



SURFACE VEHICLE STANDARD

J1668™**MAR2021**

Issued 1993-06
Revised 2016-05
Reaffirmed 2021-03

Superseding J1668 MAY2016

Diesel Engines - Fuel Injection Pump Testing

RATIONALE

SAE J1668 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

The correct setting and adjustment of fuel injection pumps requires standardized testing conditions.

This SAE Standard summarizes the design and operating parameters for test benches so that, using certain information supplied by the pump manufacturer, the pump test schedule, and certain information supplied by the test bench manufacturer, it can be determined whether a particular test bench is suitable for driving a particular injection pump.

This document is in most cases a summary of the ISO Standard 4008, Parts 1, 2, and 3 and is intended to provide its critical aspects. Standard ISO 4008 should be referred to for more details.

1.1 Field of Application

This document is primarily applicable to test benches suitable for the calibration of fuel injection pumps for diesel engines requiring a fuel delivery of up to 300 mm³/st/cylinder at full load.

2. REFERENCES

2.1 Applicable Publications

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

2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J967 Calibration Fluid

SAE J968 Calibrating Nozzle and Holder Assemblies

SAE J1549 Diesel Fuel Injection Pump—Validation of Calibrating Nozzle Holder Assemblies

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Full document details: SAE J1668_202103

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https://www.sae.org/standards/content/J1668_202103

Documents

Document Sharing Hub

2.1.2 ANSI Publication

Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI/ASME B40.100 Pressure Gauges and Gauge Attachments

2.1.3 ISO Publications

Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 4008—Part 1 Fuel injection pump testing—Dynamic conditions

ISO 4008—Part 2 Fuel injection pump testing—Static conditions

ISO 4008—Part 3 Fuel injection pump testing—Application and test procedures

ISO 4020-2 Fuel filters for automotive compression-ignition engines—Part 2, Test values and classification

ISO 8984 Testing of fuel injectors for compression-ignition engines

2.2 Other Publications

"Fuel Injection and Controls," 1962 by P. Burman and F. De Luca

3. DYNAMIC TIMING

3.1 Speed Variation at Constant Load

The mean speed of the driveshaft under any steady admissible load shall not vary more than $\pm 1/4\%$ above 800 rpm and ± 2 rpm below 800 rpm for at least 1 min.

3.2 Flywheel Inertia

The test bench flywheel shall ensure that the instantaneous speed drop of a pump during injection (i.e., cyclic speed variation) shall be less than 1% at any critical calibration point. Based on this criterion, the required flywheel inertia can be calculated from Equations 1 and 2:

$$I = \frac{Q_{\max} \times p_{pa}}{1.31 \times n^2} \quad (\text{Eq. 1})$$

or

$$Q_{\max} = \frac{I \times n^2 \times 1.31}{p_{pa}} \quad (\text{Eq. 2})$$

where:

I = Moment of inertia ($\text{kg} \cdot \text{m}^2$)

$Q_{\max}$ = Pump delivery at calibration point ($\text{mm}^3/\text{st}/\text{outlet}$)

p_{pa} = Peak Line Pressure (bar)

n = Pump Test Speed (rpm)

To prevent torsional resonance with other mass in the transmission, the flywheel shall be as close to the coupling output as possible.

3.3 Driveshaft Stiffness

The maximum instantaneous angular driveshaft deflection under any operating conditions shall be 0.02 degrees.

The required driveshaft stiffness is calculated as shown in Equation 3:

$$S_d = \frac{Q_{\max} \times p_{pa}}{22.4} \quad (\text{Eq. 3})$$

where:

S_d = Driveshaft Stiffness (Nm/°)

$Q_{\max}$ = Maximum pump delivery (mm³/st/outlet)

p_{pa} = Peak Line Pressure (bar)

The driveshaft is considered to be the part connecting the flywheel to the test bench coupling. (On some test benches there is no driveshaft because the coupling is mounted directly to the flywheel).

3.4 Coupling Stiffness

The maximum instantaneous angular deflection of the drive coupling under operating conditions shall be 0.1 degree.

The required coupling stiffness is given by Equation 4:

$$S_c = \frac{Q_{\max} \times p_{pa}}{125.6} \quad (\text{Eq. 4})$$

where:

S_c = Coupling Stiffness (Nm/°)

$Q_{\max}$ = Maximum pump delivery (mm³/st/outlet)

p_{pa} = Peak Line Pressure (bar)

In Equations 1 to 4, it is assumed that the mean injection pressure is represented by a sine wave and the injection duration is 10 degrees of pump rotation.

3.5 Pump Mounting Stiffness and Alignment

The injection pump mounting shall be stiff enough to ensure that deflection of the pump body flange (or base bracket) about its driveshaft is less than 0.02 degree with respect to ground during injection. Special apparatus to measure pump mounting stiffness is fully described in ISO 4008 Part 1.

