It takes a leader to run a nation.
Abstract:
There are number of grease thickeners available for making lubricating greases. However, each one of them possesses its own strengths and weaknesses. Calcium sulfonate complex greases, not new to the industry, are known for over six decades and have been improved over times by various people to make suitable grease for different applications. This class of grease is known for having excellent high temperature, extreme pressure and rust protection characteristics. The down side of its performance is poor pumpability, poor low temperature properties and higher cost compared to lithium greases.

In general, the art in preparing this class of greases involves converting liquid overbased calcium sulfonate to grease containing calcite particles. The degree of conversion to calcite form can greatly influence the properties of the finished grease and therefore the art lies how best one controls the process parameters and incorporate the other performance enhancing ingredients during processing stage.

The worldwide volume for calcium sulfonate greases is increased from 1.2% in 2005 to 1.4% in 2010. In North America, its volume increased significantly from 3.8% in 2005 to 5.4% in 2010, where in India it’s merely about 0.8%. In North America by virtue of its characteristics these greases are gaining more popularity over others and are gradually becoming true multi-purpose greases.

Besides having robust multi-purpose calcium sulfonate greases, the authors have recently developed some innovative specialty sulfonate greases as a result of perfecting unique process parameters and optimized compositions. One of the products developed is a super heavy duty grease for extreme pressure conditions that exhibit 800 kg weld load and 70 lbs Timken OK load. Other grease covered in this paper is grease for marine applications having excellent rust protection and passing 1000 hrs salt fog test and the third one is arctic grease for extreme low temperature characteristics having mobility of 18 gm / minutes at -40°C. The details of those performance characteristics will be covered in this paper.

Key Words: Lubricating grease, Calcium sulfonate, Weld load, Penetration

Introduction
Over based calcium sulfonate greases, also popularly known as sulfonate greases, are not new to the industry as it appears and were patented as early as in 1940’s. One of the reasons for development of this class of greases appears to be the efforts to improve the high temperature capabilities of calcium greases. Calcium base greases are known to possess excellent water resistance and low temperature properties but poor in high temperature capabilities. Zimmer et al, patented sulfonate base grease having good water resistance and having melting point over 400 °F (204 °C) (1,2). Sproule and Pattenden (3) reported that grease prepared using combination of high and low molecular weight sulfonates as thickening agent provide grease with higher drop point. McMillen in 1960’s patented calcium sulfonate greases having dropping point over 500 °F (260°C). Since then, the basic principle of making gelled overbased calcium sulfonate greases using liquid over based calcium sulfonate with total base number (TBN) ranging from 300 to 500 remains practically unchanged. In a general process, highly overbased sulfonate is mixed with base oil and treated with acid, lime and suitable promoters where amorphous
calcium carbonate is converted into desired crystalline calcite form followed by removal of promoters and water from the mixture (5). During the process, amorphous calcium carbonate can readily be converted either to calcite (desired form) or vaterite, an undesired form of calcium carbonate. The process is highly sensitive to the processing parameters and ingredients used and therefore, end use properties greatly depend upon how the grease is processed. Muir et al, reported high performance calcium borate modified calcium sulfonate complex grease exhibited drop point over 570 °F (299 °C) and excellent other performance characteristics (6).

Conventional overbased calcium sulfonate greases reported, in general, are known to possess high dropping point, good water resistance and rust protection properties, and superior inherent extreme pressure properties. The down side of these greases is found to be inferior low temperature and limited pumpability due to high thickener content used to make these greases. Due to their superior characteristics over other greases especially over most popular lithium greases, its volumes worldwide are on gradual increase. NLGI 2010 worldwide market survey indicates that volumes of calcium sulfonate greases has increased from 1.2 % in 2005 to 1.4 % in 2010 (7). These greases are gaining more popularity in North America with its volume increase from 3.8 % in 2005 to 5.4 % in 2010. By virtue of greater awareness and unique characteristics, this class of greases has started to gain importance in Indian industry as well, though the volumes are just merely 0.8 % in 2010.

