Chapter 5
Grease

5-1. Description

Grease is a semifluid to solid mixture of a fluid lubricant, a thickener, and additives. The fluid lubricant that performs the actual lubrication can be petroleum (mineral) oil, synthetic oil, or vegetable oil. The thickener gives grease its characteristic consistency and is sometimes thought of as a “three-dimensional fibrous network” or “sponge” that holds the oil in place. Common thickeners are soaps and organic or inorganic nonsoap thickeners. The majority of greases on the market are composed of mineral oil blended with a soap thickener. Additives enhance performance and protect the grease and lubricated surfaces. Grease has been described as a temperature-regulated feeding device: when the lubricant film between wearing surfaces thins, the resulting heat softens the adjacent grease, which expands and releases oil to restore film thickness.

5-2. Function

“The function of grease is to remain in contact with and lubricate moving surfaces without leaking out under gravity or centrifugal action, or be squeezed out under pressure. Its major practical requirement is that it retain its properties under shear at all temperatures that it is subjected to during use. At the same time, grease must be able to flow into the bearing through grease guns and from spot to spot in the lubricated machinery as needed, but must not add significantly to the power required to operate the machine, particularly at startup.” (Boehringer 1992)

a. Applications suitable for grease. Grease and oil are not interchangeable. Grease is used when it is not practical or convenient to use oil. The lubricant choice for a specific application is determined by matching the machinery design and operating conditions with desired lubricant characteristics. Grease is generally used for:

(1) Machinery that runs intermittently or is in storage for an extended period of time. Because grease remains in place, a lubricating film can instantly form.

(2) Machinery that is not easily accessible for frequent lubrication. High-quality greases can lubricate isolated or relatively inaccessible components for extended periods of time without frequent replenishing. These greases are also used in sealed-for-life applications such as some electrical motors and gearboxes.

(3) Machinery operating under extreme conditions such as high temperatures and pressures, shock loads, or slow speed under heavy load. Under these circumstances, grease provides thicker film cushions that are required to protect and adequately lubricate, whereas oil films can be too thin and can rupture.

(4) Worn components. Grease maintains thicker films in clearances enlarged by wear and can extend the life of worn parts that were previously oil lubricated. Thicker grease films also provide noise insulation.

b. Functional properties of grease.

(1) Functions as a sealant to minimize leakage and to keep out contaminants. Because of its consistency, grease acts as a sealant to prevent lubricant leakage and also to prevent entrance of corrosive

contaminants and foreign materials. It also acts to keep deteriorated seals effective (whereas an oil would simply seep away).

(2) Easier to contain than oil. Oil lubrication can require an expensive system of circulating equipment and complex retention devices. In comparison, grease, by virtue of its rigidity, is easily confined with simplified, less costly retention devices.

(3) Holds solid lubricants in suspension. Finely ground solid lubricants, such as molybdenum disulfide (moly) and graphite, are mixed with grease in high temperature service (over 315 °C [599 °F]) or in extreme high-pressure applications. Grease holds solids in suspension while solids will settle out of oils.

(4) Fluid level does not have to be controlled and monitored.

c. Notable disadvantages of grease:

(1) Poor cooling. Due to its consistency, grease cannot dissipate heat by convection like a circulating oil.

(2) Resistance to motion. Grease has more resistance to motion at start-up than oil, so it is not appropriate for low torque/high speed operation.

(3) More difficult to handle than oil for dispensing, draining, and refilling. Also, exact amounts of lubricant cannot be as easily metered.

5-3. Grease Characteristics

Common ASTM tests for the grease characteristics listed below are shown in Table 5-3.

a. Apparent viscosity. At start-up, grease has a resistance to motion, implying a high viscosity. However, as grease is sheared between wearing surfaces and moves faster, its resistance to flow reduces. Its viscosity decreases as the rate of shear increases. By contrast, an oil at constant temperature would have the same viscosity at start-up as it has when it is moving. To distinguish between the viscosity of oil and grease, the viscosity of a grease is referred to as "apparent viscosity." Apparent viscosity is the viscosity of a grease that holds only for the shear rate and temperature at which the viscosity is determined.

