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STRATCO® Contactor™ Reactor

Economic Analysis

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By

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Introduction

STRATCO, Inc. has been supplying grease manufacturing equipment and engineering for over 70 years. The first STRATCO® Contactor™ reactor, which is at the heart of the STRATCO® Contactor™ Process, was installed in 1929 and is still operating today. Over the years, many technical papers have been written and presented addressing a variety of issues associated with the Contactor (see footnote below), such as operating advantages [1] [2] [3] [4] [5], pilot plant versus commercial production correlation [6] and operating techniques [7]. The focus of this paper is to compare the economics of operating a grease manufacturing facility utilizing a Contactor versus conventional open kettles. This study will address, in greater detail than previous papers, the potential cost savings related to raw materials, labor and utilities, by adding a Contactor to a conventional open kettle grease process.

STRATCO Contactor and Kettle Reactors

In order to fully appreciate the inherent differences between the Contactor Process and conventional kettle process, the physical differences between the Contactor and the open, or, atmospheric, kettle must be understood. The STRATCO Contactor reactor, shown in Figure 1, consists of a pressure vessel, a circulation tube and a hydraulic head assembly complete with the mixing impeller and driver.

The outstanding feature of the Contactor reactor is its highly turbulent circulation in a closed–cycle path. A double-walled circulation tube within the vessel conducts the product downward through the core to the impeller. The impeller forces the product down to the hydraulic head, where diffuser vanes straighten the stream into axial turbulent flow. The contoured hydraulic head then reverses the flow, directing the stream upward through the annular space between the circulation tube and the Contactor's jacketed shell. It is conducted by this annulus over the top of the circulation tube and back down to the impeller. The impeller is driven by a two-speed motor, with the high speed normally turning at 1200 or 1500 RPM, depending upon the nature of the electrical service.

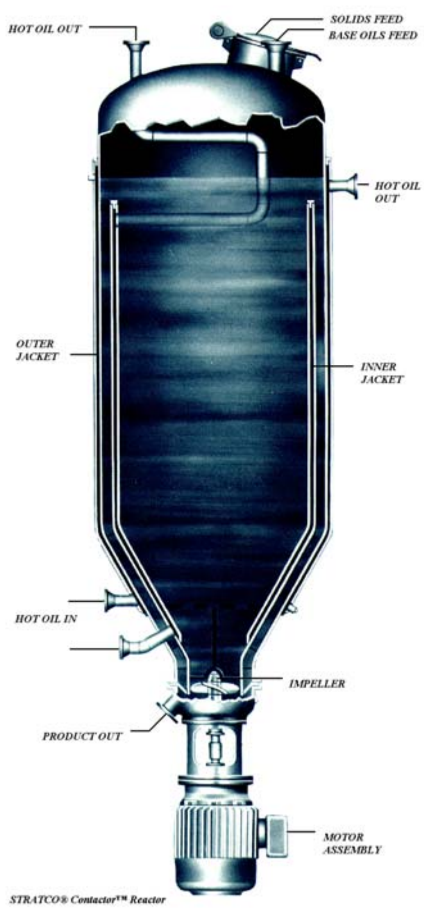
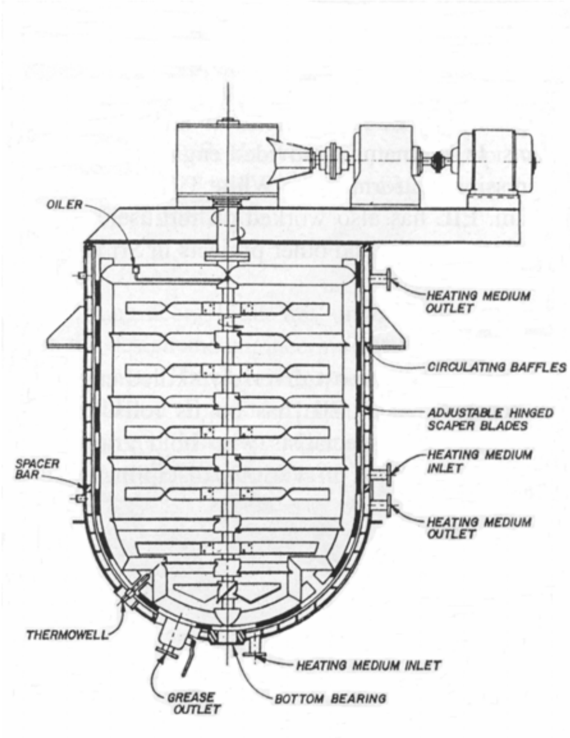


