CORROSION PROTECTION BY GEAR LUBRICANTS IN THE PRESENCE OF MOISTURE

1. SCOPE
1.1 This method is used for determining the corrosion protective properties of gear lubricants. It duplicates normal service conditions wherein moisture condenses on the metal parts during cyclic ambient temperatures. The procedure is applicable to fresh oil samples and to used oil drawn from previously operated gearcases.

Note 1. Although developed for extreme pressure lubricants, this method is adaptable to chemically less active mineral-base or synthetic lubricants.

1.2 The method is performed as either a one-day test or a seven-day test, as required by the applicable specification. The one-day test consists of four hours of operation followed by 18 hours of storage in a controlled-temperature storage box. The seven-day test consists of four hours of operation followed by 162 hours of storage in the controlled-temperature storage box.

2. SAMPLE
2.1 Approximately 2.5 pints of the lubricant to be tested.

3. APPARATUS
3.1 Test unit, Spicer differential assembly (part No. SKA 58391-1X, Dana Corp., Toledo, Ohio, or equal) securely mounted so that the pinion shaft is horizontal and the pinion axis is 6-3/4 inches above the test stand table top.

Note 2. For a seven-day test a new unit is required; for a one-day test a used unit with a new cover plate may be employed.

(a) Pressure-relief valve, (James Bond Clark, Model 259B-2PP, or equal) set for 1 psi shall be provided for venting the test unit during operation. It should be mounted by a street elbow screwed into the coverplate fill hole. A pipe plug shall be provided for closing the vent opening of the relief valve.

(b) Axle seals (2), similar to those shown in Figure 1, for plugging the axle-shaft openings during operation.

3.2 Driving mechanism. The test setup shall include a driving mechanism consisting of an electric motor of approximately 1-1/2 hp at 2500 rpm, a pulley arrangement for producing a...
pinion speed of 2500 rpm and a means of measuring the pinion speed.

3.3 Temperature recording and controlling equipment. The test setup shall include a means of maintaining the test unit within a specific temperature range during operating, and of continuously recording the temperature. The equipment shall include a temperature probe, a temperature recording device, two heat lamps, and an electric fan.

(a) Temperature probe, preferably a resistance bulb (Foxboro Model E-742, or equal), installed in the differential housing through the drain plug so that at least one inch of the probe is immersed in the lubricant and the sensitive portion of the probe is approximately 1/2 inch from the ring-gear face.

(b) Temperature recording and controlling device with automatic controls (Foxboro Dynalog Model 9135W-M2-“754S1-11” or equal) connected to the temperature probe. The device must be capable of maintaining a temperature of 180° ± 2°F, within the test unit by alternately operating the heat lamps and the fan.

(c) Heat lamps and electric fan. Two 250-watt heat lamps and an electric fan, operated alternately by the temperature recording device, shall be placed as shown in Figure 2.

3.4 Controlled temperature storage box. The test equipment shall include a heated enclosure for maintaining the test unit at a uniform temperature during specified storage periods. The enclosure shall be capable of providing a uniform circulation of heated air for maintaining
the temperature of the oil in the test unit at 125° ± 2°F. (See Figure 3 for the recommended construction of the storage box.)

3.5 Sandblasting equipment.

4. MATERIALS

4.1 Solvent, dry-cleaning (P-D 680, Type 2).

4.2 Sand, 99.8 percent silicon dioxide, Moh hardness No. 7 American Foundryman’s Society grain fineness No. 26 (Wedron Sand No. 4098, Wedron Silica Co., Chicago, Ill., or equivalent).

4.3 Distilled water.

5. PROCEDURE

5.1 Determine and record the torques required to break and to turn the pinion shaft of the completely assembled test unit. The break torque must be 15 ± 3 lb-in; the turn torque 10 ± 3 lb-in. If necessary, adjust the torque as follows:

(a) Remove the carrier assembly from the housing.

(b) Check the pinion shaft torque. The break torque must be 7 to 10-in; the turn torque not more than 5-lb-in. Adjust by adding or removing shims as necessary.

(c) Adjust the carrier preload by adding or removing shims as necessary.

5.2 Prepare the unit for test as follows:

(a) Disassemble the test unit, and clean all parts with dry-cleaning solvent P—D—680, Type 2.

