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(Revision of ANSI/AGMA 9005-E02)

American National Standard

Industrial Gear Lubrication

ANSI/AGMA 9005-F16

**American
National
Standard*****Industrial Gear Lubrication***

ANSI/AGMA 9005-F16

[Revision of ANSI/AGMA 9005-E02]

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ABSTRACT

This standard provides lubrication guidelines for enclosed and open gearing installed in general industrial power transmission applications. It is not intended to supplant specific instructions from the gear manufacturer.

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Foreword

[The foreword, footnotes and annexes, if any, in this document are provided for informational purposes only and are not to be construed as a part of ANSI/AGMA Standard 9005-F16, *Industrial Gear Lubrication*.]

AGMA formed the Lubrication Committee in 1938 to study gear lubrication problems. This committee drafted tentative standard 250.01, *Lubrication of Enclosed and Open Gearing*, which was accepted in 1943 and adopted as a full standard in 1946. Lubrication Standard 250.01 was revised to include only industrial enclosed gearing and was accepted by the membership in 1955 as AGMA 250.02. AGMA 250.03, which was published in 1972, superseded AGMA 250.02 as well as AGMA 250.02A, *Typical Manufacturer's Oils Meeting AGMA Standard 250.02*, May, 1956, and AGMA 252.02, *Mild Extreme Pressure Lubricants*, May 1959. The list of Typical Manufacturer's Oils was eliminated due to difficulties in keeping such a list up to date. AGMA 250.03 contained instead, a list of detailed specifications that had to be met before an oil could be recommended for use in AGMA rated gear drives. It then became the responsibility of the oil supplier to certify a particular product as meeting AGMA specifications. AGMA 250.04, published in 1981, eliminated lead naphthenate as an EP additive and adjusted the AGMA lubricant numbering system to be coincident with the viscosity ranges established by the American Society for Testing Materials (ASTM D 2422), the British Standards Institute (B.S. 4231), and the International Standards Organization (ISO 3448).

The elimination of open gearing, where the bearings are lubricated separately, from AGMA 250.02 created the need for a new standard to cover this area of lubrication. AGMA Standard AGMA 251.01, *Lubrication of Industrial Open Gearing*, was approved in April 1963. This standard was revised in September, 1974. AGMA 251.02 extended coverage to bevel gears. Other changes included the addition of AGMA Lubricant Numbers based on the ASTM viscosity system and complete specifications for R & O gear oils and EP gear lubricants, and the addition of an appendix on test procedures and limits.

AGMA Standard 9005-D94 again combined enclosed and open gearing, superseding AGMA 250.04 and AGMA 251.02. In addition, it was updated to reflect market changes in availability of heavy bodied open gear lubricants. It was also expanded to provide coverage of modern technology in the area of synthetic oils. Synthetic oils were recognized as a separate class of lubricants with their own specification requirements. Specifications of EP oils were upgraded to reflect advances in technology. EP oils were no longer recommended for wormgear service. Pitch line velocity replaced center distance as the parameter for lubricant selection in other than double enveloping wormgear applications. Annex B provided a copy of Table 3 from AGMA 250.04 for information only.

References to Saybolt viscosity (SSU) were eliminated in favor of kinematic viscosity (mm^2/s , commonly referred to as cSt). This was consistent with practices of the American Society for Testing Materials, the Society of Tribologists and Lubrication Engineers, the British Standards Institution, and industry in general. Annex A provided information on the theory of elastohydrodynamic lubrication.

ANSI/AGMA 9005-E02 attempted to offer the end user and equipment builder more definitive guidelines for selecting lubricants based on current theory and practice in the industry, and attempted to align with current ISO standards. The document was focused on providing the correct viscosity and performance level for the application by providing the user a series of informative tables to match their equipment type, operation, and needs to define an appropriate finished lubricant. The first draft of ANSI/AGMA 9005-E02 was made in May 1999. It was approved by the AGMA membership on March 13, 2003. It was approved as an American National Standard on December 31, 2002.

ANSI/AGMA 9005-F16 incorporates updated lubricant performance characteristic test methods and criteria.

Historically, antiscuff lubricants have been called extreme pressure or EP. Extreme pressure is a generic term that is not an accurate description of a lubricant type. Users of this standard are encouraged to transition their terminology away from EP and toward antiscuff or AS.