In addition, the pump mounting shall align the pump driveshaft with the test bench output within 0.13 mm radially and 0.05 degree angularly (or 0.25 mm over 300 mm length).

3.6 Backlash

There shall be no backlash between the flywheel and the pump drive coupling.

3.7 Angular Creep

There shall be no angular movement between connecting parts situated between the flywheel and the pump drive coupling when subject to torque reversals equal to twice the peak injection torque according to Equation 5:

$$T \geq Q_{\max} \quad (\text{Eq. 5})$$

where:

T = Peak injection torque (N·m)

$Q_{\max}$ = Numeric value of pump max delivery

The formulae for driveshaft and coupling stiffness as well as limits for pump mounting stiffness and angular creep were derived during extensive testing.

3.8 Power Output

Test bench power output may be significantly less than the drive motor rated power and is not constant through the speed range. It depends on the type of transmission used. Therefore, output power shall be checked using a dynamometer connected to the test bench driveshaft, and results plotted on a graph as shown in Figure 1. Speed droop (no load to full load) if any, and speed variation at constant load over 1 min shall also be measured using a dynamometer.

3.9 Conditions

In order to meet 3.2, 3.3, 3.4, 3.5, and 3.8 of this part of the Standard, the test bench manufacturer and the injection pump manufacturer must provide information to the user to enable him to determine the suitability of a certain test bench to test and calibrate a specific injection pump.

a. Test bench manufacturer shall publish

1. Continuous horsepower at the drive coupling available to drive the injection pump. This should be presented in the form of a graph as shown in Figure 1. If maximum horsepower is given, then maximum duration, ambient temperature, or other conditions and limitations must be stated.
2. Flywheel moment of inertia (kg·m²)
3. Coupling stiffness (Nm/°)
4. Driveshaft stiffness (Nm/°)
5. Flange and/or base bracket stiffness (Nm/°)

Furthermore, the test bench manufacturer shall provide a graph showing the permissible operating envelope based on formulae given in 3.2, 3.3, and 3.4. For simplicity, a peak injection pressure of 628 bar is assumed for this graph. If actual peak pressure is not 628 bar, then fuel delivery must be corrected as described in 3.10 in order to use the graph. An example of the graph is shown in Figure 2. (If the curve showing the stiffness of the flange or base brackets lies outside of the permissible operating envelope, it does not have to be shown in the graph.)

b. Injection pump manufacturer shall publish

1. Maximum horsepower that the injection pump absorbs
2. Fuel delivery ($\text{mm}^3/\text{stroke}$)
3. Peak injection pressure (bar)

at each critical test point in the pump specification.

