The Next Generation Food Machinery Grease 10 Years On

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Introduction

The most critical industry on the planet today is that of food production and any disruption in that industry can have significant impact on the human population. Disruptions can include natural ones such as drought and blight to human caused ones such as contamination and can lead to a lack of product, product recall, sickness and even death. All of this can cause fear, panic, and anger in various populations particularly if negligence or worse, intentional acts were involved. Looked at another way, this will cost companies significant dollars and can ultimately lead to higher prices for consumers. Therefore it is imperative that all stages of the food process be managed in a safe and effective manner. Many large intermediate food supply companies and end marketing companies are now insisting that all stages of the food process be administered in a safe manner. Lubrication and lubricants are a small but critical part of all stages of that process.

The contamination of food by lubricants will and should always be a concern. Lubricants designed for food processing are incidental contact products i.e. potential but minimal contact. They are not designed for full consumption and the FDA rules limit food contact to 10 ppm. Leaks due to a variety of reasons can never be fully eliminated. Grease can get washed out of the bearings by the process material or during cleaning. As long as lubricants are required in the food processing equipment, no amount of design or engineering effort will completely eliminate the potential for food contact.

While the FDA limits food contact by an approved food grade lubricant to 10 ppm, it limits a non-food grade lubricant to ZERO contamination. Therefore any contamination of the food by a non-food grade material would require the entire batch of food to be discarded. This could involve a major recall. Gebarin (1) noted in his White Paper, several documented lubricant related product recalls, one of which stands out:

> "In 2000, 86,000 lbs. of sliced and packaged turkey products (mostly deli meats) were voluntarily recalled from exposure to a non-food grade lubricant. Consumers reported off-odor and off-flavor product. A few experienced temporary intestinal discomfort"

Why therefore would a company involved in any stage of the food process open themselves up to liability by using the wrong lubricant? It would seem that choosing the right lubricant would be the simplest of all of the decisions that a food processor would have to worry about. Nothing however is ever simple. The lack of lubricant education, the lack of hygiene education, the lack of high performance grease (compared to industrial products), laziness, improper information from lubricant suppliers, and even negligence are all possible causes for this to happen.

In 2002, a new grease technology for food grade applications was introduced (2). Calcium Sulfonate Complex grease technology has now demonstrated that the lack of high performance food grade grease is no longer a valid excuse. This paper follows the paper given in 2002 on the development and commercialization of Calcium Sulfonate Complex food grade grease. It will briefly examine the requirements of food grade grease and examine two aspects of its performance in closer detail - performance at high and low temperatures.

Approval Requirements for Food Grade Grease

The most recognized classification globally for food grade lubricants is the H1 and H2 classifications. H1 lubricants are lubricants that may come in contact with food "incidentally" at not more than 10 ppm. H2 lubricants are products that are acceptable to be used in food processes where no contact with food will occur - typically ancillary equipment like garage door sliders and tow motor bearings. While this was developed by the USDA and is therefore US based, a large selection of countries readily recognizes it. Even those that have their own approval process and requirements, such as Canada (CFIA) and Australia (AQIS), recognize the H1 classification to the extent that H1 approved products are rarely if ever rejected. Food inspectors in those countries still expect to see local approval.

The H1 and H2 approval process is based solely on the Code of Federal Regulations Section 21 (Food and Drugs) - known simply as 21 CFR. There are several sections within 21 CFR that pertain to lubricants or components of lubricants. 21 CFR 178.3570 contains information specific to food grade lubricants. This includes thickeners, additives, some fluids and other components. It also references GRAS (Generally Regarded As Safe) substances which are listed under parts 182 and 184. Other sections of interest include: 21 CFR 178.3620 which covers White Mineral Oil, 21 CFR 172.878 for USP Mineral Oil, and 21 CFR 172.882 which covers synthetic iso-paraffinic hydrocarbons.

Further substances not listed may be acceptable for use if there is a letter of opinion from the FDA or a qualified legal firm. As well, the NSF, an organization that is the de facto US certifying body for food grade lubricants, has begun their own program of approving new substances for use in lubricants for incidental contact. This program is called the H1-X program.

There is no rule that says lubricants cannot be self-certified, however, most marketers and end users desire third party certification. As noted in the US the organization that is certifying products is the NSF. Recently, an organization called InS, has begun offering the same type of service out of the EU.

Kosher and Halal

On top of certification due to food safety requirements, there are religious requirements as well. There are two prominent religious based certifications in the marketplace, Kosher (Jewish) and Halal (Muslim). Kosher means "suitable" and Halal means "permissible". While the requirements of each have been applied to food itself since the faith began, the application to food grade lubricants is a much newer process. Each requires an ingredient review, supplier review, an understanding of how raw materials are handled, a regular plant audit, and education and training of manufacturing personnel. At the successful completion of the process the product is allowed to carry the symbol of the organization granting the certification.