Figure 1: STRATCO® Grease Contactor™ Reactor

The Contactor is constructed with a design pressure of 150 psig (1033 kPag) to full vacuum and design temperature between 500°F. (260°C) and 600°F (315°C). Although this study evaluates a Contactor served by a hot oil system, a configuration with an internal coil circulation tube is available for use with steam heating.

Figure 2 provides a sectional view of a basic open grease kettle. A typical open kettle is comprised of a jacketed shell, an internal counter-rotating stirrer assembly, and one or two motor drivers connected to the stirrer assembly through a gearbox. The stirring assembly is comprised of a center shaft, with attached stirring blades, rotating in one direction and a scraper frame or anchor stirrer, with attached stirring blades, rotating opposite to the center shaft. Mounted on the anchor stirrer are scraper blades, which scrape the inside shell wall to prevent accumulation of a residue. Stirrer speeds are typically in the range of 10 to 60 RPM, with the anchor stirrer commonly turning at half the rate of the center shaft. The external jacket can be configured as a single or dual circuit, the latter providing benefits for reduced batches and improved temperature gradients between the jacket heat transfer fluid and product. Heating can be provided via steam, hot oil, direct-fired gas or electric resistance. Cooling is typically provided by cooling oil or water.

The kettle can be designed to operate under elevated pressure or at atmospheric pressure. The pressure kettle offers some advantage over the atmospheric kettle in that the batch temperature can be raised to a higher temperature without boiling off the water, thus reducing the cycle time for saponification. However, nearly as much water is required with the pressure kettle as that for the atmospheric kettle to facilitate dispersion of the alkali and catalyze the reaction. The time required for saponification is still greater for the pressure kettle than for the Contactor reactor due to the lower heat transfer rate and heating surface area of the former.



The two primary advantages realized in the use of the Contactor are (1) improved yield of the finished grease and (2) improved heat transfer rate. The improved yield is due to the more uniform dispersion of the soap in the oil and the high shear mixing. As discussed in previous works, the finer the soap particle, the more powerful is its gelling action [8]. The improved heat transfer rate results in reduced equipment operating time and corresponding savings in electrical energy and fuel consumption. The shorter cycle time improves the operating efficiency of the grease plant, resulting in reduced labor, and electrical requirements associated with direct process needs, and with plant space heating and ventilating.

Figure 2: Double Motion Kettle

The Contactor Reactor Grease Manufacturing Process

The basic Contactor Grease Manufacturing Process (Contactor Process) typically consists of a Contactor reactor (utilized for saponification), multiple finishing kettles, a mill or homogenizer, a grease filter, a vacuum system, and several product transfer pumps. Although there is quite a variety of auxiliary equipment and systems used in manufacturing plants, this study will consider a relatively basic configuration. Figure 3 illustrates the configuration of the basic Contactor Process. The production capacity assumed in this study is two 10.2 metric ton batches for 250 working days, totaling 5100 metric tons per year.

