



SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Test Method for Measuring Performance of Engine Cooling Fans

RATIONALE

This document has been updated to improve its clarity, to make use of more recent technical learnings regarding the conditions and methods for which airflow measurements are undertaken and to correct a typographical error found in Equation 6.

1. SCOPE

This SAE Recommended Practice is intended for use in testing and evaluating the approximate performance of engine-driven cooling fans. This performance would include flow, pressure, and power. This flow and pressure information is used to estimate the engine cooling performance. This power consumption is used to estimate net engine power per SAE J1349. The procedure also provides a general description of equipment necessary to measure the approximate fan performance.

The test conditions in the procedure generally will not match those of the installation for which cooling and fuel consumption information is desired. The performance of a given fan depends on the geometric details of the installation, including the shroud and its clearance. These details should be duplicated in the test setup if accurate performance measurement is expected. The performance at a given air density and speed also depend on the volumetric flow rate, or the pressure rise across the fan, since these two parameters are mutually dependent. These parameters depend on the pressure drop across the radiator core and the ram pressure due to vehicle motion. For these reasons, the test procedure should be recognized as providing only an approximate measure of installed fan performance.

Although the test procedure is based on running the fan with a motoring dynamometer, the actual installation can be used as a test fixture if an accurate torque meter is available. In this case, the same qualifications discussed apply. Finally, for the effect of a fan clutch in reducing fan use and power consumption, which is not a part of this procedure, refer to SAE J1342.

1.1 Purpose

This document provides a recommended test procedure for measuring and comparing the performance of fans over a range of pressure and speeds. The resulting performance data are intended for predicting the cooling performance and fuel consumption of engines using these fans, and in comparing one fan versus another.

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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 J1342 Test Method for Determining Power Consumption of Engine Cooling Fan Drive Systems

SAE J1349 Engine Power Test Code - Spark Ignition and Compression Ignition - Net Power Rating

SAE J2867 Laboratory Testing of Light Duty Vehicle Electric Cooling Fan Assemblies for Airflow Performance

2.1.2 ANSI Publication

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

ANSI/AMCA Standard 210-07 ANSI/ASHRAE Standard 51-2007 American National Standard "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating"

3. TEST PROCEDURE

3.1 Equipment and Facilities (see Figure 2)

- 3.1.1 A calibrated motoring dynamometer or drive motor having speed and torque capacity to suit the intended fan characteristic measurement, a drive shaft and mounting provision for the fan or fan clutch (this can be bimetallic or Electro viscous) , and a calibrated torque meter. If a fan clutch is used, it should be locked up to guarantee constant fan speed throughout a test.
- 3.1.2 Structure with minimum length, width, and height of 200% of the fan diameter to support a sharp-edge orifice (or other fan shroud), which includes a suitable plenum chamber. A calibrated flow measurement orifice or nozzle (one with experimentally determined coefficient k_n) should be coupled to this structure. The plenum chamber should preferably contain perforated "straightening" screens to dissipate jets of air and provide uniform air movement. A separate belt drive using an auxiliary power source can facilitate power measurement.
- 3.1.3 An auxilliary (boost) fan and/or shutters to vary the plenum pressure.
- 3.1.4 A calibrated tachometer.
- 3.1.5 Equipment necessary for measurement of air temperature, barometric pressure, the pressure across the flow measurement orifice, and the pressure inside the plenum chamber. For additional accuracy, ambient air humidity during the airflow test can be included in the data acquisition and calculations. See ANSI/AMCA Standard 210-07 for additional information.
- 3.1.6 The ANSI/AMCA Standard referenced in Section 2.1.2 above provides guidance on preferred flow meter construction, instrument accuracy, and alternative airflow calculations. Although it is primarily for fans with integral housings, its guidelines are applicable for non-ducted fan performance and test apparatus.

3.2 Test Conditions

3.2.1 Sharp Edge Orifice Test Conditions

This type of test is also known as a Knife-Edge or Flat Plate Airflow test. This test is useful for generating general information on fan performance and providing a standard test condition to allow comparison to other fans.

The fan is mounted within a sharp-edged orifice that is typically 20 to 50 mm larger than the fan diameter. The fan is mounted such that 50% of its projected width penetrates the orifice.

The measured performance from Sharp-Edge Orifice testing is generally not demonstrated in the application due to geometric differences.