b. Bleeding, migration, syneresis. Bleeding is a condition when the liquid lubricant separates from the thickener. It is induced by high temperatures and also occurs during long storage periods. Migration is a form of bleeding that occurs when oil in a grease migrates out of the thickener network under certain circumstances. For example, when grease is pumped though a pipe in a centralized lubrication system, it may encounter a resistance to the flow and form a plug. The oil continues to flow, migrating out of the thickener network. As the oil separates from the grease, thickener concentration increases, and plugging gets worse. If two different greases are in contact, the oils may migrate from one grease to the other and change the structure of the grease. Therefore, it is unwise to mix two greases. Syneresis is a special form of bleeding caused by shrinking or rearrangement of the structure due to physical or chemical changes in the thickener.

c. Consistency, penetration, and National Lubricating Grease Institute (NLGI) numbers. The most important feature of a grease is its rigidity or consistency. A grease that is too stiff may not feed into areas requiring lubrication, while a grease that is too fluid may leak out. Grease consistency depends on the type and amount of thickener used and the viscosity of its base oil. A grease's consistency is its resistance to deformation by an applied force. The measure of consistency is called penetration. Penetration depends on whether the consistency has been altered by handling or working. ASTM D 217 and D 1403 methods measure penetration of unworked and worked greases. To measure penetration, a cone of given weight is allowed to sink into a grease for 5 seconds at a standard temperature of 25 °C (77 °F). The depth, in tenths of a millimeter, to which the cone sinks into the grease is the penetration. A penetration of 100 would represent a solid grease while one of 450 would be semifluid. The NLGI has established consistency numbers or grade numbers, ranging from 000 to 6, corresponding to specified ranges of penetration numbers. Table 5.1 lists the NLGI grease classifications along with a description of the consistency of each classification.

Table 5.1
NLGI Grease Classification

NLGI Number	ASTM Worked Penetration 0.1 mm (3.28×10^{-4} ft) at 25 °C (77 °F)	Consistency
000	445 - 475	Semifluid
00	400 - 430	Semifluid
0	355 - 385	Very soft
1	310 - 340	Soft
2	265 - 295	Common grease
3	220 - 250	Semihard
4	175 - 205	Hard
5	130 - 160	Very hard
6	85 - 115	Solid

d. Contaminants. Greases tend to hold solid contaminants on their outer surfaces and protect lubricated surfaces from wear. If the contamination becomes excessive or eventually works its way down to the lubricated surfaces the reverse occurs -- the grease retains abrasive materials at the lubricated surface and wear occurs.

e. Corrosion- and rust-resistance. This denotes the ability of grease to protect metal parts from chemical attack. The natural resistance of a grease depends upon the thickener type. Corrosion-resistance can be enhanced by corrosion and rust inhibitors.

f. Dropping point. Dropping point is an indicator of the heat resistance of grease. As grease temperature rises, penetration increases until the grease liquefies and the desired consistency is lost. Dropping point is the temperature at which a grease becomes fluid enough to drip. The dropping point indicates the upper temperature limit at which a grease retains its structure, not the maximum temperature at which a grease may be used. A few greases have the ability to regain their original structure after cooling down from the dropping point.

g. Evaporation. The mineral oil in a grease evaporates at temperatures above 177 °C (350 °F). Excessive oil evaporation causes grease to harden due to increased thickener concentration. Therefore, higher evaporation rates require more frequent relubrication.

h. Fretting wear and false brinelling. Fretting is friction wear of components at contact points caused by minute oscillation. The oscillation is so minute that grease is displaced from between parts but is not allowed to flow back in. Localized oxidation of wear particles results and wear accelerates. In bearings, this localized wear appears as a depression in the race caused by oscillation of the ball or roller. The depression resembles that which occurs during Brinell hardness determination, hence the term "false brinelling." An example would be fretting wear of automotive wheel bearings when a car is transported by train. The car is secured, but the vibration of the train over the tracks causes minute oscillation resulting in false brinelling of the bearing race.

i. Oxidation stability. This is the ability of a grease to resist a chemical union with oxygen. The reaction of grease with oxygen produces insoluble gum, sludges, and lacquer-like deposits that cause sluggish operation, increased wear, and reduction of clearances. Prolonged high-temperature exposure accelerates oxidation in greases.