The FE 8 roller bearing test has been added to the antiscuff table.

A new section has been added describing lubricant enhanced performance characteristics to aid the user in selecting a lubricant with enhanced characteristics.

The previous edition of this standard moved the focus toward lubricant performance characteristics. This edition continues this trend with the lubrication application information present in previous editions being transitioned to AGMA application standards. Those standards are best suited to address the specific lubrication needs for each application. This change will take a full revision cycle of all the applicable AGMA application standards to be fully implemented. Therefore, some application information has been retained but is expected to diminish or be eliminated in future editions of this standard.

The end user is encouraged to work with their equipment builder and lubricant supplier to achieve the most reliable system for their needs.

The first draft of ANSI/AGMA 9005-F16 was created in May 2012. It was approved by the membership on February 2016 and as an American National Standard on March 23, 2016.

Suggestions for improvement of this standard will be welcome. They may be submitted to tech@agma.org.

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American National Standard— Industrial Gear Lubrication

1 Scope

This standard provides lubricant classifications, guidelines for minimum performance characteristics, and generalized application and servicing guidelines for both open and enclosed metallic gearing that has been designed and rated in accordance with applicable AGMA Standards. The applicable gear types include spur, helical including double helical and herringbone, worm, non-offset bevel, and face gears.

This standard does not address grease lubricated enclosed gearboxes or aerospace applications. The special regulatory requirements associated with food or drug handling applications are not addressed in this standard, however, the minimum performance characteristics apply. This standard is not intended to replace any existing application standards such as aerospace, automotive, marine, industrial enclosed drives, high speed applications, mill, kiln, or wind turbines. See applicable AGMA application standards for lubrication specific guidelines.

NOTE: This standard is not intended to supplant any specific recommendations of gear manufacturers.

2 Normative references

The following documents contain provisions, which through reference in this text, constitute provisions of this American National Standard. At the time of publication, the editions listed were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to apply the most recent editions of the standards indicated below:

ASTM D2596-15, *Standard Test Method for Measurement of Extreme-Pressure Properties of Lubricating Grease (Four-Ball Method)*

ASTM D2711-11, *Standard Test Method for Demulsibility Characteristics of Lubricating Oils*

ASTM D2893-04(2014)e1, *Standard Test Method for Oxidation Characteristics of Extreme-Pressure Lubrication Oils*

ASTM D2983-15, *Standard Test Method for Low-Temperature Viscosity of Lubricants Measured by Brookfield Viscometer*

ASTM D5950-14, *Standard Test Method for Pour Point of Petroleum Products (Automatic Tilt Method)*

DIN 51819-3:2016-02, *Testing of lubricants – Mechanical-dynamic testing in the roller bearing test apparatus FE8 – Part 3: Test method for lubricating oils, axial cylindrical roller bearing*

ISO 2160:1998 (ASTM D130-12), *Petroleum products – Corrosiveness to copper – Copper strip test*

ISO 2592:2000 (ASTM D92-12b), *Determination of flash and fire points – Cleveland open cup method*

ISO 2909:2002 (ASTM D2270-10e1), *Petroleum products – Calculation of viscosity index from kinematic viscosity*

ISO 3016:1994 (ASTM D97-16), *Petroleum products – Determination of pour point*

ISO 3104:1994 (ASTM D445-15a), *Petroleum products – Transparent and opaque liquids – Determination of kinematic viscosity and calculation of dynamic viscosity*

ISO 3448:1992 (ASTM D2422-97(2013)), *Industrial liquid lubricants – ISO viscosity classification*

ISO 4263-4:2006 (ASTM D943-04a(2010)e1), *Petroleum and related products – Determination of the ageing behaviour of inhibited oils and fluids – TOST test – Part 4: Procedure for industrial gear oils*

ISO 6247:1998 (ASTM D892-13), *Petroleum products – Determination of foaming characteristics of lubricating oils*

ISO 7120:1987 (ASTM D665-14e1), *Petroleum products and lubricants – Petroleum oils and other fluids – Determination of rust-preventing characteristics in the presence of water*

ISO 12937:2000 (ASTM D6304-07), *Petroleum products – Determination of water – Coulometric Karl Fischer titration method*

