Test Capabilities
## Rust & Corrosion Test Capabilities

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Designation</th>
<th>DIN Designation</th>
<th>IP Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper Corrosion (Industrial Lubricants)</td>
<td>D 130</td>
<td>51 759</td>
<td>154</td>
</tr>
<tr>
<td>Copper Corrosion (Grease)</td>
<td>D 4048</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emcor Corrosion</td>
<td>D 6138</td>
<td>51 802</td>
<td>220</td>
</tr>
<tr>
<td>Grease Rust (Static – Distilled Water)</td>
<td>D 1743</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grease Rust (Static – Synthetic Sea Water)</td>
<td>D 5969</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humidity Cabinet</td>
<td>D 1748</td>
<td>51 359</td>
<td>366</td>
</tr>
<tr>
<td>Kesternich Cabinet</td>
<td></td>
<td>50 017</td>
<td></td>
</tr>
<tr>
<td>Iron Chip Corrosion</td>
<td>D 4627</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt Spray (Fog) Cabinet</td>
<td>B 117</td>
<td>50 021</td>
<td></td>
</tr>
<tr>
<td>Rust Preventive Steel Corrosion</td>
<td>D 665 A&amp;B</td>
<td>51 585 A&amp;B</td>
<td>135</td>
</tr>
</tbody>
</table>

## Extreme Pressure & Antiwear Test Capabilities

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Designation</th>
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<th>IP Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falex Pin &amp; Vee (Extreme Pressure)</td>
<td>D 3233</td>
<td></td>
<td></td>
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<tr>
<td>Falex Pin &amp; Vee (Wear)</td>
<td>D 2670</td>
<td></td>
<td></td>
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<tr>
<td>Four Ball Wear (Ind. Lub.)</td>
<td>D 4172</td>
<td></td>
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<tr>
<td>Four Ball Wear (Grease)</td>
<td>D 2266</td>
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<tr>
<td>Four Ball Weld (Ind. Lub.)</td>
<td>D 2783</td>
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<tr>
<td>Four Ball Weld (Grease)</td>
<td>D 2596</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FZG Gear Test</td>
<td>D 5182</td>
<td>51 354</td>
<td>334</td>
</tr>
<tr>
<td>SRV 4 (Ind. Lub.)</td>
<td>D 6425</td>
<td>51 834</td>
<td></td>
</tr>
<tr>
<td>Timken (Ind. Oils &amp; Greases)</td>
<td>D 2782 &amp; D 2509</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FE-8 Bearing Test Rig</td>
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<td>51 819</td>
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# Oxidation Test Capabilities

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<thead>
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<tr>
<td>Industrial Gear Oil</td>
<td>D 2893</td>
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<tr>
<td>Rotating Pressure Vessel</td>
<td>D 2272</td>
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<tr>
<td>Turbine Oil Oxidation</td>
<td>D 943</td>
<td>51 587</td>
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<tr>
<td>Turbine Oil Sludge (1,000 hours)</td>
<td>D 4310</td>
<td></td>
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<tr>
<td>DKA (CEC L-48-A-95)</td>
<td>D 6186</td>
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<tr>
<td>PDSC (Pressure Differential Scanning Calorimetry)</td>
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<td>Norma Hoffman Grease Oxidation</td>
<td>D 942</td>
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# Miscellaneous Test Capabilities

<table>
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<tr>
<th>Test</th>
<th>ASTM Designation</th>
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<tr>
<td>AFNOR Filtration (Wet &amp; Dry)</td>
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<tr>
<td>Denison Filtration (Filtration Test – Hydraulic Fluids)</td>
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<tr>
<td>CM Cincinnati Milacron Thermal Stability</td>
<td>D 2070</td>
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<tr>
<td>Cone Penetration (Grease)</td>
<td>D 217</td>
<td>51 858</td>
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<tr>
<td>Demulsibility (Oil/Water Separation)</td>
<td>D 1401</td>
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<tr>
<td>Demulsibility (Emulsion Separation)</td>
<td>D 2711</td>
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<td>Dropping Point (Grease)</td>
<td>D 2265</td>
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<tr>
<td>Hydrolytic Stability</td>
<td>D 2619</td>
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Significance: The ASTM D 130 test method is used to detect the corrosivity of petroleum products to yellow metals. This test is widely used for R&O, turbine, hydraulic and gear oils where non-ferrous bushings, gears and bearings are used as well as for cutting fluids used in the machining of non-ferrous metals.