j. Pumpability and slumpability. Pumpability is the ability of a grease to be pumped or pushed through a system. More practically, pumpability is the ease with which a pressurized grease can flow through lines, nozzles, and fittings of grease-dispensing systems. Slumpability, or feedability, is its ability to be drawn into (sucked into) a pump. Fibrous greases tend to have good feedability but poor pumpability. Buttery-textured greases tend to have good pumpability but poor feedability.

k. Shear stability. Grease consistency may change as it is mechanically worked or sheared between wearing surfaces. A grease's ability to maintain its consistency when worked is its shear stability or mechanical stability. A grease that softens as it is worked is called thixotropic. Greases that harden when worked are called rheopectic.

l. High-temperature effects. High temperatures harm greases more than they harm oils. Grease, by its nature, cannot dissipate heat by convection like a circulating oil. Consequently, without the ability to transfer away heat, excessive temperatures result in accelerated oxidation or even carbonization where grease hardens or forms a crust. Effective grease lubrication depends on the grease's consistency. High temperatures induce softening and bleeding, causing grease to flow away from needed areas. The mineral oil in grease can flash, burn, or evaporate at temperatures above 177 °C (350 °F). High temperatures, above 73-79 °C (165-175 °F), can dehydrate certain greases such as calcium soap grease and cause structural breakdown. The higher evaporation and dehydration rates at elevated temperatures require more frequent grease replacement.

m. Low-temperature effects. If the temperature of a grease is lowered enough, it will become so viscous that it can be classified as a hard grease. Pumpability suffers and machinery operation may become impossible due to torque limitations and power requirements. The temperature at which this occurs depends on the shape of the lubricated part and the power being supplied to it. As a guideline, the base oil's pour point is considered the low-temperature limit of a grease.

n. Texture. Texture is observed when a small sample of grease is pressed between thumb and index finger and slowly drawn apart. Texture can be described as:

- Brittle: the grease ruptures or crumbles when compressed.
- Buttery: the grease separates in short peaks with no visible fibers.
- Long fiber: the grease stretches or strings out into a single bundle of fibers.
- Resilient: the grease can withstand moderate compression without permanent deformation or rupture.
- Short fiber: the grease shows short break-off with evidence of fibers.
- Stringy: the grease stretches or strings out into long, fine threads, but with no visible evidence of fiber structure.

o. Water resistance. This is the ability of a grease to withstand the effects of water with no change in its ability to lubricate. A soap/water lather may suspend the oil in the grease, forming an emulsion that can wash away or, to a lesser extent, reduce lubricity by diluting and changing grease consistency and texture. Rusting becomes a concern if water is allowed to contact iron or steel components.

5-4. Fluid Lubricants

Fluid lubricants used to formulate grease are normally petroleum or synthetic oils. For petroleum oils in general, naphthenic oils tend to chemically mix better with soaps and additives and form stronger structures than paraffinic oils. Synthetic oils are higher in first cost but are effective in high-temperature and low-temperature extremes. With growing environmental concerns, vegetable oils and certain synthetic oils are also being used in applications requiring nontoxic or biodegradable greases. Separate chapters in this manual are devoted to lubricating oils and environmentally acceptable oils. They describe the characteristics that each type of oil brings to grease. The base oil selected in formulating a grease should have the same characteristics as if the equipment is to be lubricated by oil. For instance, lower-viscosity base oils are used for grease applications at lower temperatures or high speeds and light loads, whereas higher-viscosity base oils are used for higher temperatures or low speed and heavy load applications.

5-5. Soap Thickeners

a. Dispersed in its base fluid, a soap thickener gives grease its physical character. Soap thickeners not only provide consistency to grease, they affect desired properties such as water and heat resistance and pumpability. They can affect the amount of an additive, such as a rust inhibitor, required to obtain a desired quality. The soap influences how a grease will flow, change shape, and age as it is mechanically worked and at temperature extremes. Each soap type brings its own characteristic properties to a grease.

b. The principal ingredients in creating a soap are a fatty acid and an alkali. Fatty acids can be derived from animal fat such as beef tallow, lard, butter, fish oil, or from vegetable fat such as olive, castor, soybean, or peanut oils. The most common alkalies used are the hydroxides from earth metals such as aluminum, calcium, lithium, and sodium. Soap is created when a long-carbon-chain fatty acid reacts with the metal hydroxide. The metal is incorporated into the carbon chain and the resultant compound develops a polarity. The polar molecules form a fibrous network that holds the oil. Thus, a somewhat rigid gel-like material "grease" is developed. Soap concentration can be varied to obtain different grease thicknesses. Furthermore, viscosity of the base oil affects thickness as well. Since soap qualities are also determined by the fatty acid from which the soap is prepared, not all greases made from soaps containing the same metals are identical. The name of the soap thickener refers to the metal (calcium, lithium, etc.) from which the soap is prepared.

