



## 1. SCOPE

This SAE Information Report was prepared by the SAE Fuels and Lubricants Technical Committee for two purposes: (a) to assist the users of automotive equipment in the selection of axle<sup>1</sup> and manual transmission lubricants for field use, and (b) to promote a uniform practice for use by marketers of lubricants and by equipment builders in identifying and recommending these lubricants by a service designation.

## 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 or ASTM 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 724-776-4970 (outside USA), [www.sae.org](http://www.sae.org).

SAE J306 Automotive Gear Lubricant Viscosity Classification

SAE J2360 Lubricating Oil, Gear Multipurpose (Metric) Military Use

LRI Gear Lubricant Review Procedures

#### 2.1.2 ASTM Publications

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, [www.astm.org](http://www.astm.org).

ASTM D 92 Flash and Fire Points by Cleveland Open Cup

ASTM D 94 Saponification Number of Petroleum Products

ASTM D 97 Pour Point

ASTM D 129 Sulfur in Petroleum Products by the Bomb Method

ASTM D 130 Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test

ASTM D 287 API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)

ASTM D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)

ASTM D 471 Test Method for Rubber Property—Effect of Liquids

ASTM D 524 Ramsbottom Carbon Residue of Petroleum Products

ASTM D 664 Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration

ASTM D 808 Chlorine in New and Used Petroleum Products (Bomb Method)

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<sup>1</sup> Axle in this document is defined as a drive axle incorporating reduction gearing and/or differential gears.

- ASTM D 874 Sulfated Ash from Lubricating Oils and Additives
- ASTM D 892 Test Method for Foaming Characteristics of Lubricating Oils
- ASTM D 893 Insolubles in Used Lubricating Oils
- ASTM D 1091 Phosphorus in Lubricating Oils and Additives
- ASTM D 1500 ASTM Color of Petroleum Products (ASTM Color Scale)
- ASTM D 1552 Sulfur in Petroleum Products (High-Temperature Method)
- ASTM D 2270 Calculating Viscosity Index from Kinematic Viscosity at 40 and 100 °C
- ASTM D 2622 Sulfur in Petroleum Products (X-Ray Spectrographic Method)
- ASTM D 2887 Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
- ASTM D 2983 Test Method for Low-Temperature Viscosity of Lubricants Measured by Brookfield Viscometer
- ASTM D 3228 Total Nitrogen in Lubricating Oils and Fuel Oils by Modified Kjeldahl Method
- ASTM D 4047 Phosphorus in Lubricating Oils and Additives by Quinoline-Phosphomolybdate Method
- ASTM D 4057 Manual Sampling of Petroleum and Petroleum Products
- ASTM D 4177 Automatic Sampling of Petroleum and Petroleum Products
- ASTM D 4294 Sulfur in Petroleum Products by Non-Dispersive X-Ray Fluorescence Spectrometry
- ASTM D 4628 Analysis of Barium, Calcium, Magnesium and Zinc in Unused Lubricating Oils by Atomic Absorption Spectrometry
- ASTM D 4629 Trace Nitrogen in Liquid Petroleum Hydrocarbons by Syringe/Inlet Oxidative Combustion and Chemiluminescence Detection
- ASTM D 4927 Elemental Analysis of Lubricants and Additive Components—Barium, Calcium, Phosphorus, Sulfur, and Zinc by Wavelength-Dispersive X-Ray Fluorescence Spectroscopy
- ASTM D 4951 Determination of Additive Elements in Lubricating Oils by Inductively-Coupled Plasma Atomic Emission Spectrometry
- ASTM D 5182 Test Method for Evaluating the Scuffing (Scoring) Load Capacity of Oils
- ASTM D 5185 Determination of Additive Elements, Wear Metals and Contaminants in Used Lubricating Oils by Inductively-Coupled Plasma Emission Spectrometry
- ASTM D 5579 Test Method for Evaluating the Thermal Stability of Manual Transmission Lubricants in a Cyclic Durability Test
- ASTM D 5662 Test Method for Determining Automotive Gear Oil Compatibility with Typical Oil Seal Elastomers
- ASTM D 5704 Test Method for Evaluation of the Thermal and Oxidative Stability of Lubricating Oils Used for Manual Transmissions and Final Drive Axles

ASTM D 5760 Standard Specifications for Performance of Normal Transmission Gear Lubricants

ASTM D 6121 L-37 Test—Performance Test for Evaluating the Load Carrying Capacity of Automotive Gear Lubricants Under Conditions of Low Speed and High Torque

ASTM D 7038 L-33—Performance Test for Evaluating the Moisture Corrosion Tendencies of Automotive Gear Lubricants

L-42 Performance Test for Evaluating the Load Carrying Capacity of Automotive Gear Lubricants under Conditions of High Speed Shock Loading

### 2.1.3 API Publication

Available from American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005-4070, Tel: 202-682-8000, <http://api-ec.api.org>.