Note 3. If a used test unit is being employed for a one-day test, it is not necessary to disassemble the unit. Simply remove the cover plate, spray out the unit carefully with dry-cleaning solvent, and inspect it. Then proceed with step 5.2(d).

(b) Carefully inspect all parts for evidence of corrosion, and record the location and extent of corrosion present.

Note 4. The unit should be discarded if corrosion is noted on the ring or pinion gears, or on any bearings. The cover plate must be discarded if not completely rust-free.

(c) Reassemble the test unit except for the cover plate. Mount unit in position for testing. Connect driving mechanism and install temperature control system.

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![Figure 3.—Controlled temperature storage box.](attachment:image)

1. Outer box (24-1/2 by 24-1/2 by 18 inch), aluminum, welded seams.
2. Inner baffle (21 by 21 by 11 inch), aluminum, welded seams.
3. Toggle switch (Cutler-Hammer No. 7560-K5, or equivalent)
4. Plug, female (Amphenol No. 61F, or equivalent)
5. Connector, male (Amphenol No. 61M11, or equivalent)
6. Shells (Amphenol No. 61-61, or equivalent)
7. Plug, male (Amphenol No. 61M, or equal)
8. Connector, female (Amphenol No. 61F11, or equivalent)
9. Fan Motor, 1/80-hp (Dayton Electric Co. Model 4K102, or equivalent)
10. Fan impeller, aluminum, 6-inch diameter, 6 blades (1-1/2 by 1-1/4 inch)
11. Thermoswitch (Fenwall Cat. No. 17752, or equivalent)
12. Heating element, 110-V, 500-W (Chromolox strip heaters No. S3450, or equivalent)
(d) Sandblast cover plate until all of the original surface has been removed.

CAUTION
After blasting, avoid handling sandblasted surface and protect from all foreign materials.

(e) Pour one quart of dry-cleaning solvent over cover plate, and allow to drain and air-dry.

Note 5. Do not spray solvent or blow air into cover plate since entrained moisture may be present.

(f) When the cover plate is dry, pour a small amount of the test oil over the entire sandblasted area, and immediately install on test unit.

(g) Insert the axle seals; leave one of the seals loose to vent the housing while adding oil and water. Install street elbow in cover plate fill hole.

(h) Remove the relief valve and fill the test unit with 2.5 pints of the test lubricant through the street elbow.

5.3 Operate the test unit as follows:
(a) Turn on the driving mechanism, and bring the pinion speed to 2500 rpm. Note and record the time, and the temperature of the lubricant.

(b) Add one ounce (29.6 ml) of distilled water to the lubricant in the test unit, and reinstall the relief valve. Immediately tighten the axle seals.

(c) Adjust the temperature control equipment to maintain a lubricant temperature of 180° ± 2°F, and allow the unit to warm up.

(d) When the lubricant temperature reaches 180°F, record the time and install the pipe plug in the relief valve vent opening, and continue to operate the test unit for four hours at 2500 rpm.

5.4 At the end of four hours of operation, disconnect the motor from the test unit, and remove the heat lamps and the fan. Immediately cover the unit with the controlled-temperature storage box. (See Figure 4.) Turn on the circulating fan, but do not connect the heaters until the temperature within the box reaches approximately 140°F.

5.5 When the enclosure temperature reaches 140°F, connect the heaters and store the test unit at 125° ± 2°F, for the stipulated time.

5.6 At the end of the specified storage period, drain the lubricant and remove the cover plate.

5.7 If conducting a one-day test, record the percentage of the area corroded on the cover plate above the oil level. Also indicate the intensity and color of the corrosion products. Report the results on a test report form similar to that shown in Figure 4.

5.8 If conducting a seven-day test, record and report conditions noted in paragraph 5.7. Also disassemble the test unit, inspect all parts for corrosion, and report the conditions on the report form.
# LABORATORY TEST QUESTIONNAIRE AND FINAL SUMMARY OF RESULTS

## A. GEAR LUBRICANT IDENTIFICATION
1. **Company**
2. **Brand Name**
3. **Formula No.**
4. **Viscosity Grade**

## B. GEAR TEST IDENTIFICATION
1. **Test run at**
2. **Under Code No.**
3. **Test No.**
4. **Date of Start**
5. **Finish**
6. **Test Duration**

