PERFORMANCE OF GEAR LUBRICANTS IN AXLES AT LOW SPEED AND HIGH TORQUE

1. SCOPE

1.1 This method is used for determining the load-carrying, wear, stability, and corrosion characteristics of gear lubricants in axles under conditions of low speed and high torque.

2. SAMPLE

2.1 Approximately 2 gallons of the gear oil to be tested.

3. APPARATUS

3.1 **Test unit.** The test unit shall consist of a new, 3/4-ton Army truck, hypoid rear-axle carrier, 5:83 to 1 ratio (Dodge part No. 930215, Chrysler Corp., Engineering Division, Detroit, Michigan). No change in any of the tooth contact or bearing adjustments shall be made.

CAUTION

Rebuilt carriers shall not be used. Only units especially selected by the manufacturer for this test work shall be used. Therefore, when ordering, specify a "special carrier for oil tests, to be checked by Gear Engineering Department", and designate whether the gears shall be phosphate coated or uncoated, as required by the applicable specification.

3.2.2 *Axle housing.* The carrier shall be installed in the axle housing (part No. 929922) for which it was designed. The housing shall be provided with a vent and an inspection opening as specified below. All other openings which might allow water leakage must be sealed with a suitable sealing compound (Permatex No. 2, or equivalent).

Note 1. When sealing, pay particular attention to all studs holding the carrier to the axle housing, the oil filler hole, drain, and inspection plugs, and to the thermocouple and vent fittings.

(a) *Axle vent.* The axle shall be vented to atmosphere throughout the entire test. The vent shall be arranged so that no water can enter the axle housing.

(b) *Inspection opening.* The axle-housing cover shall be modified to include an inspection opening of sufficient size (approximately 1-1/2 inch pipe size) and so located above the level of the cooling-pan edge that the ring-gear tooth-contact surfaces can be readily inspected by removing the plug or cover.

3.3 **Temperature control.** The test setup shall include a means of maintaining the lubricant at a specified temperature. This shall include a thermocouple, a temperature recording instrument, and a cooling bath.

(a) *Thermocouple.* A thermocouple shall be installed in the axle housing in such a manner that the junction will be on the centerline of the housing, one inch from the tooth side of the ring gear and one inch from the bottom of the housing. This thermocouple shall actuate a temperature-recording instrument and control an automatic cooling bath.

(b) *Temperature-recording instrument.* A temperature-recording instrument (Leeds and Northrup Micromax, Model S-40000, or equivalent) shall be provided for recording the temperature of the lubricant in the axle housing.

(c) *Cooling bath.* A water bath shall be provided for controlling the temperature of the lubricant in the axle housing. The bath shall consist of an electrically operated water-control valve, and spray nozzles arranged to spray cooling water over the top of the axle housing, and a water pan installed around the axle. The water-control valve shall start and stop the flow of water, and shall be actuated by the thermocouple through the temperature-recording instrument. (Cloths may be laid over the top of the housing to prevent splashing and to assist in the uniform distribution of the coolant.) The water level in the pan shall be fixed by a suitable overflow, located at about the centerline of the pinion shaft. An outlet in the bottom of the water pan shall be provided, of such size that, when the water supply is cut off, the pan will be drained in approximately 20 to 30 seconds. After the water level is adjusted, the drain shall remain open throughout the test run. The water supply shall be sufficient to keep the pan full to

the overflow point while water is running out the bottom drain.

3.4 Dynamometer. An axle dynamometer with suitable control equipment shall be used. The control equipment shall have sufficient sensitivity of adjustment and control to permit maintenance of a uniform ring-gear torque to within 2 percent and a uniform speed to within 1 percent. The dynamometer shall have a revolutions counter so that the number of revolutions of the ring gear during the test may be recorded.

4. MATERIALS

4.1 Preservative oil conforming to MIL-L-3150.

4.2 Sealing compound, Permatex No. 2 or equivalent.

5. PROCEDURE

5.1 Prepare the apparatus for the test as follows:

(a) Determine and record the torques required to break and to turn the pinion shaft of the completely assembled test unit. (This should not exceed 100 lb-in.)

(b) Connect the dynamometer to the axle.

(c) Fill the axle housing to the correct level with the test lubricant.

(d) Install cooling water pan.

(e) Set the revolutions counters to zero (or record the readings).