5-6. Complex Soap

a. The high temperatures generated by modern equipment necessitated an increase in the heat-resistance of normal soap-thickened greases. As a result, "complex" soap greases were developed. The dropping point of a complex grease is at least 38 °C (100 °F) higher than its normal soap-thickened counterpart, and its maximum usable temperature is around 177 °C (350 °F). Complex soap greases are limited to this temperature because the mineral oil can flash, evaporate, or burn above that temperature. Generally, complex greases have good all-around properties and can be used in multipurpose applications. For extreme operating conditions, complex greases are often produced with solid lubricants and use more highly refined or synthetic oils.

b. A "complexing agent" made from a salt of the named metal is the additional ingredient in forming a complex grease. A complex soap is formed by the reaction of a fatty acid and alkali to form a soap, and the simultaneous reaction of the alkali with a short-chain organic or inorganic acid to form a metallic salt (the complexing agent). Basically, a complex grease is made when a complex soap is formed in the presence of a base oil. Common organic acids are acetic or lactic, and common inorganic acids are carbonates or chlorides.

5-7. Additives

Surface-protecting and performance-enhancing additives that can effectively improve the overall performance of a grease are described in Chapter 7. Solid lubricants such as molybdenum disulfide and graphite are added to grease in certain applications for high temperatures (above 315 °C or 599 °F) and extreme high-pressure applications. Incorporating solid additives requires frequent grease changes to prevent accumulation of solids in components (and the resultant wear). Properties of solid lubricants are described in Chapter 6. Not mentioned in other chapters are dyes that improve grease appearance and are used for identification purposes.

5-8. Types of Greases

The most common greases are described below.

a. *Calcium grease.*

(1) Calcium or lime grease, the first of the modern production greases, is prepared by reacting mineral oil with fats, fatty acids, a small amount of water, and calcium hydroxide (also known as hydrated lime). The water modifies the soap structure to absorb mineral oil. Because of water evaporation, calcium grease is sensitive to elevated temperatures. It dehydrates at temperatures around 79 °C (175 °F) at which its structure collapses, resulting in softening and, eventually, phase separation. Greases with soft consistencies can dehydrate at lower temperatures while greases with firm consistencies can lubricate satisfactorily to temperatures around 93 °C (200 °F). In spite of the temperature limitations, lime grease does not emulsify in water and is excellent at resisting "wash out." Also, its manufacturing cost is relatively low. If a calcium grease is prepared from 12-hydroxystearic acid, the result is an anhydrous (waterless) grease. Since dehydration is not a concern, anhydrous calcium grease can be used continuously to a maximum temperature of around 110 °C (230 °F).

(2) Calcium complex grease is prepared by adding the salt calcium acetate. The salt provides the grease with extreme pressure characteristics without using an additive. Dropping points greater than 260 °C (500 °F) can be obtained and the maximum usable temperature increases to approximately 177 °C (350 °F). With the exception of poor pumpability in high-pressure centralized systems, where caking and hardening sometimes occur calcium complex greases have good all-around characteristics that make them desirable multipurpose greases.

b. Sodium grease. Sodium grease was developed for use at higher operating temperatures than the early hydrated calcium greases. Sodium grease can be used at temperatures up to 121 °C (250 °F), but it is soluble in water and readily washes out. Sodium is sometimes mixed with other metal soaps, especially calcium, to improve water resistance. Although it has better adhesive properties than calcium grease, the use of sodium grease is declining due to its lack of versatility. It cannot compete with water-resistant, more heat-resistant multipurpose greases. It is, however, still recommended for certain heavy-duty applications and well-sealed electric motors.

c. Aluminum grease.