## C. EVALUATION OF TEST PARTS
1. **Before Test:**
2. **After Test**
   - a. **Cover Plate:**
   - b. **Ring Gear:**
   - c. **Pinion Gear:**
   - d. **Bearings:**
   - e. **Differential Gear:**
   - f. **Housing and Miscellaneous Parts:**

## D. GENERAL OPERATING CONDITIONS
1. **Bearing Preloads**
   - a. Case-carrier assembly interference, inches:
   - b. Pinion torque, lb-in:
   - c. Full differential assembly, lb-in:
2. **Warm up**
   - a. **Time:** Start Finish
   - b. **Temperature, °F:** Start Finish
3. **Motoring Phase**
   - a. **Time:** Start Finish
   - b. Average Pinion Speed RPM
   - c. Oil Temperature, °F: Avg; Max; Min

## FIGURE 4—Typical report form.
APPENDIX V-a

A CRC group is currently active in developing a new moisture corrosion test to replace the L-33. The following describes a modification of the L-33 as accepted in the interim by the Army Materiel Command.

OUTLINE

The test lubricant and one ounce of distilled water are mixed in a new unloaded hypoid differential carrier assembly by driving the pinion gear with an electric motor at 2,500 rpm for four hours with the bulk oil temperature at 180 F. The sealed assembly is then enclosed by a heated, double-walled, aluminum box and stored for an additional 162 hours at 125 F with no rotation. The carrier assembly is disassembled at the end of the test and the components rated for stains, rust and corrosion, with particular emphasis on the cover plate which is sandblasted before the start of the test. Requirements for passing the test include having less than 1% area rust on the cover plate and no rust on the internal gears and bearing surfaces (functional parts).

EQUIPMENT DESCRIPTION

The portable test stand is self-contained with the exception of a wall-mounted temperature recorder/controller. The major components of the test apparatus are:

A. Gear Carrier and Cover Assembly:

   Available from Dana Corporation, Axle Division, Dana Part No. 26217X, includes No. 32538 cover plate.

B. Variable Speed Pulley and Mounting Accessories:

   1. Dodge "Dyn-Adjust" Belt
      Series 19 - 1-3/16" x 13/32" pitch length

   2. Slide motor base, "Dyn-Adjust" No. 20-C.


C. Driving Motor:

   U.S. Motors, 1-1/2 hp, enclosed, 3,600 rpm, 7/8" dia. shaft.
APPENDIX V-a  Modified L-33

D. Pressure Relief Valve

James, Pond and Clark
Model 259B-2PP, set for 1 psi
Brass, 1/4"-18 NPT

E. Fan and Heat Lamps

Two 250-watt heat lamps with individual mounting stands.
Household-type electric fan with 12" dia. blades.
Heat lamps and fan to be mounted as shown in Figure 1.

F. Temperature Controller/Recorder

Honeywell recorder, Model No. 452CLL-33-P1-75.
Rosemount Engineering Co. temperature probe, Model 104MC-7AEA, with mating connector (platinum).

G. Sandblasting Material

99.8% SiO_2, Moh hardness of 7.
American Foundryman's Soc. grain fineness No. 26.
Available from: Wedron Sand Co.
135 S. LaSalle St.
Chicago, Illinois
Wedron Sand No. 4098

H. Axle Seals

Make from materials as shown in Figure 2.

I. Storage Box

The box is constructed according to drawings supplied with the Armour Research Foundation Report (see Section X). The particulars regarding construction of the box and the recirculating fan blade should be closely followed.

The electrical wiring should be connected to allow the recirculating fan to run with and without the strip heaters being on.

LUBRICANT REQUIREMENTS

One gallon of test fluid is required for the test. The capacity of the carrier assembly is 2.5 pints. The remaining oil is used for coating the test parts during assembly and for pouring over the cover plate after it has been sandblasted before test.
APPENDIX V-a

EQUIPMENT STANDARDIZATION

A. Reference Fluid

There are no official reference oils; however, RGO-110 (SAE 90) should give borderline results when the test is run as specified in this procedure (7-day duration).

B. Repeatability-Reproducibility

To be determined.

C. Quality Control

Strict attention to differential build-up procedure is essential to controlling test repeatability.

MECHANICAL PROCEDURES

A. Place a new differential assembly in a bench-mounted holding fixture. Remove and inspect the cover plate. The cover plate must be rust-free to be used in the test.