Test Procedure: A three inch copper strip is prepared by cleaning and polishing all sides so that no discoloration or blemishes are visible. The strip is then placed in the test oil and held for a specified time at a specified temperature. Three hours at 100°C is the typical starting point. At the end of the exposure period, the strip is removed, wiped clean and matched with colored reproduction strips characteristic of the descriptions provided in Table I - Copper Strip Classifications.

Classification results are reported as well as the duration of the test and the test temperature.

### Table I - Copper Strip Classifications

<table>
<thead>
<tr>
<th>Classification</th>
<th>Appearance Designation</th>
<th>Color Description</th>
</tr>
</thead>
</table>
| 1              | Slight tarnish         | a = Light orange, almost the same as the freshly polished strip  
|                |                        | b = Dark orange   |
| 2              | Moderate tarnish       | a = Claret red    
|                |                        | b = Lavender      
|                |                        | c = Multicolored with lavender blue or silver, or both, overlaid on claret red  
|                |                        | d = Silvery       
|                |                        | e = Brassy or gold|
| 3              | Dark tarnish           | a = Magenta overcast on brassy strip  
|                |                        | b = Multicolored with red and green (peacock), but no gray |
| 4              | Corrosion              | a = Transparent black, dark gray or brown with peacock green barely showing  
|                |                        | b = Graphite or lusterless black  
|                |                        | c = Glossy or jet black |

Photo Above - Copper test strips showing varying degrees of tarnish and corrosion.
Significance: The ASTM D 4048 test method is similar to the ASTM D 130 test used for industrial oils but is designed to evaluate the copper corrosion prevention properties of greases.

Test Procedure: A polished and cleaned 3 inch copper strip as prescribed in ASTM D 130 is placed in a jar in which the copper strip is totally immersed in the test grease. The jar is capped and heated to a specified temperature for a defined period of time. Commonly used conditions are 100°C for 24 hours. At the end of the exposure period, the strip is removed, wiped clean and matched with colored reproduction strips characteristic of the descriptions provided in Table I - Copper Strip Classifications.

Classifications results are reported as well as the duration of the test and the test temperature.

Table I - Copper Strip Classifications

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|                |                        | d = Silvery        
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| 3              | Dark tarnish           | a = Magenta overcast on brassy strip  
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| 4              | Corrosion              | a = Transparent black, dark gray or brown with peacock green barely showing  
|                |                        | b = Graphite or lusterless black  
|                |                        | c = Glossy or jet black |

Photo Above - Copper test strips showing varying degrees of tarnish and corrosion.
**Significance:** The ASTM D 6138 test method is commonly referred to as the “Emcor Test” and is an adopted version of the IP 220 European procedure. This test is a dynamic procedure used to determine the corrosion protection of a grease in the presence of water approximating typical service conditions.

**Test Procedure:** Double row self-aligning ball bearings are packed with grease and run to distribute the grease evenly. The bearings are exposed to either distilled water, synthetic sea water or sodium chloride solution, and the test rig is operated under alternating running and standing conditions for one week. After cleaning, the bearing races are examined for corrosion and rated “0” to “5” as detailed in Table I.

The test rig will simultaneously run eight bearings. Duplicate determinations are required, so the rig is normally used to evaluate four different formulations at a time.

**Table I - Emcor Classifications**

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No evidence of corrosion</td>
</tr>
<tr>
<td>1</td>
<td>No more than three spots of a size just sufficient to be visible.</td>
</tr>
<tr>
<td>2</td>
<td>Up to 1% surface corrosion</td>
</tr>
<tr>
<td>3</td>
<td>Between 1% and 5% surface corrosion</td>
</tr>
<tr>
<td>4</td>
<td>Between 5% and 10% surface corrosion</td>
</tr>
<tr>
<td>5</td>
<td>More than 10% surface corrosion</td>
</tr>
</tbody>
</table>
Significance: Since the early 1960’s, one of the most popular grease rust tests in the United States has been ASTM D 1743. This method determines the corrosion preventive properties of greases using tapered roller bearings which are stored under static conditions in the presence of distilled water.

Test Procedure: Tapered roller bearings are packed with grease and run under a light load to distribute the grease evenly. The bearings are exposed to distilled water, then stored at 52°C and 100% relative humidity for 48 hours. After cleaning, the bearing races are examined for corrosion.

Since 1987, the ASTM D 1743 procedure has specified a pass or fail rating on the basis of a single corrosion spot of 1.0 mm or larger in the longest dimension on two of three bearings tested simultaneously.