A wide variety of overbased calcium greases are reported in literature and are commercially available with different claims. However, the properties of this grease are greatly dependent upon the process parameters, reacting components and the type of additives used to enhance the properties. The conventional additives used in other greases like lithi ums do not necessarily provide the similar effect in calcium sulfonate greases. Royal Mfg Co LP has been making overbased calcium sulfonate greases for decades and the formulae and compositions have been customized and perfected many times so as to meet most severe application requirements of the industry. We have recently developed 3 new products, one super heavy duty grease having 800 kg weld load, second one for marine applications passing over 1000 hrs in salt fog test and the third one with extreme low temperature properties exhibiting mobility of 18 gm/minutes at - 40 °C as per US steel mobility test. The performance characteristics of these greases have been covered in this paper.

Experimental

The base oils used in preparing greases are commercially available mineral and/or synthetic oils of different viscosities. The mineral oils used are either neat or blend of paraffinic and / or naphthenic oils. The overbased calcium sulfonate thickeners were prepared using 400 TBN sulfonate. The greases reported in this paper are commercially manufactured in oil heated counter rotating kettles having capacity of about 5 Tons per batch and were either milled through Charlotte mill or APV Gaulin homogenizer. The greases were tested as per standard ASTM / IP test methods. The grease mobility has been tested as per US Steel mobility test. The salt spray test was tested as per ASTM B 117 test method.

Results and Discussion

Development of Heavy Duty Calcium Sulfonate Grease

There are different kinds of greases being regularly used in automotive and industrial applications. In general, extreme pressure (EP) greases used in automotive wheel bearing, chassis, disc brake, universal joints, fifth wheel etc are either lithium/ lithium complex, aluminum complex, and calcium sulfonate greases meeting NLGI GC-LB specifications. Similar kind of greases can also be used in industrial applications with minor modifications for moderate operating conditions. Typical properties of commercially marketed grease for medium to high speed bearings are tabulated in Table -1. Such greases are normally made with group I or naphthenic base oils and fall in viscosity grade ranging VG 150-220. Typically these greases possess weld
load of the range 250-400 kg and Timken OK load to the tune of 40-50 lbs where calcium sulfonate greases possess little higher Timken load of about 50 lbs or more. The water washout for these greases typically is less than 15 % wt @ 79 °C. However, there are some more severe applications like off high-way applications, construction and mining equipments which require much better extreme pressure and heavy load carrying characteristics and other properties compared to typical NLGI GC-LB or multi-purpose grease. The EP greases used in such severe industrial applications like in metal processing industry, mining, construction, drilling, paper mill, are typically lithium/lithium complex, aluminum complex, clay base and calcium sulfonate greases and general characteristics of those greases are tabulated in Table-2. The industrial applications where the loads are much heavier and bearing sizes sometime are larger, VG 320-460 oil based greases are recommended and are doped with higher amount of EP additives to meet stringent requirement of the industry. On the other hand calcium sulfonate greases do not require much additives to meet these requirements. Interestingly, it is difficult to further boost the EP characteristics of the calcium sulfonate grease.

As there are a number of manufactures and suppliers of these classes of greases, there is increasing emphasis from the market to develop some niche products having heavy duty grease capable of handling not only extreme heavy duty and shock load conditions but also stand out providing competitive advantage. In view of this, we have recently developed a heavy duty greases specially designed for heavy duty industrial operations like in mining, steel and construction industries. The comparative test data of this grease are tabulated in Table-3. The data indicate that the new heavy duty grease exhibit superior performance characteristics compared to conventional sulfonate greases available in the

