Today's Decision in Grease Manufacturing

Kettle Vs. A Grease Contactor™ Reactor

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Introduction

When thirty-four people met in 1933 to form the National Lubricating Grease Institute, the first STRATCO® Grease Contactor™ reactor (note 1) had been operating for four years. Since then more than 100 units have been installed in over 21 countries, including the U.S. and Canada. Many of these early units are still in operation.

Every grease manufacturer wants an efficient production method that yields a high profit margin in conjunction with a superior return on investment. These needs can only be achieved after careful analysis of capital expenditure, payout, market opportunity, production cost and overhead. Once the decision has been made to enter into the science of grease manufacturing, one other decision must be made: Should we employ conventional kettles, a Contactor reactor or a continuous method? As "Only a few greases are used in large enough quantities to permit continuous operation" (1), we address the conventional kettles vs the Contactor reactor issue.

For over 4,000 years, man has made use of solid or semi solid materials for lubrication. During this time, many methods have been used for their manufacture. The processes used have ranged from a simple hand-stirred pot over an open fire to a completely instrumented continuous manufacturing process. The two most widely used methods today employ a STRATCO Contactor reactor operating in conjunction with a stirred kettle or only a kettle.

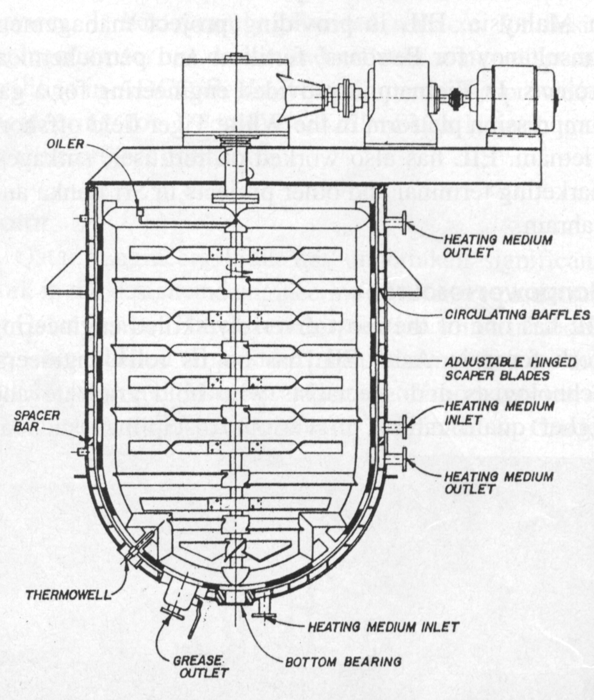
Note 1: STRATCO ®, STRATCO ®, and Contactor™ are trademarks of STRATCO, Inc.

Kettles

The design of kettles for the manufacture of lubricating grease has been improved over the years. Discussion on the design of grease kettles is given by Timm (2). A drawing of a modern grease kettle is shown in Figure 1.

The kettle shown is a vertical vessel with an open top. This type vessel is designed to operate at atmospheric pressure. However, some kettles are constructed with closed tops for pressure operation.

FIGURE 1
DOUBLE MOTION GREASE KETTLE



The outer shell surfaces of the kettle are usually jacketed for heating and cooling of the kettle contents. The heating medium is normally hot oil designed for 75 psig (517 kPa) at a maximum temperature of 500°F (260°C). To reach these same temperatures with high pressure steam would require a jacket designed for over 680 psig (4869 kPa).

A kettle for this pressure would requireconsiderably thicker walls. A significant increase in shell and jacket thickness results in a loss of heat transfer efficiency.

Cooling is then supplied by this same heat transfer fluid. The oil from the jacket is circulated through a water or air cooled exchanger and back through the jacket. Where multiple kettles are installed, hot and cold oil circulating loops can be set up to operate as a utility. Mixing and heat transfer in the kettle are enhanced by an internal stirring and scraping mechanism. A rotating U-shaped scraper framework is installed in the kettle. This framework, driven by a top mounted motor, is equipped with adjustable hinged scraper blades. The blades remove material from the wall increasing heat transfer rates and avoiding local overheating and the resultant degradation of the product.

This U-shaped frame has fixed cross support blades with outer portions that pump in an upward direction and center portions that pump in a downward direction to generate a flow pattern for uniform mixing.

A second center paddle framework with shaft extends the full length of the vessel and is supported, along with the scraper framework, by a bottom bearing. The second mixing assembly or the paddle blades, creates a flow pattern similar to the outer U-shaped scraper assembly. This center paddle assembly is counter-rotated at approximately twice the speed of the U-shaped scraper assembly by a motor driven speed reducer and drive head. Counter rotation creates shear in the kettle for mixing. The drive motor is mounted above the kettle and dry ingredients are loaded from the top.

STRATCO® Contactor™ reactor

The STRATCO Contactor reactor was developed primarily to overcome the limited batch production speed of the kettle. It is a pressure reactor used for the formation of a soap concentrate which can be diluted with oils in a kettle to produce the desired grade of finished grease.