Photo Below - Three bearing races showing varying degrees of corrosion. The race using NA-SUL BSN passed while the other two failed.
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Grease Rust Test
(Static Grease Rust Test - Synthetic Sea Water)

**Significance:** The ASTM D 5969 test method is the synthetic sea water version of ASTM D 1743 which specifies the use of only distilled water. The test methods are identical except the following changes which are incorporated into the ASTM D 5969 method:

- The tapered roller bearings are exposed to desired concentrations of synthetic sea water (prepared as in test method ASTM D 665B) diluted with distilled water.
- The test time is reduced from 48 hours to 24 hours.

**Test Procedure:** Tapered roller bearings are packed with grease and run under a light load to distribute the grease evenly. The bearings are exposed to desired concentrations of synthetic sea water, then stored at 52°C and 100% relative humidity for 24 hours. After cleaning, the bearing races are examined for corrosion.

This procedure specifies a pass or fail on the basis of a single corrosion spot of 1.0 mm or larger in the longest dimension on two of three bearings tested simultaneously.

*Photo Above - Tapered rolling bearing.*
Significance: The ASTM D 1748 test method is used to evaluate the relative abilities of metal preservatives to prevent the rusting of steel panels under conditions of 100% relative humidity at 50°C.

This test is not as severe as the Salt Spray Test. It is not uncommon for test panels to run well over 1,000 hours before the onset of rust.

Test Procedure: Steel panels are prepared to a prescribed surface finish, dipped in the test fluid, allowed to drain and then suspended in the humidity cabinet. A continuous supply of air is delivered to the cabinet which is maintained at 50°C. Panels are periodically checked for signs of rust. A failure occurs at the point in time when either a rust spot larger than 1 mm in diameter appears or four rust spots of any size are observed.

Results are reported as hours to failure as described above.
**Significance:** The DIN 50 017 KFW* test method is used to evaluate the relative abilities of metal preservatives to prevent the rusting of steel panels under conditions of 100% relative humidity at 40°C for 8 hours followed by a 16 hour dry period under ambient conditions.

This cycling is designed to test panels under more realistic conditions than 100% constant humidity.

**Test Procedure:** Test panels are prepared, dipped in the test fluid, allowed to drain and then suspended in the humidity cabinet. The panels are checked daily for signs of rust or corrosion. A rust spot larger than 1 mm in diameter or multiple spots within the test area is a failure.

Results are reported as cycles to failure as described above. One cycle consists of 8 hours wet and 16 hours dry, equal to 1 day.

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* Alternating humidity conditions.
**Significance:** Also known as the Cast Iron Chip Test, the ASTM D 4627 test method evaluates the ferrous corrosion control characteristics of water dilutable metalworking fluids. The results obtained by this test are useful in determining the ability of water-diluted metalworking fluids to prevent or minimize rust under specific conditions.

**Test Procedure:** Cast iron chips are placed in a petri dish containing a filter paper and a water-diluted metalworking fluid. The dish is covered and allowed to stand for 20 to 24 hours. At the end of the test period, the filter paper is rinsed with water and the percent of the filter paper area which was stained by the rusting chips is estimated. The amount of rust stain on the filter paper is an indication of the corrosion control provided by the fluid. The “breakpoint” is defined as the weakest concentration tested that left no stain on the filter paper.

This procedure is typically used for screening and comparative purposes.
Significance: The ASTM B 117 Salt Spray Test, also referred to as the Salt Fog Test, offers an accelerated method to differentiate the rust prevention characteristics afforded by a coating. For example, failure (rusting) can occur in a few hours for a thin, oily coating, or in thousands of hours for a thick hard coating.

Often used as a screening test due to the speed at which results can be obtained, an aqueous solution of 5% sodium chloride is continuously sprayed in the cabinet engulfing the test panels which creates an environment conducive to corrosion.

Test Procedure: The test apparatus consists of a cabinet capable of maintaining a temperature of 35°C where pressure and the introduction of the salt containing vapors (spray) can be controlled. Test panels are set on internal racks and are subjected to the salt fog atmosphere for variable amounts of time.

Results are typically reported as the number of hours to failure (onset of rust).
Significance: Originally designed to determine the rust prevention characteristics of steam-turbine oils when contaminated with water, the ASTM D 665 test method now is used to indicate the rust preventive properties of other types of industrial lubricants particularly circulating oils.

Particles of rust in an oil can act as catalysts tending to increase the rate of oil oxidation. Rust particles being abrasive in nature, can also cause wear. Additionally, the particles can cause filter plugging.

