WHITE PAPER

Lubrisense™ 201213

The STRATCO® Contactor™ Reactor Method of Grease Manufacturing

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Eighty years on …

with historical input from

Richard Howell, Senior Advisor
Axel Americas LLC

AXEL
AXEL CHRISTIERNSSON

THE STRATCO® CONTACTOR™ REACTOR METHOD OF GREASE MANUFACTURING

DIANE GRAHAM, is Chief Executive Officer of STRATCO, Inc. Diane holds a Master's degree in Media Psychology from Fielding University and a Master's degree in Social Sciences/Leadership from Azusa Pacific. From 1986-88 she attended the Harvard Business School Owner/President Management Program and graduated with a B. S. degree in Business Administration and Economics in 1976 from Culver-Stockton College in Missouri. Graham was elected President of STRATCO in 1981 and was the first female President of NLGI in 1992. Graham was on the NLGI Board when ELGI was formed. She had two White House Appointments in 1996.

JOHN KAY, is currently Vice President of Engineering for STRATCO, Inc. John graduated summa cum laude from Christian Brothers University in Memphis, Tennessee in 1979 with a B. S. degree in Mechanical Engineering. At CBU he was inducted into both Alpha Chi and Tau Beta Pi Honor Societies. He was employed as an engineer by a major design/build mechanical contractor in St. Louis, Missouri from 1980 through 1996, where he was the Principal Design Engineer for nine years. He joined STRATCO in 1997, where he works out of the office in Scottsdale, Arizona as Vice President of Engineering. He is a Licensed Professional Engineer, is a member of the American Society of Mechanical Engineers and the American Society of Heating, Refrigerating and Air-Conditioning Engineers. He has provided on-site consulting for Grease Plants in North and South America, Africa, Europe, Asia and the Middle East and has designed grassroots Grease Plants in North America and Asia-Pacific. He has authored multiple technical papers for ELGI and NLGI and served on the NLGI Board of Directors for 10 years.

Beginning as early as 1650 B. C. in Egypt[1], lubricating grease has been a product that helps make the world go around. From usage on chariot axles to reduce friction in 1400 B. C. until the present day, these semi-liquid or semi-solid products have been utilized to improve the quality of life for people on every continent. When you think about nearly everything you purchase to keep you alive, to clothe you, to communicate with others, to use for sports or leisure, to make you feel or look better, and to transport you from one place to another, please thank the people in the lubricating grease industry. Their expertise provides the best lubricants for the sophisticated machinery necessary to manufacture those products for you.

In the early 1900s, in the United States, Kansas City, Kansas (just west of Kansas City, Missouri) was already established as the hub of grease manufacturing in the United States due to the stockyards and their ready supply of beef tallow (animal fat). Tallow was, and still is, used in soap making and soap making is the basis for most lubricating grease manufacturing. JESCO (now Axel Americas LLC), the S in Jesco standing for Stratford, by the way, Southwest Petrochem (now ExxonMobil), Stratford Engineering (now STRATCO®, Inc.) and The National Lubricating Grease Institute (NLGI®) were all founded in the Kansas City area.

How, you may ask, are these life-changing semi-liquid or semi-solid products made? Think of a cross between a fermenter and a kitchen blender—a mixer that is so well designed and engineered that it can last 83 years! When Axel Christiernsson purchased the assets of JESCO in 2011, they acquired the first STRATCO Contactor reactor which was installed in 1929 and had been operating for 82 years.

For many years, the standard equipment used to manufacture lubricating greases was a large kettle, in which the ingredients were heated to react and form the fibers that provide grease its binding structure for holding the lubricating oil in place. While modifications were made to improve the kettle's heating ("cooking") performance, e.g. motorized stirrers, counter-rotating stirring assemblies, wall scrapers, improvements in heating media, jacket design and heating control, pressure-cooking, etc., this type of vessel was limited by the basic design of the mixing and heating effectiveness. With these limitations in mind, Mr. C. W. Stratford, in 1928, designed and patented a very unique combination mixer and heat exchanger for the purpose of manufacturing lubricating greases. This equipment was called the STRATCO Contactor reactor. More than eighty years later, this STRATCO Contactor reactor, operating in conjunction with a stirred finishing kettle, represents the most efficient and consistent method of manufacturing lubricating greases in such a short time that it is characterized by many as a semi-continuous system. This paper will concentrate on the various aspects associated with the manufacture of lubricating greases with the STRATCO Contactor reactor.

