction Factor, CA:

$$CA = (fa)^{fm} \qquad \text{(Eq.5)}$$

where:

$$fa = \left(\frac{B_{dr}}{B_{do}}\right)^{\alpha}\left(\frac{t_o+273}{t_r+273}\right)^{\beta} = \left(\frac{99}{B_{do}}\right)^{\alpha}\left(\frac{t_o+273}{298}\right)^{\beta}$$