Test Procedure: A steel rod (spindle) is placed in a bath of 300 ml of oil and 30 ml of water which is stirred at 60°C. It is customary to run the test for 24 hours. The 10% water addition to the oil can be either distilled water (ASTM D 665 A) or synthetic sea water (ASTM D 665 B).

The test is normally run in duplicate and any visible rust on both rods indicates failure. Results are reported as a pass or fail. Due to its severity, the synthetic sea water test procedure (B) is frequently used as a screening test.

Results should always specify which procedure A or B was used and the amount of time the test was run.
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**Falex Pin & Vee Test**
**Falex Extreme Pressure Test - Industrial Oils**

**Significance:** The ASTM D 3233 test method covers two procedures for making a preliminary evaluation of the load carrying properties of industrial oils.

**Test Procedure:** For both procedures, a test pin is placed between two stationary vee blocks and immersed in the sample oil. The pin is driven at 290 rpm, and a load is applied to the vee blocks by a ratchet mechanism.

In Test Method A, an increasing load is continuously applied.

In Test Method B, loads are applied in 250 lbf increments with each load maintained for one minute.

For both methods, there is a five minute run-in period at 300 lbf.

The results are reported as the load at which the test pin or shear pin breaks or when the inability to maintain or increase the load occurs. If no failure occurs, the last load run is reported with a plus (+) sign after the value.

**Falex Pin & Vee Test**  
*(Falex Wear Test - Industrial Oils)*

**Significance:** The ASTM D 2670 test method is used for making preliminary evaluations of the wear properties of industrial oils.

**Test Procedure:** A test pin is placed between two stationary vee blocks and immersed in the test oil. The pin is driven at 290 rpm, and a prescribed load is applied to the vee blocks by a ratchet mechanism. Wear is determined and recorded as the number of teeth the ratchet system advanced to maintain constant load during the test.
**Four Ball Wear Test**

*(Four Ball Wear Test - Industrial Oils)*

**Significance:** The ASTM D 4172 test procedure is used for making preliminary evaluations of the anti-wear properties of industrial oils. The oil is tested in a four ball system where a rotating ball slides over three stationary balls.

**Test Procedure:** Three ½ inch diameter steel balls are clamped together and covered with the test oil. The oil is heated to 75°C, and then a forth identical ball (referred to as the top ball) is pressed downward with a force of 15 kgf or 40 kgf into the cavity formed by the three clamped, stationary balls. This arrangement forms a three-point contact. The top ball is then rotated at 1200 rpm for 60 minutes. (In Europe, the rotational speed of the top ball is usually 1500 rpm.)

The average scar diameter (mm) of the three stationary balls and the load used in the test are reported.

*Photos: Above - The Four Ball Wear test apparatus.*
Significance: The ASTM D 2266 test procedure is used to determine the relative anti-wear properties of lubricating greases. The grease is tested in a four ball system where a rotating ball slides over three stationary balls.

Test Procedure: Three ½ inch diameter steel balls are clamped together and covered with the test grease. The grease is heated to 75°C, and then a forth identical ball (referred to as the top ball) is pressed downward with a force of 40 kgf into the cavity formed by the three clamped, stationary balls. This arrangement forms a three-point contact. The top ball is then rotated at 1200 rpm for 60 minutes.

The average scar diameter (mm) of the three stationary balls is reported.
Significance: The ASTM D 2783 test procedure is used to determine the relative load-carrying properties of industrial oils. The oil is tested in a four ball system where a rotating ball slides over three stationary balls. This test procedure differs from the Four Ball Wear Test in that it is run at higher loads to the point where the test balls are "welded" together.

Test Procedure: Three ½ inch diameter steel balls are clamped together and covered with the test oil. The oil is brought to between 65°F and 95°F, and then a forth identical ball (referred to as the top ball) is pressed downward into the cavity formed by the three clamped, stationary balls. This arrangement forms a three-point contact. The top ball is rotated at 1800 rpm, and a series of tests of 10 seconds duration are made at increasing loads until welding of the balls occurs. (In Europe, the rotation of speed of the top ball is usually 1500 rpm and the series of tests are run for one minute durations.)

The weld point (kgf) and the load-wear index (kgf) are reported.
Significance: The ASTM D 2596 test procedure is used to determine the relative load-carrying properties of lubricating greases. The grease is tested in a four ball system where a rotating ball slides over three stationary balls. This test procedure differs from the Four Ball Wear Test in that it is run at higher loads to the point where the test balls are “welded” together.