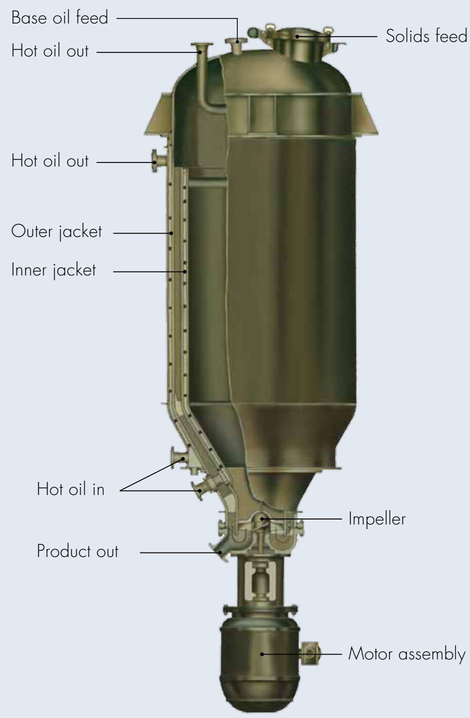


FIGURE 1 – THE STRATCO® CONTACTOR™ REACTOR

Grease manufacturing in the STRATCO® Contactor™ reactor

There are different types of soap thickeners used for lubricating greases, including hydrated calcium soap, sodium soap, aluminum soap, lithium soap, anhydrous calcium soap, and also complex forms of these same soap types. There are also non-soap type thickeners used for making greases, such as polytetra-fluoroethylene (PTFE), hectorite and bentonite clays, polypropylene, silica gel, polyethylene and polyurea. While soap-based greases are considered especially suited for manufacture in the Contactor reactor, it has been shown to be effective for some non-soap greases, also.

The STRATCO Contactor reactor, shown in Figure 1, consists of a pressure vessel shell, an internal circulation tube (labeled inner jacket) and a hydraulic head assembly complete with the mixing impeller and driver. The Contactor reactor by design has a highly turbulent circulation path. All energy input through the mixing impeller is

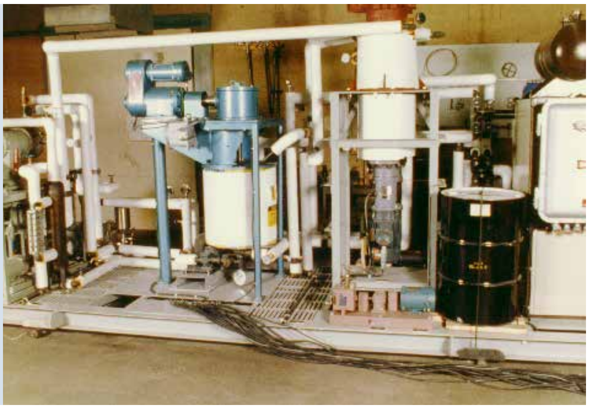


FIGURE 2 – SKID MOUNTED PILOT PLANT

expended within the materials being mixed. The high dispersion mixing in the Contactor reactor is achieved by the proprietary hydraulic head assembly. Frequent and forced changes in velocity and direction of flow occur around the impeller area. This results in a zone of high shear and intense mixing, which ensures intimate mixing of the raw ingredients and results in the most complete chemical reaction.

Material is pulled down through the center of the circulation tube by the impeller, reversed and then forced up through the annular space between the circulation tube and shell. Because the impeller is located on the bottom, dry materials are kept in suspension until they dissolve or are reacted. The heating medium is circulated through the double-walled circulation tube inside the Contactor. The outside of the Contactor reactor is also jacketed. An alternate design substituting a large diameter pipe coil for the jacketed circulation tube has been used in the past for high pressure steam as a heating media. The Contactor reactor has approximately three times the heat transfer area of an open kettle or other pressure (autoclave) type reactor of the same volume due to the double-walled circulation tube and the outside jacket. Also, the heat transfer rate in the Contactor reactor is enhanced by the high velocity of material flowing over the heat transfer surfaces.