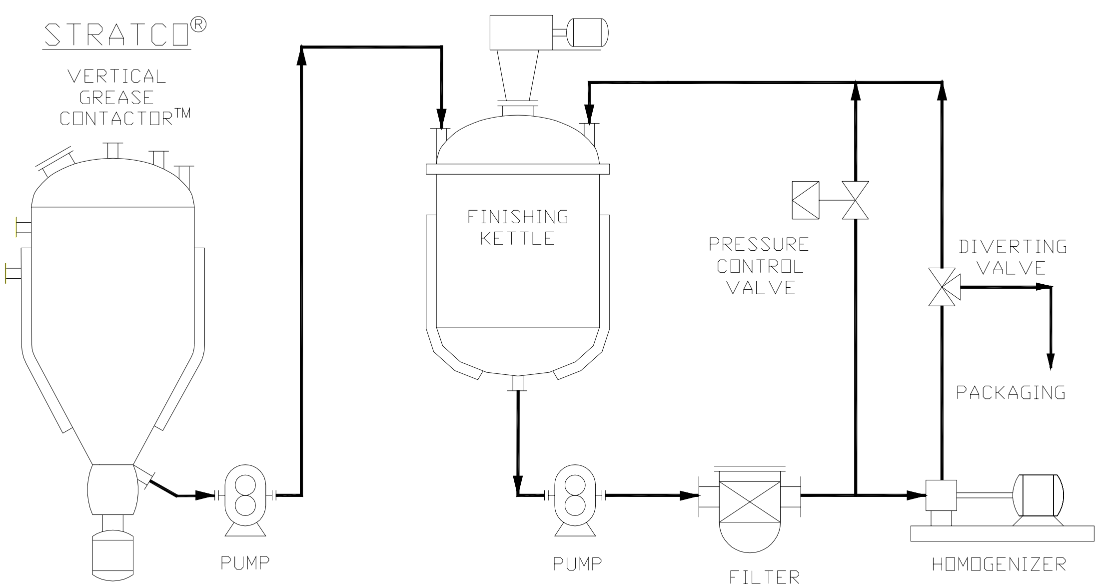


Figure 2: STRATCO® Contactor™ Reactor Process

The Contactor Process will commence with the saponification of the soap base in the Contactor reactor, which will amount to approximately 5.1 metric tons. A portion of the base oil will be added at the end of the saponification process to provide quenching or cooling. After the quenching oil is added, the contents will be transferred to a finishing kettle. The remaining base oil will be added to the finishing kettle, a portion of which will be circulated briefly in the Contactor reactor to flush out any residual soap base. The total batch in the finishing kettle will experience most of the cooling from the added base oil, which is at ambient temperature when added. Additional cooling in the finishing kettle will be provided by water in the kettle's jacket through. The cooling water can be once through cooling water, if a source is readily available. If not, a small, closed loop cooling water system would be used. The closed loop cooling water system is directly affected by the ambient conditions, providing the best cooling rates during cold weather. Thermal oil can be used for cooling, but is less attractive since the heat capacity of thermal oil is about half of that for water. Since water provides the best cooling for the finishing kettle, the water cooled kettle model will be used for cost comparisons.

Additives will be incorporated in the finishing kettle after the batch has sufficiently cooled as required by the additives. When the batch is cooled to the appropriate packaging temperature, it will be milled and transferred to the packaging lines, passing through a vacuum tank providing deaeration. (Some procedures include the application of a vacuum to the Contactor reactor after the saponification is complete in order to effectively dehydrate the grease. For simplicity, this step will not be considered in this analysis.)

<u>The Atmospheric Kettle Grease Manufacturing Process</u>

Figure 4 illustrates the basic atmospheric kettle process. For comparison purposes, it will be assumed that one saponification kettle will be used for both batches and the working volume of the saponification kettle will be approximately half the working volume of the finishing kettles, similar to the Contactor process. This will allow cooling from the additional base oil, similar to the Contactor process. Consequently, the saponification kettle will have a 1,500 US gallon (5.67 m^3) working volume and will be agitated with a 50 HP (37.3 kW) motor.