The Contactor reactor normally is installed on the second floor of a grease plant. The top manway is approximately 30 inches (76 mm) above the second floor to ease loading of dry chemicals. The vessel then extends down into the space above the first floor. Figure 2 is a picture taken from the econd floor. Tables 1 and 2 are partial lists of the standard size Contactor reactors and kettles showing overall dimensions.

Table 1 - Typical STRATCO Contactor Reactor Sizes

Operating Volume (U.S. Gallons)	Surface Area (Square Feet)	Outside Diameter (Inches)	Overall Height (feet)	Motor (Horse Power)
1840	510	82	20	75*
1500	490	70	21	75*
1250	455	64	21	75*
1000	350	64	18	75*
750	232	64	16	75*
500	195	52	16	75*
375	157	45	15	40
140	36	34	12	30
12.5**	8.5 - 14.5	15	7	5

* Furnished with two-speed motor
** Utilized for pilot plant studies

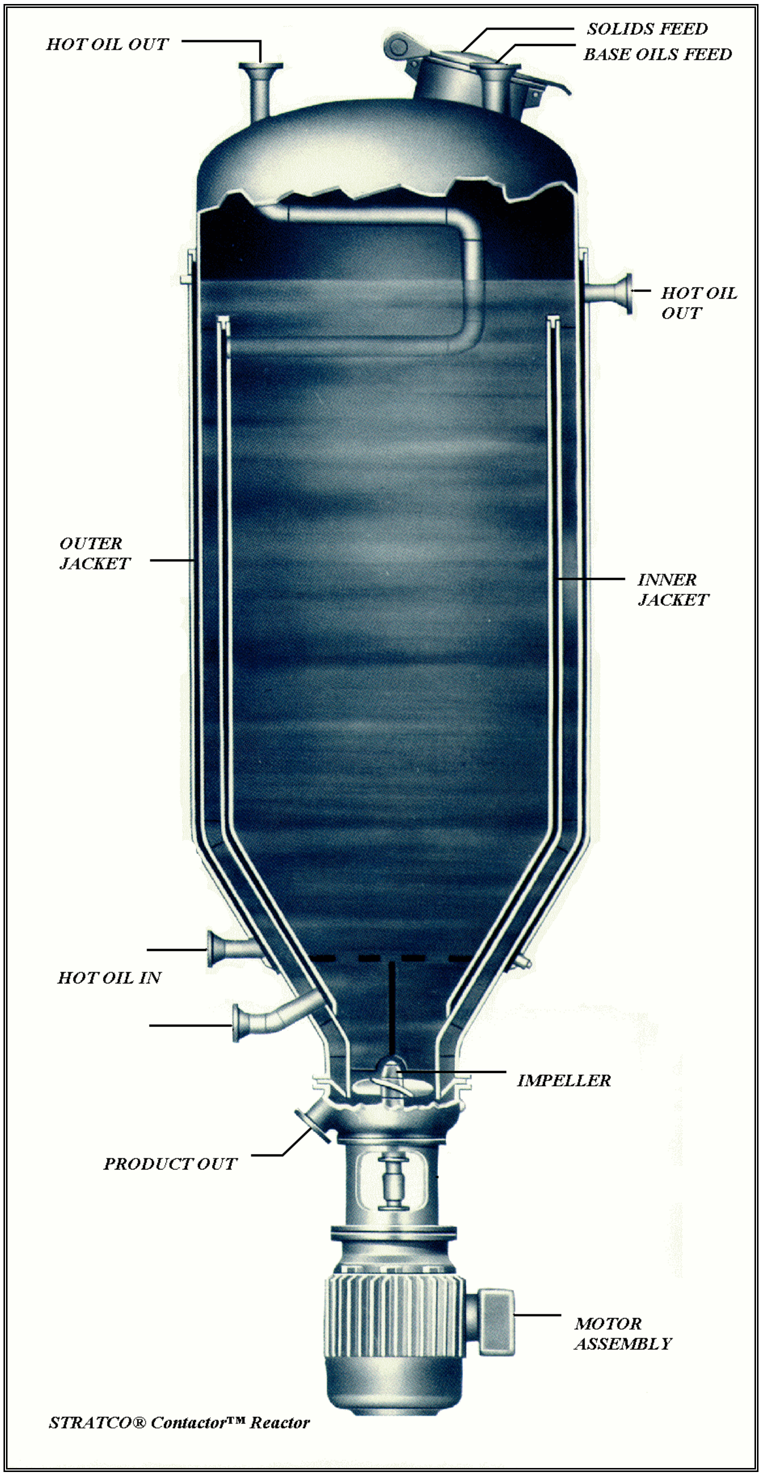
Table 2 - Available Standard Sizes - Double Motion, Atmospheric Pressure, Grease Kettles

Size		Working Volume Gallons	Nominal Capacity Pounds
8' - 6" Diameter	x 7' - 0" Shell	3800	26,000
7' - 6"	x 7' - 0"	2850	20,000
7' - 6"	x 5' - 6"	2350	16,000
6' - 6"	x 6' - 0"	1800	12,000
6' - 6"	x 4' - 6"	1450	10,000
5' - 6"	x 5' - 0"	1050	8,000
5' - 6"	x 4' - 0"	900	6,000
4' - 6"	x 5' - 6"	750	5,000

The Contactor reactor shown in Figure 4 consists of a pressure vessel, circulation tube, hydraulic head assembly with mixing impeller and driver. High dispersion mixing is achieved by the hydraulic head assembly. The rotating impeller, operating in conjunction with stationary vanes, produces a zone of intense mixing and circulation. The impeller circulates the material downward at the center of the Contactor reactor. Material is pulled down through the center of the circulation tube by the impeller, reversed and then forced up through the annular space.

