

Submitted for recognition as an American National Standard

Axle Efficiency Test Procedure

1. Scope

- 1.1 Data from this SAE Recommended Practice permit mapping axle efficiency and/or waste energy over the operating range of trucks, busses, and other highway vehicles based on truck chasses.
- 1.2 The procedure can be applied to single axles, tandem axles as a system, or other systems, by combining separate tests, such as tests of the front axle and power divider and rear axle of tandem or tri-drive type.

2. References—There are no referenced publications specified herein.

3. Objectives

- 3.1 To provide a means for measuring and comparing axle efficiency and the influence of materials, lubricants, and design factors on axle efficiency.
- 3.2 To outline a series of tests which encompass the typical range of axle operation in terms of load, speed, and lubricant temperature.
- 3.3 To result in data which are comparable from one test to another and between laboratories.

4. Equipment Requirement

- 4.1 An axle dynamometer with torque and speed capabilities consistent with the size axle being tested. Separate absorbers for each output are preferred.
- 4.2 A separate test stand without absorbers for the no-load portion of the test is optional.
- 4.3 Capability of measuring input speed with an accuracy of $\pm 1\%$ of the actual speed.
- 4.4 Capability of measuring all torques specified with an accuracy of $\pm 0.5\%$ of the actual torque.
- 4.5 Means for measuring and controlling sump lubricant temperatures to ± 6.0 °C for steady-state temperature test sequences.
- 4.6 Means for cold soaking the axle assembly to -35 °C when efficiency at low temperature is to be measured.

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5. Test Preparation

5.1 The test axle is to be representative of the particular axle design. Setting of bearing preloads, backlash, etc., outside of design specification limits is permissible only if that is the purpose of the test. This applies to production and experimental designs.

5.2 To preclude differential gear rotation as a source of inefficiency, all differentials are to be locked or mechanically blocked from rotating.

NOTE—Some dynamometers with automatic feedback systems to control relative speeds of absorbers may require deactivation of the feedback system.

5.3 The axle is to be equipped to measure sump temperature.

5.4 The axle assembly is to be tested at the attitude in which it would be installed in a vehicle, unless otherwise specified.

5.5 The axle is to be filled with lubricant recommended for in-vehicle use or the specific lubricant being evaluated.

5.6 Lubricant quantity is to be the axle manufacturer's recommendation by mass or volume, unless lubricant quantity is a variable under test.

5.7 Calculate output speeds and output torque for the break-in and test sequence. See Figure 1 and 7.3.

5.8 Calculate power requirements and determine whether break-in or test sequence must be modified as outlined in 6.1 and 7.3.

NOTE—If a tandem front axle is to be tested separately, the rated test torque for each axle would be one-half the tandem rating.

6. Break-in—An axle is considered to have passed through the break-in period when the efficiency of the axle has stabilized. To minimize the running time required for axles to achieve efficiency stabilization, select the appropriate schedule from 6.1 and 6.2. Previously-run axles and axles in which the lubricant has been changed may not be completely stabilized. Therefore, all test axles are to be stabilized in the selected break-in schedule before final testing.

6.1 If 125% of rated torque at 65 km/h does not exceed realistic in-service horsepower for the axles, run new axles for break-in to the following sequence at 65 km/h:

- a. 50% of rated output torque for 90 min
- b. 100% of rated output torque for 120 min
- c. 125% of rated output torque for 90 min

6.2 To determine friction stability, measure the efficiency at the start, middle, and end of each break-in load setting run. If friction has not stabilized during the highest load run, repeat the total break-in schedule.