3.2.2 Engine Mounted Fan Ring Conditions

In some cases an engine mounted fan shroud is used, defined as: a tight tip clearance contoured shroud mounted on an engine. Because the fan and shroud are both mounted on the engine, they move together, precluding blade contact even at fan blade tip-to-shroud clearances that are much lower than possible with a traditional body-mounted fan shroud. Typical fan blade tip to engine mounted shroud clearances would be in the range of 6 to 10 mm. As fan blade to shroud clearance is reduced, fan airflow and efficiency (flow vs input power) increase for a given fan rpm or fan power. therefore, noise is typically reduced.

3.2.3 Application Specific Test Conditions

This type of test is useful for generating application specific information on fan performance.

The fan is mounted in the shroud intended for the application at the tip clearance and insertion planned for the application and/or with any components used in the application up to and including the complete application or vehicle.

Care must be taken to assure that a statistical combination of a) vehicle build variation, b) part variation, and c) engine movement due to torque reaction and road acceleration inputs cannot result in contact between the fan and the shroud for the fan application environment.

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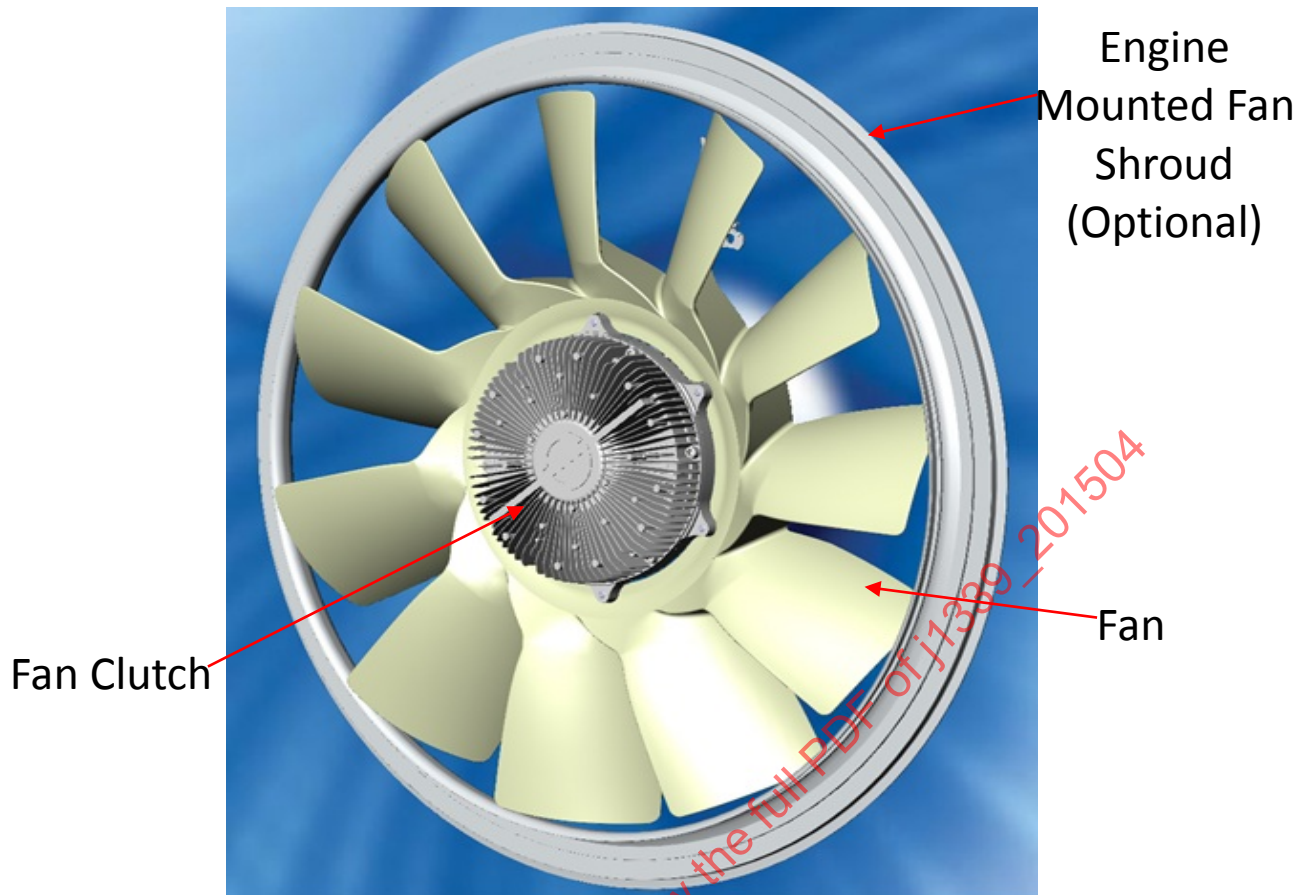