A double walled circulation tube is installed to effect the heat transfer and create a continuous flow path for the soap concentrate. The heating medium is circulated through the external jacket and the circulation tube jacket for heating.

Figure 2- STRATCO Grease Contactor Reactor



Manufacturing

Kettle

The first step in producing a batch of metallic soap grease is the saponification of a suitable fatty acid with an alkali. This can be accomplished in either the Contactor reactor or a kettle. In a kettle, the solid ingredients are added through an opening in the top and the base oils and water are added in measured amounts through a vessel connection. After the kettle has been charged, hot oil flow is established through the kettle jackets. As the saponification reaction proceeds, more water is generated. This process must be carefully controlled to avoid excessive foaming during the reaction period.

After the soap has been formed, it is diluted with additional oil as a flow of cold oil is established through the kettle jackets. The scraper blades enhance the cooling rate. When the final amount of finishing oil has been added and the kettle contents are cooled to an acceptable level, additives are blended into the grease. Additives are generally added at this stage because they are heat sensitive.

Final penetrations are checked by the quality control laboratory. Small quantities of oil may be blended into the grease to meet specifications. The finished grease may need to be milled or passed through a deaerator to improve its appearance and texture. After all tests are made and specifications are met, the grease is released for packaging.

STRATCO Contactor reactor

The Contactor reactor process is similar to that of the kettle, but is slightly more sophisticated. A simplified flow diagram of the system is shown in Figure 5. Dry materials are charged through the top manway and liquids are added in measured amounts through a vessel connection. Usually about one-half of the final oil is first charged to the Contactor reactor.

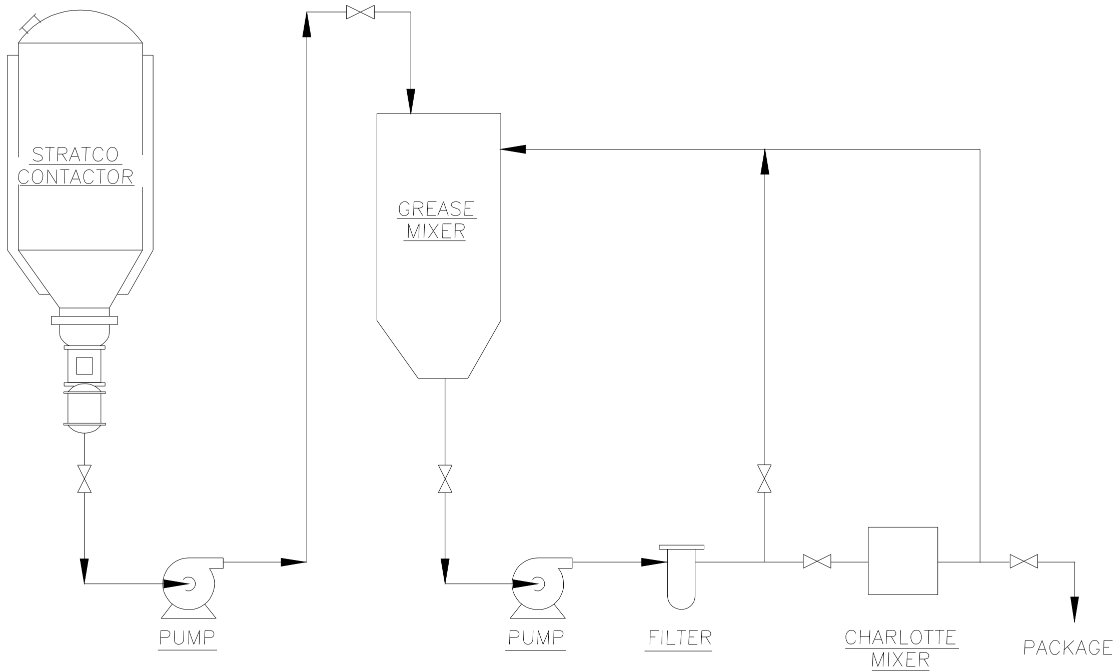


Figure 5 – Block Flow Diagram of Stratco Grease Plant

After the ingredients are charged, about five gallons of water are added before sealing the manway. This water aids in increasing the pressure by vaporizing during saponification. Operating at elevated pressure eliminates the possibility of foaming.

After agitation is established, hot oil is circulated through the jacket and circulation tube jacket. Normally, the hot oil is maintained at a maximum temperature of 500°F (260°C). It has been found that some oils used in greases have autoignition temperatures that are below 500°F (260°C). In this case, the maximum oil temperature should be lowered to avoid this hazard.