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1. Wheel rev/km at 100 km/h _____ revs/km
2. Torque rating of axle assembly _____ Nm
3. Overall axle gear ratio
4. Input shaft speed for test:
 - a. Break-in:

$$\frac{(\text{Item 1}) * (\text{Item 3}) * 65 \text{ km / h}}{(60 \text{ min per hour})}$$
 _____ rpm
 - b. Efficiency tests:

$$\frac{(\text{Item 4a}) * (\text{test road speed km / h})}{(65 \text{ km / h})}$$
 _____ rpm
5. Overall efficiency — %

$$\frac{(\text{Total output torque}) * 100}{(\text{Input torque}) * (\text{Item 3})}$$
6. Energy loss, kilojoules per kilometer (kJ/km):

$$6.2832 * (\text{input torque Nm}) * (\text{Item 1}) * (\text{Item 3}) * \frac{(1 - \text{efficiency})}{100\ 000}$$

FIGURE 1—CALCULATIONS

- 6.3 Control total output torque and speed to $\pm 5\%$ of target values established in 5.7.
- 6.4 Cool lubricant as required to maintain $90\ ^\circ\text{C} \pm 5\ ^\circ\text{C}$ sump temperature.
7. **Efficiency Tests**—Four conditions of operation are recognized. These are listed in Table 1 in order of importance relative to energy use and durability:

TABLE 1—CONDITIONS OF OPERATION

Correlation	Power Flow	Rotation
Forward drive	Engine to axle	Primary design
Forward coast	Wheels to axle	Primary design
Reverse drive	Engine to axle	Opposite to primary design
Reverse coast	Wheels to axle	Opposite to primary design

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The procedure has been developed for the forward driving mode only because that is by far the dominant condition of operation in the typical over-the-road application. As a guide to extending the procedure to the forward coasting mode, the suggested approach is to: Run break-in at 25% of rated output torque (entered on line 2 of Figure 1) and 65 km/h until stabilized, then follow the test schedule in 7.3, but limit the maximum drive gear torque to 25% of the rated output torque. For this coast test, the axle shaft is the driving member and the propeller shaft (or equivalent) is the driven member. Because fuel economy is influenced to a minor degree by forward coasting, and to an insignificant degree by the reverse modes in typical over-the-road use, these procedures have not been developed. The committee welcomes comments from users regarding the procedures outlined and the need to extend the procedures.

- 7.1 Efficiency is calculated by the formula in Figure 1, item 5. Use the precise ratio computed from tooth combinations rather than a nominal ratio.
- 7.2 Measured output torque and speed are to be controlled within $\pm 5\%$ of the target value and temperature within $\pm 5^\circ\text{C}$ of the target value.
- 7.3 Axle efficiency for a given lubricant and axle may vary with torque, speed, and temperature. Complete determination at 6 torques, 6 speeds, and 5 temperatures would require 180 data points. For some purposes, mapping efficiency with load and speed variations at one steady-state temperature will be adequate. This standard test is to be at 90°C with output torque and speed sequences as in Table 2.

TABLE 2—OUTPUT TORQUE AND SPEED SEQUENCES

Output Torque % of Rating	Output Speed Increments (km/h)				
100%	20.0	40.0	60.0	80.0	100.0
50%	20.0	40.0	60.0	80.0	100.0
25%	20.0	40.0	60.0	80.0	100.0
15%	20.0	40.0	60.0	80.0	100.0
10%	20.0	40.0	60.0	80.0	100.0
0%	20.0	40.0	60.0	80.0	100.0

- 7.4 Other evaluations may require similar testing over a broader range of steady-state temperatures. If so, it is recommended that the previous sequence be repeated at the temperatures of interest or in 30°C increments from the standard 90°C temperature.
- 7.5 For cold start, short duration trip evaluations, an optional transient temperature test is recommended. Standard speed for this test is 80 km/h, and standard output torque is 25% of rating. Additional speeds and torques are optional. The procedure for this optional test is as follows.
 - 7.5.1 Thoroughly cold soak the test axle to approximately -35°C .
 - 7.5.2 Accelerate and stabilize at test speed and torque.
 - 7.5.3 Determine input and output torque as soon as stabilization is achieved, with -20°C as a target for the first readings.
 - 7.5.4 Record torques at 15°C increments as the axle warms up from the friction being generated.
 - 7.5.5 Continue the test through 120°C or the maximum anticipated operating temperature (whichever is lower). Auxiliary heating may be required for low-load, high-temperature testing.

8. Test Presentation—(See Figures 2 through 5.)

8.1 Specific end uses of this procedure and the forms in which data may be best presented for specific purposes are so varied that a standardized recommended data sheet is not provided. Figures 2 to 5 illustrate typical reduction of data to performance curves.