HACCP

HACCP stands for Hazard Analysis and Critical Control Point. This is a methodology that was developed by NASA in the 1960s and in the late 1990's became a requirement for food processing plants in the US and Canada. It is also used extensively in the cosmetic and pharmaceutical industries. The program focuses on taking a proactive approach to preventative measures for controlling contamination of foodstuffs throughout the manufacturing process. It will fit well into most ISO systems and is very similar to the techniques applied in Six Sigma. It should be noted that it is not a stand-alone program and any good food processing plant will have other systems in place such as GMP (good manufacturing practices), a personal hygiene plan, and a well-developed set of sanitation procedures. Lubricants and proper lubrication are an integral part of any HACCP program. This system can be applied to other industries or processes, including food grade lubricant manufacture. However, at this time it is not a requirement.

The seven principles of an HACCP plan include:

1) Hazard analysis
2) Identify critical control points (CCP)
3) Establish critical limits for each CCP
4) Monitor the CCPs
5) Establish corrective actions
6) Good record keeping
7) Verify that the plan is effective

Under HACCP, no non-food grade grease should be allowed to be used in a critical control point within the facility. Improved food grade lubricants could be a benefit to an HACCP plan if they can reduce or eliminate critical limits in various CCPs.

ISO21469

Where HACCP was not developed for the manufacture of lubricants and is not a requirement, ISO21469 was developed specifically for it. It is not yet a requirement but has been adopted by several lubricant manufacturers. ISO21469 was designed to essentially take the H1 program for certification to the next level. The current H1 program is simply a paper exercise, as far as certification is concerned. The complete composition of the product, based on CAS number is certified against 21 CFR noted above. No sample is analyzed and there is no product audit or manufacturing facility audit to ensure compliance via third party. It is based on the word and reputation of the manufacturing and marketing companies that their H1 certified products are what they say they are.

ISO 21469 is a system that incorporates, on top of the H1 certification (or applicable certification in the country of interest), a requirement for a plant risk assessment - HACCP would work well here - and plans for GMP including hygiene and sanitation procedures. It requires that a sample be submitted at the time of initial approval to which all future samples may be compared via Fourier Transform Infrared analysis to ensure that the composition remains the same. Finally a regular plant audit is required to monitor compliance to the submitted product and plans.

For the most part, the majority of manufacturers and marketers are reputable and realize that the consequences of negligence or fraud could be disastrous. The products that they market are fully acceptable for food grade use. However, there is always the possibility of fraud or negligence and ISO21469 was developed in part to address this.

A Note on Allergens

Food allergies in people have always been present, however, as more science is dedicated to studying them, much more information and attention has developed. Most schools in North America now ban peanut products from their premises due to the potential for severe allergic reactions in affected children. Manufacturers of food products go to great lengths to control allergens in their facilities so that the food they produce can safely meet their customer's needs. This has pushed the requirement for allergen knowledge down to suppliers of material for food processing facilities, including lubricants. Some companies that have allergen free manufacturing lines are particularly concerned with obtaining allergen free material as even trace amounts can have serious impacts.

Table 1 lists the common allergens that companies look for. In lubricants, the first line of defense

Table 1
Common Food Allergens

Peanuts product (Including Peanut Oil)	Fish, Crustacean shellfish, Shellfish
Sesame Seeds	Soy products
Milk products	Wheat products
Egg products	Sensitive ingredients Yellow #5 & #6, Red 40
Sulphites	
Tree Nuts Almond, Brazil nut, Cashew, Hazelnut/Filbert, Macadamia nut, Pecan, Pine nut, Pistachio, Walnut/Heartnut, Coconut	

is in selecting raw materials that do not come from or contain these allergens. Many raw materials should be suitable; however many products could be derived from natural sources, particularly seed and nut oils. As well, apart from the raw materials used, care may also be required to ensure that operator hygiene and education regarding allergens (such as those that may come from employee meals) as well as plant sanitation procedures be put in place to reduce contamination of the lubricant.

Available Thickener Technologies

Within the scope of acceptable chemistry for use in H1 lubricants, several thickener systems are available. They include simple Calcium grease (Calcium Anhydrous), Aluminum Complex Grease, Clay grease, Polyurea grease, silica thickened grease, PTFE thickened grease, and Calcium Oleate thickened grease. As noted in 2002, Calcium Sulfonate Complex grease is now also approved. Lithium and Lithium Complex grease is not approved for use.