ISO 14635-1:2000 (ASTM D5182-97(2014)), *Gears – FZG Test procedures – Part 1: FZG test method A/8,3/90 for relative scuffing load-carrying capacity of oils*

ISO 14635-2:2004, *Gears – FZG test procedures – Part 2: FZG step load test A10/16, 6R/120 for relative scuffing load-carrying capacity of high EP oils*

ISO 14635-3:2005, *Gears – FZG test procedures – Part 3: FZG test method A/2, 8/50 for relative scuffing load-carrying capacity and wear characteristics of semifluid gear greases*

3 Terms and definitions

acid number. A measure of the amount of potassium hydroxide needed to neutralize the acidity of a petroleum product. Commonly referred to as AN.

additive. A minority component that is added by the lubricant manufacturer that provides specific improved performance characteristics to a lubricant. Common additives are:

- **antiscuff (previously known as extreme pressure, EP).** Additives designed to minimize severe adhesive wear during boundary lubrication. They form low shear strength sacrificial films by reacting with metal surfaces. See Annex G.
- **antirust.** Lubricant additives based on polar molecules that adsorb on metal surfaces and serve as a barrier against water and protect ferrous metal against rust.
- **anticorrosion.** Lubricant additives that form films on metal surfaces to protect them against the attack of acids and peroxides.
- **antifoam.** Lubricant additives that alter the oil film around air bubbles, reducing the interfacial tension. This leads to the agglomeration of small bubbles into larger bubbles that then rise to the surface, preventing foam formation.
- **antioxidants.** Additives used to inhibit oxidative degradation of base oils by trapping free radicals or decomposing peroxides formed in the oxidation process.
- **antiwear.** Lubricant additives designed to minimize mild adhesive wear during boundary lubrication. They form low shear strength sacrificial films by bonding with the oxide layer. See Annex G.
- **demulsifier.** One of a class of bulk fluid active chemicals that when included in the lubricant causes separation of water in oil emulsions.
- **extreme pressure additive.** See antiscuff.
- **friction modifiers.** Additives that change the friction characteristics of a surface.
- **fatty oils.** Typically manufactured from tallow or other animal byproducts, they are intended to add lubricity.

base fluid. A component or a blend of components, that constitutes the majority of a formulation without any additives or diluents added. These may also be referred to as base oils. Common base fluids are:

- **mineral base.** Manufactured by refining crude oil.
- **synthetic base.** Manufactured by chemical synthesis.

critical gearset. The gearset that has the highest probability of failure in the given application.

efficiency. The ratio of energy output to energy input of a gearbox or other mechanical system. Efficiency is always expressed as a value less than one, with the loss due to friction that generates heat.

elastohydrodynamic lubrication, EHL. EHL lubrication exists when the formation of the fluid film is influenced by the elastic deformation of the contacting surfaces when under highly loaded sliding and rolling conditions, see AGMA 925 [1] for additional details.

high loads. High load applications operate at rated power near the full mechanical rating of the gear drive.

dynamic viscosity. Also known as shear viscosity. The resistance of two layers moving against each other.

kinematic viscosity. The ratio of the dynamic viscosity to the density of a liquid, typically reported in units of mm²/s, cSt.

light loads. Light load applications operate at rated power much lower than the full mechanical rating of the gear drive.

micropitting. A fatigue phenomenon that occurs in Hertzian contacts that operate in elastohydrodynamic or boundary lubrication regimes and have combined rolling and sliding. Damage is the generation of numerous ultra-small cracks that grow at a shallow angle to the surface forming micropits that are about 10–20 µm deep. The micropits coalesce to produce a continuous fractured surface that appears as a dull, matte surface to the observer. See ANSI/AGMA 1010 [2].

residual lubricant. Lubricants of very high viscosity levels typically made from the residual products of the refining process.

viscosity index, VI. A dimensionless number that describes the change in viscosity in relation to temperature commonly calculated using kinematic viscosity. Higher VI means less change in viscosity with changes in temperature.

4 Overview

The lubricant used shall be appropriate for the gears. The lubricant selection should also consider other lube system and mechanical components such as bearings, seals, and auxiliary equipment, such as pumps and heat exchangers, which are affected by the choice of lubricant. Additionally, compatibility with oil seals, sealants, paints, sight gauge material, backstops, clutches, and behavior in the presence of moisture should be checked.