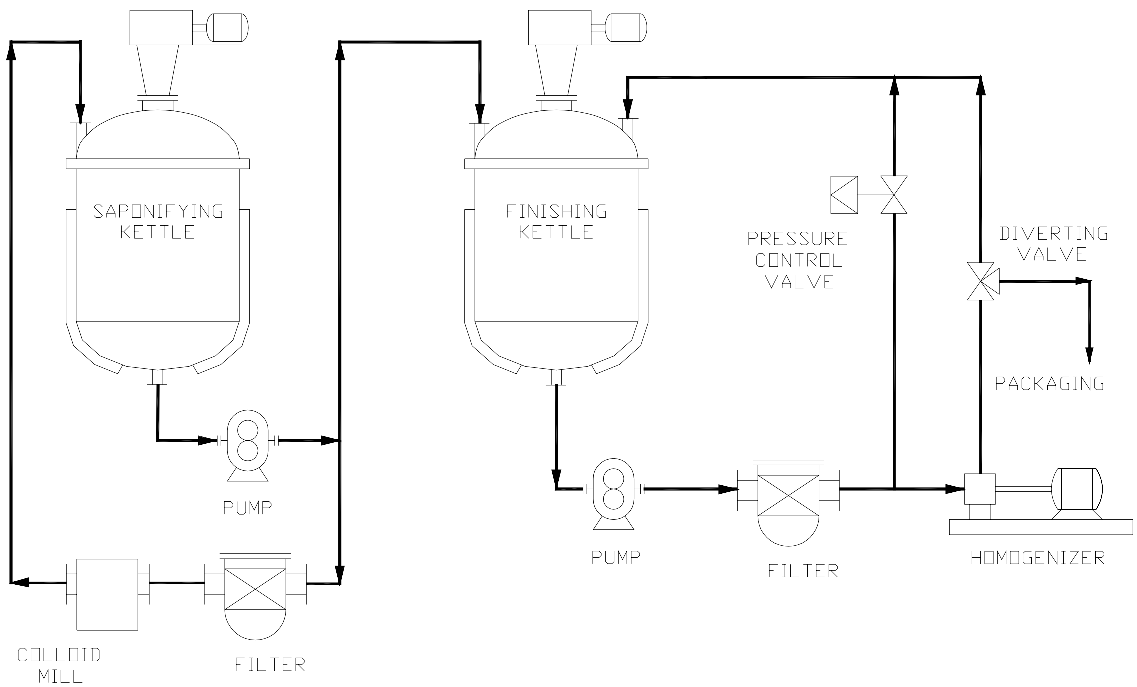


Figure 3: Conventional Kettle Process

The process commences with the saponification in the cooking kettle utilizing thermal oil heating. When the maximum temperature is reached, in four to eight hours, depending on the amount of water used to suspend/disperse the alkali, the contents are recirculated and milled for one and a half hours. The contents are then transferred to the finishing kettle, where additional base oil is added at ambient temperature. It is then cooled to the necessary temperature for additive addition. The contents of the kettle are recirculated during the entire finishing cycle. When the grease has been cooled to packaging temperature, it will be milled and transferred to the packaging lines, in some cases, passing through a vacuum tank providing deaeration.

Manufacturing Cost Comparisons

In order to fully appreciate the advantages of the Contactor reactor process over the conventional kettle process, it is necessary to quantify these advantages in terms of costs. Cost categories evaluated herein will include: (1) electrical consumption, (2) heating fuel consumption, (3) raw material costs and (4) labor costs. It must be understood that, in order to establish these cost comparisons, certain assumptions must be made regarding utility costs, raw material costs and wage rates. Although values used for these unit costs are considered to be reasonable and application of the resulting savings shown to individual manufacturers would require adjustment to reflect their specific operations and actual costs, the relative cost savings remain universal. The goal of this study is to provide a conceptual basis for cost comparisons through an example providing reasonable unit costs and operating parameters. Tables No. 1 and No. 2 illustrate the equipment operating schedules associated with the Contactor reactor process and the conventional kettle process, respectively. The values in the cells indicated the operating time in hours. The schedules shown are based upon the manufacturing procedures described above. What is dramatically shown by these two schedules is the substantial reduction in total processing time. By slightly staggering the packaging operators, both batches can be completely finished in a single 8-hour shift using the Contactor reactor, while two full shifts are required to complete two batches using open kettle saponification. In fact, it has been proven that four batches can be completely finished in one 8-hour shift.