Fluids and Additives

Fluids available are of course more limited than an industrial grease. Most products are typically formulated with white oil, either technical or USP, as it offers the lowest cost. White oils come in a range of viscosities, however they tend to be ISO 100 or lower. They can be sourced from either paraffinic or naphthenic stock.

For higher performance most formulators turn to Polyalphaolefins (PAO), synthetic fluids which offer a very broad operating range. They are available in low viscosity versions (2 to 10 cSt @ 100°C) and in high viscosity versions (40 and 100 cSt @ 100°C). Newer technology is being offered with viscosities much greater than 100 cSt, although it is unknown at this point if these will meet H1 status.

Other approved fluids include Polyalkylene Glycol (PAG), Dimthylpolysiloxane (silicones) with viscosity >300 cSt, and Polybutenes. As well, new fluids to the list include alkylated naphthalene and several synthetic esters.

Calcium Sulfonate Complex Grease Technology

The technology of Calcium Sulfonate Complex grease is now well known. While the technology did exist as early as the 1960's, it should be widely accepted that the modern, high performance technology that is sold today, was developed by Muir and Blokhuis in 1985 (3). Muir first presented the technology at the 1987 NLGI and NPRA meetings (4, 5). It was their addition of Calcium Borate and 12-Hydroxystearic Acid to the process that produced a truly high temperature, low thickener content, multipurpose grease. Further patents by Muir et. al (6, 7) demonstrated alternate ways to further reduce the thickener content, thus reducing cost and improving performance such as pumpability and low temperature properties. Barnes showed that an alternate alcohol promoter also worked and that Calcium Phosphate could be substituted for Calcium Borate (8). Denis and Sivik have produced a good overview of the manufacture of Sulfonate grease (9).

The technology, simply described, involves reacting an amorphous Overbased Calcium Sulfonate (preferably 400 TBN) with 12-Hydroxystearic Acid in the presence of a promoter (water, alcohol etc.) to form a thickened product. Much of the thickening arises from the conversion of amorphous calcium carbonate into crystalline Calcite calcium carbonate. This is the preferential form for Sulfonate technology, as it has shown improved EP, AW, Corrosion resistance, dropping point, and most importantly mechanical stability, versus the alternate crystalline Vaterite form. The Calcium Borate is further reacted into the product to give it its high temperature viscosity properties. Calcium Borate may also improve the AW and EP properties (4,5,12).

All of this reaction is performed in the presence of the desired lubricating oil. The final product generally only requires a good antioxidant and perhaps some polymer for additional water resistance and tackiness.

The development of a food grade version of this technology required the careful selection of raw materials such that they met H1 requirements, while maintaining the high performance properties that the technology is known for. In fact no performance was lost in the creation of the food grade versions.

The previous paper on Calcium Sulfonate Complex food grade grease (1) provided the data in *Table 2*. The study compared two Sulfonate products, one PAO based and one white oil based, versus several commercial technologies found in the market place. The work clearly showed that mechanical stability, high temperature performance, load carrying and antiwear properties, and water resistance were all improved through the use of Calcium Sulfonate Complex food grade grease. It was suggested that these improved properties would lead to better lubrication, longer life of the product, reduced maintenance and reduced potential for contact with the food being produced. The technology has now been used in most food processing applications and has certainly found its place in the food grade grease market place.

Further Examination of Calcium Sulfonate Food Grade Grease

Since the first two products were introduced, a number of other formulations were developed to meet application and market requirements. Most of those involved the use of PAO to provide increased viscosity for load carrying and to increase the high temperature performance of the products.

This work will examine two performance aspects of the use of PAO in Sulfonate food grade grease – the effect on high temperature performance and the effect on low temperature performance. Some additional comparative testing was also run on the non-Sulfonate food grade products as well.

The Sulfonate products that were examined are found in *Table 3*. All of the products were grade 2 as this is by far the most common grade of grease. All of the Sulfonate products contain a high quality, high performance H1 approved antioxidant. Their formulations are all quite similar except for the use and blend ratio of the PAO fluid. They are blends of low and high viscosity PAO designed to give the correct final oil viscosity.

Table 2. Comparison of Several Food Machinery Greases (1).