Test Procedure: Three ½ inch diameter steel balls are clamped together and covered with the test grease. The grease is brought to between 65°F and 95°F, and then a forth identical ball (referred to as the top ball) is pressed downward into the cavity formed by the three clamped, stationary balls. This arrangement forms a three-point contact. The top ball is rotated at 1800 rpm, and a series of tests of 10 seconds duration are made at increasing loads until welding of the balls occurs.

The weld point (kgf) and the load-wear index (kgf) are reported.
Significance: The FZG test rig is used to determine the scuffing properties of industrial lubricating oils as defined by the total damaged surface area of the gear teeth.

Test Procedure: Special gears are run in the test oil at a constant speed of 1450 rpm for a fixed period of 21,700 revolutions (about 15 minutes) at successively increasing loads. The load on the gears is increased through 12 stages or until the failure criteria is reached.

Starting at load stage 4, the initial oil temperature is specified to be 90°C and the gears are examined after each load.

The test is complete when the total width of damage on all of the gear teeth equals the width of one tooth. The failure load stage is reported along with a description of the gear teeth damage. If the failure criteria is not met at the end of load stage 12, then the failure load stage is reported as greater than 12. This test is used for oils with mild EP/AW performance.
**Significance:** The ASTM D 6425 test method covers an extreme pressure (EP) lubricating oil's coefficient of friction and its ability to protect against wear when subjected to high-frequency, linear oscillatory motion. The test method can be used at selected temperatures and loads specified for use in applications in which high-speed vibration or stop-start motions are present for extended periods of time under initial high Hertzian point contact pressures. This method has found application as a screening test for lubricants used in gear or cam/follower systems.

**Test Procedure:** This test method is performed on the SRV test machine using a test ball oscillated at constant frequency and stroke amplitude. A 300 N load is applied against a test disk that has been moistened with 0.3 ml of the test lubricant. The platform to which the test disk is attached is held at a constant temperature. The test is run for 2 hours.

At the completion of the test, the wear scar diameter and coefficient of friction trace are reported along with the test parameters (temperature, break-in load, frequency, stroke, ball material, and disk material).
Significance: This test method is used widely for specification purposes and is used to differentiate between greases having low, medium, or high levels of extreme pressure characteristic. The results may not correlate with results from service.

Test Procedure: This tester is operated with a steel test cup rotating against a steel test block. The rotating speed is 800 rpm. Two determinations are made: the minimum load (score value) that will rupture the lubricant film being tested between the rotating cup and the stationary block and cause abrasion and the maximum load (OK value) at which the rotating cup will not rupture the lubricant film and cause abrasion between the rotating cup and the stationary block.
Significance: This process is used for mechanical-dynamical tests of oils and greases in roller bearings. The determination of the wear protection of oils and greases takes place under practice related conditions.

In the wear test, the test duration and the loss of weight of the bearing components are used to classify the aptitude of the lubricants.

Test Procedure: For oil tests, the test bearings are cylindrical roller thrust bearings. For grease tests, the test bearing are either tapered roller bearings or angular contact ball bearings.

Two specific test bearings are assembled into each test head, the load as specified on the test method is applied to the test head that is then assembled onto the test rig.

The friction torque is continuously recorded during the entire test as the summary friction torque of both bearings.

Both bearing temperatures are recorded and allocated to the temperature controls of the heating and the cooling unit.

Before and after the examination, the weights of the bearing elements are measured and used to evaluate the quality of the oil or grease.
Significance: The ASTM D 2893 test procedure is used to evaluate the oxidation characteristics of extreme pressure fluid lubricants, gear oils, and mineral oils.

Test Procedure: A 300 ml sample of test oil is placed in a bath maintained at 95°C/121°C (A/B version). Dried air is delivered to the system at a rate of 10 liters per hour. The test is run for 312 hours (13 days). The changes in viscosity and precipitation number of the test oil are reported.

Photo Above - Bath apparatus in operation. Aluminum block heater.
Significance: The ASTM D 2272 test method, widely known as the "RBOT" test, utilizes an oxygen-pressured cylinder to evaluate the oxidation stability of new and in-service oils in the presence of water and a copper catalyst coil at 150°C. This procedure is often used as a screening test and as a quality control test because of the speed at which results can be obtained.