The Contactor reactor's impeller is connected to a motor, which can be single speed, two-speed or variable speed over its complete speed range. The shaft is sealed from the process fluid by a mechanical

EIGHTY YEARS ON ...

It's a small world. And who could have guessed that what was going on in the American Mid-West in the late 1920´s could have such a strong influence on present day business activities in Sweden and the Netherlands. Kansas City is not only right in the middle of the North American continent, it was seemingly also the focal point of the grease world some eighty years ago. Some might argue that this is still the case, since there are presently four important lubricating grease manufacturing facilities in the greater Kansas City area. On January 31st, 2011, Axel Christiernsson purchased the majority of the assets of Jesco Resources Inc. The business is now carried forward as Axel Americas LLC continuing the proud tradition of Jesco, as being one of the leading suppliers of lubricating greases in the US market. Axel Americas now manufactures lubricating greases in two US locations, Rosedale, Mississippi and ... in North Kansas City, Missouri. The company Jesco was founded in 1929 and, that very same year, the first ever "STRATCO Contactor" was installed into their Gentry Street facility.

JESCO stands for Johnson, Edwards, Stratford, Collins and Others. One of the founders, Claude Johnson, helped design and build much of the production equipment including the "Cornell Machine", engineered by Mead Cornell from San Francisco, which was perhaps the very first practical homogenization unit for lubricating greases. One of the seal which is replaceable from below and outside the Contactor reactor without removing the head assembly. The head assembly is also typically equipped with a motor-driven lubricator to ensure proper lubrication when the impeller is operating.

Standard STRATCO Contactor reactors are supplied in many sizes from 200 to 7000 L operating volumes. Custom and larger sizes are also available. Small pilot plant Contactor reactors are also available as a 50 L unit. Many grease manufacturers have a grease pilot plant to test and develop formulations. Figure 2 shows a picture of a typical skid-mounted pilot plant prior to shipment.

STRATCO® Contactor™ reactor process

The STRATCO Contactor reactor process is similar to that of the open kettle except that less water is used (resulting in utility savings) and the process is much faster. A simplified flow diagram of the system is shown in Figure 3. Dry materials are charged through the top manway of the Contactor reactor while the base oils are normally pumped in through positive displacement meters or added through weigh tanks. The dry materials added to the Contactor reactor may consist of fatty acids and glycerides, such as hydrogenated castor oil, 12-hydroxysteric acid, beef tallow or other combinations, along with the metal alkali (i.e. lithium hydroxide, calcium hydroxide, sodium hydroxide, aluminum isopropoxide (AIP), etc.).

The Contactor is first charged with a portion of the total base oil that will be used. Depending on the grease manufacturer's preference and the type of soap being made, from one-third to all of the base oil is added. Circulation and heating of the base oil is started. The fatty acid is added so it can begin dissolving. The dry alkali is then added with some water before sealing the manway. This excess water, plus the water byproduct of the reaction, increases the Contactor reactor's operating pressure which accelerates saponification. The combination of water and pressure essentially eliminates the presence of undesirable partial glycerides when castor oil or animal fats are used as the source of fatty acid. The higher operating pressure also reduces the tendency for the soap concentrate to foam in the Contactor reactor.

original prototypes has been in continuous use since its installation in 1929. This was the forerunner of today's Cornell "Versator" homogenizers. Another of the founders, C.W. Stratford, had also started up the Stratford Engineering Corp. In 1977 Ward Graham, a Chemical Engineer and Executive Vice President of Stratford, bought the company and changed the name to Stratford/Graham Engineering Corp. (now STRATCO®, Inc.). Diane Graham, co-author of the main article in this White paper, is the present CEO of STRATCO. In addition, Claude Johnson´s son-in-law, E.R. "Dixie" Howell, joined Jesco in 1951 and initiated an aggressive sales and marketing strategy taking the company to a completely different level … from supplying the U.S. Cavalry with axle