(f) Determine (and adjust manually) the amount of water required to maintain the level at the overflow point with the bottom drain open. (Starting and stopping the flow as required to maintain the stipulated temperatures shall be controlled thereafter by the automatic electric water-control valve.)

(g) Set the temperature control to maintain a lubricant temperature of 200° to 250°F, (93.3° to 121.1°C), by turning on the water supply automatically at 250°F and off at 200°F.

(h) Determine the dynamometer field voltages required for ring-gear torques of 6000 and 32,311 lb-in. at 62 rpm.

5.2 Check the operation of the test unit as follows:

(a) Start dynamometer and apply initial load of 6000 lb-in. ring-gear torque at 62 rpm with no flow of cooling water.

Note 2. The direction of rotation shall be that required for forward movement of the vehicle using the axle.

(b) Continue operation until oil temperature reaches 140°F (60°C). Then stop the dynamometer. (Time normally required for this run is approximately 20 minutes.)

(c) Record total ring-gear revolutions.

(d) Inspect ring-gear tooth-contact surfaces through inspection hole. If contact is satisfactory, record as such, and proceed with test as defined in paragraph 5.3. If contact is unsatisfactory, install a new carrier assembly and start a new test.

5.3 Operate the test unit under full load as follows:

(a) Start dynamometer and apply test load of 32,311 lb-in. ring gear torque at 62 rpm with cooling water shut off.

(b) Allow the temperature of the oil to rise to 250°F (121.1°C), then turn on the automatically controlled water supply, and allow the oil temperature to cycle between 200° and 250°F. (The oil temperature shall be recorded continously during the test by the temperature-recording apparatus.)

Note 3. The duration of the temperature cycle cannot be controlled, since it is dependent upon the tightness of the carrier bearings and pinion-shaft oil seal, and upon the properties of the test lubricant. The normal time to cool the axle from maximum to minimum temperature under the specified procedure is from 10 to 15 minutes.

(c) Continue full-load operation for 30 hours with oil temperatures cycling in the range of 200° to 250°F.

Note 4. Preferably the test run shall be continuous; not more than four stops during which the oil is allowed to cool to room temperature are permissible.

5.4 At the conclusion of the 30-hour run, stop the test and record total ring-gear revolutions.

5.5 Immediately disconnect the axle from the dynamometer, and while the unit is hot, determine and record the torque (lb-in.) required to rotate the pinion shaft by hand.

5.6 Remove the water pan, and drain oil from the axle housing into a clean, clear-glass container. Set aside for subsequent inspection.

5.7 Allow the axle to cool to room temperature, and again determine pinion-shaft torque.

5.8 Remove axle shafts and set them aside for inspection. Determine pinion torque.
5.9 Remove carrier unit from axle housing.
5.10 Remove ring-gear and differential assemblies from carrier, and again determine pinion-shaft torque. (This gives pinion-bearing and oil-seal friction only.)
5.11 Completely disassemble differential and pinion-shaft assemblies for inspection. Do not clean parts but immediately dip them in a preservative oil (MIL-L-3150).

CAUTION

In conducting the investigation, care shall be taken in examining parts to avoid staining cleaned and polished surfaces by perspiration from the inspector's hands or moisture from other sources

5.12 Inspect the test unit as described in the following paragraphs, and report the results on a form similar to that shown in Figure 1.

CAUTION

In conducting the investigations, care shall be taken in examining parts to avoid staining cleaned and polished surfaces by perspiration from the inspector's hands or moisture from other sources.

(a) Examine the axle shafts, axle housing, carrier housing, ring-gear, pinion, differential and differential pins for discoloration, rust, condensation, or other deposits.
(b) Examine the tooth surfaces on the drive sides of the pinion and the ring gear for any burnishing (including character), scratches, wear, surface fatigue (character and extent), scoring, discoloration, and corrosion.

Note 5. Gear-tooth surface conditions, such as burnishing, are defined in Table I.

(c) Examine the bearings for discoloration, corrosion, deposits, and wear.
(d) Examine the differential pins for evidence of removal of copper plating from the surfaces.

Note 6. Do not confuse discoloration of the copper with removal of the metal.

5.13 Examine the used lubricant, comparing it with new lubricant for evidence of water, foreign material, sludge, and discoloration. If inspection reveals any unusual condition, retain the used lubricant for chemical analysis.

