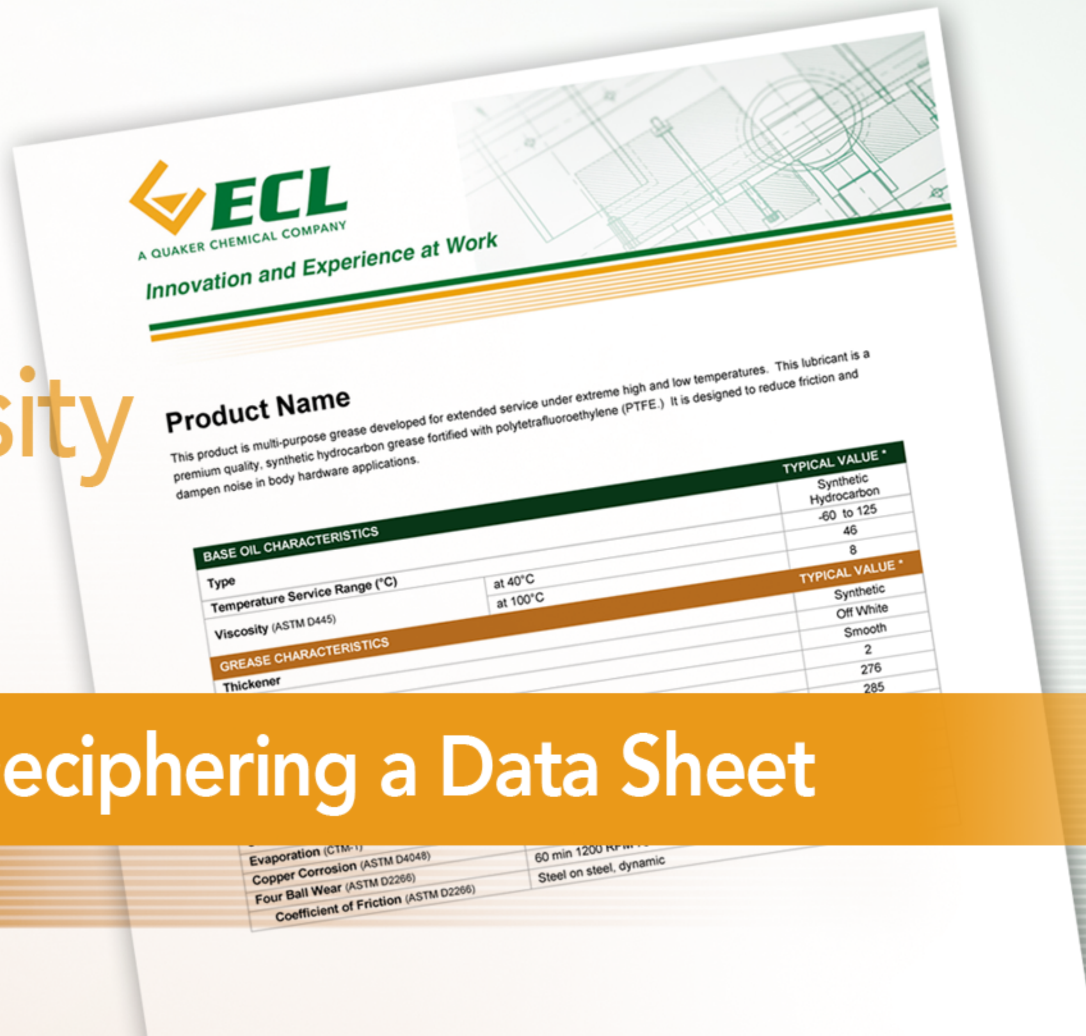
A QUAKER CHEMICAL COMPANY

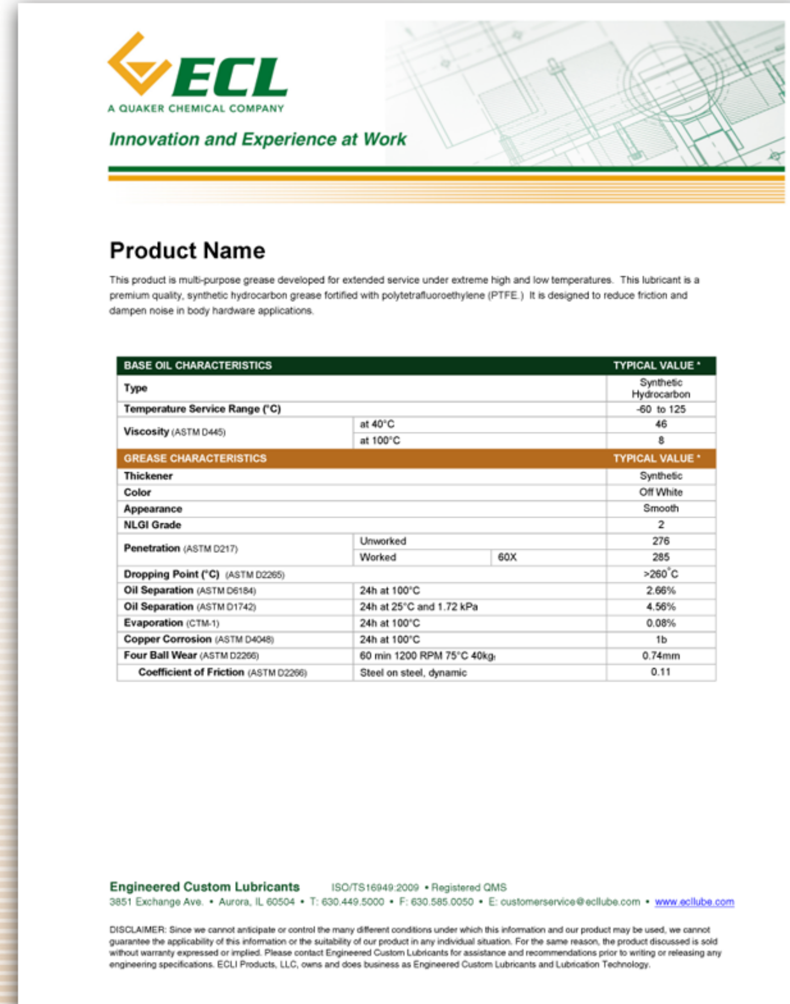
Quick-Study for Product Design Engineers

Temperature
Viscosity
Thickener
Four Ball Wear
ASTM



Deciphering a Data Sheet

Deciphering a Grease Data Sheet



ECL
A QUAKER CHEMICAL COMPANY
Innovation and Experience at Work

Product Name

This product is multi-purpose grease developed for extended service under extreme high and low temperatures. This lubricant is a premium quality, synthetic hydrocarbon grease fortified with polytetrafluoroethylene (PTFE.) It is designed to reduce friction and dampen noise in body hardware applications.

BASE OIL CHARACTERISTICS			TYPICAL VALUE *
Type			Synthetic Hydrocarbon
Temperature Service Range (°C)			-60 to 125
Viscosity (ASTM D445)	at 40°C		46
	at 100°C		8
GREASE CHARACTERISTICS			**TYPICAL VALUE ***
Thickener			Synthetic
Color			Off White
Appearance			Smooth
NLGI Grade			2
Penetration (ASTM D217)	Unworked		276
	Worked	60X	285
Dropping Point (°C) (ASTM D2265)			>260°C
Oil Separation (ASTM D6184)	24h at 100°C		2.66%
Oil Separation (ASTM D1742)	24h at 25°C and 1.72 kPa		4.56%
Evaporation (CTM-1)	24h at 100°C		0.08%
Copper Corrosion (ASTM D4048)	24h at 100°C		1b
Four Ball Wear (ASTM D2266)	60 min 1200 RPM 75°C 40kg		0.74mm
Coefficient of Friction (ASTM D2266)	Steel on steel, dynamic		0.11

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Quick Overview

Grease, like all other materials you specify, plays a key role in the performance, operating life, and cost of the product you're designing.

Data sheets typically have the information you need to choose a grease for testing, but data sheets are written by chemists, not product design engineers.

This Quick-Study will help you read a grease data sheet from a product design perspective.

The Basics: *What is grease and how does it work?*

Oils lubricate. They form a protective film between two surfaces to prevent friction and wear.

Thickeners hold the oil in place, much like a sponge holds water. When mated parts move, the thickener is sheared and releases oil to form a lubricating film between moving parts. Thickeners reabsorb oil when motion stops.

Additives enhance critical performance qualities of a grease, such as low temperature torque, corrosion protection, and oxidation resistance.

Solid lubricants like PTFE, MoS_2, and graphite are load-carrying additives that improve the lubricity of a grease, especially on start-up.

Grease data sheets usually have two sections

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One tells you about the oil

- Type (mineral, synthetic, or blend).
- Functional temperature range.
- Viscosity at specific temperatures.