Property	Method	Calcium Sulfonate A	Calcium Sulfonate B	Aluminum Complex A	Aluminum Complex B	Anhydrous Calcium A	Anhydrous Calcium B	Silica
Color	Visual	White	White	White	White	White	White	Clear
Appearance	Visual	Smooth	Smooth	Smooth and Tacky	Smooth and Tacky	Buttery	Buttery	Buttery
Base Oil Type	Literature	Synthetic	White Oil	White Oil	White Oil	White Oil	White Oil	Synthetic
Dropping Point, °C	ASTM D2265	318	318	291	286	174	174	318
Consistency, 60 stroke	ASTM D217	290	281	268	313	272	272	264
Water Washout @80 °C	ASTM D1264	0.0	0.42	6.94	3.74	0.70	---	0.00
Roll Stability, %change (2 hours, 25 grams)	ASTM D1831							
25°C, No Water		–2.4	3.6	4.1	9.5	23.2	---	0
25°C, 50% Water		0.3	2.1	0.0	–16.8	0.0	---	36.9
77°C, No Water		–1.0	2.1	–4.9	–4.8	53.6	---	8.7
77°C, 50% Water		1.4	2.1	6.91	8.31	30.1	---	65.3
Salt Fog Corrosion, hours	ASTM B117	350+	350+	144	120	96	---	24
Bearing Life, hours	ASTM D3527	280	180	80	40	80	---	160
Oil Separation @ 100°C	ASTM D6184	0.2	0.2	1.8	1.8	2.1	2.2	0.4
4-Ball EP Weld, kg	ASTM D2596	400	500	---	200	160	---	---
LWI, kg f		53.2	68.3	---	26.7	24.99	---	---
4-Ball Wear, mm	ASTM D2265	0.42	0.45	0.53	0.71	0.54	0.51	1.10
Oven Panel Testing, rating	GM9075-P modified	Remained grease-like. Very slight oil bleed	Remained grease-like. No oil bleed	Stiffened. Severe oil bleed	Remained grease-like. Moderate oil bleed.	Became hard and resinous. Severe oil bleed.	Became hard and resinous. Severe oil bleed.	Remained grease-like. Very slight oil bleed.

Calcium Sulfonate Grease A1 and Grease B1 are identical formulations to A and B found in *Table 1*, however, there is no whitener in A1 or B1. Whitener has now been removed from Calcium Sulfonate grease; ZnO has aquatic toxicity issues in Europe and TiO_2 has health and safety concerns in Canada. The use of ZnO in the EU requires labeling above 2.5wt% while TiO_2 requires MSDS disclosure above 0.1wt% in Canada. There is also a significant handling concern for the TiO_2 powder in Canada. No other chemistry was found to provide acceptable whitening efficiency Calcium Sulfonate grease. That said both whiteners are still considered acceptable for use in incidental food grade lubricants.

Effect of Elevated Temperature

ASTM D3527 bearing life is a good test to screen products for operating life at temperatures of 160°C, typically considered a good continuous operating upper limit for the majority of grease applications. Other bearing tests may be more discriminatory such as the ASTM D3336, the SKF and the FAG bearing tests. However, these are very expensive and time consuming tests to run, especially if an outside test lab is required. Therefore, for speed and cost the D3527 test is a decent test to begin with. It does appear to be able to demonstrate the difference between good and excellent mineral oil grease performance as well as the difference between a mineral oil and a PAO based grease. For this work, it appears that the white oil grease operates at roughly 70% of the life of a similarly formulated PAO grease. All of the PAO based products operate within approximately 10% of one another.

For quick, visual, and demonstrative high temperature testing, a simple oven panel test was used. This is a modified version of the GM9075-P method. In this test, cold rolled steel panels are coated with a 0.76 mm (30 mil) thickness of grease at one end. The panels are stood vertical in an oven at a controlled temperature. The test duration is typically 96 hours with the panels being monitored daily for change in color and consistency. A rating system was developed and is included as a part of *Table 4*.

The results from the oven panel test, found in *Table 4*, clearly show that a PAO based food grade Sulfonate grease should perform acceptably up

Table 3. Typical properties of the new Calcium Sulfonate Grease examined

Property	Method	Calcium Sulfonate A1	Calcium Sulfonate B1	Calcium Sulfonate C	Calcium Sulfonate D	Calcium Sulfonate E
Color	Visual	Tan	Tan	Tan	Tan	Tan
Appearance	Visual	Smooth	Smooth	Smooth	Smooth	Smooth
Base Oil Type	Literature	Synthetic	White Oil	Synthetic	Synthetic	Synthetic
Base Oil Viscosity @ 40 C	ASTM D445	50	100	100	220	400
Dropping Point, °C	ASTM D2265	318	318	318	318	318
Consistency, 60 stroke	ASTM D217	280	280	280	280	280
Water Washout @80°C	ASTM D1264	0.0	0.0	0.0	0.0	0.0
Salt Fog Corrosion, hours, 3 mil d.f.t.	ASTM B117	1000+	1000+	1000+	1000+	1000+
Bearing Life, hours	ASTM D3527	260	180	240	240	260
Oil Separation @ 100°C	ASTM D6184	0.2	0.2	0.2	0.2	0.2
4-Ball EP Weld, kg LWI, kg f	ASTM D2596	400 55	400 55	400 55	400 55	400 55
4-Ball Wear, mm	ASTM D2265	0.42	0.45	0.40	0.42	0.50