Very rapid heating during saponification occurs when the ingredients are circulated between the circulation tube and the shell. A heat rise from ambient to 400°F (204°C) will occur in 30 minutes. Saponification times vary, however, 10 minutes at 400°F (204°C) is usually sufficient to affect complete reaction of the fatty acid and alkali in the oil medium As the saponification reaction proceeds to completion, water is generated as a byproduct of the chemical reaction.

The Contactor reactor pressure is allowed to build to 75-85 psig (517- 586 kPa) and is controlled through a small vent valve. At the end of the heating cycle, the pressure is lowered by venting the accumulated steam at a controlled rate.

At this point some manufacturers apply a vacuum to the Contactor reactor to dehydrate the soap concentrate. The flow pattern in the Contactor reactor is ideal for removing traces of water from the soap concentrate. Material is continually flowing up and over the circulation tube thus exposing fresh surfaces for water removal. After dehydration, oil is added to the Contactor reactor for dilution and cooling. Cold oil flow can also be used through the Contactor reactor jackets to facilitate cooling. As the grease cools, it passes through a transition from being entirely fluid to a gel. Niazy et al (3) reported this behavior for a typical lithium based grease.

At 390°F (199°C), the soap is entirely fluid. As the temperature is lowered to 330°F (166°C), the viscosity begins to increase. At approximately 315°F (157°C), the gel structure begins to form. To maximize yield, the grease maker will add the dilution oil rapidly until the grease temperature is reduced to 330°F (166°C). At this point the rate of oil addition will be reduced until the grease has gelled. After gelling, the remainder of the oil is added rapidly.

As the grease cools, the viscosity increases, which in turn, increases the power input from the impeller. This added energy goes into the grease as shear which causes a very uniform dispersion of finely divided soap particles. By reducing the temperature of the soap, the grease maker can maximize the yield of product and reduce the necessity for further milling of the grease. Some very light greases such as an NLGI consistency No. 0 can be completely cooled and finished in the Contactor reactor. A lithium grease which is to be made into an NLGI No. 4 product, however, cannot be cooled much below 300°F (149°C). An optional two speed motor is supplied so that the Contactor reactor can be used for these heavier grades of grease.

Some manufacturers who employ the Contactor reactor are more concerned with production rate than they are with yield. They will add a portion of the dilution oil as fast as possible and pump out the Contactor reactor so that it is ready for the next batch. The remaining oil is then used to flush out the vessel to ensure that all of the soap has been transferred to the finishing kettle. These differences in how the Contactor reactor is used, illustrate its flexibility in the grease making operation.

The grease is transferred to a finishing kettle for a final dilution, testing and any additive blending that may be required. Additives can be added to the Contactor reactor if they can withstand the saponification temperature. Additive manufacturer's directions should be followed. The high intensity mixing of the impeller causes the additives to be more uniformly dispersed throughout the grease.

Thus, one Contactor reactor can supply soap to a multi-kettle operation. The production cycle time for a typical lithium grease is shown in Figure 6. It requires approximately one hour to charge the Contactor reactor, heat the contents, saponify the acid and alkali and dehydrate the soap mass. At the end of two hours, the soap concentrate has been transferred to a kettle and the Contactor reactor is available to start a second batch. Typical cooling time for the kettles is 2-4 hours.to start a second batch. Typical cooling time for the kettles is 2-4 hours.