Test Procedure: A 50g sample of the test oil, 5 ml of water and a copper wire catalyst are placed in a small cylinder and pressurized to 90 psi with oxygen at room temperature (25°C). The cylinder is then placed in a 150°C bath and rotated at 100 rpm. The pressure increases as the vessel is heated, reaches a maximum value and then drops as oxidation occurs. Once a 25 psi drop from the maximum pressure is observed, the amount of time from the vessel being placed in the bath through the drop is reported. An unmodified oil typically will run less than half an hour and a high quality formulated oil can run in excess of 1000 minutes.
Significance: The ASTM D 943 test procedure was originally developed for steam turbine oils but is now used for a broad range of industrial lubricants including hydraulic, turbine, and circulating oils. This test is often referred to as the “TOST” test and is used to evaluate the oxidation stability of oils in the presence of oxygen, water and an iron-copper catalyst at 95°C. This test procedure is often used for specification purposes and is considered to be especially valuable for estimating the oxidation stability of lubricants that are prone to water contamination. A high quality oil can run in excess of 5000 hours.

Test Procedure: This test utilizes a special piece of glassware known as an oxidation cell. A 300 ml sample of the test oil, 60 ml of water, and a catalyst (a 225 mm braided low carbon steel-copper coil) are placed in the oxidation cell which is heated in a bath to 95°C. Oxygen is delivered to the system at a rate of 3 liters per hour. A 3 ml oil sample is withdrawn at 500 hours and then at every 168 hours for acid number analysis. The test is concluded when the total acid number is 2.0 mg KOH/g or above. The time to reach the acid value of 2.0 mg KOH/g is calculated and reported in hours as the oxidation lifetime.
King Industries Inc. - Lubricant Additives Division

Turbine Oil Sludge Test
(Sludging Tendencies of Inhibited Mineral Oils - 1,000 Hours)

Significance: The ASTM D 4310 test procedure is a modification of the test method D 943. It is used to determine the tendencies of inhibited mineral oil based steam turbine lubricants and mineral oil based anti-wear hydraulic oils to corrode copper catalyst metal and to form sludge during oxidation. The test is conducted in the presence of oxygen, water, and copper and iron metals at an elevated temperature. This test method is also used for testing circulating oils having a specific gravity less than that of water and containing rust and oxidation inhibitors.

Test Procedure: This test utilizes a special piece of glassware known as an oxidation cell. A 300 ml sample of the test oil, 60 ml of water, and a catalyst (a 225 mm braided low carbon steel-copper coil) are placed in the oxidation cell which is heated in a bath to 95°C. Oxygen is delivered to the system at a rate of 3 liters per hour. The test is run for 1000 hours.

Upon completion of the test, the weight of the insoluble material (sludge) that is formed and the total amount of copper in the oil, water, and sludge phases is reported.
**Significance:** The method accesses the tendency of transmission lubricants to deteriorate by oxidation under specified conditions. It applies to fully formulated transmission lubricants (ATF and gear oils).

**Test Procedure:** Samples are subjected to oxidation conditions by heating to 160ºC (or other specified temperature) and passing air through it at a specified flow rate during a period of 192 hours. Two different apparatus can be used, referred to as A and B.

Samples are evaluated for sludge residue on the test glassware. The change in viscosity at 40ºC and 100ºC, and the difference in acid number between fresh oil and oxidized oil are measured.

Photos:
Above - DKA Apparatus B
Significance: The ASTM D 6186 test method is used to determine the oxidation induction time of lubricating oils subjected to oxygen at 3.5 MPa (500 psig) and temperatures between 130 and 210°C. This test method is faster than other oil oxidation tests and requires a very small amount of sample.

Test Procedure: A 3 mg sample of test oil is weighed into a new sample pan and placed in a test cell. The cell is heated at a rate of 100°C/min to a specified test temperature and then pressurized with oxygen to 3.5 MPa. The pressure is maintained using a flowrate of 100 mL/min. The test is run for 120 minutes or until after the oxidation exotherm has occurred.

The oxidation induction time is defined as the time from when the oxidation valve is opened to the onset time for the oxidation exotherm. The onset time is extrapolated from the thermal curve. If more than one oxidation exotherm is observed, then the largest exotherm is reported.
Norma Hoffman Grease Oxidation
(Oxidation Stability of Lubricating Greases by Oxidation Pressure Vessel Method)

Significance: Reaction with oxygen may lead to deterioration of a lubricating grease. The ASTM D 942 test method, measures the net change in pressure resulting from consumption of oxygen by oxidation and gain in pressure from formation of volatile oxidation by-products. This test defines the degree of oxidation after a given period of time by the corresponding decrease in pressure. This method should be used to compare similar greases and should not be used to estimate the relative oxidation resistance of different grease types.

