WHITE PAPER

Lubrisense™ 201212

TAKE YOUR BEST PICK!

… on choosing the right grease

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Saving Energy

… a friction reduction programme at Volvo Powertrain

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TAKE YOUR BEST PICK

Grease is a fantastic lubricant!
With its visco-elastic solid structure and consistency, lubricating grease has a number of advantages as a lubricant compared to fluid oils.

According to the old saying, the best way of achieving the correct lubrication is a combination of choosing the right grease and then putting it in the right place, in the right amount and at the right time.

So how do we choose the right lubricating grease?
Well, earlier it used to be rather easy to choose a suitable product for any specific application. But, in the high tech society of today, where more factors have to be taken into consideration, it might be trickier than it first seems to find the right product.

Maybe the best place to start in this context is to consider the things a lubricating grease cannot be expected to do. Grease cannot be used as a coolant since it has exceptionally poor heat transfer properties. Neither is it suitable as for power transmission due to its compressible nature. As a pure lubricant, however, grease does have many advantages.

Nowadays, a variety of multipurpose products cover approximately 70% of the world market. These multipurpose greases are almost exclusively mineral oil based, lithium thickened greases with a consistency of NLGI 2. The “Lithium EP 2” product. This is basically sufficient for the lubrication of rolling and sliding bearings operating under moderate conditions and within the limited temperature range of approximately –30°C to +120°C.

Nevertheless, demands increase under more extreme conditions such as higher temperatures, heavier loads, more intense vibrations etc. To be able to choose the most appropriate grease for these “special applications”, it is important to have a deeper knowledge of the following three factors:

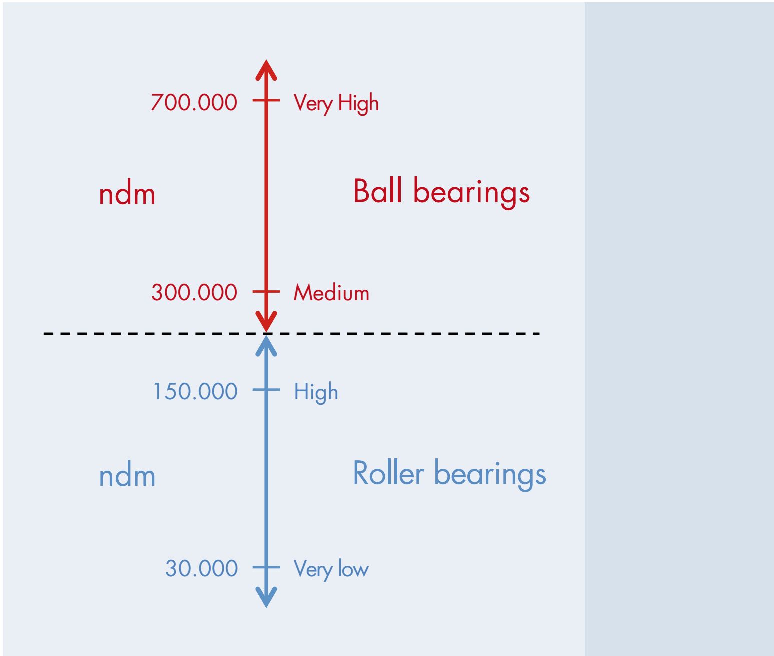
The component

The temperature

The surrounding environment

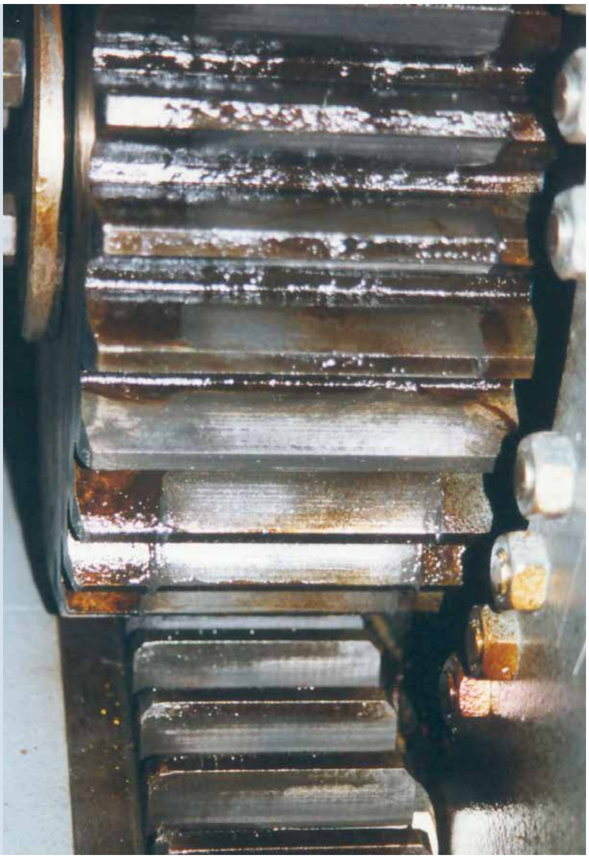
The component
The first thing to do is, of course, to identify the component. What is actually going to be lubricated? Approximately 90% of all greases are used in rolling bearings, sliding bearings, gears or couplings, where rolling bearings stand for the major part. Of course, these different components, as such, require different properties of the lubricating grease but there are also more factors that need to be taken into account.

Size and speed
Two important factors for choosing the right grease are the size and the speed of the bearing. These stand in relation both to the strength and the thickness of the lubricating film. Using fairly simple calculation models, the required base oil viscosity can easily be calculated. To simplify comparison between different conditions, a speed factor (n·dm) has been introduced. This involves multiplying the revolutions times the mean diameter of the bearing. With the speed factor, an approximate speed condition can be assigned to each bearing application.



There is unfortunately no standardised way of correlating the speed factor with the structure of the various types of lubricating grease so, for the moment, it can only function as a guideline. The calculation models commonly used only take the base oil viscosity into account and not the thickener type nor the amount. In reality, this will result in a thicker lubricating film than calculated.

Smaller bearings often rotate at high speeds. These are usually found in electrical motors, machine tools and electronic devices. Small bearings generally require stiff grease with a high amount of thickener and a base oil with a rather low viscosity. This to ensure that leakage due to high rotating speeds is reduced and a sufficient lubricating film thickness is obtained.



On the other hand, large bearings, typically roller bearings, operate at low speeds and are usually heavily loaded. Support roller bearings in the steel industry are one example of such bearings. For these applications, it is preferable to use a soft product with a high base oil viscosity. It is very likely that the grease needs a high mechanical stability and also a good extreme pressure additive to cope with the high loads.

Load

The type of the load, the size and the direction is also important to know. It all comes down to trying to keep the surfaces separated.

A common way of protecting the metal surface in mixed or boundary conditions, when the dynamic viscosity is not sufficient for separation, or under shock loads, is to use extreme pressure (EP) and anti-wear (AW) additives. In some cases even solid lubricants, commonly MoS_2 or graphite, are justified. Note that solid lubricants are not generally recommended for roller bearings except at low peripheral speeds and, in particular, are not suitable for ball bearings. Since these are rather big particles they can cause more harm

SAVING ENERGY

Volvo Powertrain is one of the world's biggest manufacturers of heavy duty diesel engines (9–18 litres) and also a major producer of heavy duty transmissions.

At one of their productions sites, they cast engine blocks and cylinder heads. A key process in the foundry there is to remove dust and particles. This is achieved using a flue gas fan and it is critical that this fan operates without disturbances since, if it does stop for any reason, the whole casting process in the foundry needs to be stopped.

Common problems that occurred in the flue gas fan were high bearing temperatures, extensive vibrations and unreliable lubrication and durability. All this at an extremely high cost. Maintenance stops were planned once a month to replace all the moving parts.

Targets set by Volvo Powertrain were to optimise lubrication and to obtain trouble free operation while, at the same time, making savings on maintenance costs and increasing productivity.

than improve performance under the wrong conditions.

Solid lubricants are more suitable for sliding contacts which have made them a popular component in lubricating greases for heavily loaded open gears. Unfortunately, solid lubricants tend to accumulate at the root of the teeth causing and amplifying vibrations which, in turn, lead to a higher degree of wear; thus keeping the amount as low as possible is preferable.

Another option for open gear lubrication is to use high quality greases based on functional soaps. These products do not necessarily contain solids but have their EP properties already incorporated into the thickener matrix. This technology gives them extreme load carrying capacity and eliminates the possibility of deposit build-up in the gears.