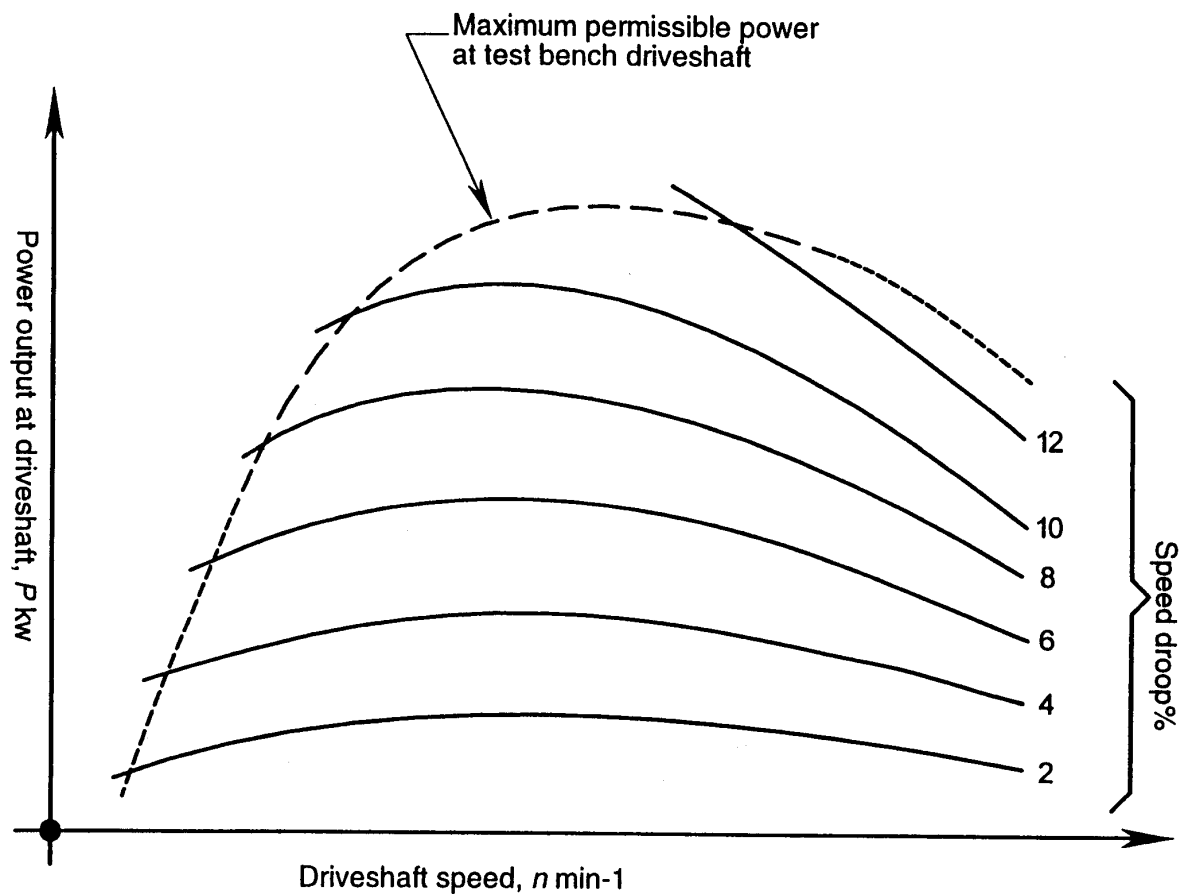


FIGURE 1 - POWER CURVE SAMPLE

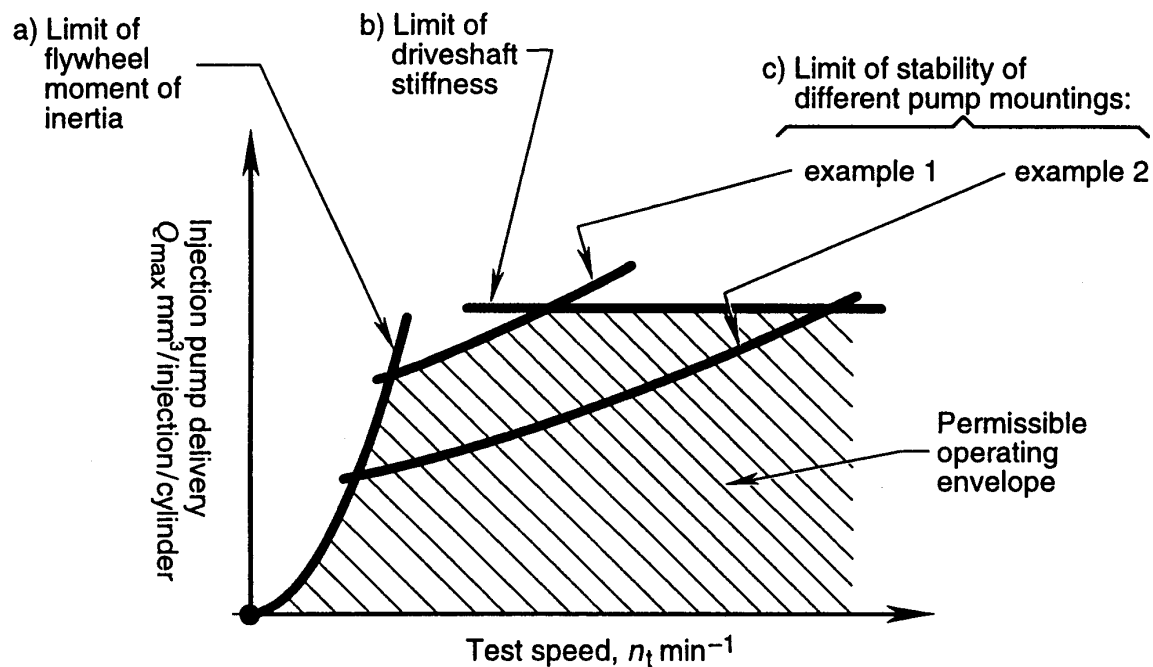


FIGURE 2 - PERMISSIBLE OPERATING ENVELOPE

If horsepower is not specified, it can be approximated by Equation 6¹:

$$HP = \frac{p_{pa} \times Q \times n \times 1.66 \times 10^{-9}}{\eta} \quad (\text{Eq. 6})$$

where:

HP =Horsepower (kW)

P_{pa} =Peak injection pressure (bar)

Q =Fuel delivery (including retraction volume) (mm³/st)

n =Number of injections per minute

η =0.75 (accounting for pump efficiency and effect of retraction volume)

3.10 Application and Use of Given Information

Assume a 6-cylinder pump delivers 180 mm³/st at 600 rpm with a peak injection pressure of 800 bar.

- Step 1—Determine Corrected Fuel Delivery—From Figure 3, correction factor at 800 bar is 1.27 (800/628). Therefore, the corrected delivery will be 1.27 x 180 = 228.6 mm³/st.
- Step 2—Plot the point on the graph (Figure 2) where the corrected delivery (228.6 mm³/st) intersects the speed (600 rpm). This must be within the operating envelope of the test bench (shaded area in Figure 2).
- Step 3—Calculate power requirement.

¹ Reference: Derived from a formula given in "Fuel Injection and Controls."