With many open gear drives, the bearings are lubricated independently of the gears, thus allowing for special fluid requirements. Most enclosed and semi-enclosed gear drives utilize one lubricant and lubricant source of supply for the gears, bearings, seals, and pumps.

Overall performance and economics should be analyzed carefully for each type of lubricant under consideration for a given application.

4.1 General

A lubricant is used in gear applications to control friction, minimize wear between the mating surfaces, and remove debris and heat from the contact area. The lubricant must have sufficient viscosity to separate the mating surfaces and have appropriate additives to minimize thermal and oxidative degradation, and provide protection against wear, scuffing, corrosion, foaming, and contribute lubricity and demulsibility.

Lubricant properties can be quite varied depending on the source of the base fluids and the type of additives used. Terminology describing the performance properties of lubricants can be just as varied depending on the definition used. The descriptions provided in this standard are intended to provide the user with information about the term, how it is applied in this standard, and how it is measured. Examples of some properties used to assess lubricant suitability for gear applications are discussed in Annex A.

The physical properties of a lubricant, such as viscosity and pour point, are largely derived from the selected base fluids. While viscosity is the most common property associated with a lubricant, there are

many other properties that contribute to the characteristics of the finished product. The properties of finished gear lubricants result from a combination of base fluid selection and the additives used.

4.2 Lubricant selection

Appropriate lubricant selection depends on matching its properties to the particular application. A detailed elastohydrodynamic lubrication, EHL, analysis of the gear system is the most desirable and thorough assessment of the gear lubrication requirements, but this is not always practical due to the amount of information required. For more information about this approach, see AGMA 925 [1].

Gear manufacturer lubricant recommendations should be followed. However, in the absence of such a recommendation and when detailed information about gear geometry and loading is not available, it is recommended that the user follow the tables in Annex B. These tables provide estimates of the appropriate viscosity grade based on both operating speed and bulk oil operating temperature. Annex B contains four tables since the viscosity grade selected is dependent on the viscosity-temperature characteristics, such as viscosity index of the fluid. The four viscosity indices chosen are considered representative of most fluids currently used in industrial applications. They include viscosity indices of 90, 120, 160, and 240.

The user must identify the type of gearing in, and performance characteristics of, the gearbox to select the correct lubricant. The user should be prepared to identify:

- the materials of all system components, such as:
 - gears;
 - bearings;
 - seals;
 - piping and hoses;
 - sight gauges;
 - paints;
 - sealants;
- operating conditions such as:
 - ambient temperature;
 - operating lubricant temperatures;
 - minimum and maximum pitch line velocities;
- critical special circumstances such as:
 - low temperature start-up;
 - ambient temperatures above 50°C;
 - transient loads.

Using the above information, one can estimate the appropriate viscosity for the particular application based on the effective operating temperature the gears will see in service. Since industrial gear applications involve a wide variety of operating conditions and gear types, lubricants are classified according to their general performance characteristics as well as by their viscosity.

CAUTION: The addition of additives to finished lubricants can have unpredictable and harmful results and should not be attempted by anyone other than the original lubricant manufacturer.

Table 1 is provided as a cross reference for former AGMA grades and currently used ISO viscosity grades.

NOTE: With the change from AGMA viscosity grade equivalents to ISO viscosity grade classifications, the designations S, EP, R, and COMP will no longer be used as part of the viscosity grade nomenclature.

Table 1 – Viscosity grade requirements

ISO viscosity grade	Mid-point kinematic viscosity at 40°C, mm ² /s ¹⁾	Kinematic viscosity limits at 40°C, mm ² /s ¹⁾		Former AGMA grade equivalent
		min	max	
ISO VG 32	32	28.8	35.2	0
ISO VG 46	46	41.4	50.6	1
ISO VG 68	68	61.2	74.8	2
ISO VG 100	100	90.0	110	3
ISO VG 150	150	135	165	4
ISO VG 220	220	198	242	5
ISO VG 320	320	288	352	6
ISO VG 460	460	414	506	7
ISO VG 680	680	612	748	8
ISO VG 1000	1000	900	1100	8A
ISO VG 1500	1500	1350	1650	9
ISO VG 2200	2200	1980	2420	10
ISO VG 3200	3200	2880	3520	11

NOTES:

¹⁾ The preferred unit for kinematic viscosity is mm²/s, commonly referred to as centistoke (cSt).