1929 JESCO "MEETING" IN NORTH KANSAS CITY (USA)

1928 ROADSTER

1927 VOLVO "JAKOB"

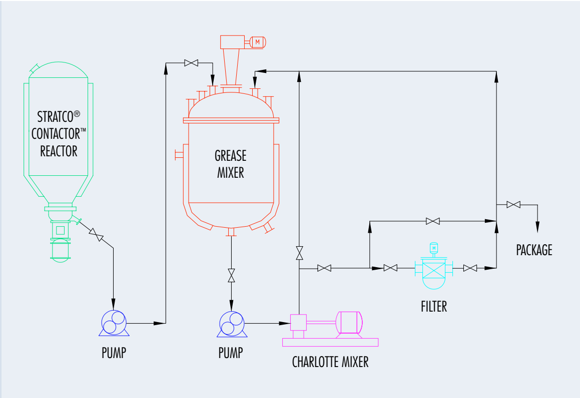


FIGURE 3 – SIMPLIFIED FLOW DIAGRAM

Very rapid heating during saponification occurs when the ingredients are circulated between the circulation tube and the shell. A heat rise to about 200 °C occurs in approximately thirty minutes. While saponification times vary, 10–15 minutes at 200 °C is usually sufficient to affect complete reaction between the saponifiable materials and alkali in the oil medium.

As the saponification reaction proceeds to completion, water is generated as a by-product of the chemical reaction. The Contactor reactor pressure is allowed to build to about 550 kPa and is controlled through a small vent valve. At the end of the heating cycle, the pressure is lowered to atmospheric pressure by venting the accumulated steam over a 15 minute period. Some manufacturers apply a vacuum to the Contactor reactor after the pressure is vented to dehydrate the soap concentrate. The Contactor is especially effective in this regard, as the circulation pattern continuously exposes fresh surface area while flowing over the top of the circulation tube.

After the saponification reaction is complete, the soap concentrate is typically cooled to about 170ºC with additional oil before it is transferred to the finishing kettle, which allows the soap fibers to form the necessary structure for the grease. The Contactor reactor is not opened if it is above the flash temperature of the oils unless the fumes can be vented into a strong and safe vent scrubbing system. If necessary, cool oil can be circulated through the Contactor reactor's jacket. However, cooling the Contactor reactor's jacket will increase the grease plant's overall

(Axel?) greases and gun oils to state-of-the-art solutions for the more modern industrial world. Success stories include the introduction of a novel Cotton Picker Spindle Grease and complete product lines for both the railroads and the mining industries. In the 1980´s, Dixie´s sons, Richard and John Howell, assumed the leadership of Jesco until the recent acquisition by Axel Christiernsson.

It is indeed a small world. Jesco (Axel Americas), STRATCO, and the very first Contactor can all be traced back to Kansas City in 1929. In 1929, Axel's grease plant was located in Huddinge just outside Stockholm. The novelty at that time was a new potassium-calcium grease, SKF 28, which had been designed to improve the lubrication of "Jakob", the first Volvo passenger car, introduced on the market two years earlier. When Axel Christiernsson acquired the assets of Jesco

CONTACTOR NO. 1 (IMPELLER ASSEMBLY)

CONTACTOR NO. 1 NORTH KANSAS CITY (USA)

1929 AXEL GREASE PLANT IN HUDDINGE (SE)

operating costs by increasing the energy and time requirements for the next batch. The shearing action of the Contactor helps produce a uniform dispersion of the soap particles to increase yield. Care needs to be taken so as not to cool the grease below the temperature where it can easily circulate in the Contactor. The viscosity of the grease is monitored by observing the Contactor motor amperage during the cooling portion of the production cycle.

Since most grease manufacturers desire to maximize the production rate in the grease plant complex, they will add only a portion of the finishing oil to the Contactor. The soap concentrate is pumped out of the Contactor reactor to the finishing kettle. Some of the remaining finishing oil is then used to flush the Contactor reactor to ensure that all of the soap has been transferred to the finishing kettle. The Contactor can then be used to produce another batch of soap concentrate while the previous batch is being finished in a kettle.