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Property</th>
<th>Test Method</th>
<th>Lithium Grease</th>
<th>Li-complex Grease</th>
<th>Al-complex Grease</th>
<th>Ca-sulfonate Grease</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Thickener type</td>
<td>-</td>
<td>Lithium 12</td>
<td>Li-complex</td>
<td>Al-complex</td>
<td>Calcium sulfonate</td>
</tr>
<tr>
<td>2.</td>
<td>Appearance</td>
<td>Visual</td>
<td>Smooth</td>
<td>Smooth</td>
<td>Smooth</td>
<td>Smooth</td>
</tr>
<tr>
<td>3.</td>
<td>NLGI grade</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td>Penetration after 100,000 strokes</td>
<td>+ 30</td>
<td>+ 30</td>
<td>+ 30</td>
<td>+ 25</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Drop point, °C</td>
<td>ASTM D 2265</td>
<td>180 Min</td>
<td>260 min</td>
<td>260 min</td>
<td>260 min</td>
</tr>
<tr>
<td>7.</td>
<td>Viscosity grade</td>
<td>ASTM D 445</td>
<td>VG 220</td>
<td>VG 220</td>
<td>VG 220</td>
<td>VG 220</td>
</tr>
<tr>
<td>8.</td>
<td>Copper Corrosion</td>
<td>IP 112 / ASTM 4048</td>
<td>1a</td>
<td>1a</td>
<td>1a / 1b</td>
<td>1a</td>
</tr>
<tr>
<td>10.</td>
<td>Weld load, kg</td>
<td>ASTM D 2596</td>
<td>&gt; 250</td>
<td>315</td>
<td>315</td>
<td>400</td>
</tr>
<tr>
<td>11.</td>
<td>Wear scar dia, mm</td>
<td>ASTM D 2266</td>
<td>0.60 mm</td>
<td>0.60 mm</td>
<td>0.60 mm</td>
<td>0.50</td>
</tr>
</tbody>
</table>
# Table-2

Typical Properties of Conventionally Used Greases in Heavy Duty / Critical Applications

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Property</th>
<th>Test Method</th>
<th>Li-complex</th>
<th>Al-complex</th>
<th>Ca-sulfonate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Thickener type</td>
<td>-</td>
<td>Li-complex</td>
<td>Al-complex</td>
<td>Ca-sulfonate</td>
</tr>
<tr>
<td>2.</td>
<td>Appearance</td>
<td>Visual</td>
<td>Smooth</td>
<td>Smooth</td>
<td>Smooth</td>
</tr>
<tr>
<td>3.</td>
<td>NLGI Grade</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td>Penetration after, 100,000</td>
<td></td>
<td>+ 30</td>
<td>+ 30</td>
<td>+ 30</td>
</tr>
<tr>
<td>6.</td>
<td>Drop Point, °C</td>
<td>ASTM D 2265</td>
<td>260 Min</td>
<td>260 min</td>
<td>277 min</td>
</tr>
<tr>
<td>7.</td>
<td>Copper Corrosion</td>
<td>IP 112</td>
<td>1a</td>
<td>1a/1b</td>
<td>1a</td>
</tr>
<tr>
<td>8.</td>
<td>Rust preventive properties</td>
<td>ASTM D 1743</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>10.</td>
<td>Weld load, kg</td>
<td>ASTM D 2596</td>
<td>315</td>
<td>315</td>
<td>400</td>
</tr>
<tr>
<td>11.</td>
<td>Wear Scar Dia, mm</td>
<td>ASTM D 2266</td>
<td>0.60</td>
<td>0.60</td>
<td>0.50</td>
</tr>
<tr>
<td>12.</td>
<td>Timken OK load, lbs</td>
<td>ASTM D 2509</td>
<td>45-50</td>
<td>40-45</td>
<td>50-55</td>
</tr>
<tr>
<td>14.</td>
<td>Water Spray off, % wt</td>
<td>ASTM D 4049</td>
<td>50</td>
<td>40</td>
<td>30</td>
</tr>
</tbody>
</table>

# Table-3

Comparative Test Data of Regular Calcium Sulfonate and New Heavy Duty Calcium Sulfonate Grease