4.3 Lubricant classifications

For the purposes of this document, lubricants are considered to be in one of three distinct classes: inhibited, antiscuff, or compounded. Each class has its own set of requirements and is intended to provide the correct performance for each application. Open gear lubricants include other classifications such as residual and greases. For more on these types of lubricants refer to ANSI/AGMA 6114 [3].

4.3.1 Inhibited

These are commonly referred to as rust and oxidation inhibited, R&O, lubricants. They are typically formulated with highly refined petroleum or synthetic base fluid and contain additives that enhance oxidation stability, provide corrosion protection, and suppress foam. Other base fluids may be considered, provided they meet the required performance criteria. Their superior oxidation stability typically sets them apart from other gear oil types, however, their load carrying capabilities may be less than other lubricant classes. These lubricants are generally associated with higher speed and lighter load applications. See Table 2 for minimum performance requirements.

4.3.2 Antiscuff

Antiscuff lubricants were formerly known as extreme pressure, EP, lubricants. In addition to protection against corrosion and oxidation, these lubricants contain additives that provide protection against scuffing. These lubricants are typically formulated with mineral or synthetic base fluids. They were developed to protect geared systems operating at high loads and severe impact or reversing conditions. High continuous loads and momentary overloads increase gear tooth contact pressure and surface temperature. If lubricant film thickness is insufficient to support the applied loads, additional additives are required to resist metal-to-metal contact. Consult the gear manufacturer before using these lubricants with internal backstops, over-running clutches, or hold-backs. See Table 3 for minimum performance requirements.

4.3.3 Compounded

Compounded gear lubricants are typically a blend of mineral base fluids with three to ten percent of natural or synthetic fatty oils. These lubricants are traditionally used in wormgear drives. See Table 4 for minimum performance requirements.

5 Minimum performance requirements

Tables 2 through 4 list the minimum requirements for lubricants designated for use as inhibited, antiscuff, and compounded oils. These represent minimum standards in the absence of specific guidelines issued by the equipment manufacturer. In addition to the minimum requirements outlined in Tables 2 through 4, the choice of lubricant should address special circumstances or modes of operation not addressed within this document. Examples of special circumstances include low start-up temperatures, abrasive contaminants, and elevated operating temperatures. These issues should be reviewed with the gear manufacturer and lubricant manufacturer to ensure the proper lubricant is chosen for the conditions.

Table 2 – Minimum performance requirements for inhibited, R&O, lubricants

Property	Test method: ISO/ASTM	Requirements											
Viscosity grade	3448/D2422	32	46	68	100	150	220	320	460	680	1000–3200	>3200	
Viscosity @ 40° C, mm²/s	3104/D445	See Table 1										Report ¹⁾	
Viscosity @ 100° C, mm²/s	3104/D445	Report ¹⁾											
Viscosity index ²⁾ , min	2909/D2270	90								85		Report ¹⁾	
Flash point, °C, min	2592/D92	180			200								
Pour point, °C max	3016/D5950/ D97	-12				-9			-3		Report ¹⁾		
Viscosity at -20 °C ³⁾ mPa S	None/D2983	Report ¹⁾											
Resistance to aging – hours @ 95°C to reach 2.0 acid number, min	4263/D943	1500			750		500		Report ¹⁾				
Water content ⁴⁾ , ppm, max	12937/D6304	300										Report ¹⁾	
Foam suppression – volume of foam, ml, max after:	6247/D892				Temperature		5 min blow		10 min settle		5 min blow		10 min settle
		Seq. I			24°C		50		0		75		10
		Seq. II			93.5°C		50		0		75		10
		Seq. III			24°C		50		0		75		10
Cleanliness		See 7.1.5 and A.2.											
Demulsibility ⁵⁾ - % H ₂ O in oil after 5h test, max	None/D2711 (Procedure A)											Report ¹⁾	
- Emulsion after centrifuging, ml, max		0.5					2.0						
- Total free H ₂ O collected during entire test, starting with 45 ml, H ₂ O ml, min		2.0					4.0					Report ¹⁾	
		30.0					30.0					Report ¹⁾	
Rust prevention, Part A	7120/D665	Pass											
Copper corrosion prevention, 3h @ 121°C, rating, max	2160/D130	1b											
NOTES:													
¹⁾ Lubricant supplier to report value in accordance with stated test method for informational purposes.													
²⁾ Viscosity indices less than the minimum values listed are acceptable if agreed upon by the end user and equipment manufacturer and lubricant supplier.													
³⁾ This information can then be used for the determination of cold start temperature, method of gear drive lubrication, and fluid pumpability. See A.14.													
⁴⁾ Water content of virgin lubricant as packaged. Acceptable value may be greater for some full synthetics, such as polyalkylene glycols (PAG), synthetic blends, or blends of synthetic and mineral base fluids. Value should be agreed upon by the end user and equipment manufacturer and lubricant supplier.													
⁵⁾ Maximum values shown are for mineral oils. Acceptable values may be greater for some full synthetics, such as PAG, synthetic blends, or blends of synthetic and mineral base oils. Acceptable values should be agreed upon by the end user and equipment manufacturer and lubricant supplier.													