API 1560 (July, 1995) Lubricant Service Designation for Automotive Manual Transmissions and Axles

### 2.1.4 CRC Publications

Available from Coordinating Research Council, 3650 Mansell Road, Suite 140, Alpharetta, GA 30022, Tel: 678-795-0506, [www.crao.com](http://www.crao.com).

Coordinating Research Council Manual 21

### 2.1.5 Military Publication

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-PRF-2105E

## 3. PERFORMANCE CHARACTERISTICS

In axles and manual transmissions, gears and bearings of different designs are employed under a variety of service conditions. Therefore, the selection of a lubricant involves careful consideration of the performance characteristics required. The following sections describe performance characteristics of axle and manual transmission lubricants which are important in field service. A lubricant is a blend of base stocks and additives optimized for a particular service. Additive packages enhance base stock performance for each performance characteristic.

### 3.1 Load-Carrying Capacity

One of the most important performance characteristics is load-carrying capacity. The load on gear teeth is a function of the contact area of, and the force applied to the surfaces in contact. Contact area is controlled by gear design; applied force is determined by the power needed to drive the equipment. The load-carrying capacity of a gear lubricant is defined by the maximum load which can be sustained by the lubricant without failure of gear teeth surfaces. If the load-carrying capacity is exceeded, the lubricant fails to protect the gears and the gear teeth become damaged. The most common forms of damage are adhesive wear (scuffing) and scoring.

Load-carrying capacity is determined by a fluid's viscosity at the operating temperature, and by additives. Gear lubricants compounded to achieve increased load-carrying capacity may be referred to as "extreme pressure" (EP) lubricants. However, when this term is applied to a gear lubricant, it means only that the load-carrying capacity of the lubricant is greater than that of untreated oil,<sup>2</sup> with no distinction as to how much greater it may be. The American Petroleum Institute (API) has developed a classification system which addresses this concern (see Section 5).

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<sup>2</sup> Untreated oil is defined as either refined petroleum or synthetic lubricant base oil containing no supplemental performance additives.

## 3.2 Viscosity

Viscosity specifications are generally determined by equipment manufacturers. Refer to SAE J306 for axle and manual transmission lubricant viscosity classification information.

### 3.2.1 Viscosity Loss—Multigrade Lubricants

Viscosity and film thickness are critical in both axle and transmission applications. Some multigrade gear lubricants are formulated with viscosity modifiers. Caution should be exercised when multigrade gear lubricants are used, since these may experience significant viscosity loss due to shear in field service. The shear stresses and shear rates encountered in gear applications can be significantly greater than those in most other lubricant applications.

## 3.3 Thermal Stability and Oxidation Resistance

Factors affecting thermal stability (cleanliness) and oxidation (thickening) characteristics while the lubricant is in service include ambient temperature, duty cycle, length of service, and the effects of contamination. Poor lubricant performance can result in oil thickening and/or the formation of deposits on parts. Even when lubricants are stored (prior to use), care should be exercised to ensure that they are not exposed to extreme temperatures and are kept free of contaminants. These precautions are intended to ensure optimum lubricant life.

Modern vehicle designs have resulted in significantly higher operating temperatures in axles and transmissions. Oils which do not have a high degree of thermal stability and oxidation resistance can form significant carbon and varnish deposits, which can cause premature seal failure and/or interfere with frictional surfaces used for traction control.

For automotive axles and transmissions in mild service, the temperature of the lubricant may not be sufficiently high to cause significant oxidation. For vehicles operating in moderate to severe conditions of service such as passenger cars pulling trailers, or for trucks or buses in service where higher temperatures occur, thermal stability and oxidation resistance are important factors. Accordingly, only oils with a high degree of thermal stability and oxidation resistance should be used in these applications. The vehicle operator should consult the manufacturer's service guide for drain and refill recommendations.