	Processing Time (hours)															
Description	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Charge Contactor R1	0.25		0.25													
Cook Contactor R1	0.75	0.75	0.75	0.75												
Transfer Contactor R1 to FK1		0.25														
Transfer Contactor R1 to FK2				0.25												
Finish Kettle FK1			1.00	1.00	0.50											
Finish Kettle FK2					1.00	1.00	0.50									
Mill/Transfer/Package Kettle FK1					0.50	1.00	1.00									
Mill/Transfer/Package Kettle FK2							0.50	1.00	1.00							

Table 1: Contactor Reactor Process Equipment Operating Schedule

	Processing Time (hours)															
Description	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Charge Kettle CK1	0.25					0.25										
Cook Kettle CK1	0.75	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	1.00						
Mill Kettle CK1					1.00					1.00						
Transfer Kettle CK1 to FK1						0.25										
Transfer Kettle CK1 to FK2											0.25					
Finish Kettle FK1						0.75	1.00	0.75								
Finish Kettle FK2											0.75	1.00	0.75			
Mill/Transfer/Package Kettle FK1								0.25	1.00	1.00	0.25					
Mill/Transfer/Package Kettle FK2													0.25	1.00	1.00	0.25

Table 2: Conventional Kettle Process Equipment Operating Schedule

Table No. 3 illustrates an electrical cost between the two processes considered. The equipment operating schedules forming the basis of the electrical consumption are from Tables No. 1 and No. 2. These operating schedules are based upon actual manufacturing operations. Although operating procedures vary greatly from one manufacturer to another, the schedules used in this study represent reasonable scenarios. Manufacturing procedures more and less efficient than those presented are used in the industry in both cases. The table shows a substantial increase in electrical consumption of the kettle process over the Contactor reactor process. Notable differences include reactor operating time and milling requirements. Although not quantified in this study, there would be increased non-process electrical consumption for the additional operating shift of the kettle operation related to space lighting, heating and ventilating.

		Contactor™ Process		Atmospheric Kettle Process	
Equipment	**Electrical Load (KW)**	**Hours of Operation**	**Electrical Consumption (KWH)**	**Hours of Operation**	**Electrical Consumption (KWH)**
Contactor™	30	4	120	0	0
Contactor™ Lubricator	0.15	4	0.6	0	0
Grease Pump #1	20	0.50	10	2.5	50
Saponification Kettle	30	0	0	10	300
Finishing Kettle	50	5	250	5	250
Grease Pump #2	20	5	100	5	100
Oil Heater	0.3	2	0.6	8.5	2.55
Hot Oil Pump	14	3.5	49	9.5	133
Colloid Mill	50	5	250	7	350
Grease Pump #3	20	5	100	5	100
Total Batch Electrical Consumption (KWH)			**880.20**		**1,285.55**
Unit Electricity Cost ($/KWH)			$0.1102		$0.1102
Total Batch Electrical Costs ($)			**$96.9980**		**$141.6676**
Annual Batches Produced			500		500
Total Annual Electrical Costs ($)			**$48,499.02**		**$70,833.81**

Table 3: Process Electrical Cost Comparison

Table No. 4 illustrates a labor cost comparison between the two processes. Again, the labor schedule is determined by the operating schedules presented in Tables No. 1 and No. 2. As stated previously, personnel requirements can differ significantly from one manufacturer to another, as can unit labor costs. The unit labor costs shown are intended to represent basic wages and labor burdens and are considered by the authors to be reasonable approximations, although wages can vary substantially due to local prevailing wage rates and the local supply of labor. The labor costs are almost doubled by expanding from one shift to two shifts per day. It should be noted that the comparison reflects one and a half in lieu of two shifts for packaging personnel for the kettle process, based upon the assumption that packaging activities span nine hours plus some allowance for preparation, change-over, etc. Based upon the wages assumed, this cost difference is significantly more than the utility costs.

Personnel	annual working days	hours per shift	persons per shift	Contactor™ Reactor Process				Kettle Process			
				Shifts per day	annual man-hours	hourly wage ($)	annual wages ($)	shifts per day	annual man-hours	hourly wage ($)	annual wages ($)
Production Foreman	250	8	1	1	2,000	$20.00	$40,000.00	2	4,000	$20.00	$80,000.00
Greasemaker	250	8	1	1	2,000	$20.00	$40,000.00	2	4,000	$20.00	$80,000.00
Lab Technician	250	8	1	1	2,000	$30.00	$60,000.00	2	4,000	$30.00	$120,000.00
Packaging Operator	250	8	2	1	4,000	$13.50	$54,000.00	1.5	6,000	$13.50	$81,000.00
Material Handler	250	8	2	1	4,000	$14.50	$58,000.00	2	8,000	$14.50	$116,000.00
Totals			**7**		**14,000**		**$252,000.00**		**26,000**		**$477,000.00**