(1) Aluminum grease is normally clear and has a somewhat stringy texture, more so when produced from high-viscosity oils. When heated above 79 °C (175 °F), this stringiness increases and produces a rubberlike substance that pulls away from metal surfaces, reducing lubrication and increasing power consumption. Aluminum grease has good water resistance, good adhesive properties, and inhibits rust without additives, but it tends to be short-lived. It has excellent inherent oxidation stability but relatively poor shear stability and pumpability.

(2) Aluminum complex grease has a maximum usable temperature of almost 100 °C (212 °F) higher than aluminum-soap greases. It has good water-and-chemical resistance but tends to have shorter life in high-temperature, high-speed applications.

d. Lithium grease.

(1) Smooth, buttery-textured lithium grease is by far the most popular when compared to all others. The normal grease contains lithium 12-hydroxystearate soap. It has a dropping point around 204 °C (400 °F) and can be used at temperatures up to about 135 °C (275 °F). It can also be used at temperatures as low as -35 °C (-31 °F) . It has good shear stability and a relatively low coefficient of friction, which permits higher machine operating speeds. It has good water-resistance, but not as good as that of calcium or aluminum. Pumpability and resistance to oil separation are good to excellent. It does not naturally inhibit rust, but additives can provide rust resistance. Anti-oxidants and extreme pressure additives are also responsive in lithium greases.

(2) Lithium complex grease and lithium soap grease have similar properties except the complex grease has superior thermal stability as indicated by a dropping point of 260 °C (500 °F). It is generally considered to be the nearest thing to a true multipurpose grease.

e. Other greases. Thickeners other than soaps are available to make greases. Although most of these are restricted to very special applications, two nonsoap greases are worthy of mention. One is organic, the other inorganic.

(1) Polyurea grease.

(a) Polyurea is the most important organic nonsoap thickener. It is a low-molecular-weight organic polymer produced by reacting amines (an ammonia derivative) with isocyanates, which results in an oil-soluble chemical thickener. Polyurea grease has outstanding resistance to oxidation because it contains no metal soaps (which tend to invite oxidation). It effectively lubricates over a wide temperature range of -20 to 177 °C (-4 to 350 °F) and has long life. Water-resistance is good to excellent, depending on the grade. It works well with many elastomer seal materials. It is used with all types of bearings but has been particularly effective in ball bearings. Its durability makes it well suited for sealed-for-life bearing applications.

(b) Polyurea complex grease is produced when a complexing agent, most commonly calcium acetate or calcium phosphate, is incorporated into the polymer chain. In addition to the excellent properties of normal polyurea grease, these agents add inherent extreme pressure and wear protection properties that increase the multipurpose capabilities of polyurea greases.

(2) Organo-clay. Organo-clay is the most commonly used inorganic thickener. Its thickener is a modified clay, insoluble in oil in its normal form, but through complex chemical processes, converts to platelets that attract and hold oil. Organo-clay thickener structures are amorphous and gel-like rather than the fibrous, crystalline structures of soap thickeners. This grease has excellent heat-resistance since clay does not melt. Maximum operating temperature is limited by the evaporation temperature of its mineral oil, which is around 177 °C (350 °F). However, with frequent grease changes, this multipurpose grease can operate for short periods at temperatures up to its dropping point, which is about 260 °C (500 °F). A disadvantage is that greases made with higher-viscosity oils for high thermal stability will have poor low-temperature performance. Organo-clay grease has excellent water-resistance but requires additives for oxidation and rust resistance. Work stability is fair to good. Pumpability and resistance to oil separation are good for this buttery textured grease.

5-9. Compatibility

a. Greases are considered incompatible when the physical or performance characteristics of the mixed grease falls below original specifications. In general, greases with different chemical compositions should not be mixed. Mixing greases of different thickeners can form a mix that is too firm to provide sufficient lubrication or more commonly, a mix that is too soft to stay in place.

b. Combining greases of different base oils can produce a fluid component that will not provide a continuous lubrication film. Additives can be diluted when greases with different additives are mixed. Mixed greases may become less resistant to heat or have lower shear stability. If a new brand of grease must be introduced, the component part should be disassembled and thoroughly cleaned to remove all of the old grease. If this is not practical, the new grease should be injected until all traces of the prior product are flushed out. Also, the first grease changes should be more frequent than normally scheduled.