Table 3 – Minimum performance requirements for antiscuff (AS) lubricants

Property	Test method: ISO/ASTM	Requirements										
Viscosity grade	3448/D2422	32	46	68	100	150	220	320	460	680	1000–3200	>3200
Viscosity @ 40° C, mm²/s	3104/D445	See Table 1										Report ¹⁾
Viscosity @ 100° C, mm²/s	3104/D445	Report ¹⁾										
Viscosity index ²⁾ , min	2909/D2270	90								85		Report ¹⁾
Flash point, °C, min	2592/D92	180			200							
Pour point, °C max	3016/D5950/ D97	-12				-9			-3		Report ¹⁾	
Viscosity at -20 °C ³⁾ mPa S	None/D2983	Report ¹⁾										
Resistance to aging @ 121°C – max % increase in kinematic viscosity @ 100°C	None/D2893	6						8	10	15	Report ¹⁾	
Water content ⁴⁾ , ppm, max	12937/D6304	300									Report ¹⁾	
Foam suppression – volume of foam, ml, max after:	6247/D892				Temperature		5 min blow	10 min settle		5 min blow	10 min settle	
		Seq. I		24°C		50	0		75		10	
		Seq. II		93.5°C		50	0		75		10	
		Seq. III		24°C		50	0		75		10	
Cleanliness		See 7.1.5 and A.2.										
Demulsibility ⁵⁾ - % H ₂ O in oil after 5h test, max	None/D2711 (Procedure B)	2.0					2.0					Report ¹⁾
- Emulsion after centrifuging, ml, max		1.0					4.0					Report ¹⁾
- Total free H ₂ O collected during entire test, starting with 90 ml, H ₂ O ml, min		80.0					50.0					Report ¹⁾
Rust prevention, part A	7120/D665	Pass										
Copper corrosion prevention, 3h @ 100°C, rating, max	2160/D130	1b										
Scuffing load capacity, FZG, A/8.3/90, fail stage, min	14635-1/ D5182	10	12				>12 ⁶⁾					
FE 8 roller bearing test D7.5/80-80	DIN 51819-3											
- roller wear, mg max		30										
- cage wear, mg		Report										

NOTES:

- ¹⁾ Lubricant supplier to report values in accordance with stated test method for informational purposes.
- ²⁾ Viscosity indices less than the minimum values listed are acceptable if agreed upon by the end user and equipment manufacturer and lubricant supplier.
- ³⁾ This information can then be used for the determination of cold start temperature, method of gear drive lubrication, and fluid pumpability. See A.14.
- ⁴⁾ Water content of virgin lubricant as packaged. Acceptable value may be greater for some full synthetics, such as polyalkylene glycols (PAG), synthetic blends, or blends of synthetic and mineral base fluids. Value should be agreed upon by the end user and equipment manufacturer and lubricant supplier.
- ⁵⁾ Maximum values shown are for mineral oils. Acceptable values may be greater for some full synthetics, such as PAG, synthetic blends, or blends of synthetic and mineral base oils. Acceptable values should be agreed upon by the end user and equipment manufacturer and lubricant supplier.
- ⁶⁾ For viscosities >3200, it is recommended to achieve 400 kgf using Four Ball Weld Test ASTM D2596 in place of FZG.