Table 4: Process Labor Cost Comparison

Tables No. 5 and No. 6 represent raw materials required for the Contactor reactor and kettle processes, respectively. These tables reflect a difference in thickener content required between the two processes. It has been well documented that the high shear mixing provided by the Contactor reactor can improve the yield of the finished grease. Although this might not be experienced by all manufacturers, specific cases have resulted in operations that have reduced thickener content from as high as 8% to 18%. This study assumes a savings of 4% in thickener content. It is clearly illustrated that significant cost savings can be realized through thickener content reductions of just a few percent. It should also be noted that the use of excess water to drive the reaction can be eliminated by using the Contactor reactor. The pressurized operation, vigorous mixing, and retention of moisture of the Contactor reactor during the saponification process contribute to lower initial water requirements, more significantly affecting the heating costs than in the cost of the water itself.

Description	Raw Mat'l Qty (kg)	Unit Cost ($/kg)	Total Cost	Finished Batch Wt. (kg)
Base Oils	9,392	$0.3659	$3,436.20	9,392.0
12 Hydroxy Stearic Acid	800.9	$1.6199	$1,297.46	
Lithium Hydroxide Monohydrate	111.8	$3.306	$369.74	
Water (excess)	0.0	$0.001203	$0.00	
Lithium 12 Hydroxystearate soap				816.7
Total Batch Weight (kg)	**10,304.7**			**10,209**
% Soap				8.0%
Material Cost			**$5,103.33**	
Material Cost ($/kg)			$0.4999	
Annual Production (kg)			5,104.356	
Total Annual Material Cost ($)			**$2,551,666.23**	

Table 5: Contactor Reactor Process Raw Material Cost

Description	Raw Mat'l Qty (kg)	Unit Cost ($/kg)	Total Cost	Finished Batch Wt. (kg)
Base Oils	8,983.7	$0.3659	$3,286.80	8,983.7
12 Hydroxy Stearic Acid	1,201.3	$1.6199	$1,946.19	
Lithium Hydroxide Monohydrate	167.8	$3.306	$554.60	
Water (excess)	780.9	$0.001203	$0.94	
Lithium 12 Hydroxystearate soap				1,225.0
Total Batch Weight (kg)	**11,133.6**			**10,209**
% Soap				12.0%
Material Cost			**$5,788.44**	
Material Cost ($/kg)			$0.5670	
Annual Production (kg)			5,104,356	
Total Annual Material Cost ($)			**$2,894,218.93**	

Table 6: Kettle Process Raw Material Cost

Table No. 7 represents a comparison of the heating requirements between the two processes. Although the physical mass of the Contactor reactor is greater than that of the kettle due to its internal circulation tube, the overall heating requirements of the kettle are substantially greater. Not only is the amount of water being heated much greater in the kettle, but also the heat of vaporization of the water is noticeably reduced at the elevated pressure, which is assumed to be 60 psig (413 kPag) in this study. It should also be noted that, although half of the finished batch weight is heated in the kettle reactor, only 37.5% of the total batch is heated in the Contactor reactor. This reserves a portion of the Contactor reactor working volume for quenching oil. Due to the internal design of the Contactor reactor, the reduced volume still benefits from the entire heat transfer surface area. The kettle must be filled to its maximum working volume capacity in order to utilize all of the jacket heat transfer surface area. This operational difference consequently reduces the heating requirements. Table No. 8 summarizes the total process heating requirements of the two processes and quantifies the differences monetarily with assumptions regarding heater efficiency, reactor heat losses, heating system losses, and natural gas costs. The reactor losses are based upon surface areas and temperature profiles, including equal insulation thicknesses. For the purposes of this study, the heating system losses are assumed to be approximately 3% of the process heating loads.