5-10. Grease Application Guide

When selecting a grease, it is important to determine the properties required for the particular application and match them to a specific grease. A grease application guide is shown in Table 5-2. It shows the most common greases, their usual properties, and important uses. Some of the ratings given are subjective and can vary significantly from supplier to supplier. Common ASTM tests for the grease characteristics described in paragraph 5-3 are shown in Table 5-3.

Table 5-2
Grease Application Guide

Properties	Aluminum	Sodium	Calcium-Conventional	Calcium - Anhydrous	Lithium	Aluminum Complex	Calcium Complex	Lithium Complex	Polyurea	Organo-Clay
Dropping point (°C)	110	163-177	096-104	135-143	177-204	260+	260+	260+	243	260+
Dropping point (°F)	230	325-350	205-220	275-290	350-400	500+	500+	500+	470	500+
Maximum usable temperature (°C)	79	121	93	110	135	177	177	177	177	177
Maximum usable temperature (°F)	175	350	200	230	275	350	350	350	350	350
Water resistance	Good to excellent	Poor to fair	Good to excellent	Excellent	Good	Good to excellent	Fair to excellent	Good to excellent	Good to excellent	Fair to excellent
Work stability	Poor	Fair	Fair to good	Good to excellent	Good to excellent	Good to excellent	Fair to good	Good to excellent	Poor to good	Fair to good
Oxidation stability	Excellent	Poor to good	Poor to excellent	Fair to excellent	Fair to excellent	Fair to excellent	Poor to good	Fair to excellent	Good to excellent	Good
Protection against rust	Good to excellent	Good to excellent	Poor to excellent	Poor to excellent	Poor to excellent	Good to excellent	Fair to excellent	Fair to excellent	Fair to excellent	Poor to excellent
Pumpability (in centralized system)	Poor	Poor to fair	Good to excellent	Fair to excellent	Fair to excellent	Fair to good	Poor to fair	Good to excellent	Good to excellent	Good
Oil separation	Good	Fair to good	Poor to good	Good	Good to excellent	Good to excellent	Good to excellent	Good to excellent	Good to excellent	Good to excellent
Appearance	Smooth and clear	Smooth to fibrous	Smooth and buttery	Smooth and buttery	Smooth and buttery	Smooth and buttery	Smooth and buttery	Smooth and buttery	Smooth and buttery	Smooth and buttery
Other properties		Adhesive & cohesive	EP grades available	EP grades available	EP grades available, reversible	EP grades available, reversible	EP grades antiwear inherent	EP grades available	EP grades available	
Principal Uses	Thread lubricants	Rolling contact economy	General uses for economy	Military multiservice	Multi-service[1] automotive & industrial	Multi-service industrial	Multi-service automotive & industrial	Multi-service automotive & industrial	Multi-service automotive & industrial	High temp. (frequent relube)

[1] Multiservice includes rolling contact bearings, plain bearings, and others.
Reference: NLGI Lubricating Grease Guide, 4th ed.