Test Procedure: In this test, five glass dishes are filled with 4 grams of test grease and placed in the pressure vessel. The vessel is sealed and pressurized to 100 psi with oxygen and then placed in a bath held at 99°C. The pressure in the vessel is recorded at prescribed intervals throughout the test. At the end of the specified test time, usually 100, 200, or 500 hours, the pressure drop is calculated and reported.
Significance: The AFNOR Filtration Test is designed to evaluate mineral oils used for hydraulic applications. It measures the ability of an oil to pass through a fine filter without plugging under wet or dry conditions. The wet variation is more severe.

Procedure: A 320 ml sample of the test oil is poured into a 500 ml jar. If wet filtration is to be run, 0.2% distilled water is added to the jar at this time. The jar is capped and is placed in an oven at 70°C for two hours. The jar is then removed from the oven, and the test sample is mixed for 5 minutes at 1500 rpm. The jar is re-capped and returned to the oven for 70 hours. After 70 hours in the oven, the jar is removed and placed in a dark cabinet for 24 hours at room temperature. The test sample is then pressure filtered at 14.5 psi through a fine filter into a graduated cylinder. The times to filter several specified volumes of the test oil are recorded, and a ratio of these filtration times is calculated. This ratio is reported as the filterability index for the test sample.
Significance: This procedure is intended to evaluate filterability characteristic of petroleum base and synthetic hydraulic fluids.

Many fluids used in industrial and mobile hydraulic systems do not filter easily, especially in the presence of small amounts of water contamination in the system. This may result in plugging of system filters and thereby drastically increase the contamination wear of pumps and other components in the system. This test permits the evaluation of this important quality of the hydraulic fluids with and without water.

Test Procedure: According to method A-TP-02100, the test requires 100 ml samples of test fluid, with and without water, to be filtered through a 1.2 micron filter by vacuum.

Report the time required to filter 75 ml of the test fluid. Inspect the filter and report any residues or other signs of contamination.
Significance: The ASTM D 2070 test method is widely known as the “Cincinnati Milacron” test. This test method is designed to evaluate the thermal stability of hydrocarbon based hydraulic oils in the presence of copper and steel at 135°C. However, oxidation may also occur during the test.

Test Procedure: Clean, polished, pre-weighed copper and steel rods are placed in a 250 ml beaker which contains 200 ml of the test oil. The beaker is placed in an aluminum block in an oven for 168 hours at a test temperature of 135°C. At the completion of the test, the copper and steel rods are rated visually for discoloration and the oil is analyzed for the quantity of sludge formation.
**Significance:** The consistency of a grease determines its effectiveness in providing proper lubrication. If it is too soft, the grease will not stay in place, resulting in poor lubrication. Conversely, if it is too hard, the grease may not be properly distributed, resulting in poor lubrication.

ASTM D 217 covers four procedures for measuring the consistency of lubricating greases by the penetration of a cone of specified dimensions, mass, and finish. Penetration numbers are useful in classifying greases for particular applications or service requirements as well as for measuring the consistency of a given grease from batch to batch. The consistency normally changes somewhat when a grease is worked (as in actual use). The National Lubricating Grease Institute (NLGI) classifies greases according to their consistency as measured by worked penetration. These classifications are shown in Table 1.

**Test Procedure:** To measure the penetration, the test grease is packed into a worker cup and brought to 25°C. The cone assembly is placed directly over the surface of the grease. The cone is then released and allowed to drop freely into the grease for 5 seconds. The penetration of the cone into the grease is measured in tenths of a millimeter. Three determinations are made and averaged to give the reported result. The four test variations consist of measuring the penetrations of unworked and worked grease samples. The test variations are as follows:

- **Unworked Penetration**
- **Worked Penetration - 60 double strokes in the grease worker**
- **Prolonged Penetration - typically 10000+ double strokes in the grease worker**
- **Blocked Penetration - unworked penetration of a hard cube of grease**

### Table I - NLGI Grade Classifications

<table>
<thead>
<tr>
<th>NLGI Grade</th>
<th>ASTM Worked Penetration (Depth in tenths of a millimeter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>445 - 475</td>
</tr>
<tr>
<td>00</td>
<td>400 - 430</td>
</tr>
<tr>
<td>0</td>
<td>355 - 385</td>
</tr>
<tr>
<td>1</td>
<td>310 - 340</td>
</tr>
<tr>
<td>2</td>
<td>265 - 295</td>
</tr>
<tr>
<td>3</td>
<td>220 - 250</td>
</tr>
<tr>
<td>4</td>
<td>175 - 205</td>
</tr>
<tr>
<td>5</td>
<td>130 - 160</td>
</tr>
<tr>
<td>6</td>
<td>85 - 115</td>
</tr>
</tbody>
</table>
**Significance:** The ASTM D 1401 test method measures the demulsibility characteristics of oils. Demulsibility is the ability of an oil to separate from water. This test measures how rapidly and completely an oil/water emulsion separates after mixing equal volumes of the oil and water for 5 minutes at an elevated temperature.