## 3.4 Foaming and Air Entrainment

Excessive foaming may interfere with proper lubrication of gear and bearing surfaces and, consequently, should be avoided. Further, foaming can cause leakage via normal venting passages, thereby reducing lubricant sump volume. Foam can appear as a heavy froth on the surface of the oil. Air entrainment occurs when tiny air bubbles remain suspended in the body of the oil.

## 3.5 Corrosion

Corrosion is a chemical reaction of a metal surface with oil additives, contaminants or oil degradation by-products which produces a surface film and/or soluble metal salts. Corrosion of ferrous or copper-containing metals can result in a build-up of iron and copper in the oil, leading to decreased oxidation resistance (see 3.3). As defined by the Coordinating Research Council, corrosion is "a general alteration of the finished surfaces accompanied by roughing not attributable to mechanical action."

Excessive corrosion of heavy-duty components can lead to: (a) the reduction of designed contact areas, (b) an increase in insoluble debris, and (c) excessive movement ("play") of corroded components.

### 3.5.1 Rusting

Rusting is a special case of corrosion of ferrous metals in the presence of water. Rust deteriorates or alters the original metal surface. It is evidenced by at least two of the following characteristics:

- a. Color (usually red, yellow, brown, or black)
- b. Depth (build-up or depression relative to adjacent areas)
- c. Texture (such as etching or scale)

(See Coordinating Research Council Manual 21.)

### 3.6 Seal Compatibility

While the primary function of a gear lubricant is to protect gears and bearings, consideration must be given to the effect of a lubricant on seal elastomers used in the design of the component. Factors that can lead to early seal failure are loss of elongation or the ability to follow the shaft; change in hardness, which can lead to cracking; and volume change or swell, causing increased seal wear. Immersion testing, at conditions specific for axles and transmissions, may be used to establish the relative compatibility of the lubricant and the seal material. Dynamic seal tests which simulate the mechanical action of a seal and a fluid may also need to be run. Seal compatibility can be affected by choice of base stocks and additives. Seal effectiveness can also be degraded by oil degradation products.

### 3.7 Energy Efficiency

As federally based fuel economy and emissions control regulations become increasingly severe, energy efficiency of transmission and axle fluids becomes increasingly important. Energy efficiency can be impacted by both the viscometric characteristics of the oil and the frictional properties of additives used in the formulation. Optimizing a formulation for fuel economy requires a thorough understanding of the mechanical and chemical aspects of the system so that durability will not be sacrificed.

### 3.8 Limited Slip

Limited Slip axles have special friction requirements. Axle manufacturers often recommend a particular limited slip additive that should be formulated into lubricants for these axles. Oils formulated with the improper type or amount of friction modifier may cause these axles to develop noise and/or fail prematurely.

## 4. USE AND HANDLING OF GEAR LUBRICANTS

### 4.1 Mixing Gear Lubricants

As a general practice, the mixing of lubricant types should be avoided. Specifically, mixing gear lubricants with engine oils can result in incompatibility due to reactions between the additive chemicals. Such reactions may result in a significant loss of performance or gear protection.

The mixing of SAE J2360 type approved lubricants as in a top-up situation should not impair lubricant performance. SAE J2360 type lubricants are required to demonstrate satisfactory storage stability and compatibility when mixed with previously qualified gear lubricants.

## 5. API GEAR LUBRICANT CLASSIFICATION

The following designations have been amended with the objective of improving user understanding of intended lubricant application. Refer to API Publication 1560, July 1995, for further information.

## 5.1 Service Designations Not in Current Use

The following categories were declared inactive by SAE Technical Committee 3 on March 1, 1995. Oils with these inactive categories may be found in the marketplace. However, ASTM does not plan to maintain the performance tests associated with these categories. In some cases these tests can no longer be run because parts or test installations are not available.

- 5.1.1 API GL-2 designates the type of service characteristic of automotive type worm-gear axles operating under such conditions of load, temperature, and sliding velocities, that lubricants satisfactory for API GL-1 service will not suffice.

Products suited for this type of service contain antiwear or very mild extreme-pressure agents which provide protection for worm gears. Oils containing overly active extreme pressure agents may cause corrosive wear of copper based worm gear components. Special care should be given to selecting the proper lubricant for worm gear applications.