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Property</th>
<th>Test Method</th>
<th>Regular Ca-sulfonate Grease</th>
<th>New Heavy Duty Ca-sulfonate Grease</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Thickener type</td>
<td>-</td>
<td>Ca-sulfonate</td>
<td>Ca-sulfonate</td>
</tr>
<tr>
<td>2.</td>
<td>Appearance</td>
<td>Visual</td>
<td>Smooth</td>
<td>Smooth</td>
</tr>
<tr>
<td>3.</td>
<td>NLGI Grade</td>
<td>ASTM D 217</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>Penetration, 60 x strokes</td>
<td>ASTM D-217</td>
<td>265-295</td>
<td>265-295</td>
</tr>
<tr>
<td>5.</td>
<td>Penetration after, 100,000</td>
<td></td>
<td>+ 20</td>
<td>+ 20</td>
</tr>
<tr>
<td>6.</td>
<td>Drop Point, °C</td>
<td>ASTM D 2265</td>
<td>277 min</td>
<td>277 min</td>
</tr>
<tr>
<td>7.</td>
<td>Viscosity Grade</td>
<td>ASTM D 445</td>
<td>220</td>
<td>460</td>
</tr>
<tr>
<td>8.</td>
<td>Copper Corrosion</td>
<td>IP 112</td>
<td>1a</td>
<td>1a</td>
</tr>
<tr>
<td>9.</td>
<td>Rust preventive properties</td>
<td>ASTM D 1743</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>10.</td>
<td>Weld load, kg</td>
<td>ASTM D 2596</td>
<td>400-500</td>
<td>800</td>
</tr>
<tr>
<td>11.</td>
<td>Wear Scar Dia, mm</td>
<td>ASTM D 2266</td>
<td>0.50</td>
<td>0.45</td>
</tr>
<tr>
<td>12.</td>
<td>Timken OK load, lbs</td>
<td>ASTM D 2509</td>
<td>50-60</td>
<td>70</td>
</tr>
<tr>
<td>13.</td>
<td>Water Washout, 79 °C, % wt</td>
<td>ASTM D 1264</td>
<td>5 max.</td>
<td>1.3 max.</td>
</tr>
<tr>
<td>14.</td>
<td>Water Spray off, % wt</td>
<td>ASTM D 4049</td>
<td>&lt; 40</td>
<td>20 max</td>
</tr>
<tr>
<td>15.</td>
<td>USS Mobility Test</td>
<td>USS DM 43</td>
<td>13.6</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>@ 0 °F, gm/min</td>
<td></td>
<td>4.0</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>@ -20 °F, gm/min</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
market. The conventional calcium sulfonate greases available in the market exhibit weld load of about 400 to 500 kg range where as new developed grease has indicated maximum possible weld i.e., 800 kg tested as per ASTM D 2596 Method without adding molybdenum disulphide or graphite. Similarly the Timken OK load for conventional greases ranges from 45-55 lbs where as the new grease has exhibited much superior Timken OK load of 70 lbs.

This superior performance could possibly be attributed due to the combination of factors. One of them is optimizing the process parameter in such a way where total conversion amorphous calcium carbonate to crystalline calcite takes place minimizing the formation of undesirable vaterite form. Greases having dominant calcite form of calcium carbonate are reported to possess better EP properties as compared to the one having predominant vaterite form of calcium carbonate. Calcite fish like platelet structure is reported to help in better film formation and thus provide superior EP properties whereas carbonate particles in vaterite are oriented perpendicularly (8). On the other hand, conventional EP additives like sulphur-phosphorous and/or antimony-zinc type additives typically used in lithium greases do not perform well in sulfonate greases and therefore it is rather difficult to further boost EP properties of calcium sulfonate grease. Additionally, we have identified a synergistic combination of additives that help to achieve highest weld load of 800 kg and very high Timken of 70 lbs. Figure-1 comparatively indicate that new heavy duty calcium sulfonate grease exhibit much superior EP properties in terms of weld load with respect to its other counterpart. Besides this, this new greases exhibited very good pumpability characteristics at normal and below normal temperatures. As per US Steel mobility test (USS DM 43), this grease indicated mobility of 13.2 g/minutes at – 18 °C (0 °F) and 3.2 gm/minutes at –30 °C (–20 °F) which is considered good and comparable to our conventional grease having base oil viscosity of VG 220. This makes this grease better suitable for applications where greases are pumped through centralized lubrication systems especially in steel mills and mining.