Figure 1 - Fan and clutch with engine-mounted shroud

3.2.4 Best Penetration Fan Performance Test Conditions

Mount the fan in a flat plate shroud, or the shroud intended for the application, and adjust the insertion to obtain maximum airflow at each data point.

3.2.5 Specify which test conditions were used on the fan test report, plots, and /or tabulated data.

3.3 Test Procedures

Operate the test fan over a range of speeds representative of the intended use. Select sufficient discrete speeds to establish performance for the speed range. At each discrete test speed vary the plenum pressure across the pressure operating range of the fan in the installation. Usually a minimum of 10 discrete pressure points from zero to maximum pressure would be recorded at each speed. Measure torque, plenum pressure, and the flow nozzle pressure differential at each point. Measure and record laboratory ambient temperature and atmospheric pressure for calculation of air density. Calculate the fan flow, pressure, and power using the formulas of 4.2.

The excel data example below is a very simple illustration of how data may be gathered at different fan speeds and airflow delta-p input conditions. At each of those fixed input conditions, the outputs are then either measured directly or calculated from the required input and output values. See section 4 Computations and Results for specific definitions and formulas for calculation.

The table below illustrates only fan speed and delta-p as input variables. Fan immersion into the shroud is another variable that may want to be measured and optimized.

Fan Performance Data Example

Input Conditions		Measured or Calculated Output Conditions				
Fan Speed	Plenum Pressure	Nozzel Delta-P	Calculated Airflow	Measured Fan Torque	Calculated Fan Power	Calculated Fan Efficiency
A	1					
A	2					
A	3					
A	4					
A	5					
B	1					
B	2					
B	3					
B	4					
B	5					
C	1					
C	2					
C	3					
C	4					
C	5					