The other tells you about the grease

- Thickener (soap or non-soap).
- Color, appearance, and NLGI grade.
- Results of several standard lab tests that can be used to select the grease most likely to pass product testing.

Oil Characteristics

Types and Temperatures: *First Step in Selecting Grease*

Operating Temperatures for Oils

Mineral	-30 to 100°C
PolyAlphaOlefin (PAO) Synthetic HydroCarbon (SHC)	-60 to 150°C
Ester	-70 to 150°C
PolyAlkylene Glycol (PAG)	-40 to 180°C
Silicone	-75 to 200°C
PerFluoroPolyEther (PFPE)	-90 to 250°C

Mineral or Synthetic?

- If your part needs to run at temperatures lower than -30°C or higher than 100°C, you'll need a synthetic or a mineral-synthetic blend.
- Material compatibility may also mandate a synthetic oil.

Consider oil blends to increase temperature performance at lower cost

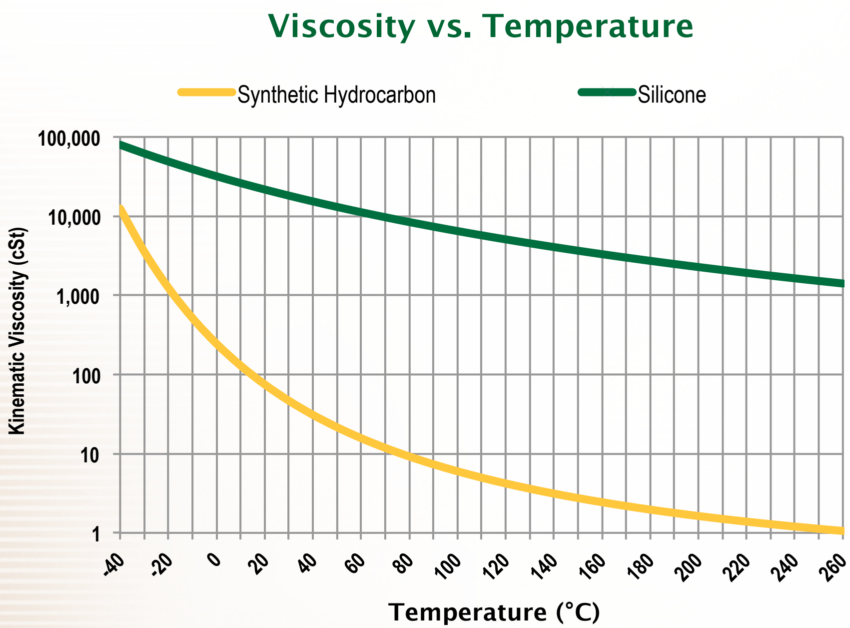
- Mineral oil can be blended with PAOs and esters, but not with other oils.
- Esters and PAGs ***are*** compatible.
- Silicones and PFPEs ***are not*** compatible with other oils.

Choosing a Synthetic Oil

- Temperature performance and oil/material compatibility determine the type of synthetic oil you need.
- As temperature ranges of the base oil expand, cost increases. Don't "buy" more than you need "as a buffer." Oil temperature ranges can be considered accurate during the design and test phases.

Oil Characteristics

Kinematic Viscosity: *Think load, speed, and temperature*



Kinematic Viscosity is an oil's resistance to flow and shear at specific temperatures.

The viscosity of an oil gets thicker at low temperatures and thinner at higher temperatures.

Viscosity and Load

- An oil film must separate two surfaces to reduce friction and wear.
- Heavier loads require higher-viscosity oils to maintain a lubricant film from start to stop. Lighter loads require lower-viscosity oils to prevent viscous drag.

Viscosity and Speed

- Typically, the viscosity of oil does not change with shear, but moving parts generate heat, which can lower the viscosity of an oil.

Viscosity and Temperature

- As temperature increases, the viscosity of the oil decreases — and vice versa.
- Viscosity Index (VI) is a dimensionless number that indicates how much an oil's viscosity will change with temperature. The higher the VI, the less change in viscosity with temperature. To ensure consistent performance over wide temperatures, specify a high VI.

Oil Characteristics

Flash Point and Pour Point: *Fire and "Flow-ability"*

The temperature at which an oil ignites.

Flash Point tells you about the risk of ignition at high temperatures

- Flash Point is the temperature at which an oil momentarily flashes in the presence of a test flame.
- Flash Point is a major consideration in lubricating machinery that handles highly flammable material.
- Make sure the Flash Point is well above the high temperature limit of your part.