- 5.1.2 API GL-3 designates the type of service characteristic of manual transmissions and spiral-bevel axles operating under mild to moderate to severe conditions of speed and load. These service conditions require a lubricant having load-carrying capacities greater than those that will satisfy API GL-1 service, but below the requirements of lubricants satisfying the API GL-4 service.

Gear lubricants designated for API GL-3 service are not intended for hypoid gear applications.

- 5.1.3 API GL-6 designates the type of service characteristic of gears designed with a very high pinion offset. Such designs typically require (gear) score protection in excess of that provided by API GL-5 gear oils. The original API GL-6 test equipment is obsolete.

## 5.2 Service Designations in Current Use

- 5.2.1 API GL-1 designates the type of service characteristic of manual transmissions operating under such mild conditions of low unit pressures and minimum sliding velocities, that untreated oil may be used satisfactorily. Oxidation and rust inhibitors, defoamers, and pour depressants may be used to improve the characteristics of lubricants intended for this service. Friction modifiers and extreme pressure additives shall not be used.

Due to the speeds and loads involved, untreated oil is generally not a satisfactory lubricant for many passenger car manual transmissions.<sup>3</sup> For some truck and tractor manual transmissions, untreated oils may be used successfully. In all cases, the transmission manufacturers' specific lubricant recommendations should be followed.

- 5.2.2 API GL-4 designates the type of service characteristic of spiral-bevel and hypoid<sup>4</sup> gears in automotive axles operated under moderate-speeds and loads. These oils may be used in selected manual transmission and transaxle applications. (Users should consult axle/transmission manufacturers' specific lubricant recommendations.)

While this service designation is still used commercially to describe lubricants, some test equipment used for performance verification is no longer available. SAE is reviewing the performance requirements of this category.

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<sup>3</sup> Automatic or semiautomatic transmissions, fluid couplings, torque converters, and tractor hydraulic systems usually require special lubricants. For the proper lubricant to be used, consult the equipment manufacturer or lubricant supplier.

<sup>4</sup> Friction requirements for axles equipped with limited slip differentials are normally defined by the axle manufacturer.

5.2.3 API GL-5 designates the type of service characteristic of gears, particularly hypoids in automotive axles operated under high-speed and/or low-speed, high-torque conditions. Lubricants qualified under SAE J2360 satisfy the requirements of the API GL-5 service designation. Details of the API GL-5 performance tests can be found at the ASTM Test Monitoring Center website: [www.astmtmc.cmu.edu](http://www.astmtmc.cmu.edu).

5.2.4 API MT-1 designates lubricants intended for non-synchronized manual transmissions used in buses and heavy-duty trucks. Lubricants meeting API MT-1 provide protection against the combination of thermal degradation, component wear, and oil seal deterioration which is not provided by lubricants meeting only the requirements of API GL-4 and GL-5.

API MT-1 does not address the performance requirements of synchronized transmissions and transaxles in passenger cars and heavy-duty applications.

API MT-1 lubricants should not be mixed with engine oils in the same transmission unit.

Transmission manufacturers' specific lubricant quality recommendations should be followed.

### 5.3 Performance Tests

Table 1 lists lubricant tests which are used to evaluate the performance characteristics discussed in Section 3. Tests which are used to define the performance levels of active API Categories are noted.

Successful performance on such tests does not automatically ensure satisfactory performance under field service conditions.

#### 5.3.1 Reference Oils

Most tests used to define performance for the API gear oil categories are calibrated using selected reference oils. These oils are maintained by the ASTM Surveillance Panels which are responsible for the tests. The testing and inventory of these oils is carried out by the ASTM Test Monitoring Center. The oils are normally available only to laboratories which maintain or are qualifying test stands which are certified for LRI approval testing of oils. Information about reference oils can be obtained by contacting the Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206 (Tel: 412-365-1000).

## 6. OEM SPECIFICATIONS

Over the last 25 years competitive and regulatory pressures have accelerated the pace of nearly all facets of vehicle innovation including the axle and transmission. Lubricants for these components have had to evolve to maximize the benefits available from the new designs. In many cases the new commercial needs could not be satisfied with a typical MIL Spec oil. This led many axle and manual transmission builders to develop their own specifications. OEM's have built more stringent requirements into some of their specifications to achieve higher levels of performance from their vehicles.