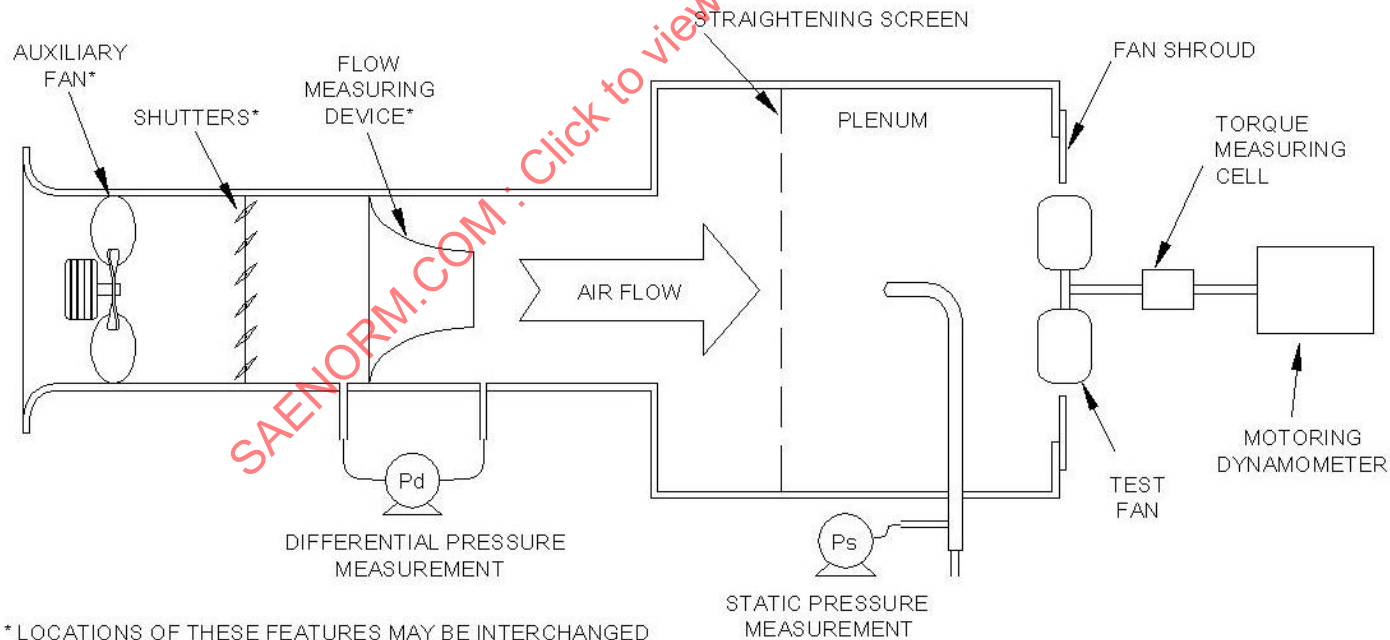


Figure 2 - Fan performance test set up

4. COMPUTATIONS AND RESULTS

4.1 Definition of Symbols

See Table 1.

Table 1 - Definition of symbols

Symbol	Definition	Units SI	Units English
A	Absolute temp. conversion factor	273 °C	460 °F
B	Barometric pressure	kPa	in-Hg
C	Air density correction factor	none	none
D	Air density	kg/m ³	lbm/ft ³
Es	Fan static efficiency	%	%
t	Ambient temperature	°C	°F
P	Fan power	kW	hp
N	Fan speed	r/min	r/min
T	Fan torque	N-m	lbf-ft
Q	Airflow	m ³ /sec	ft ³ /min
Ps	Static pressure	kPa	in-H ₂ O
Pd	Nozzle pressure (Delta P)	kPa	in-H ₂ O
Pp	Plenum pressure	kPa	in-H ₂ O
Pth	Theoretical static air power	kW	hp
K	Density conversion factor (dry air)	$\frac{3.487 \text{ kg}^\circ\text{C}}{\text{m}^3 \text{ kPa}}$	$\frac{1.32 \text{ lbm}^\circ\text{F}}{\text{ft}^3 \text{ in Hg}}$
X	Power conversion factor	$\frac{9549 \text{ N-m r/min}}{\text{kW}}$	$\frac{5252 \text{ lbf-ft r/min}}{\text{hp}}$
Dsa	Standard air density	1.20 kg/m ³	0.075 lbm/ft ³
k _f	Flow conversion constant	35.0	5.97
k _n	Nozzle flow coefficient	Function of nozzle geometry	
d _n	Nozzle diameter	meters	inches
RH	Relative humidity	%	%
U	Air power conversion factor	1.0	6356
Subscripts			
c	Corrected to standard air density		

4.2 Calculations

4.2.1 Air Density

$$D = K \cdot B / (t + A) \quad (\text{Eq. 1})$$

NOTE: Other sources such as the ANSI Publication in Section 2.1.2 provide computations for using relative humidity RH to obtain more accurate values of air density. At 20°C, relative humidity affects density by ±1.2%.

4.2.2 Air Density Correction Factor

$$C = D_{sa} / D \quad (\text{Eq. 2})$$

4.2.3 Fan Power

$$P = N \cdot T / X \quad (\text{Eq. 3})$$

4.2.4 Corrected Fan Power

$$P_c = P \cdot C \quad (\text{Eq. 4})$$

4.2.5 Fan Airflow (SCFM or SCMS)

$$Q_c = k_f \cdot k_n \cdot d_n^2 \cdot (P_d / D)^{0.5} \quad (\text{Eq. 5})$$

4.2.6 Fan Static Pressure

$$P_{sc} = C \cdot P_p \quad (\text{Eq. 6})$$

4.2.7 Theoretical Static Air Power (to produce Q_c airflow at P_{sc} static pressure)

$$P_{th} = Q_c \cdot P_{sc} / U \quad (\text{Eq. 7})$$

4.2.8 Fan Static Efficiency

$$E_s = P_{th} / P_c \quad (\text{Eq. 8})$$

4.3 Presentation of Results

The fan flow (Q_c), fan static pressure (P_{sc}), and fan power (P_c) shall be plotted at each fan speed N , as shown in Figure 3. When only fan power data are required the fan power shall be plotted versus fan speed at a given system restriction, as shown in Figure 4. The test conditions, i.e., shroud type, fan penetration, air density, fan speed, and any special conditions must be noted on the plots and tabulated data.