The temperature at which an oil no longer flows.

Pour Point tells you the ability of an oil to flow at low temperatures

- Pour Point is the temperature at which oil becomes semi-solid and loses its ability to flow — and therefore its lubricating ability.
- Low-temp operating requirements must be higher than the Pour Point.
- Pour Point depressant additives lower an oil's natural pour point.

Grease Characteristics

Thickeners: *Check compatibility with oil and with operating temperatures and conditions*

How Thickeners Perform under Operating Conditions

	Aluminum	Aluminum Complex	Amorphous Silica	Barium Complex	Bentonite	Calcium	Calcium Complex	Calcium Sulfonate	Lithium	Lithium Complex	Polyurea	PTFE	Sodium Complex
Adhesive	🟢	🟢	🔴	🟢	🟡	🟡	🟢	🟢	🟡	🟢	🟡	🔴	🟢
Autophoretic Paint Process	🟢	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟢	🟢	🟡
Corrosion	🟢	🟢	🟡	🟢	🟡	🟡	🟢	🟢	🟡	🟡	🟢	🟡	🟢
Dropping Point	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟡	🟢	🟢	🟢	🟡
Fretting	🟡	🟡	🟡	🟡	🟡	🟡	🟢	🟢	🟡	🟡	🟡	🟡	🟡
Low Friction	🟢	🟡	🔴	🟡	🔴	🟡	🟡	🔴	🟡	🟡	🟡	🟢	🟡
Salt Water	🟢	🟡	🟢	🟡	🟡	🔴	🟡	🟢	🔴	🟡	🟡	🟢	🟡
Water	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟡	🟡	🟢	🟢	🟢	🔴
Wear	🟢	🟢	🔴	🟢	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Worked Stability	🟢	🟢	🟡	🟢	🟡	🟡	🟡	🟢	🟢	🟢	🟡	🟢	🟡

🟢 Should be safe 🟡 May or may not work 🔴 Don't try it

Some oils and thickeners don't mix well

- Mineral, PAO, and ester oils mix with any thickener except silica.
- Silicone oil mixes only with lithium, silica and PTFE.
- PFPE oil can be thickened only with PTFE.

Thickeners begin to degrade at specific temperatures

- Aluminum <80°C.
- Barium Complex and Lithium <135°C.
- Aluminum Complex, Calcium Complex, Calcium Sulfonate, and Lithium Complex <175°C
- Extreme-temp thickeners include Polyurea (<200°C), PTFE (<275°C), and Amorphous Silica (<300°C).

Some thickeners are better suited to some operating conditions

- Low-temperature performance, corrosion, fretting, low friction, salt water, and wear prevention are all factors to consider when selecting a thickener.

Penetration measures of the relative hardness of a grease

"NLGI Grade"
The relative hardness of a grease, as specified by the National Lubricating Grease Institute (**NLGI**).

NLGI Number	Worked Penetration *(60 strokes)@25°C*	Consistency
000	445 - 475	Ketchup
00	400 - 430	Brown Mustard
0	355 - 385	Tomato Paste
1	310 - 340	Peanut Butter
2	265 - 295	Vegetable Shortening
3	220 - 250	Frozen Yogurt
4	175 - 205	Smooth Pate
5	130 - 160	Cheddar Cheese
6	85 - 115	Caulking Compound

Penetrometers measure consistency of greases

- A cone penetrates the grease for five seconds. Value = depth of penetration (mm) x 10.
- Grease "worked" for 60 or more double strokes simulates consistency of grease in an operating environment.

Selecting the right NLGI Grade

- **NLGI Grades** classify the consistency of worked grease at 25°C, where Grade 000 is semi-fluid like ketchup, and Grade 6 is solid like caulking compound.
- **Use higher NLGI grades** for high operating temperatures, to seal out the environment, and to minimize water washout, oil bleed, or part leakage.
- **Use lower NLGI grades** for cold temperature performance, especially at low speeds, and for sealed, lubed-for-life gearboxes. A lower NLGI grade may also be required to ensure the grease can be pumped through automated and semi-automated dispensing systems

Grease Characteristics

Dropping Point and Oil Separation: *How a grease behaves over time and at high temperatures*