B. Remove the carrier bearing caps and lift the carrier assembly from the housing.

C. Remove the spider gears from the carrier assembly.

D. Remove the pinion gear from the housing.

E. Drill and tap the housing for the temperature probe. The location of the probe is shown in Figure 3.

F. Spray each component individually with Stoddard solvent and thoroughly air-dry. Make certain that the grease applied to bearings by the manufacturer has been completely removed.

G. Carefully inspect all parts for rust. Discard the ring gear, pinion gear or bearings if there is any rust on them. Light surface rust on other parts may be removed with fine emery paper or a wire brush. Record the extent and location of any rust found and removed on the data sheet. The parts should be recleaned with Stoddard solvent after the rust has been removed.

H. Install the pinion gear and support bearings in the housing. Thoroughly coat the housing, gear, shaft, and bearings with the test fluid during assembly.
APPENDIX V-a

I. Determine and record on the data sheet the pinion shaft torque. The break torque should be 7-10 in-lb; the turning torque should be 5 in-lb or less. The torque may be adjusted by adding or removing shims from the pinion shaft as necessary.

J. Install the spider gears in the carrier and place the assembly in the housing. Use a new 1" paint brush to cover all parts and surfaces with test oil during assembly. Install temperature probe in housing.

K. Determine and record on the data sheet the break and turning torque of the assembled unit. The break torque should be 15 ± 3 in-lb; the turning torque should be 10 ± 3 in-lb. If necessary, adjust the carrier preload by adding or removing shims behind the carrier bearings as required.

L. Make a cover plate gasket from a manila folder of sufficient size. It is important that this material be used because of its effect on corrosion at the cover plate/housing interface.

M. Thoroughly clean a new rust-free cover plate using Stoddard solvent and a fiber brush. Sandblast the plate using approx. 1 quart of new sand (specified in III.G.) and 100 psi air pressure with a 1/8" dia. nozzle. It is important that the inside of the plate be evenly and completely resurfaced.

After the sandblasting is finished, do not touch the surface. Clean the cover by pouring Stoddard solvent over the plate and allow it to stand until dry. (Do not use compressed air for drying as it may contain moisture.) Rinse the plate again using acetone and allow it to stand until dry.

N. Pour approximately one quart of the test oil over the sandblasted surface of the cover plate. The entire surface must be wetted. Allow the excess oil to drain from the cover and bolt it to the axle housing.

O. Install the axle shaft plugs in the housing, but do not tighten. The plugs should be inserted in the housing until they touch the carrier bearings.

P. Install the completed assembly on the test stand. Connect the drive shaft, variable speed pulley drive, and temperature probe.

Q. The test should be started the same day the cover plate is installed.

R. Install the fan and heat lamps as shown in Figure 1.
OPERATIONAL PROCEDURES

A. Add 2.5 pints of test oil to the assembly through the cover plate fill hole.

B. Adjust the temperature controller to 180 F.

C. Start the driving motor and adjust the variable speed pulley to give a pinion speed of 2500 ± 25 rpm. Use a strobe light to check the speed. Record the time and the initial oil temperature on the data sheet.

D. Add one ounce of distilled water to the lubricant. Immediately tighten the axle shaft seals and install the relief valve in the cover plate.

E. Some lubricants may foam enough, after the addition of the water, to leak past the relief valve (set at 1 psi). When this occurs, loosen the axle seal on the side opposite the heat lamps to vent the housing until the leakage stops. Immediately tighten the axle seal. Repeat this procedure, if necessary, minimizing the time the axle seals are loosened, until the temperature reaches 180 F.

F. Install a pipe plug in the open end of the relief valve when the lubricant temperature reaches 180 F. Record the time on the data sheet. Continue the motoring phase for four hours at 180 ± 2 F.

G. Record the time when the four-hour motoring phase has been completed; disconnect the drive shaft from the test unit; remove the heat lamps and fan from the test stand. Immediately cover the assembly with the storage box (see VII. I.). Turn on the circulating fan. When the oil temperature reaches 140 F, turn on the heater switch and record the time on the data sheet (storage phase, start).

H. Control the test oil temperature at 125 ± 2 F indirectly by maintaining the air temperature in the box at 125 F with the Fenwal controller. Once the Fenwal has been correctly adjusted, it should not be necessary to readjust it for subsequent tests.