Superior Calcium Sulfonate Grease for Marine Applications

In applications like marine and off shore drilling, grease exposed to either directly or indirectly to salt water and therefore rusting of equipments is pretty common. For such applications having sultry environment, lubrication of bearings, gears and wire ropes requires grease having resistance to water washout, water spray off and resistance to corrosion in salt water environment. In such applications, calcium sulfonate greases are an obvious choice, having inherent properties of rust inhibitions. The water washout characteristics are tested by ASTM D 1264 method and water spray off by ASTM D 4049 test method. For testing anti-rusting properties for marine applications, salt fog spray test (as per ASTM B117) has emerged to be better than other rust tests. Some of the customers are demanding greases meeting salt fog spray test data as high as 1000 hrs. This stringent test requirement is not met through lithium or even a majority aluminum complex greases. If calcium sulfonate grease is not formulated carefully, it may not meet this stringent requirement. We have developed grease specifically for marine application meeting this requirement and test data are tabulated in Table-4. This grease exhibited excellent mechanical stability; very good extreme pressure properties in terms of 620 kg weld load and 65 lbs Timken OK load and excellent rust protection properties as tested by ASTM D 1743 test and salt spray test ASTM B 117. This grease passes rust test (ASTM D 1743). In salt

Fig. 1: Comparative EP Properties of Greases
spray test this grease exhibited excellent performance in terms of passing over 1000 hrs salt spray test where other greases failed early. This grease might have run more hrs but test was discontinued after completing target 1000 hrs. Other grease which is also calcium sulfonate base grease in same viscosity range failed after 360 hrs (Figure-2) thus providing the superior performance. The reasons for this superior performance are not completely understood however, it could possibly be attributed due to interaction of polar heads of overbased calcium sulfonate with the other ingredients/additives.

**Table-4**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Property</th>
<th>Test Method</th>
<th>Regular Ca-sulfonate Grease</th>
<th>New Ca-sulfonate Grease for Marine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Thickener type</td>
<td>–</td>
<td>Ca-sulfonate</td>
<td>Ca-sulfonate</td>
</tr>
<tr>
<td>2.</td>
<td>Appearance</td>
<td>Visual</td>
<td>Smooth</td>
<td>Smooth</td>
</tr>
<tr>
<td>3.</td>
<td>NLGI Grade</td>
<td>ASTM D 217</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>Penetration, 60x strokes</td>
<td>ASTM D-217</td>
<td>265-295</td>
<td>265-295</td>
</tr>
<tr>
<td>5.</td>
<td>Drop Point, °C</td>
<td>ASTM D 2265</td>
<td>277 min</td>
<td>277 min</td>
</tr>
<tr>
<td>6.</td>
<td>Viscosity Grade</td>
<td>ASTM D 445</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>7.</td>
<td>Weld load, kg</td>
<td>ASTM D 2596</td>
<td>620</td>
<td>620</td>
</tr>
<tr>
<td>8.</td>
<td>Wear Scar Dia, mm</td>
<td>ASTM D 2266</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>9.</td>
<td>Timken OK load, lbs</td>
<td>ASTM D 2509</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>10.</td>
<td>Water Washout, 79 °C, % wt</td>
<td>ASTM D 1264</td>
<td>2.3max.</td>
<td>1.3max.</td>
</tr>
<tr>
<td>11.</td>
<td>Water Spray off, % wt</td>
<td>ASTM D 4049</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>12.</td>
<td>Copper Corrosion</td>
<td>ASTM D 4048</td>
<td>1a</td>
<td>1a</td>
</tr>
<tr>
<td>13.</td>
<td>Rust Preventive Properties</td>
<td>ASTM D 1743</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>14.</td>
<td>Salt Spray Test, hrs</td>
<td>ASTM B 117</td>
<td>360 hrs</td>
<td>&gt; 1000 hrs</td>
</tr>
</tbody>
</table>
Arctic Calcium Sulfonate Grease for Cold Climate Applications