Table I.--Gear-tooth surface condition terminology

Condition	Definition
Burnish----------	Alteration of original surface to a dull or brightly polished condition.
Scratching----------	Formation of random irregular grooves in the direction of sliding of the surfaces, such as is caused by abrasive particles.
Wear----------	Removal of metal (without evidence of surface fatigue or scoring) with partial or complete elimination of toolmarks. Also development of a discernible shoulder ridge at bottom of contact area near root or at toe or heel end of pinion tooth.
Surface Fatigue-----	Rippling--More or less regular pattern resembling ripples on water, or fish scales (evident under oblique lighting). Condition may be accompanied by ridging.
	Ridging--Series of parallel raised and polished diagonal ridges partially or completely across tooth surface of hypoid gear.
	Pitting--Formation of small irregular cavities resulting from breaking out of small surface areas.
	Spalling--Breaking out (more extensive than pitting) of irregular flakes of tooth surface.
Scoring ----------	Displacement of metal from one tooth to another to produce a matte finish.
Discoloration-------	Any alteration in normal color of finished steel surfaces.
Corrosion----------	General discoloration, accompanied by roughening not attributable to mechanical action.
Deposits----------	Pasty, gummy, or brittle material adhering to or collecting around working parts.

LABORATORY TEST QUESTIONAIRE AND FINAL SUMMARY OF RESULTS

A. GEAR LUBRICANT IDENTIFICATION

1. Company _____ Brand Name _____

2. Formula No. _____ Viscosity_____

B. GEAR TEST IDENTIFICATION

1. Test run at _____
   under their code no. _____

2. Date of start _____
   Date of completion__ _____

C. EVALUATION OF TEST PARTS

1. For load-carrying ability and wear.

	Pinion Gear	Ring Gear
a. Gear-tooth surface condition	_____	____
(1) Burnish	_____	____
(2) Wear	_____	____
(3) Surface fatigue		
(a) Rippling	_____	____
(b) Ridging	_____	____
(c) Pitting	_____	____
(d) Spalling	_____	____
(4) Score	_____	____
(5) Discoloration	_____	____
(6) Corrosion	_____	____
(7) Deposits	_____	____

b. Backlash

(1) Initial _____

(2) After tests _____

(3) Avg. increase _____

2. For stability and corrosion (indicate extent and nature of deposits, discoloration, corrosion, or rusting)

a. Axle shafts_____
b. Axle housing_____
c. Carrier housing_____
d. Pinion assembly_____
e. Ring-gear assembly_____
f. Bearings_____
g. Differential assembly_____
h. Differential pins_____

3. For stability

a. Pinion-shaft torque, lb-ft (before test)

(1) Full axle assembly:
break_____ turn_____

b. Pinion-shaft torque, lb-ft (after test)

(1) Full axle assembly (hot):
break_____ turn_____
(2) Full axle assembly (cool):
break_____ turn_____
(3) Axle shafts removed:
break_____ turn_____
(4) Pinion assembly:
break_____ turn_____

D. GENERAL OPERATING CONDITIONS

1. Break-in run (6000 lb-in ring-gear torque)

a. Revolution counter reading:
start_____ finish_____
Total _____ Avg. rpm ____

b. Time: start_____ finish_____
Total time, minutes _____

c. Oil temperature:
start_____ finish_____

3. Remarks _____
_____
_____
_____
_____
_____
_____
_____

4. Photographic evidence. Show by photographs: (1) tooth surface condition of pinion gear and ring gear; (2), any evidence of deposits, corrosion, or rusting.

2. Test run (32, 311 lb-in ring-gear torque)

a. Revolution counter reading:
start_____ finish_____
Total _____ Avg. rpm ____

b. Time: start _____ finish____
Total time _____
hours_____ minutes_____

(Note: If test is divided into 2 to 4 runs with cooling off period between runs, record time of start and finish of each test period.

c. Room temperature,
max_____min_____avg._____

d. Cooling-water temperature,
avg._____

e. Gear-lubricant temperature,
avg. max _____avg. min_____

f. Axle temperature cycles,
number _____
Duration (minutes), max_____
min_____Character (uniform, smooth, variable, rough, etc.) _____

g. The complete temperature-time chart shall be attached to and become a part of this report.

FIGURE 1. - Typical report form.