Vibrations

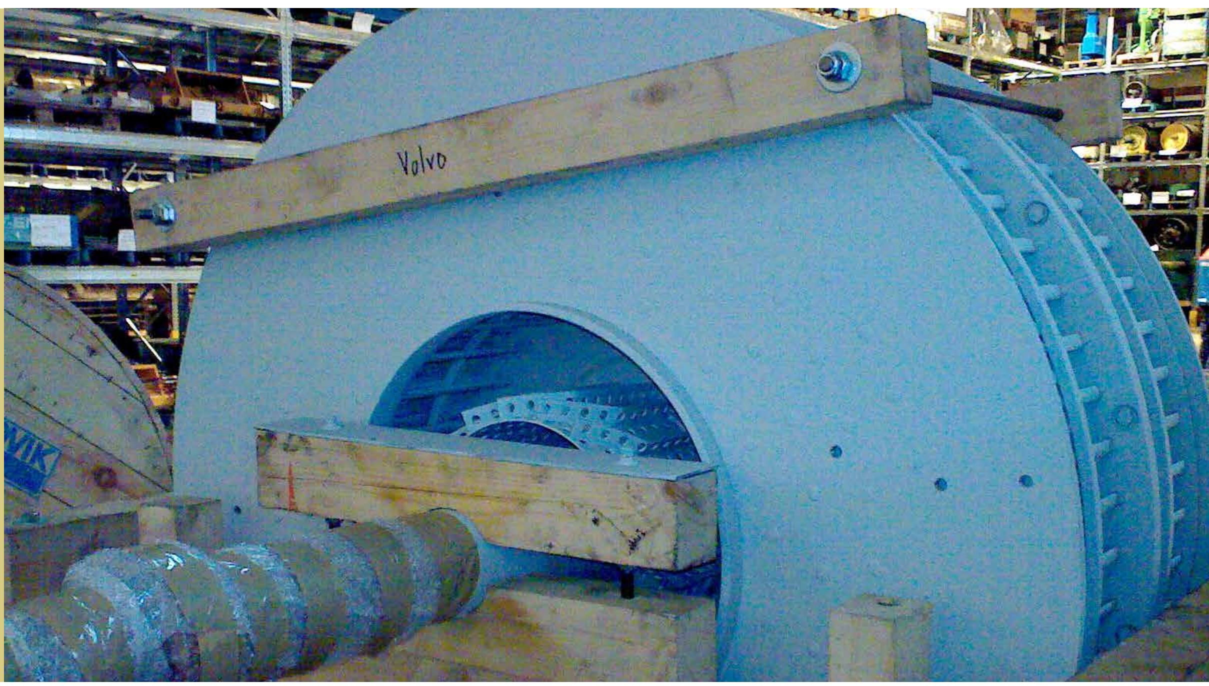
Vibrating applications can contribute to lubrication problems if the right product is not chosen. Vibrations often cause leakage and increased oil separation. Problematic applications might be fans and of course sieves, found for example in the mining industry.

To deal with vibrations, it is important for the lubricating grease to have a high thickener content to prevent leakage and also to strongly trap the base oil within its matrix. A high degree of mechanical stability is favourable which makes complex greases suitable for these applications.

Another application that needs special attention is flexible couplings. Couplings work under high centrifugal forces which contribute to the separation of the thickener and base oil in the grease. Specific products designed for the lubrication of flexible couplings are often formulated with a thickener and a base oil of a similar density to prevent separation as much as possible. These products often fulfil the specifications set up by the American Gear Manufacturers Association (AGMA).

Oscillation

It is important that new grease enters into the contact zone but, for oscillating movements in, for example, sliding bearings on off-road vehicles, it is hard to



replenish and build up a strong lubricating film. Depending on the bearing manufacturer, the lubricating tracks are designed differently and it is important to assure that these tracks spread the lubricant in the right way. The grease therefore needs to have excellent adhesion to the metal in order to simplify transport to the contact zone.

Usually, such equipment works in wet and dirty environments which demands a lubricating grease with both good sealing ability and corrosion protection. Traditionally “Lithium EP 2” has been fortified with MoS_2 and/or tacky polymers to cope with these conditions. More modern formulations based on anhydrous calcium or calcium sulphonate complex are excellent choices for these types of applications.