Table 5-3
ASTM Tests for Grease Characteristics

Grease Characteristic	ASTM Test Method	Description
Apparent viscosity / pumpability	D 1092 - Measuring Apparent Viscosity of Lubricating Greases	Apparent viscosities at 16 shear rates are determined by measuring the hydraulic pressure on a floating piston which forces grease through a capillary tube. Eight different capillary tubes and a 2-speed hydraulic gear pump are used.
Consistency and shear stability	D 217 - Cone Penetration of Lubricating Grease D 1403 - Cone Penetration of Lubricating Grease Using One-Quarter and One-Half Scale Cone Equipment	Depth, in tenths of a millimeter, a 150-g (0.33-lb) cone penetrates the surface of worked and unworked grease at 25 °C (77 °F) in 5 seconds. D 1403 is used when only a small amount of grease is available.
	D 1831- Roll Stability of Lubricating Grease	A 5- kg (11-lb) roller and 50 g (0.11 lb) of grease are put into a 165-rpm revolving chamber for 2 hours at room temperature. The difference in penetrations measured before and after rolling is an indicator of shear stability.
Corrosion and rust resistance	D 1743 - Determining Corrosion Preventive Properties of Lubricating Greases	A grease-packed bearing is spun for 1-minute at 1750 rpm. Excess grease is thrown off and a thin layer remains on bearing surfaces. The bearing is exposed to water and stored for 48 hours at 52 °C (125 °F) and 100% humidity. It is then cleaned and examined for corrosion.
	D 4048 - Detection of Copper Corrosion from Lubricating Grease	A copper strip is immersed in grease inside a covered jar and heated in an oven or liquid bath for a specified time. The strip is removed, washed, and compared and classified using the ASTM Copper Strip Corrosion Standards.
Dropping point	D 566 - Dropping Point of Lubricating Grease D 2265 - Dropping Point of Lubricating Grease over Wide-Temperature Range	Grease and a thermometer are placed in a cup inside a test tube and heated until a drop falls through the cup. That temperature is the dropping point. The test tube assembly is heated in an oil bath for D 566 and inside an aluminum block oven for D 2265.
Evaporation	D 972 - Evaporation Loss of Lubricating Greases and Oils D 2595 - Evaporation Loss of Lubricating Greases over Wide-Temperature Range	Two liters per minute of heated air is passed over grease inside a chamber for 22 hours. Temperature range is 100 - 150 °C (212 - 302 °F) for D 972 and 93 - 315 °C (200 - 599 °F) for D 2595. Evaporation is calculated from grease weight loss, in percent.
Heat resistance / Consistency	D 3232 - Measurement of Consistency of Lubricating Greases at High Temperatures	Can also indicate flow at high temperatures. Grease in a cylindrical opening in an aluminum block is heated at a rate of 5 °C (10 °F)/min while a trident probe turns at 20 rpm in the grease. A Brookfield viscometer attached to the probe measures torque at temperature increments. From this, apparent viscosities are determined at different temperatures.
Leakage	D 1263 - Leakage Tendencies of Automotive Wheel Bearing Greases	A seal-less, grease-packed wheel bearing encircled by a collector ring is spun for 6 hours at 660 rpm at 105 °C (221 °F). Grease thrown off into the ring is weighed and leakage is determined.

(Continued)

Table 5-3 (Concluded)

Grease Characteristic	ASTM Test Method	Description
Oxidation Stability	D 942 - Oxidation Stability of Lubricating Greases by the Oxygen Bomb Method	Indicates oxidation from storage when grease charged with oxygen at 758 kPa (110 psi) is sealed in a “bomb” at 99 °C (210 °F). As grease oxidizes, it absorbs oxygen. Pressure is recorded at time intervals and degree of oxidation is determined by the corresponding drop in oxygen pressure.
	D 3336 - Performance Characteristics of Lubricating Greases in Ball-Bearings at Elevated Temperatures	There are no ASTM tests for oxidation in service, but this test relates oxidation stability to failure rate of bearings at desired elevated temperatures.
Water Resistance	D 1264 - Determining the Water Washout Characteristics of Lubricating Greases	Measures grease washout of a bearing turning at 600 rpm with water flowing at 5 mL/sec for 1 hour at 38 °C (100 °F) and 79 °C (175 °F).
	D 4049 - Determining the Resistance of Lubricating Grease to Water Spray	Measures removal of grease 0.8 mm (1/32 in) thick on a plate by water through a nozzle for 5 minutes at 38 °C (100 °F) and 275 kPa (40 psi).
Wear Resistance	D 2266 - Wear Preventive Characteristics of Lubricating Grease (Four-Ball Method)	A rotating steel ball is pressed against three, grease-coated, stationary steel balls for 60 minutes. Scar diameters on the three stationary balls are relative measures of wear. Balls are 12.7 mm (0.5 inch). Applied load is 40 kgf (392 N) rotating at 1200 rpm. Temperature is 75 °C (167 °F).
	D 2596 - Measurement of Extreme-Pressure Properties of Lubricating Grease (Four-Ball Method)	Same steel ball setup as above, but load is incrementally increased every 10 seconds until seizure occurs. This is the weld point. Load wear index is then calculated. Maximum load is 800 kgf (7845 N) rotating at 1770 rpm. Temperature is 27 °C (80 °F).
	D 2509 - Measurement of Extreme Pressure Properties of Lubricating Grease (Timken Method)	The outer edge of a continuously grease-fed bearing race rotates at 800 rpm and rubs against a fixed steel block for 10 minutes. Successive runs are made with increasingly higher loads and any surface scoring is reported. Grease is applied at 25 °C (77 °F). The Timken OK load is the highest load in which no scoring occurs.