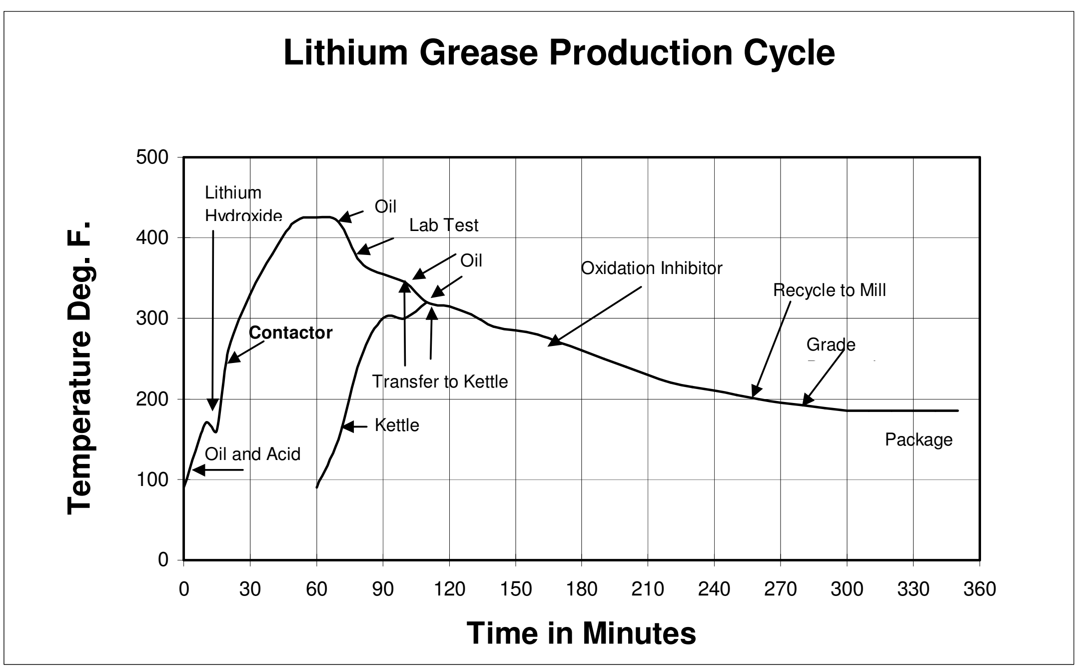


Figure 4 - Lithium Grease Production Cycle

Advantages of the STRATCO Contactor reactor

The Contactor offers the following advantages over an open kettle in producing the soap concentrate:

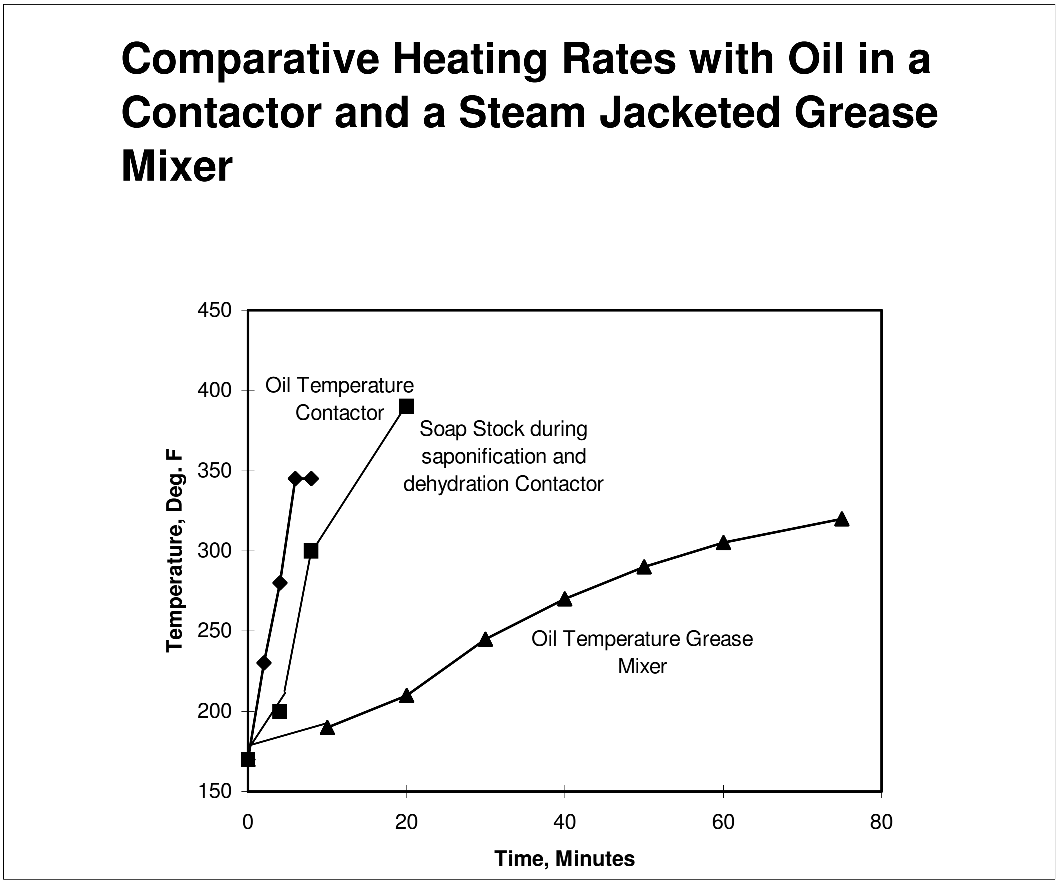
1. Shorter heating time.
2. Shorter reaction time.
3. Improved yield.
4. Reduced milling requirements.
5. Increased production capacity.
6. Reduced maintenance.
7. Consistent and uniform product

1. Shorter *Heating Time*

The Contactor reactor has approximately three times the heat transfer area of a conventional grease kettle of the same volume. Because of the unique flow path, the total heating surface area is in contact with the circulating material. In an open kettle, only the surface below the liquid level is available for heat transfer. In a typical 1500 gallon (5.77m^3) Contactor reactor filled with 600 gallons (2.3m^3) of oil, all 490 ft^2 (45.5m^2) of heat transfer surface is available; whereas in a 1500 gallon (5.7m^3) open kettle filled with the same volume of oil only 70 ft^2 (6.5 m^2) of surface is in contact with the liquid.

