RATIONALE

Five-Year Review. This document has been reviewed and revised for increased clarity.

1. SCOPE

The techniques outlined in this SAE Recommended Practice were developed as part of an overall program for determining and evaluating fuel consumption of heavy-duty trucks and buses, but it is applicable to off highway vehicles as well.

It is recommended that the specific operating conditions be carefully reviewed on the basis of actual installation data. Cooling requirements are affected by all heat exchangers that are cooled by the fan drive system. These may include radiators, condensers, charge air coolers, oil coolers, and others.

Because of the variation in size, shape, configuration, and mountings available in cooling fans and fan drive systems, specific test devices have not been included.

Using known power/speed relationships for a given fan, this procedure can be used to calculate the fan drive system's power consumption for cooling systems using the types of drives listed below. This power consumption may then be used in determining engine net power per SAE J1349. For more fan power/speed relationships, refer to SAE J1339.

1.1 Purpose

The purpose of this document is to provide a recommended method for determining and comparing the power consumption of fan drives over a variety of operating conditions. The resulting power consumption data is useful in predicting the fuel consumption of engines using these fan drives and in comparing one fan drive to another on the basis of power consumption. There is no known comparable ISO specification.

1.2 Types of Drives

1.2.1 Direct-driven fans with fixed ratio (fan:engine speeds); i.e., no drive.

1.2.2 Mechanically actuated on/off drives (clutches), engaged by compressed air and springs.

1.2.3 Bimetal actuated viscous drives operating in on/off mode.

1.2.4 Bimetal actuated viscous drives operating in speed modulated mode.

1.2.5 Electronically actuated viscous drives operating in speed modulated mode.

1.2.6 Hydraulic motor drives operating in speed modulated mode.

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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 +1 724-776-4970 (outside USA), www.sae.org.

SAE J1339   Test Method for Measuring Performance of Engine Cooling Fans

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

3. METHOD OF PRESENTING TEST DATA

To evaluate the power requirement differential between the fixed ratio fan drive and a speed modulating or on/off drive, the following formula will be utilized for all duty cycle conditions. Typical curves are shown in Figure 1. It should be noted that the curves shown in Figure 1, of the fan power and fan drive power, should be measured in the actual application. Since this is very difficult to do, an alternative method will be discussed in Section 5. If an approximation is all that is desired, the fan power can be measured, using a dynamometer during a laboratory airflow test, with the fan in the same shroud as the application and an engine silhouette positioned behind the fan at an appropriate distance.

To evaluate the power, use Equation 1:

$$\text{Total Power} = (N_i - N_o)(N_o{}^2)(K) + (N_o{}^3)(K) + P_l \qquad \text{(Eq. 1)}$$

where:

$(N_i - N_o)(N_o{}^2)(K)$ = slip/drag power (kW)

$(N_o{}^3)(K)$ = fan power (kW)

N_i = fan drive input speed (r/min)

N_o = fan drive output speed or fan speed (r/min)

K = fan constant = fan power ÷ (fan speed)^3

P_l = power loss associated with the fan drive system minus the fan and clutch but including belts, pulleys, and pulley bearings (kW)

Note that slip/drag power = 0 for a fixed ratio fan drive because $N_i = N_o$
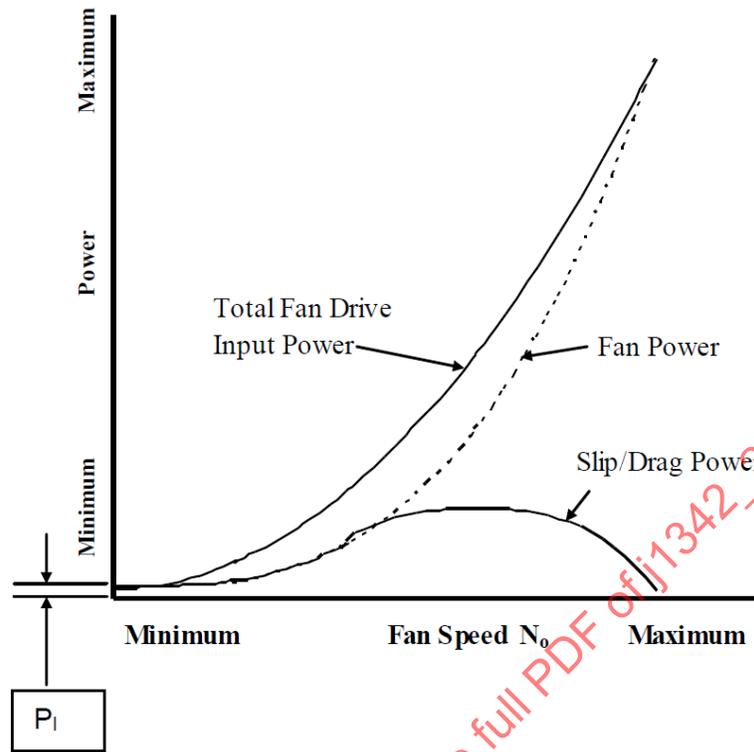
Input Speed Constant