A Guide to Oil-Thickener Compatibility

Thickener		Upper Temp. Limits
Aluminum	AL	<80°C
Aluminum Complex	AL Comp	<175°C
Amorphous Silica	Si	<300°C
Barium Complex	Ba Comp	<135°C
Bentonite Clay	Bentone	<200°C
Calcium	Ca	<110°C
Calcium Complex	Ca Comp	175°C
Calcium Sulfonate	Ca Sul	175°C
Lithium	Li	<135°C
Lithium Complex	Li Comp	175°C
Polyurea	Urea	<200°C
PolyTetraFluoroEthylene	PTFE	<275°C
Sodium Complex	Na Comp	<125°C

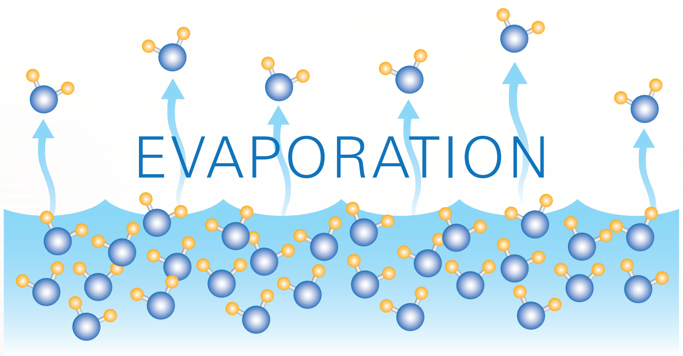
Dropping Point: Indicator of heat resistance

- Dropping Point is the upper temperature limit at which a thickener will hold the oil.
- When heated above its Dropping Point and then allowed to cool, grease may not regain its original consistency, and its performance subsequently may be unsatisfactory.

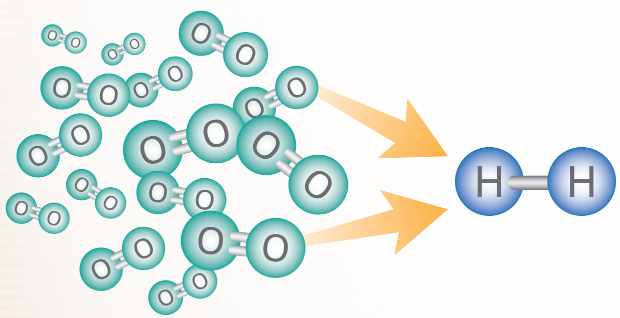
Oil Separation: Tendency of a grease to bleed

- For a grease to be effective, a small amount of oil must separate from the thickener. Expect higher oil separation for softer greases, less for thicker greases.
- Static bleed (ASTM D1742) measures tendency of a grease to separate oil during storage in containers. Separated oil can be decanted or stirred back into the thickener.
- Dynamic bleed (ASTM D6184) measures the tendency of a grease to separate oil at an elevated temperature. Note that dynamic bleed is usually self-healing and should not be extrapolated for extended periods of time.

Evaporation and Oxidation Stability indicate how a grease performs at high temperatures



Evaporation makes grease drier and stiffer.



Oxidation produces insoluble gum, sludge, or lacquers.

Evaporation: High-Heat Oil Loss

- Exposure of grease to high temperatures may cause evaporation of some of the oil, causing the grease to become drier and stiffer — both undesirable changes in grease structure
- Greases that have the least evaporation loss will perform better in high-temperature service.

Oxidation Stability: Ability of a grease to resist oxidizing at high temperatures

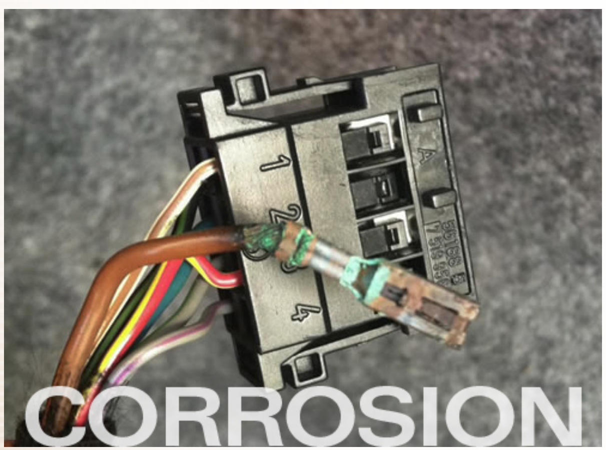
- Prolonged exposure to high temperatures accelerates oxidation in greases.
- Oxidation of grease produces insoluble gum, sludge, or lacquers that cause sluggish operation, increased wear, and reduced clearance.
- For extended operating periods, an oxidation inhibitor is essential, along with a rust inhibitor.