The heat transfer in the Contactor reactor is also enhanced by the higher velocity of material past the heat transfer surfaces. In the kettle, the convective transfer is aided only by the circulation achieved by the relatively slow speed scraper blades. Ronan et al (4) presents heating rates for the Contactor reactor and a conventional grease mixer equipped with counter rotating paddles and scraper blades. Each vessel was filled with 8000 pounds (3629 kg) of oil and heated using high pressure steam. The plot of time versus temperature is shown in Figure 7. The overall heat transfer coefficient for the Contactor reactor is over 200 BTU/h ft^2 °F (1132 W/m^2 °K); a value of 70 (398) was calculated for the kettle.

Figure 7 - Comparative Heating Rates with Oil in a Contactor Reactor and a Steam Jacketed Grease Mixer



Ronan also presents the time/temperature cycles for various grease formulations. Figure 8 is the manufacturing cycle for a lithium 12-hydroxystearate grease. The process using the Contactor reactor and a scraped surface kettle is finished in just over four hours. The process using only a kettle requires about nine hours to complete. Figure 9 shows the same data for a mixed base grease where the Contactor reactor reduced the cycle time from ten hours to five hours. For the calcium complex grease shown in Figure 10, the processing time was reduced from twelve to eight hours.

In each of these cases the Contactor reactor shortened the grease manufacturing cycle by four to five hours due to its improved heat transfer rates. In this operating cost conscious world this can eliminate an entire shift.

Figure 8 - Time-Temperature Cycle for a Lithium 12-Hydroxystearate Grease Manufactured in Contactor Reactor

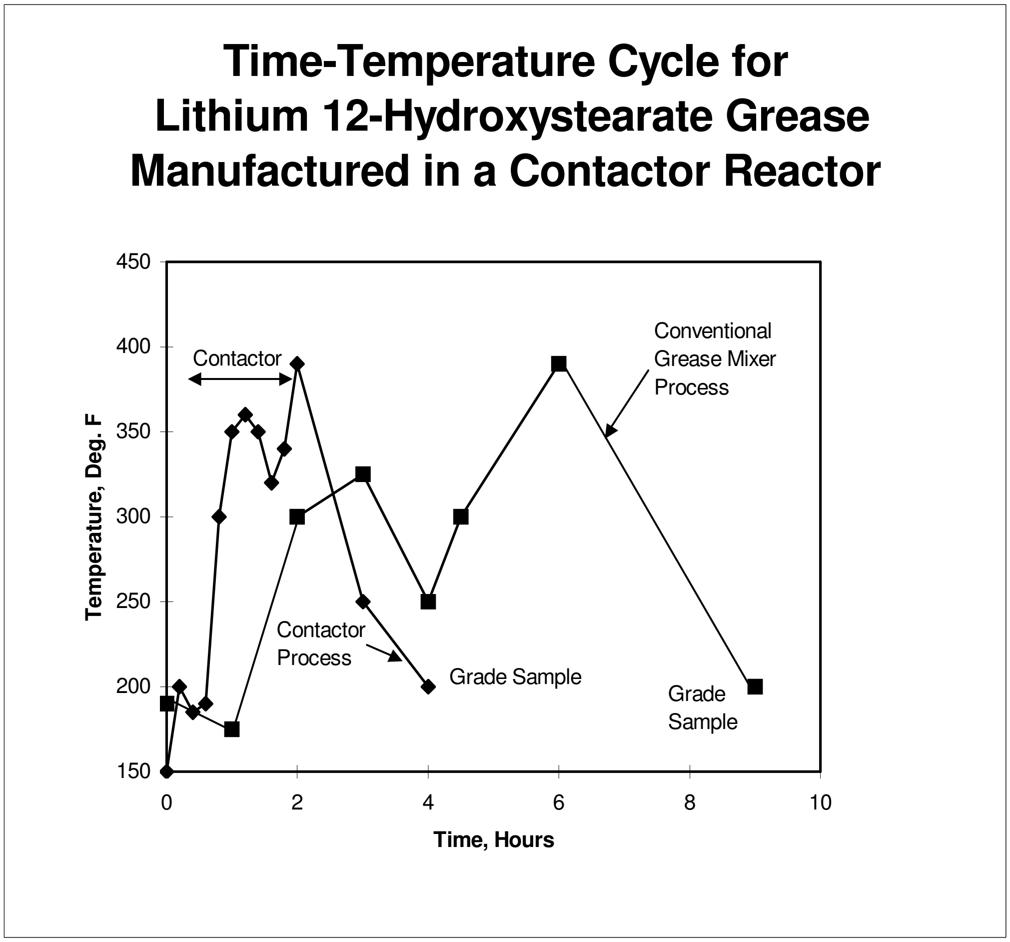


Figure 9 - Time-Temperature Cycle for a Lithium Calcium Stearate Grease Manufactured in Contactor