CLS

Using centralised lubrication systems is a popular and good way to ensure that the bearings are continuously lubricated. The dilemma is that the properties of a good grease for these systems are a non-elastic thickener, a low soap content and a soft consistency. In contrast, a good bearing grease often requires a high soap content and a consistency level that assures that the lubricant stays in place. In addition to this, greases are more or less elastic per definition.

But again, manufacturers of these systems have different specifications on what type of greases that should be used. It is important that this is investigated and that the actual application determines which lubricating grease to use and that the centralised lubricating system is then chosen thereafter.

In some cases, lubricating greases doubtfully named “centralised lubrication greases” can be found. These products are often of consistency NLGI 00 and may perform well in lubrication systems that are not designed to pump a proper bearing grease. These NLGI 00 greases are usually designed for the lubrication of closed gear boxes, rail flanges or in arctic conditions.

The temperature

The temperature interval for basic multipurpose greases runs from approximately –30°C to +120°C. This range covers the majority of grease lubricated applications and, looking at this temperature,

Initially, the fan bearings were lubricated with a grease based on a lithium complex thickener and a mineral base oil with a viscosity of 210 mm^2/s at 40°C. In other words, quite a standard, high quality industrial grease. The temperatures in the roller bearings of the fan were in the region of 100°C to 110°C and the wear was extensive.

After a closer investigation, it was established that the lubricant was a major contributor to the problems experienced. It was also concluded that the base oil viscosity was far too high.

By using a lubricating grease with a base oil viscosity of 210 mm^2/s at 40°C, the film thickness becomes robust and excessive. Full film lubrication is achieved and this is not the most advantageous regime for roller bearings. This can cause the rollers in the bearing to slide and wobble on the lubricant. Normally this leads to extensive wear in terms of smearing and flaking of the raceway. All of this was confirmed by the practical problems experienced in the actual flue gas fan bearings.

A more thorough film thickness calculation needed to be made on fully formulated grease, taking both the base oil and the thickener system into consideration in order to determine the required viscosity level for optimal lubrication.

mineral oil based lithium grease is a good candidate. But problems can occur rapidly at both ends of the temperature range.

Low temperature applications are more uncommon that their high temperature counterparts but still they put high demands on the lubricating grease. Typical low temperature problems are related to high start and running torques and poor performance in centralised lubrication systems.

A common way of increasing the low temperature performance is to use low viscous mineral base oils or a synthetic base oil with a low pour point. It is also important to choose the right thickener and study the rheological properties at these temperatures to avoid that the grease stiffens or becomes elastic. Lithium complex soap is an example of a thickener that has proven to have good performance at low temperatures. The products can usually ensure good lubrication down to –50°C. At lower temperatures, steel components get brittle and it is more a question of component material rather than the lubricant. Nevertheless there are specific greases, based on inorganic thickeners and low viscous synthetic

Unfortunately, when looking at already available film thickness calculation methods commonly used today to establish the required base oil viscosity, they are only valid for Newtonian behaviour, i.e. for liquids. However, by developing the methods further and adding a new parameter to the calculation, the elastic modulus, the thickener systems´ contribution can be established giving a more accurate lubricating film thickness estimate and thus securing proper lubrication.

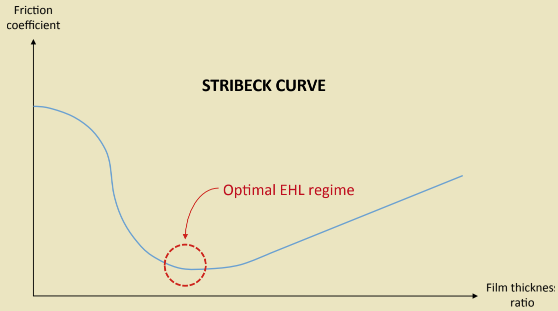
Aiming for low friction in the EHL (elasto-hydrodynamic lubrication) regime, calculations were made on fully formulated greases. The conclusion was to reduce the base oil viscosity by a factor of 4–5, giving the roller bodies a slight metal to metal contact and thus the rollers and the rotating ring the same linear speed. There is also an additional advantage in that there will be less "dynamic viscosity" to shear, thereby keeping the bearing temperature at a lower level, which gives a better control over the viscosity and a smoother roller bearing operation.