Grease Characteristics

Water Washout and Copper Corrosion

Water Washout: Ability of a grease to withstand the presence of water

- Water can reduce lubricity by washing away oil or by changing grease consistency.
- Minimize water washout by selecting the right type and percentage of thickener in a grease formula.
- ASTM notes that the results of standard water washout tests are not to be considered the equivalent of service evaluation tests.



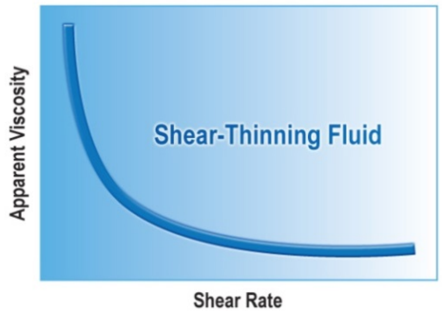
Copper Corrosion: Tendency of a grease to corrode copper under static conditions

- The test: A copper strip is immersed in the grease and placed in an oven. The strip is then cleaned and the tarnish is observed.
- The results: Rated by an ASTM numerical system, where 1 is very little tarnish and 4 is "glossy black." A rating above 2 indicates poor protection.
- ASTM notes that "no correlations with actual field service, most of which are under dynamic conditions, have been established."

Grease Characteristics

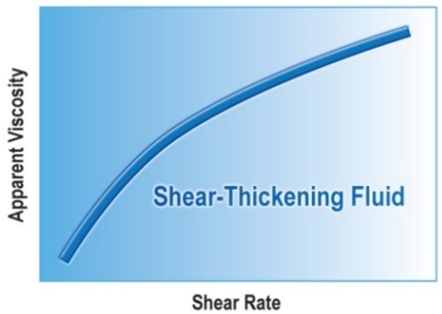
Apparent Viscosity: *It's about shear*

Thixotropic Grease: Shear-Thinning
Viscosity Decreases with Shear



The viscosity of a grease changes when sheared.
Apparent Viscosity, reported in centipoise,
gives a design engineer an indication of the "shear
quality" of a grease at specific temperatures.
(Water is about 1 cP. Wood putty is about 1 million cP.)

Dilatant Grease: Shear-Thickening
Viscosity Increases with Shear



Apparent vs. Kinematic Viscosity

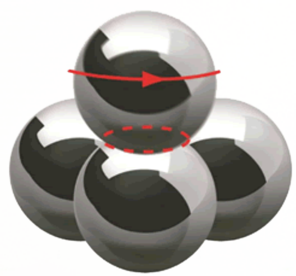
- **Kinematic viscosity** is a characteristic of the base oil. The viscosity of oil may change with temperature or compression but, typically, ***is not affected*** by shear.
- **Apparent viscosity** is a characteristic of the grease. The viscosity of grease ***is affected*** by shear. It will become thinner or thicker.
- **Thixotropic greases** become less viscous when sheared, like butter stirred at room temperature.
- **Dilatant greases** become more viscous when sheared, like water and flour stirred at room temperature.

Apparent Viscosity as a Design Tool: Think Shear

- Knowing the speed, load, and operating temperature range of the part, as well as the grease's viscosity profile, makes it easier to specify the viscosity needed for a mechanical system to operate reliably.
- Knowing a grease's viscosity also helps in evaluating its pumpability, pourability, ease of handling, and suitability for dipping or coating operations — important production and assembly considerations.

Measuring wear and start-up resistance; and estimating amount of grease per part

Four Ball Wear



Four Ball Wear: Steel-on-steel test to indicate how well a grease prevents wear

- Grease is placed on a loaded steel ball that is rotated in a nest of three similar steel balls, after which a wear scar is measured.
- Smaller wear scars = better protection. (0.50 mm under a 40 kg load is considered very good).

Specific Gravity

$$sg = \frac{d_{sample}}{d_{water}}$$

Specify Gravity: Relative density of grease compared to water at 25°C (1.00 g/cm3)

- Helps determine how much grease to put on the part or total grease consumption.
- A part using a high density grease like PFPE (twice the density of water) would need twice as much grease when replacing standard density hydrocarbon, silicone, or ester-based greases, whose specific gravities are close to 1.

Low Temp-Torque

Low Temperature Torque: Resistance Start-Up

- ASTM D1478 measures how much a grease retards the rotation of a slow-speed ball bearing at -40°C.
- Helpful for selecting greases for low-powered mechanisms to ensure there is enough power to shear the grease and create a lubricating film.

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