Since the Contactor reactor remains warm, it is immediately available for the next batch. Thus, one Contactor reactor can supply soap to a multi-kettle operation. For a typical lithium grease, it requires approximately one hour to charge the Contactor reactor, heat the contents, saponify the acid and alkali, and dehydrate the soap mass. In two hours, the soap concentrate has been made, transferred to a kettle, and the Contactor reactor is available to start the next batch of soap. Four batches of simple base grease concentrate can be produced in an eight-hour shift, depending upon the availability of finishing kettles and personnel to operate the equipment. By using multiple kettles, and with the proper scheduling, the STRATCO Contactor reactor method of manufacturing lubricating greases can be a continuous operation.

The Contactor reactor does not require a highly complicated control system when automatic controls are installed. For effective and efficient control, the rate of heating of the Contactor reactor and the Contactor reactor pressure during the manufacturing process can be automatically controlled. Also, the amperage load of the motor is monitored during the cooling of the soap mass. Introduction of the base oil into the Contactor reactor can also be included in any automatic control scheme.

resources in 2011, this included the original STRATCO Contactor which had been installed in 1929. The capacity of the kettle was/is about 1000 gallons (no metric units in 1929!) and featured a man-way type opening at the top through which all the ingredients could be introduced into the kettle. Two 500 gallon weighing tanks were suspended above and to either side of the kettle. Oil was pumped into the tanks and the weight was read on dial-style indicators (these are also still there, by the way). The oil was then poured into the kettle using the force of gravity by opening a valve and simply pointing the pipe from the bottom of the tank into the top of the kettle. The top opening was then secured with 12 bolts and nuts using wrenches and rope style sealing materials. Modern Contactors are slightly more sophisticated ! Jesco's second manufacturing facility was opened in Rosedale, Mississippi in 1986. This then

CONTACTOR BEING INSTALLED IN HEIJNINGEN (NL)

CONTACTOR IN ROSEDALE MISSISSIPPI (USA)

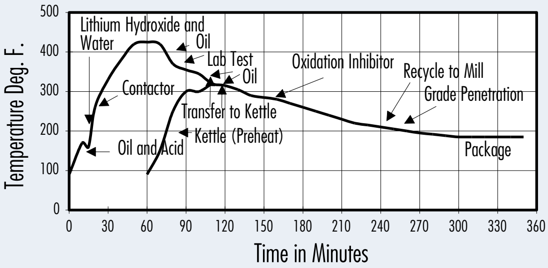


FIGURE 4 – LITHIUM GREASE PRODUCTION CYCLE

Figure 4 shows the production cycle of a typical simple lithium grease manufactured in a STRATCO Contactor reactor. The benefits of the Contactor reactor are discussed below in greater detail:

Yield

As the soap crystallizes in the Contactor reactor, the mixing action of the impeller forms a uniform dispersion of finely divided soap fibers. As discussed in literature, the finer the soap fiber, the more powerful its gelling action[2]. The result is an increase in yield in terms of unit weight of finished grease produced per unit weight of metallic soap produced when using a STRATCO Contactor reactor. In several instances, it was reported that the amount of soap required to achieve the same penetration grease is reduced by 30–50% when compared to the kettle process.[2]

A sealed pressure vessel, such as the STRATCO Contactor reactor, is needed to achieve complete reaction of the saponifiable materials without respect to the source of these materials. This complete reaction essentially eliminates the presence of the undesirable partial glycerides in the soap concentrate, thereby improving product quality significantly.

Production Time

Because of the double walled circulation tube, the Contactor reactor has approximately three times the heat transfer area of a kettle or other pressure (autoclave) type reactor of the same volume. Also, the flow path forces the total heat transfer surface to remain in contact with the circulating material at all times. In the kettle, only the surface below the liquid level is available for heat transfer. A typical 5.8 m^3 Contactor reactor operating with 2.3 m^3 of

state-of-the-art facility included a second (and more modern) STRATCO Contactor.