The new product chosen was still based on a lithium complex thickener but the base oil was changed to a polyalphaolefin (PAO) with a viscosity of 46 mm^2/s at 40°C. By choosing a synthetic base oil, the viscosity index (VI) increases keeping the viscosity more stable in relation to fluctuating temperatures as in the case of the flue gas fan.

esters, claimed to provide good performance down to –70°C. These products are usually found in aviation applications.

Increasing temperatures lower the lifetime of a grease. A good rule of thumb is that, above 70°C, lifetime is reduced by half with every increase of 15 C°. It is therefore important to increase the thermal stability of all components, thickener, base oil and additives, in a lubricating grease if the product is to be used at elevated temperatures.

The range between 120°C and 150°C is basically covered using complex greases or polyureas with thermally stable base oils and additives. The dense fibre structure of the complex thickeners protects the oil from oxidation, allowing use at higher temperatures. It is also important that the thickener keeps the oil in the structure since increased temperature lowers the base oil viscosity and hence increases the separation rate. Needless to say, the importance of re-lubrication increases with increased temperatures.



A field trial was started with this optimised lubricating grease and focus was put on monitoring the roller bearing temperature and the degree of vibration. Vibration monitoring was used to establish re-lubrication intervals and determining when maintenance stops need to be carried out.

The first thing observed, once the lubricant had stabilised, was a significant reduction of the roller bearing temperature. The temperature dropped some 20 to 30 C°, the exact magnitude depending on the degree of utilisation and the flue gas temperature. A lot of unnecessary friction was thus removed. A rapid drop in the vibrations was also noticed and the fan unit operated much more smoothly.

Real problems occur at temperatures between 150°C and 200°C. Most of the additives start to decompose and form reactive degradation products which will speed up the oxidation of the grease. Mineral oil based products can seldom cope with these conditions for more than very short periods of time. Often, synthetic base oils, such as polyalphaolefines or synthetic esters, are chosen but even then, it is important to assure good lubrication with appropriate re-lubrication intervals.

To lubricate at temperatures above 200°C is extremely difficult. Some available high temperature greases can handle this challenge but will operate well only for a very limited period of time. Greases based on PTFE and fluoropolyethers can be used in special applications at temperatures between 200°C and 280°C. The drawback of these problem-solver greases is that they are expensive and that they can form toxic gases at temperatures above 280°C.

The surrounding environment

The most complicated parameter when trying to identify suitable greases for a given situation is probably the surrounding environment. Unfortunately this is often the part that is missed.

The most common problem occurring is the presence of water. Water can flush away the grease, destroy the lubricating film or generate corrosion. Therefore, the biggest challenges can be found in marine applications and also in heavy industrial applications such as the steel or pulp & paper industries that utilise process water.

These environments are often very corrosive and the contamination varies in volume, origin, rate and type. To formulate a lubricant with a suitable anti-corrosion additive is very difficult and usually not sufficient. Properties such as mechanical stability, adhesion and sealing ability contribute to the lubricating grease's overall performance in offering good rust protection.

Very specific grease qualities are also a requirement for other industries such as food manufacturers. Greases in those kinds of environments have to be H1-listed and preferably ISO 21469 certified which imply the use of very specific raw materials. Greases for hospital equipment such as oxygen and anaesthetic apparatuses have to be completely inert in order not to react with the pressurised gases.

The remaining vibrations basically originated from particle deposition on the fan blades. The reduction of friction and lowering of vibrations is also expected to lead to a decrease of bearing wear which, in turn, should considerably extend the life of the bearing.

At the planned maintenance stop, one month later, nothing indicated that the fan was in any need of overhauling. Bearing temperatures stayed at the lower level and vibrations had not significantly increased. It was decided to continue to run the flue gas fan and, at the same time, closely monitor vibration levels until they increased to levels that normally called for replacement actions.

After six months of operation, still running smoothly, the fan was shut down, just to be on the safe side, and all the rotating parts were examined. Nothing negative was observed, apart from some minor polishing of the outer ring raceway. The roller bearings were in very good shape and could be re-used.

All in all, the field trial was a great success.

Volvo Powertrain is continuously working with optimising lubricants and lubricating routines and they have recently introduced EPOCH technology (Lubrisense White Paper issue 2007#07). Applying an EPOCH product, Volvo

Environmentally friendly greases

Our growing concern for the environment has lead the way to bio products, Bio greases degrade into simple substances not harmful to the ecosystem and are, in some cases, even based on renewable raw materials.