Description	Contactor™ Process				Atmospheric Kettle Process			
	Heating Rate (kJ/kg*K)	Quantity (kg)	Temp. Rise (K)	Total Heating (kJ)	Heating Rate (kJ/kg*K)	Quantity (kg)	Temp. Rise (K)	Total Heating (kJ)
Water Heating	4.1868	101.9	127.77	54,511.1	4.1868	924.8	78.88	305,419.6
Water Vaporization*	2100	101.9	-	213,990.0	2253	924.8	-	2,083,574.4
Reactor Heating	0.4605	10,435.0	188.88	907,628.4	0.4605	8,167.0	188.88	710,359.5
Product Heating	2.3	3,818.0	188.88	1,658,630.8	2.3	5,104.3	188.88	2,217,430.4
Total Heating				**2,834,760.3**				**5,316,783.9**

(* Heat of Vaporization in kJ/kg)

Table 7: Process Heating Comparison

Description	Contactor™ Process			Atmospheric Kettle Process		
	Heating Rate (Av.:kJ/H)	Duration (H)	Total Heating (kJ)	Heating Rate (Av.:kJ/H)	Duration (H)	Total Heating (kJ)
Reactor Losses	7,483	0.75	5,612.3	13,702.0	4.5	61,659.0
System Losses	113,390	0.75	85,042.8	35,445.2	4.5	159,503.5
Reactor, Product, & Water Heating			2,834,760.3			5,316,783.9
Total Batch Heating Output (kJ)			2,925,415.4			5,537,946.4
Total Annual Batches			500			500
Annual Heating Output (kJ)			1,462,707,702			2,768,973,208
Heater Efficiency (%)			80.0%			80.0%
Annual Heating Input (kJ)			1,828,384,628			3,461,216,510
Natural Gas Heating Value (kJ/cu. m)			36,833			36,833
Annual Natural Gas Consumption (cu. meters)			49,640			93,971
Unit Gas Cost ($/cu. m)			$0.1766			$0.1766
Annual Natural gas Cost ($)			**$8,766.40**			**$16,595.20**

Table 8: Annual Heating Cost Comparison

Summary and Conclusions

Table No. 9 summarizes the cost comparisons presented in the previous tables. Based upon the proposed operating schedules and the various assumptions previously shown, a grease plant producing 11,250,000 pounds (5102 metric tons) of standard lithium grease per year could realize annual cost savings of USD$597,716, or, approximately 12¢ per kilogram. As stated earlier, potential savings from one manufacturer to another could vary significantly based upon personnel, unit labor costs, raw material costs, utility costs and manufacturing procedures. However, this study clearly shows that significant cost savings are very possible and, indeed, probable. The magnitude of the cost and operational time savings clearly demonstrate that the Contactor process is substantially more beneficial than the standard kettle method of manufacturing greases. The cost savings can easily result in a rapid return on the investment of installing a Contactor reactor and the time savings provide excellent opportunity for future capacity expansion through multiple shifts.

Category Description	**Contactor™ Process**	**Kettle Process**
Annual Process Electrical Cost	$48,499.02	$70,833.81
Annual Heating Fuel Cost	$8,766.40	$16,595.20
Annual Manufacturing Labor Cost	$252,000.00	$477,000.00
Annual Raw Material Cost	$2,551,666.23	$2,894,218.93
Totals	**$2,860,931.65**	**$3,458,647,94**
Annual Production (kg)	5,104,356	5,104,356
Unit Manufacturing Costs ($/lb)	$0.560	$0.677
Potential Annual Cost Savings	**$597,716.29**	

Table 9: Annual Manufacturing Cost Comparison Summary

Furthermore, the consistent quality between batches using the Contactor reactor can reduce waste and costs associated with reworking "out of spec" batches. With case histories of completely finishing batches of simple lithium grease in three hours, aluminum complex in four hours and lithium complex in three and a half hours, the benefits of a Contactor reactor are applicable to a wide range of manufacturers. In an industry experiencing minimal or negative growth, one of the best solutions to a similar trend in sales is to reduce manufacturing costs, thereby providing greater profit margins or increased market share through selling price reductions. A modest capital investment could, therefore, produce revenue benefits throughout the future.

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