In Europe, Axel Christiernsson has progressed from being a local Scandinavian grease plant to a more global supplier providing products and services to the major oil companies and other strong international and regional players. In addition, in the early 1980´s Axel changed places in the supply chain from offering direct sales to Swedish end users to becoming a B2B operation and on a much wider geographical scale. Now concentrating entirely on lubricating greases, Axel has become a very attractive option for many lubricant suppliers to source their grease portfolio from a specialist operation. And sales have increased dramatically! In 1982, a new grease plant was built in Nol, Sweden, close to the port of Gothenburg and in 1991, to be able to supply to a much wider European customer base, Axel acquired Timac BV, an existing grease manufacturing facility in the Netherlands. So, in total, starting from about 2,500 MT in the early 1980´s, annual sales in 2002 were fast approaching 12,000 MT. To meet this new demand, the installation and commissioning of a new production line was carried out at Axel Christiernsson BV (formerly Timac). This was based on a STRATCO Contactor and provided the possibility of further improving production capacity and efficiency in regards to the manufacturing of standard lithium greases. Yet another quantum jump in business was achieved in 2004 and sales were expected to reach 20,000 MT. To be able to produce this volume of grease Axel purchased a “modular grease plant” consisting of a STRATCO Contactor and two finishing kettles. This was also installed in the Dutch facility and brought on line in 2006. And, most reactants, has 45.5 m^2 of heat transfer surface area.[3] In an identical size kettle filled with the same volume of reactants, approximately 6.5 m^2 of surface area is in contact with the liquid at any one time[4].

In addition, heat transfer in the Contactor reactor is enhanced by the high velocity of material flowing past the heat transfer surfaces. In the kettle, the heat transfer is aided only by the circulation achieved by the scraper blades. As a result, the reported overall heat transfer coefficient for the Contactor reactor can be enhanced almost four-fold compared to a kettle served by the same heating medium[5].

The net result is a significant reduction in manufacturing time when using the Contactor reactor and kettles together rather than kettles alone. Savings of 5 hours in production time is typical when manufacturing lithium 12-hydroxystearate grease[5]. Similar differences have been reported for other metallic soaps.

Energy Requirements
A principal cause for the difference in energy requirements between grease manufacturing processes is due to the volume of excess water that is added to the reaction zone. Because the Contactor reactor is a pressure reactor, only a minimum amount of excess water is required. The atmospheric kettle requires approximately ten times the amount of excess water since the water is vaporized out of the kettle during the reaction step. Significant energy savings are also realized due to the reduction in equipment operating time afforded by the Contactor reactor, as compared to the atmospheric kettle process.

Capital Costs
Because of the savings in production time discussed above, a grease manufacturing plant equipped with a Contactor reactor usually requires less equipment. For example, six to eight kettles are required to equal the production rate of a plant with a Contactor reactor and two kettles. For a new facility, this represents a significant savings in initial capital investment.

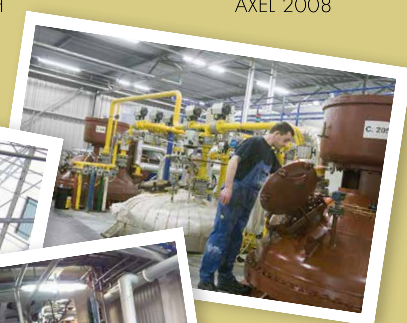
Maintenance Costs
Maintenance costs for most grease equipment are fairly low. Maintenance costs will vary in accordance with the duty or production schedule.

recently, Axel has invested in yet another STRATCO Contactor, this time at the Swedish site. Commissioning was delayed somewhat due to the global economic recession of 2009, but the unit was eventually completed in 2010 and is now in full operation.

So, from the very first prototype, installed in North Kansas City in 1929 to one of the most modern versions in operation in the Swedish facility, Axel has now five STRATCO Contactors faithfully manufacturing batch after batch of high quality lubricating greases on a regular daily basis.

MODULAR GREASE PLANT WITH CENTRAL CONTACTOR (NL)

AXEL 2008



CONTACTOR SET-UP ENVIRONMENT IN NOL (SE)

The modern Contactor reactor typically only requires maintenance repairs every three to five years.

Product Consistency and Uniformity

The high heat transfer coefficient and high circulation rate of the Contactor results in tight time-temperature control. This, in turn, results in a high level of repeatability and consistent product quality between batches.

Summary

Because of its design, the Contactor reactor achieves complete reaction of the saponifiable materials regardless of the source of these materials. This complete reaction essentially eliminates the presence of the undesirable partial glycerides in the soap concentrate, improving product quality significantly. Very little water needs to be added to the reaction mixture reducing time and energy requirements to vaporize the water from the soap concentrate mass.