Table 4. Oven Panel testing of several FG grease products.					
Grease	Oven Panel Test - 96 hours				
	(see notes on Rating)				
	150°C	160°C	170°C	180°C	200°C
Al Complex A	2 +	-	*	-	-
Al Complex B	1	-	*	-	-
Calcium Anhydrous A	4 ++	-	*	-	-
Silica FG	0	-	4 ++	-	-
Calcium Sulfonate A1	-	0	0	3	6 +
Calcium Sulfonate B1	0	0	0	-	-
Calcium Sulfonate C	0	0	0	-	-
Calcium Sulfonate D	0	0	0	-	-
Calcium Sulfonate E	-	0	0	2	1

0 = No change
1 = Slightly darker overall or dark brown areas < 25% of surface
2 = General brown appearance or dark brown areas < 50% of surface
3 = Dark Brown 75% of surface
4 = Dark Brown 100% surface
5 = Dark Brown w/some Black areas
6 = Black >75% of surface

\+ Stiffened
++ Hard and resinous
*ran off panel in 1st 24 hours

to 170°C. *Figure 1* shows the panel results. It does not appear that the addition of high viscosity PAO is required to boost the high temperature performance of the grease at temperatures up to 170°C and over 96 hours. Additional testing is in progress to look at the life of each product at 160°C beyond 96 hours. The use of a higher viscosity PAO is anticipated to demonstrate an increase in the life of the technology. Two products were tested at 200°C - the low viscosity PAO product (A1) and the high viscosity product (E). It is clear that the higher viscosity PAO provided significant thermal and oxidative stability in the product. *Figure 2* shows the excellent performance of the grease at 200°C. The panels in *Figure 2* were monitored closely for weight loss. *Table 5* lists the volatility of the two products over 96 hours. The high viscosity PAO product suffered far less evaporation than the low viscosity PAO product.

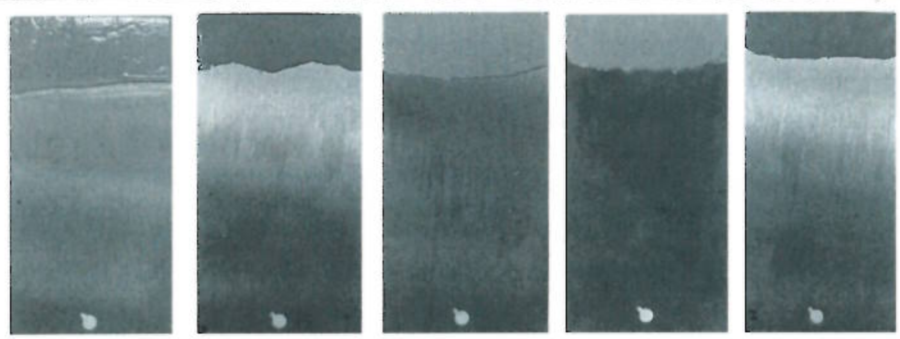


Figure 1 – Calcium Sulfonate Food Grade Grease – Oven Panel Test at 170°C for 96 hours

Table 5 Volatility testing of Oven panels at 200°C. See Figure 2 for the panels.		
Time (hours)	Calcium Sulfonate A1 % Loss by mass	Calcium Sulfonate E % Loss by mass
24	15.38	12.50
48	20.39	15.00
72	29.25	17.81
96	43.62	23.08

Interestingly, the white oil sample B1 performed as well as all of the others up to 170°C. Its bearing life test value is, as noted, about 70% of the PAO based products. Extended panel testing may help differentiate it from the others.

Some limited PVOT (ASTM D942) and PDSC is also included in this work. PDSC testing, found in *Table 6*, at 210°C (chosen by the operator to keep runs to a maximum of 60 minutes) do not show significant difference between white oil product, low viscosity PAO product or high viscosity PAO product. Limited PVOT testing on the white oil versus the high viscosity PAO product does not show any difference in performance between the two products – see *Table 7*.