Calcium sulfonate greases are known to be inferior in pumpability due to higher thickener used to make NLGI 2 grease compared to other greases like lithium complex and aluminum complex greases. Calcium sulfonate complex greases, on the other hand, have proved to advantageous over lithium complex and aluminum complex greases in certain applications like mining and steel due to better extreme pressure and natural rust protection properties. Aluminum complex greases are also known for better water resistant properties and thus the candidate for mining and drilling operation. However, the more popular greases in these applications are either lithium or lithium complex greases so far and for transition, the choice lies between either aluminum complex or calcium sulfonate complex grease. Calcium sulfonate complex earns more points due to better compatibility with lithium and lithium complex greases over aluminum complex greases.

There are some applications in mining and drilling operations like up in Canada, China and some European countries where the temperatures can be very low specially in winter and the greases are required to pump as low as −40 °C/°F. Therefore the challenge lies to make a grease having good pumpability at such low temperatures and many of the calcium sulfonate available in the market do not meet this requirement. The greases used in these applications are generally synthetic oil based lithium, calcium and or aluminum complex greases. In some cases there are two grades of greases used like summer grade in NLGI 2 consistency and winter grade in NLGI 1 grade. Synthetic greases do fill this void to an extent but their high cost is the limiting factor.

We have recently developed arctic calcium sulfonate grease in semi-synthetic base oil, meeting cold climate requirements. The test data are tabulated in Table-5. Table -5 indicates that the grease in NLGI 2 consistency exhibited excellent mechanical stability only 11 units change in 100,000 double strokes
penetration and a high drop point of +277 °C. Weld load of 620 kg and Timken OK load of 60 lbs indicates that this grease encompasses excellent extreme pressure properties as well. This grease also possesses good rust preventive properties as indicated by ASTM D 1743 test. US steel mobility test data conducted at -18°C and -40°C/°F indicate its mobility 140 gm/min at -18°C and 18 gm/min at -40°C/°F. In general, the customer requirement for such applications is minimum 4 gm/min mobility at -40°C/°F and therefore this arctic grease has exhibited much superior data. This may primarily be attributed to the fact that we have carefully optimized and perfected our manufacturing process and control in such a way that uses reduce amount of thickener to make NLGI 2 grease and also the viscometrics are adjusted in such a way that help us to meet this stringent low temperature requirement simultaneously while retaining the other properties.

Conclusions

Overbased calcium sulfonate greases constitute significant volume of worldwide grease market and its volume is considerably increasing in North America. Calcium sulfonate greases are known to possess superior high temperature, extreme pressure and rust protection properties as compared to other greases. The drawback associated with this class of greases is limited pumpability especially at low temperatures. These greases in different base oil viscosities and grades are being regularly marketed by different manufacturers/marketers across the globe. In order to further enhance the scope of this important class of greases in critical applications areas, we have successfully developed three greases. The first grease developed exhibited very high extreme pressure properties as indicated by 800 kg weld load and 70 lbs Timken. The second grease has been intended for humid environment specially in marine and off shore drilling operations. This grease has exhibited excellent test results in salt fog test and successfully passed over 1000 test hrs. The third grease was developed for very cold climate and tested as per US Steel mobility test at -18°C and -40°C and test result indicate its mobility of 140 gm/minute and 18 gm/minutes respectively which is considered pretty good for calcium sulfonate greases.

Acknowledgements

Authors are thankfully to The Lubrizol Corporation for help in testing the grease samples and also to the Royal, Tulsa grease plant for providing the grease samples.

References

5. Fish, G., and Ward, W.C., “Calcium sulfonate greases revisited” presented at 78th NLGI Annual Meeting, Desert Palm, CA, USA, June 11-14, 2011
7. NLGI, USA annual grease market survey, 2010