Figure 1 - Power versus fan speed

Fan output speed (N_o) can be determined from curves such as those presented in Figures 2 and 3. Curves as shown in Figure 2 can be provided by the fan drive manufacturer. Curves as shown in Figure 3 would normally be derived by the fan drive user.
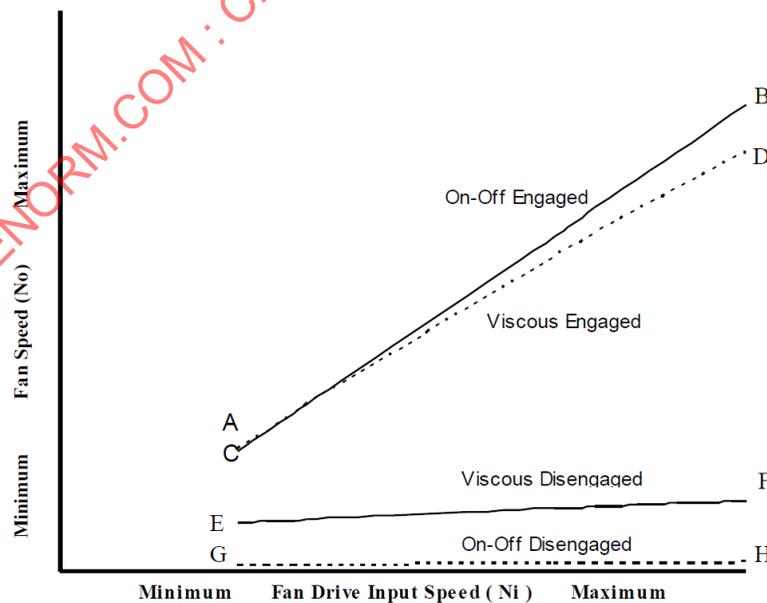

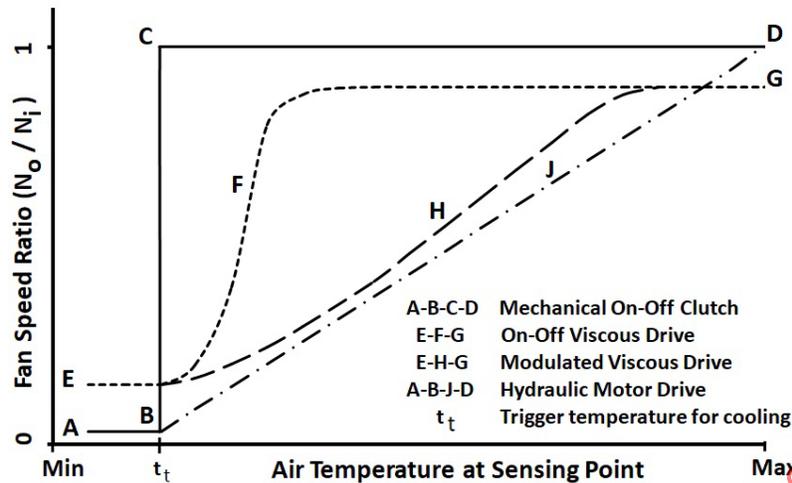*Figure 2 - Fan speed versus fan-drive input speed*

Figure 3 - Fan speed versus cooling air required

4.   PROCEDURE FOR ANALYZING VARIOUS TYPES OF FAN DRIVE SYSTEMS

4.1   The Section 3 method applied to a mechanically actuated on/off clutch is as follows:

When operating conditions do not require fan clutch actuation, fan speed (N_o) will fall on line G - H (Figure 2), or may be 0 rpm ($N_o = 0$), depending on the particular fan clutch being analyzed.

When operating conditions require fan clutch actuation, fan output speed (N_o) will fall along line A - B of Figure 2 (or line A - B - C - D of Figure 3). Given a specific input speed (N_i), the output speed (N_o) can be determined from line A - B of Figure 3.

4.2   The Section 3 method applied to viscous fan drives is as follows:

When operating conditions do not require fan drive actuation, fan speed (N_o) will fall on line E - F of Figure 2.

When operating conditions require fan drive actuation, fan speed (N_o) will fall on line E - F - G of Figure 3 (for on/off viscous) or on line E - H - G (for modulated viscous). Note that the maximum fan speed of a viscous drive will increase at lower air density due to torque considerations.

4.3   The Section 3 method applied to speed modulating hydraulic fan drives is as follows:

When operating conditions do not require fan drive actuation the hydraulic fan drive output speed (N_o) will be at minimum, similar to line G - H of Figure 2.

When operating conditions require fan drive actuation, fan speed (N_o) will fall within the boundaries of ABHG, Figure 2. Given the amount of cooling air required from the fan at a specific input speed (N_i), the output speed (N_o) can be determined from line A - B - J - D of Figure 3.

5.   ALTERNATIVE FAN POWER CALCULATION METHOD

5.1   The alternative method requires a determination of the system restriction of the heat exchangers and engine cavity of the vehicle or fan application.

5.2   The vehicle must be positioned against a wind tunnel and sealed off such that the tunnel can blow air through it in a similar manner as if the fan were actually in use. The fan should either be removed or locked against rotation. The pressure and flow are measured and recorded for this test which yields a curve of system restriction. This curve can be plotted against a known flow curve of the fan at any rpm. The intersection of the two curves determines the system operating point. The system operating point is then projected to the fan power curve. See Figure 4.