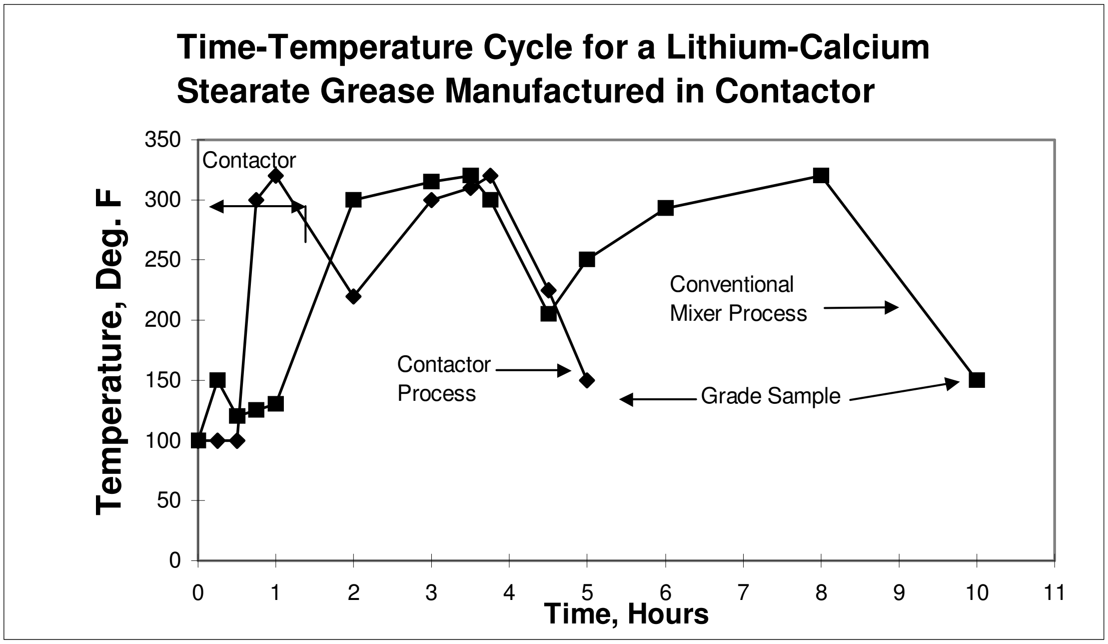
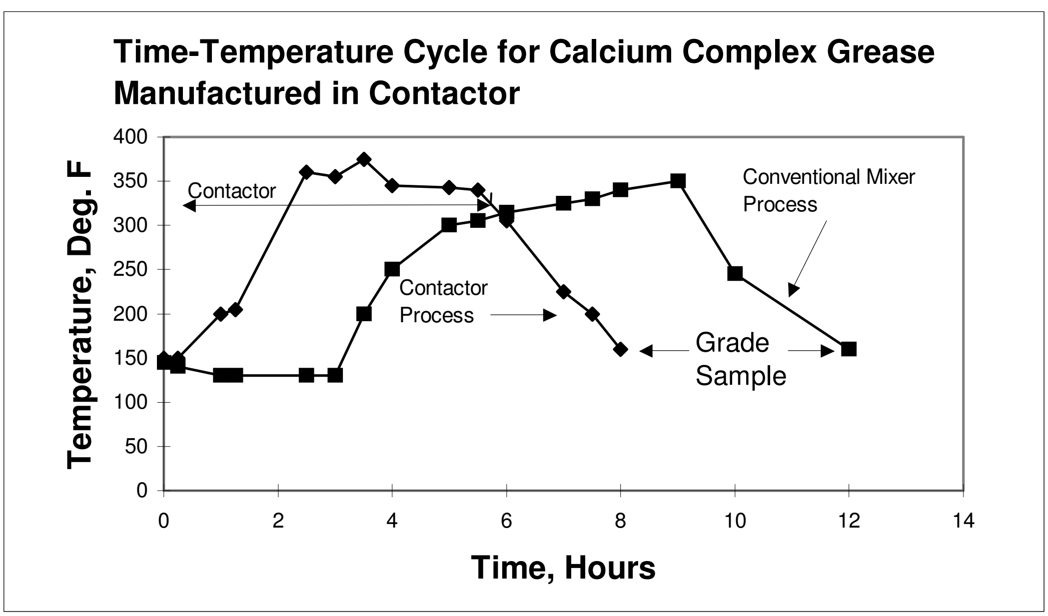


Figure 10 - Time-Temperature Cycle for a Calcium Complex Grease Manufactured in Contactor



2. Shortened Reaction Time

Because of high shear and intense mixing, the saponification reaction can be completed in a much shorter time. Graham (5) presents data showing the time/temperature cycle for charging the Contactor reactor to transferring the soap to a kettle was 45 minutes. He reports that this step previously took eight to ten hours in an open kettle.

Not only can the Contactor reactor increase the production of any grease plant, but it can also reduce the labor requirement. With the kettle process, the batch processing time normally exceeds a standard eight hour shift. The plant personnel then have to work overtime or operate with odd shifts. This creates managerial problems in scheduling personnel. With the Contactor reactor, most batches can be completed within the normal eight hour shift which greatly simplifies operating a "one shift per day " operation.

3. Improved Yield

This third advantage of using the Contactor reactor is the improved yield in terms of pounds of grease produced per pound of soap used. This is due to the more uniform dispersion of the soap in the oil. As the soap crystallizes, the mixing action of the impeller forms a uniform dispersion of finely divided soap particles. This behavior has been observed by Birkett (6). He observed that the finer the soap particle, the more powerful its gelling action. As the surface area of the soap increased, the stiffness of the lithium grease increased. The gelling ability of a soap is a surface phenomenon. The Contactor reactor has the ability to produce a finely divided soap which results in an increase in yield.