These biodegradable products are especially suitable for applications with total loss lubrication, i.e. applications where the grease cannot be prevented from leaking into the natural environment. Examples of these kinds of applications are centralised lubrication systems on heavy vehicles, off-road equipment and rail flanges.

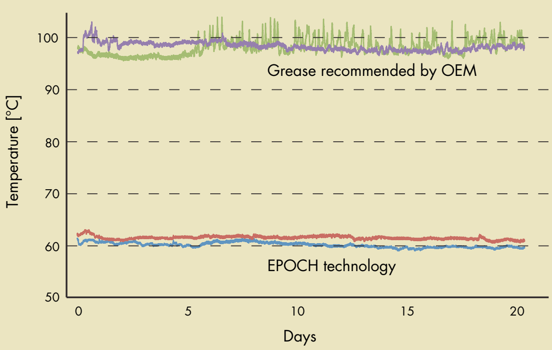
The early generation of bio greases was based on vegetable oil. These products often had poorer performance compared to their mineral oil based counterparts. Another problem was that they were prone to age hardening. Modern high quality bio greases are mainly based on synthetic bio-degradable esters with a performance as good as mineral oil based products, if not even better. (For more information regarding bio-degradable greases please read "Lubrisense White Paper issue 2006#04")

Grease you never knew existed

Lubricating greases are not only used in a wide variety of applications but they can also contain the most unusual of materials.

For example, there is a special grease used in Swiss watches. This is used to lubricate the micro-mechanisms in the watch. The grease has to be easily applied industrially in calibrated micro-droplets using a micro-dosing system. The product used was developed in the 50's and is based on kangaroo fat.

Another application where unusual material is used to fortify grease performance is products for tunnel drilling equipment. These gigantic drills are working in an extremely dirty environment and the sealing ability of the lubricant is crucial. A common way of securing this is to add textile or cellulose fibres to the grease. In some cases even shredded used clothes or old rags are used.



Powertrain has succeeded in reducing the bearing temperature of the flue gas fan by an additional 10 C°, down to an operating temperature of 60°C and this trial will continue until mid-2012.

Research is also being conducted to be able to determine the optimal re-lubrication intervals based on vibration measurements and targeting a minimum of six months operation time.

Roger Persson
Kenneth Forsberg

Some ballpoint pens are also lubricated with grease. Well not exactly lubricated, since there is no actual need for lubrication as such, but grease is used nevertheless. The grease applied is used as a seal to prevent the ink from leaking out of its container. Usually this product is based on an inorganic thickener and the rheological properties are very important.

Even fibre optic cables contain grease. The space in between the actual fibres and the outside coating is filled up. It is important that the optical fibres lie still. If not, information can easily be lost. The grease shall absorb vibrations, protecting the optical fibre, and also absorb the extension and retraction of the plastic materials due to temperature changes.

Lubricating grease is also used as release agent. When moulding and forming canopies for aircraft, a layer of grease is applied in the mould, to act as a release agent. This product is at bit strange since it is based on the formulation for a hydrated calcium thickener, but without the water. Nevertheless, the performance as a release agent is very important since distortion of the canopy makes the pilots "seasick", especially on aircraft carriers during take- off and landing.

ROGER PERSSON

With 25 years of experience in maintenance, condition monitoring and lubrication, Roger Person is currently employed as a team leader in the Advanced Technology & Research department of Volvo Group Trucks Technology. As team leader, Roger has the overall responsibility for optimising and standardising the industrial lubricants used within Volvo.

KENNETH FORSBERG

Kenneth Forsberg has a BSc in Chemistry from the University of Gothenburg, Sweden. He started at AXEL as a development engineer and has during the last 15 years worked as a technical service engineer, lately focusing on refining film thickness calculations and optimising lubricating grease selection for various types of applications.

NEXT ISSUE

The next issue of the Lubrisense™ White Papers will focus on grease manufacturing, describing the saponification process in a specific type of cooking vessel, the Stratco Contactor. Stratco themselves have kindly agreed to be the guest writers for this coming issue and we will contribute with our experiences and case studies from years of making grease in these particular pressure vessels. At present, the Axel Group have five Contactors, including the very first prototype, which is still to be found at Axel Americas in our North Kansas City facility.

As usual, we encourage reader contribution, feedback and proposals concerning relevant topics for future issues of our White Papers.

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