8.1.1 No-load drive pinion torque versus speed (Figure 2).

8.1.2 Family of efficiency versus torque curves at each output speed for each steady-state temperature test (Figure 3).

8.1.3 Efficiency versus temperature for optional transient temperature tests (Figure 4).

8.1.4 Parasitic losses and efficiency converted to waste energy per kilometer (Figure 5).

8.2 Detail information to be included in data presentation when pertinent to the purpose of the test includes—test agency, test date, test identification number, axle model and part number, axle ratio, axle rating, gear geometry detail, bearing detail, lubricant identification, lubricant detail specifications, lubricant quantity, angle of inclination of axis of input shaft, test torques and speeds, lubricant temperatures, test purpose, axle or lubricant application, numerical values for test results, conversion of data to preferred form, statistical significance of results, and prior use of axle or lubricant. Users of the procedure can choose data most appropriate for specific purposes.

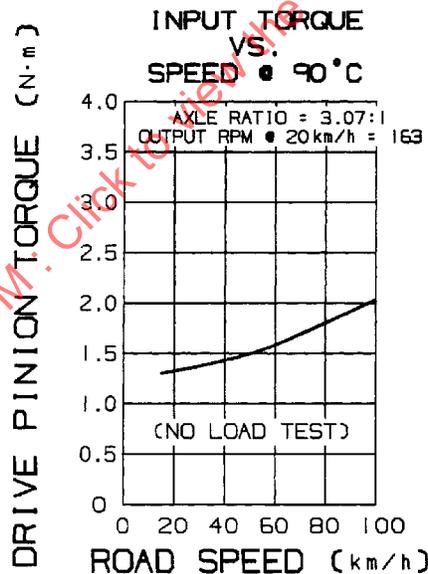


FIGURE 2—TYPICAL REDUCTION OF DATA TO PERFORMANCE CURVE—
NO-LOAD DRIVE PINION TORQUE VERSUS SPEED

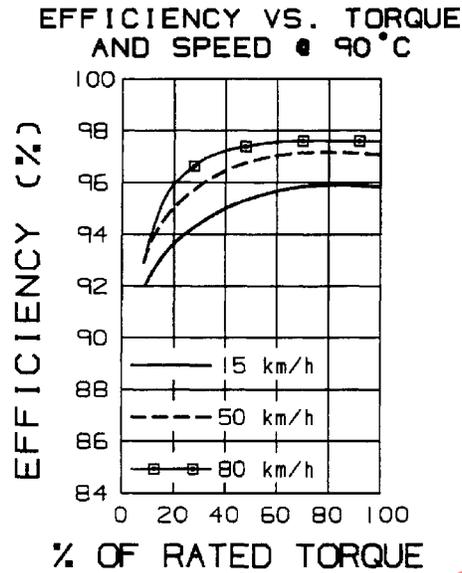


FIGURE 3—TYPICAL REDUCTION OF DATA TO PERFORMANCE CURVE—
FAMILY OF EFFICIENCY VERSUS TORQUE CURVES AT EACH OUTPUT SPEED
FOR EACH STEADY-STATE TEMPERATURE TEST

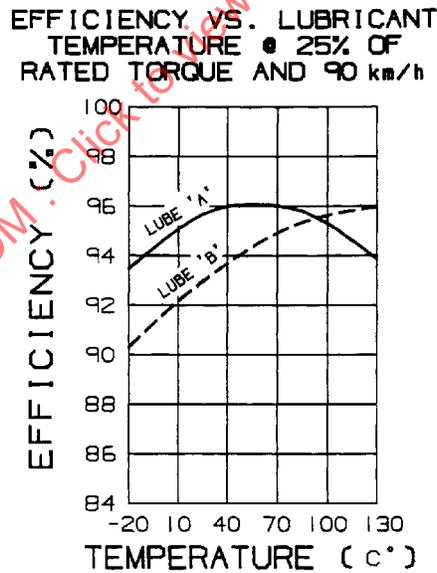


FIGURE 4—TYPICAL REDUCTION OF DATA TO PERFORMANCE CURVE—EFFICIENCY
VERSUS TEMPERATURE FOR OPTIONAL TRANSIENT TEMPERATURE TESTS