Table 3 - Grease Manufacturing Data

Grease No.	1		2		3		4	
THICKENER TYPE	NORMAL SOAP		COMPLEX SOAP		COMPLEX SOAP		INORGANIC	
TICKENER/OIL TYPE	MONOVALENT METAL SOAP/MINERAL OIL		POLYVALENT METAL SOAP/MINERAL OIL		POLYVALENT METAL SOAP/SYNTETHIC FLUID		THICKENER/MINERAL OIL	
PROCESSING	KETTLE	CONTACTOR-KETTLE	KETTLE	CONTACTOR-KETTLE	KETTLE	CONTACTOR-KETTLE	KETTLE	CONTACTOR-KETTLE
SOAP CONTENT, % (NLGI No.2)	9.0	4.5	16.0	11.0	17.0	11.0	8.0	4.5
FROP POINT OF FINISHED GREASE, ºF	350-360	360-375	460-480	490-500+	450-460	480-500	NONE	NONE
BATCH TIME, HOURS	7.0	5.0 (2 HRS IN CONTACTOR)	9.0	7.0 (2 HRS IN CONTACTOR)	9.0	7.0 (2 HRS IN CONTACTOR)	5.0	4.0 (1.5 HRS IN CONTACTOR)
MILLING (APROX. 6HRS /BATCH)	50% OF BATCHES	NO	60% OF BATCHES	NO	100% OF BATCHES	NO	100% OF BATCHES	NO

Niazy et al (7) presents data to support increased yield when using a Contactor reactor. Data for a normal monovalent soap, two complex soaps and an inorganic thickened grease is reproduced in Table 3. To achieve the same penetration required by the NLGI No.2 specification, the soap content was reduced between 30 to 50 percent when using the Contactor reactor instead of forming the soap in a kettle. If 12-hydroxystearic acid costs 0.65 dollars per pound, and lithium hydroxide is $2.61 dollars per pound, reducing the soap content from 9 percent to 4.5 percent saves about $0.045.dollars per pound of the finished grease product. For a 20 million pound per year plant, this amounts to an annual savings of $900,000.per year.

Table 3 also shows the time savings when using the Contactor reactor. In those cases when the Contactor reactor was used to produced a metallic soap, a savings of two hours was realized in the process. In the inorganic thickened grease where little heating is required, the savings was only one hour.

4. Reduced Milling Requirements

The Contactor reactor can reduce the milling requirements of the product grease as shown in Table 3. Of all the batches produced in the kettle, from 50 to 100 percent required milling. With the Contactor reactor, none of the batches had to be milled. In this particular plant, the milling operation required six hours to complete. For those batches which did require milling, the Contactor reactor reduced the processing time from fifteen hours to seven hours.

Another example is presented by Dreher et al (8). In this paper, data is presented from the manufacturing of an aluminum complex grease. Using the conventional kettle to produce the grease required recycling the kettle contents through a mill at two different points in the process. Total milling time was six hours. With the Contactor reactor, no milling was required and the process could be completed in four hours.

5. Increased Production Capacity

Because of the rapid heating rates in the Contactor reactor, plant production can be increased. To equal the production of a plant with a Contactor reactor and three kettles requires a plant with six to eight kettles without a Contactor reactor. The Contactor reactor/kettle plant represents a considerable saving in initial capital investment. For an existing plant with three kettles, production can be more than doubled with the installation of a Contactor reactor.

6. Reduced Maintenance

The grease kettle has the drive mechanisms located above the kettle. This subjects the motor to all of the fumes and dust which come out of the kettles. On the Contactor reactor, the motor is mounted below the vessel and out of the operating area. This placement results in reduced motor maintenance.

7. Consitent and Uniform Product

With the addition of some simple temperature control instrumentation, the time-temperature profile can be tightly manipulated. This is a result of the high heat transfer coefficient and the high circulation rate of the Contactor reactor. By maintaining more control over the process, a higher degree of repeatibility between batches results. This, in turn, leads to fewer off-spec batches.

Summary

The decision to purchase kettles or a Contactor reactor is predicated on the previously mentioned variables: capital expenditure, payout, market opportunity, production cost and overhead. For the manufacturer of a small grease plant, the increased efficiency of a Contactor reactor must be balanced against the incremental cost of the Contactor reactor. For a larger plant, the choice is between a plant with many kettles or a Contactor reactor with a minimum number of kettles. While the kettle plant will cost more, it will have added flexibility in terms of allocating kettles for specific services.

The use of a Contactor reactor results in increased yield, improved product quality, reduced maintenance costs, increased production capacity and, therefore, reduced labor costs. The high shear rate eliminates the necessity of milling certain types of greases; this can reduce processing time by up to six (6) hours. A cost analysis would show that an investment in a Contactor would give you, the grease manufacturer, a higher payout and the opportunity to make your grease plant operation more profitable.

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