The four competitive products examined in 2002 had a range of results. Apart from the PAO based Silica grease, bearing life was very poor. The original oven panel work at 150°C showed a wide spread in performance, with two products, Al Complex B and Silica, doing okay and the other two performing poorly. When they were re-tested at 170°C, none survived to 96 hours. The two Al Complex products liquefied and ran off the panel, as did the Anhydrous Calcium product. The Silica product remained in place on the panel and survived the first 24 hours, however, by 72 hours it was brown, hard and resinous. Pictures of these panels can be found in *Figures 3, 4,* and *5*.

Overall, it is clear that a well formulated Calcium Sulfonate Complex food grade grease can withstand high temperatures and can easily outperform the majority of the competitive thickener technologies available.

The Effect of Low Temperature

Another area of concern to the formulator and user of a grease is its ability to operate at low temperatures. There are many applications in food processing where a lubricant will see temperatures below freezing. Using the same white oil and PAO based products as were used in the high temperature testing, the effect of low temperature on the grease was examined. Four tests were chosen – two that measure flow and two that measure bearing torque.

Flow characteristics are important as many plants will use centralized or point source lubricators that require the grease to pump at the operating temperature. DIN 51805, also called the Kesternich method, looks at the pressure that the grease requires to make it flow at a given temperature.

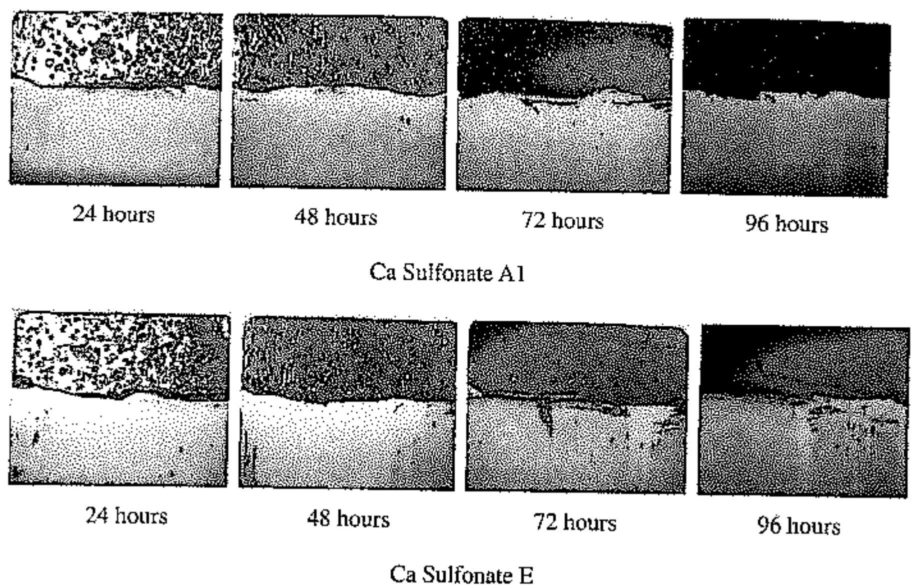


Figure 2 – Two Synthetic Sulfonate FG grease products at 200°C

Table 6. PDSC testing of Calcium Sulfonate FG grease

Grease	OIT PDSC @ 210°C, minutes				
	Run 1	Run 2	Run 3	Run 4	Average
Calcium Sulfonate B1	42.77	49.13			45.95
Calcium Sulfonate A1	49.44	52.11	61.58		54.38
Calcium Sulfonate E	36.08	37.74	42.07	65.89	45.45

The accepted maximum value is 1400 hPa with the lower the pressure being better. This is an ideal test as it is very simple and uses a minimum of grease. US Steel mobility measures the flow of grease at a set pressure for a given temperature. In this case the pressure is 1034 kPa (150 psi) and the output is measured in grams per minute. Mechanical refrigeration can achieve -35°C. For lower temperatures, dry ice is required. It requires about 300 to 500 ml. An accepted minimum value in this test is six grams per minute dispensed at a given temperature.

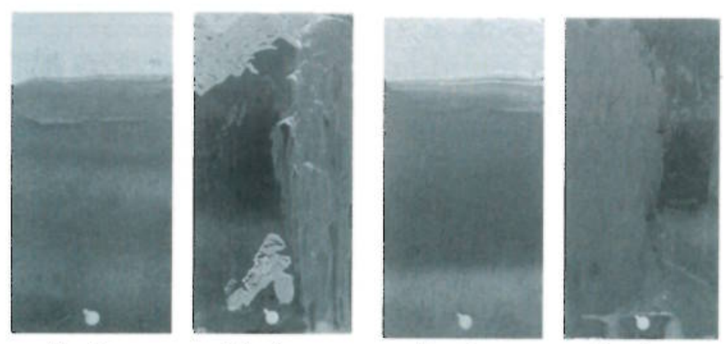
The two torque tests are ASTM D1478 and D4693. They are run in a similar fashion with D1478 using a ball bearing and D4693 using a tapered roller bearing. D1478 is typically related to industrial and aviation performance while D4693 is used to assess wheel bearing grease. In both tests, a packed bearing is cooled to the desired temperature then rotated with a given force. The torque to start the bearing moving and the torque at a given time after starting is measured. Other than directionality of results, the two tests do not necessarily correlate. D1478 data for instance, cannot be converted into a useable result in place of D4693. For D1478, a rough upper limit for acceptable starting torque is 10,000 g-cm, although it may be much lower for a given application. For D4693, the upper limit is 15.5 N-m, based on the NLGI GC/LB requirement for wheel bearings @ -40°C.