The action of the Contactor reactor's impeller improves the total finished grease yield, allowing significant raw material cost savings. An efficient and effective control system can be included in the Contactor reactor process at a reasonable cost. In this tough economic climate with any given employee performing the work of several people, the Contactor reactor can be depended on to perform the work of two to four kettles.

LITERATURE

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IN THE YEAR OF OUR LORD 1929

1929 was the year when JESCO was founded and the first ever STRATCO Contactor was installed in their North Kansas City facility. These were two important events in the history of the grease world, but there were other things happening on a somewhat wider perspective !

1929 was the year of the infamous Wall Street Crash, wiping out more than $30 billion from the New York Stock Exchange (10 times greater than the annual budget of the federal government) and ushering the world into the Great Depression. Herbert Hoover was inaugurated as the 31st President of the United States succeeding Calvin Coolidge. In the UK, Ramsay MacDonald founded a new Labour Government. In Chicago, seven gangsters, rivals of Al Capone, were murdered in what has come to be known as the St. Valentine's Day Massacre. The Privy Council, a British High Court, in overturning a ruling by the Supreme Court of Canada, decreed that women were indeed "persons" and, as such, eligible for election to the Senate. The French began building the Maginot Line as a defense against a possible German attack. The German airship LZ 127 Graf Zeppelin flew around the World in 21 days. Colour television was demonstrated for the very first time and later patented that same year. The 1st Academy Awards for film were held in Los Angeles. Agnes Gonxha Bolaxhium arrived in Calcutta from Ireland to work among the poor and the sick. She became better known as Mother Teresa. Among "celebrities" who first saw the light of day in 1929 were Martin Luther King, Jacqueline Kennedy Onassis, Grace Kelly, Yassir Arafat, Audrey Hepburn, Anne Frank, Arnold Palmer, Roger Bannister, Stirling Moss .. Popeye and (the cartoon version of) Tarzan.

STRATCO'S 85TH BIRTHDAY CAKE

MAGINOT LINE

GRAHAM & GRAHAM

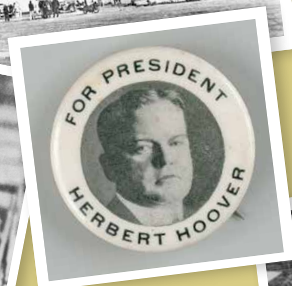
GRAF-ZEPPELIN

LUBRICATING GREASE 1929

LUBRICATING GREASE 2012

ANNE FRANK

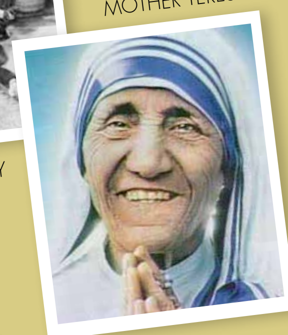
AL CAPONE



HERBERT HOOVER

ST. VALENTINE'S DAY MASSACRE

MOTHER TERESA




Santa Ana Register

FINAL EDITION

BILLIONS LOST AS STOCKS CRASH

Pantages In Jail Awaits Sentence To State Prison

SENATE "FARM BLOC" STARTS BATTLE FOR HIGHER TARIFFS

MAINSTAYS OF MARKET IN PLUNGE

GREAT DEPRESSION

YASSIR ARAFAT

POPEYE

JACKIE KENNEDY

MARTIN LUTHER KING

TARZAN

NEXT ISSUE

The next issue of the Lubrisense™ White Papers will focus on polyurea greases, a relatively new product technology for the AXEL Group. After the asset acquisition of Jesco Resources in the USA, products based on different polyurea thickeners have now become part of what we can offer. By reacting appropriate amines and isocyanates, a whole range of lubricating greases can be formulated offering exceptional performance in many different and demanding applications, both automotive and industrial. Some examples are filled-for-life bearings in electrical motors, constant velocity joints in passenger cars, high temperature applications in the steel and paper industries and even where a, by design, relatively poor mechanical stability may actually be advantageous.

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

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