I. The storage phase is continued for 162 hrs. or approx. seven days. A shortened storage phase lasting only 18 hours may be run as a screening test if desired. The procedure for shortened (1 day) test is identical to that for the seven-day test except for the length of the storage time.
APPENDIX V-a

J. Record on the data sheet the time when the 162-hour storage phase has been completed. Remove the differential assembly from the test stand and place it in the holding fixture. Do not turn the pinion shaft. Carefully remove the cover plate. Drain the oil from the housing. Indicate the fluid level on the ring gear and pinion, using a suitable marking pencil.

K. Remove the carrier bearing caps and lift the carrier assembly from the housing. It is not necessary to remove the spider gears.

L. Remove pinion gear, bearings and races from the housing.

M. Take the disassembled unit to the inspection room (Rm. 460) for rating and photographing.

INSPECTION PROCEDURES

A. Rating of Test Parts

Before rating, parts are to be sprayed lightly with Stoddard solvent, then allowed to stand until dry. This will remove the test oil so that an accurate rust rating can be determined. On the cover plate only, dry compressed air may be used to avoid stain lines from the solvent.

The following parts should be rated, indicating the amount, intensity, color, and location of any corrosion products. (Indicate whether the product is rust, sludge, stain, etc., if possible. Indicate the area percent of surface rust on the cover plate.)

1. Cover plate
2. Pinion gear
3. Spider gears
4. Ring gear
5. Bearings
6. Housing

An oil is considered to pass the test when there is less than 1% area surface rust on the cover plate and no rust on the gears or bearing surfaces. Light stain on these parts may be acceptable.
B. Photographs

The following color photographs should be taken immediately after the test is completed to avoid additional rust, corrosion, or discoloring of the test parts:

1. Cover plate.
2. Worst carrier bearing cap and outer race.
3. Ring gear, carrier, and support bearing (from ring gear side).
4. Ring gear, carrier, and support bearing (opposite side from #3).
5. Pinion gear and bearing.

C. Disposition of Test Parts

1. After rating and photographing is completed, individually coat each component with a rust preventive oil such as Mobilarma 245. Mobilarma 245 is a solvent-based, thin-film rust preventive product with water-displacing properties which meets Aeronautical Material Spec. 3065-C. Allow excess oil to drain from the part. The cast iron housing may be discarded.

2. Wrap each part in a chemically treated, corrosion-inhibiting paper (NO\textsubscript{x} Rust Vapor Wrapper, available from Daubert Chemical Co., Oakbrook, Ill.) and seal with masking tape.

3. Place the wrapped pieces in a 12" x 30" plastic bag; add 4 or 5 rust inhibiting discs (No Wrap Rust Inhibitor Discs, 350 cu. in. size, Chippewa Paper Products Co., Inc., Chicago, Ill.); and tie the end of bag.

4. Pack in suitable box for storage or shipment, as requested by test sponsor.
PLACE HEAT LAMPS AND FAN AS SHOWN
HEAT LAMPS TO BE APPROX. 2 INCHES FROM HOUSING
FAN TO BE APPROX. 6 INCHES FROM HOUSING

DIMENSIONS IN INCHES

Figure 1
Heat Lamp and Fan Arrangement
Figure 2
Axle Seals
Note: Temperature probe should be approx. 1" from ring gear teeth.

Figure 3
Temperature Probe Location
# APPENDIX V-a

## Modified L-33

## REPORT FORM

<table>
<thead>
<tr>
<th>Test Fluid</th>
<th>Lab No.</th>
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<td>Run No.</td>
<td>Charge No.</td>
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<tr>
<td>Requestor</td>
<td>Date</td>
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<td>ETL Approval</td>
<td>Date</td>
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## Operating Conditions

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<td>Break</td>
</tr>
<tr>
<td>Full Assembly Torque, lb.-in.</td>
<td>Break</td>
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<tr>
<td>Warm-up Time: Temp:</td>
<td>Start</td>
</tr>
<tr>
<td>Motoring Phase Time:</td>
<td>Start</td>
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<tr>
<td>Average Pinion Speed</td>
<td>RPM</td>
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<td>Oil Temperature, °F:</td>
<td>Avg</td>
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<tr>
<td>Storage Phase Time:</td>
<td>Start</td>
</tr>
<tr>
<td>Oil Temperature, °F:</td>
<td>Avg</td>
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## Data Summary

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