Flow tests are important to understand how and if the grease will reach the application while torque tests are important to understand how the grease will function once in place. A grease may still effectively lubricate a bearing, even if it can no longer be pumped. Many grease products will operate well below the temperature at which they will pump.

The mobility data is found in *Table 8*. Based on the data for pumpability it is clear that the white oil products stop pumping between -18°C and -29°C. The Calcium Sulfonate grease B1 does not appear any different from the competitors in this test. The PAO based products all flow at -35°C, including the silica thickened grease. The two lowest viscosity Calcium Sulfonate products may

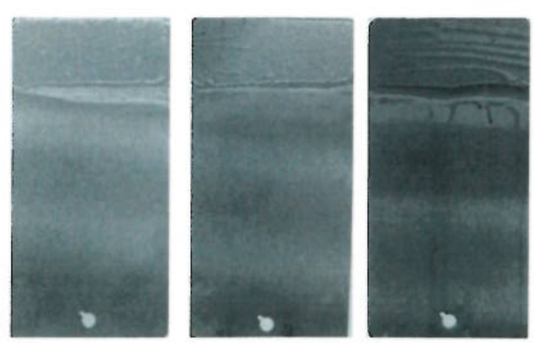
Table 7. Pressure Vessel Oxidation Test Results

Grease	D942 Pressure Vessel Oxidation		
	kPa drop @ 100°C		
	100 hrs.	500 hrs.	1000 hrs.
Calcium Sulfonate B1	6.9	27.6	41.4
Calcium Sulfonate E	6.9	24.1	37.9



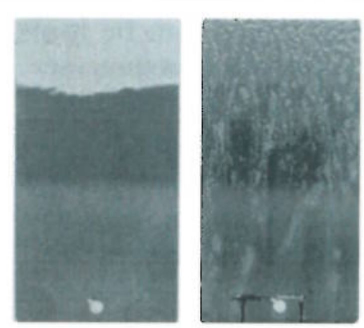
Aluminum Complex Grease A — No heat | Aluminum Complex Grease A — 24 hours | Aluminum Complex Grease B — No heat | Aluminum Complex Grease B — 24 hours

Figure 3 – Aluminum Complex Food Grade Grease at 170°C



No Heat | 24 hours | 72 hours

Figure 4 – Silica Grease - Oven panel test at 170°C



No Heat | 24 hours

Figure 5 – Anhydrous Calcium Grease A, Oven Panel Test at 170°C

be slightly better than the two high viscosity products. The US Steel mobility data confirms this as well. The 50 cSt and 100 cSt (A1 and C) products will pump between -29°C and -35°C, with the 100 cSt product very close to acceptable performance at -35°C. The 220 cSt and 400 cSt (D and E) products will pump between -18°C and -23°C. Clearly the low temperature properties of high viscosity PAO can significantly affect a formulation.

The torque results, found in *Table 9*, are more linear. All of the PAO based products will operate down to -40°C; however, the 400 cSt product (E) is borderline in the D1478 test. The white oil based product is on the borderline for operability at -29°C. The torque makes a surprising jump from -18°C to -29°C. Several applications require performance better than 10,000 g-cm, with some demanding less than 2500 g-cm. At 2500 g-cm, all of the PAO based products will only operate comfortably down to -29°C, based on these results. At this point, a softer grade may make sense. *Table 10* shows the effect of lowering the grade on torque. Here, the 50 cSt product (A1) was adjusted to grade 0.5 (350 pen) and grade 00 (410 pen) and run at various low temperatures. The data shows that the reduction in penetration, which corresponds to a reduction in thickener content and an increase in PAO content, significantly reduces torque. Therefore if a grade 2 grease cannot meet a low temperature requirement, a softer grade can be employed. However, a softer grade will not have as wide an operating range and may promote leakage from bearings that are operated at elevated temperatures. Softer grade grease is typically used for one application or condition only, where grade 2 products are more multipurpose in design.

