



AEROSPACE RECOMMENDED PRACTICE

ARP6971™

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Power and Torque Determination for UAS Engines Having Maximum Power Ratings
at or Below 22.4 kW

RATIONALE

This recommended practice is intended to provide the unmanned aviation industry with a standard means of rating the basic engine power and torque. Currently, the means of measuring and correcting the power is not standardized. This makes it very difficult for the power unit end-user to compare competing propulsion units as the rated power varies greatly with test method.

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1. SCOPE

This recommended practice is applicable to reciprocating engines powering unmanned aerial vehicles (UAV) having rated power values less than 22.4 kW, and which are not to be used for human transport.

1.1 Purpose

The purpose is to specify guidelines for measuring the performance of “basic” engine configurations so that critical parameters can be measured under highly controlled and standardized conditions. This recommended practice is not valid for the purposes of certification or regulation.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA or Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR5642	The Effect of Installation Power Losses on the Overall Performance of a Helicopter
AS20	Definitions, Aircraft Reciprocating Engine Performance
SAE J1312	Procedure for Mapping Performance-Spark Ignition and Compression Ignition Engines
SAE J1349	Engine Power Test Code-Spark Ignition and Compression Ignition-As Installed Net Power Rating
SAE J1940	Small Engine Power and Torque Rating Procedure
SAE J1995	Engine Power Test Code-Spark Ignition and Compression Ignition-Gross Power Rating
SAE J2723	Engine Power Test Code-Engine Power and Torque Certification

Sevik, J., Wallner, T., Miers, S., and Wasil, J., "Air-to-Fuel Ratio Calculation Methods for Oxygenated Fuels in Two-Stroke Engines," SAE Technical Paper 2015-01-0965, 2015.

2.1.2 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO 1585	Road vehicles-Engine test code-Net power
ISO 2533	Standard atmosphere
ISO 3046	Reciprocating internal combustion engines-Performance

2.1.3 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

14 CFR Part 33, or most recent

2.1.4 European Union Publications

Available from European Aviation Safety Agency, Postfach 10 12 53, D-50452 Cologne, Germany, Tel: +49-221-8999-000, www.easa.eu.int.

Certification Specifications and Acceptable Means of Compliance for Engines, CS-E Amendment 5 December 2018.

2.2 Definitions

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

2.2.1 BASIC ENGINE

A “basic” engine is an engine configured with only the built in equipment required for self-sustained operation. A basic engine does not include accessories that are necessary only to perform its intended service or that power auxiliary systems. If these accessories 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 gross brake power. Common “basic” engine accessory examples are listed in Table 3. This definition was copied from SAE J1995 for consistency.

2.2.2 BRAKE HORSEPOWER

The power delivered at the output shaft of the engine.

2.2.3 CORRECTED BRAKE POWER AND TORQUE

The power and torque produced by an engine at any speed when configured as a “basic” engine (per 2.2.1), corrected to the reference atmospheric conditions and/or reference diesel fuel specifications per Section 3, and tested in accordance to the applicable procedures contained in this standard.

2.2.4 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.

2.2.5 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.

2.2.6 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.

2.2.7 REFERENCE TEST CONDITIONS

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

2.2.8 FRICTION POWER

The power required to drive the engine alone as equipped for the power test. Friction power may be determined by the following methods (the value may be 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 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.

2.2.9 INDICATED POWER

Indicated power is the power generated in the cylinders. It is defined as the sum of the brake power and the friction power. This method is consistent with SAE J1995.

2.3 Symbols, Units, and Subscripts

2.3.1 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 (output shaft speed)	RPM
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 (1.365 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 customers. This table is based on Table 1 from SAE J1349.

2.4 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 3

2.5 Abbreviations

- CI Compression Ignition
- ISA International Standard Atmosphere

RH	Relative Humidity
SI	Spark Ignition
UAS	Unmanned Aerial System
WOT	Wide Open Throttle

3. REFERENCE TEST CONDITIONS AND CORRECTIONS

This section specifies the operating conditions, correction factors, and specifications for engine-based testing.

3.1 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	Notes
Inlet Air Supply Pressure (absolute)	101.325 kPa	
Dry Air Pressure (absolute)	99.96 kPa	Calculated based on 80% RH
Inlet Air Supply Temperature	15 °C	ISA at sea level

3.2 Reference SI Fuel 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 fuel. The engine rating shall be for fuel specification as stated by the manufacturer. No correction for power output is made due to fuel energy content. For each fuel tested, it is preferable to provide a certificate of analysis to confirm chemistry and performance.

3.3 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 fuel system characteristics in Table 3 have been determined to affect engine test power. Note that as indicated in 3.6.2, 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. It is preferable that a certificate of analysis is provided for each tested fuel to confirm chemistry and performance.

3.4 Glow-Assist CI Fuel Specifications

The composition of commercial fuels used in glow-assist engines typically consists of nitromethane, methanol, and mineral (or castor) oil. The ratio of these components varies significantly by manufacturer and type. The manufacturer and composition (and relative levels) of the three fuel components must be specified. This includes custom fuel chemistries that may be developed for use. Because of the highly volatile nature of nitromethane and methanol, these fuels must be kept refrigerated when not being used. Any corrections must be disclosed.

3.5 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.