Industrial oils are often contaminated with water. Water contamination can range from condensation from the atmosphere to exposure of condensed steam as in the case of turbine oils. For effective removal of water, an oil must possess good demulsibility characteristics.

**Test Procedure:** The test apparatus consists of a bath where 40 ml of the test oil and 40 ml of water are mixed in a 100 ml graduated cylinder for 5 minutes. The test is conducted at 54°C for oils having a viscosity less than 90 cSt at 40°C and at 82°C for oils having a viscosity greater than 90 cSt at 40°C. The separation of the oil/water emulsion is observed at 5 minute intervals. The time required for the emulsion to separate to 3 ml of emulsion or less is reported. The time limits for the test are 30 minutes at 54°C and 60 minutes at 82°C. For very high viscosity oils where there is insufficient mixing of oil and water, test method D 2711 is recommended.
Significance: The ASTM D 2711 test method provides a guide for determining the demulsibility characteristics of oils that are prone to water contamination and that may encounter the turbulence of pumping and circulation capable of producing water-in-oil emulsions. Demulsibility is the ability of an oil to separate from water. This test method is intended for evaluating medium and high viscosity oils.

Test Procedure: A 405 ml sample of the test oil and 45 ml of distilled water are stirred for 5 minutes at 82°C in a graduated funnel. After a 5 hour settling period, a 50 ml sample is drawn from the top of the oil and is centrifuged to determine the percent of water in the oil. Then any free water is drawn off and the amount is determined. After removing the free water, the sample is siphoned off until 100 ml remains in the funnel. The remaining sample is then centrifuged, and the volumes of the water and emulsion components are measured. The amount of water from this step is added to the amount of free water and is reported as "total free water". The following measurements are reported:
- Water in oil (%)
- Free water from funnel after centrifuging (ml)
- Total free water (ml)
- Emulsion (ml)

The average values from four determinations on each oil are reported.

While the procedure remains the same, when EP gear oils are tested, the oil sample size is reduced to 360 ml and the amount of water used is increased to 90 ml.
**Significance:** The ASTM D 2265 test method is used to determine the dropping points of lubricating greases. Dropping point is a numerical value assigned to a grease composition representing the corrected temperature at which the first drop of material falls from a test cup and reaches the bottom of a test tube. Since the ASTM D 2265 test method is a static test, it is considered to have only limited significance in predicting actual service performance. However, it is often used when formulating new greases because it shows an important effect of additives on greases. Many additives when incorporated into a grease lower the dropping point of the grease. Dropping point is also used to assist in identifying a grease as to its type and for establishing and maintaining benchmarks for quality control.

**Test Procedure:** A special grease cup containing the test grease is supported in a test tube which is placed in an aluminum block. A thermometer is placed in the tube and positioned so that it measures the temperature in the sample cup without coming in contact with the grease. The temperature is increased until a drop of material falls from the cup to the bottom of the test tube. When this occurs, the temperature of the aluminum block and the temperature in the sample cup are recorded. One third the difference between these two values is the correction factor which is added to the temperature measured in the cup. This corrected temperature is reported as the dropping point of the grease.
Hydrolytic Stability Test
(Beverage Bottle Test - Coca-Cola Test)

**Significance:** The ASTM D 2619 test method is used to measure the hydrolytic stability of hydraulic oils and turbine oils. Hydrolytically unstable oils form acidic and insoluble contaminants which can cause system malfunctions due to corrosion, valve sticking, or change in viscosity of the fluid.

**Test Procedure:** A 75 g sample of the test oil, 25 g of distilled water, and a pre-weighed copper strip are sealed in a pressure-type beverage bottle. The bottle is rotated end for end at 5 rpm for 48 hours in an oven at 93°C. Then the liquid layers are separated and the following determinations are made:
- Viscosity change of the test oil
- Acid number change of the test oil
- Total acidity of the water
- Weight of insoluble material that formed
- Weight change of the copper strip
- Appearance of the copper strip under 20x magnification

Photo Above - Test apparatus containing beverage bottles.