Summary

It is critical that all food related applications be lubricated with approved food grade products. The current process to obtain food grade certification is not difficult; all it requires is that proper thought and work be put into the development of the product. Future systems, such as ISO21469, may add complexity to the process, but they may

Table 8. Table Low Temperature Pumpability

	DIN 51805, Flow Pressure hPa			US Steel Mobility, g/min @ 1034 kPa (150 psi)			
	–18°C (0°F)	–29°C (–20°F)	–35°C (–30°F)	–18°C (0°F)	–23°C (–10°F)	–29°C (–20°F)	–35°C (–30°F)
Calcium Sulfonate A1	---	---	641.2	53.5	25.04	12.42	6.15
Calcium Sulfonate C	167.5		502	29.22	17.6	9.65	4.07
Calcium Sulfonate D	---	---	861.9	11.92	5.88	2.76	1.42
Calcium Sulfonate E	189.6	---	859.8	8.36	4.28	2.5	1.19
Calcium Sulfonate B1	530.9	2034	---	22.5	9.0	4.9	0.5
Al Complex A	458.5	2034	---	---	---	---	---
Al Complex B	622.6	2551	---	---	---	---	---
Calcium Anhydrous A	457.1	1655	---	---	---	---	---
Silica	---	---	706.7	---	---	---	---
Acceptable <1400 hPa				Acceptable > 6 grams / minute			

be necessary to add another level of security in our food industry. Product recalls and injury to the public will drive costs far higher than the cost of using the correct product. The public will continue to demand a safe food supply.

As has been shown in numerous papers (2,4,5,9-17), Sulfonate grease technology offers exceptional performance across a broad range of characteristics - high EP, AW, corrosion resistance, mechanical stability, and high dropping point. The new results contained herein, continue to support that. This includes Calcium Sulfonate Food grade grease.

It is possible to formulate a Calcium Sulfonate Complex grease such that it will provide exceptional performance up to 170°C and possibly as high as 200°C. Even a white oil based product appears to offer good high temperature performance to 170°C.

Historically, one of the criticisms of the technology was that due to the high thickener content, low temperature performance was compromised. This work clearly shows that well formulated Sulfonate grease will easily perform down to -40°C or lower. The torque data does show the benefit of the use

Table 9. Low Temp Torque Testing of Several PAO based Food Grade Sulfonate greases
All products at NLGI Grade 2

Product		ASTM D1478		ASTM D4693	
	Temp	Start Torque	Running Torque @ 1 hour	Start Torque	Running Torque @ 60 seconds
	Deg. C	g-cm	g-cm	N-m	N-m
Calcium Sulfonate A	-18	767	117		
50 cSt, PAO	-29	1827	156		
Zinc Oxide	-40	3783	598	3.81	2.49
Calcium Sulfonate A1	-18	533	117		
50 cSt, PAO	-29	1703	273		
	-40	4726	442	4.62	2.56
Calcium Sulfonate C	-18	605	130		
100 cSt, PAO	-29	1580	267		
	-40	4297	878	3.47	2.59
Calcium Sulfonate D	-18	696	137		
220 cSt, PAO	-29	1788	293		
	-40	6110	910	10.93	7.21
Calcium Sulfonate E	-18	884	208		
400 cSt, PAO	-29	2451	546		
	-40	7755	1261	7.44	5.39
Calcium Sulfonate B	-18	1404	247		
100 cSt, White Oil	-29	7527	1144		
Zinc Oxide	-40	25714	4927	17.04	11.93
Calcium Sulfonate B1	-18	813	247		
100 cSt, White Oil	-29	8554	845		
	-40	21853	2295	10.97	7.56

N/R = Not Run

of PAO versus white oil, with the performance improving considerably between -18°C and -40°C.

When all aspects are considered, a PAO based (or for the most part white oil) grade 2 Calcium Sulfonate Complex Food Grade grease offers the broadest operating range and highest performance of any other thickener technology currently available.

Therefore lack of high performance food grade grease is no longer a valid excuse for using the wrong lubricant.

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Table 10. Effect of Grade on Low Temperature Torque.

Calcium Sulfonate A1	Penetration	D1478 Low Temp Torque		
50 cSt, PAO	(1/10 mm)	Temp	Start	End
		Deg. C	g-cm	g-cm
Grade 2	275	-40	5590	644
		-55	33137	5785
Grade 0.5	350	-40	2659	312
		-55	17960	3036
		-65	Frozen	Frozen
Grade 00	410	-40	1062	206
		-55	5727	995
		-65	Frozen	Frozen