Industrial Applications for Animal Fatty Oils[1]

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ABSTRACT

Some of the animal fats that are by-products of the meat packing industry can become a valuable commodity for certain other portions of our nation's economy. This paper reviews the types of raw materials used, as well as the manufacturing techniques employed to manufacture these by-products into useful animal oils. The industrial uses for these oils include, not only petroleum and metal processing, but also the chemical and pharmaceutical industries. These oils also can be reacted chemically to produce various extreme pressure additives for the petroleum industry. In some areas it is even replacing the oil from the sperm whale whose use has been banned within the U.S.

INTRODUCTION

Oils and fats are constituents in all forms of plant and animal life, although not necessarily in sufficient quantities for commercial production. Some of the more familiar naturally occurring vegetable oils are derived from flax, corn, soybean, sunflower seed, rapeseed, peanut, cottonseed, and castor bean. Trees which yield oil bearing fruit include the coconut, palm, and olive (1). As for marine life, certain species of fish yield commercial quantities of oil. These include the commonly known fish oils, such as herring, sardine, anchoveta, cod, and menhaden. Unlike oils derived from land animals, where the animal fat is a by-product of meat production, these fish are harvested primarily for their oil content (2). Following the extraction of the usable oil, the remaining residue is used for fertilizer and chicken feed. Historically, whales provided the largest amount of oil taken from the sea.

Natural animal fats include the fats derived from three domestic animals: sheep, cattle, and hogs (2). Although fowl are raised in commercial quantities, the production of this type of fat is minimal for commercial or industrial purposes. This paper will concentrate primarily upon the animal grades of natural fats and oils and, in particular, upon the products derived from hog or pig fats.

ANIMAL FAT

Origin of Animal Fat

Animal fats can be divided into two basic classes, greases and tallows. Table I illustrates the origin and characteristics of these two types of fats. Historically, lard oils were considered to be derived from hog fat, whereas, tallow oils were considered to be a derivative of cattle or beef fat. Today, these two fats are distinguished further from each other by titer, or hardening point of the fat. A fat with a titer below 40 C is considered to be a grease, while a fat with a titer above 40 C is considered a tallow (3).

Lard oil is manufactured from hog or pig grease, and, due to the low stearine content in hog fats, the lard oil yield is generally high. This is just the opposite with tallow. The quality of these two fats is judged by their titer, free fatty acidity, and moisture, insolubles, and unsaponifiables (MIU) (4).

Rendering

Rendering is the process by which the fatty scraps from the meat packing centers are semirefined into usable fats. After rendering, hog greases are used as: (A) supplement for animal and cattle feed, (B) raw material for manufacturing lard oils and soaps, and (C) feed stock for splitting into their individual fatty acids.

A good quality hog fat, which is free from extraneous muscle and bone, will yield ca. 80-95% grease after rendering. The balance will be connective tissue, water, skin, etc. Greases also can be derived from bone stock, skins, hooves, and other such low fat areas, yielding in the area of 10-15% grease (5). Both of these greases are classified as inedible hog fat.

The difference between edible and inedible fats and lard oils is that edible lard oils can be derived from hog back fat only, and must be segregated in storage, rendering, and processing. On the other hand, the fat derived from all parts of the hog, including the fat extracted from bone stock, skins, hooves, etc., is classified as inedible. It should be pointed out that regardless of the lard oil or grease being produced, either edible or inedible, the fat or grease must be produced from clean, fresh fat obtained from standing animals, i.e. animals in good health at the time of slaughter.

There are three basic methods of rendering: the dry, the wet, and the digestive methods. Dry rendering (Fig. 1) is a straight forward method of separating fatty ingredients from other extraneous material. Due to its simplicity, this method often is used in the preparation of inedible fats. The fat is charged into a heated mixing tank, which can be under atmospheric conditions or under vacuum. The heat is applied to the tank to drive off any moisture; and, when the desired moisture level is obtained, the material is placed to drain (5). After free draining, the residue is pressed to extract the remaining amount of grease. Then the residue is ground and sold as a feed supplement, and the crude grease thus collected is filtered or centrifuged prior to marketing.

Wet rendering utilizes steam in its process and produces prime steam lard (6). The reactor is charged with the fatty scraps, and steam is introduced into the bottom of the reaction vessel. Upon reaching the proper reaction temperature, cooking is carried out for several hr. The grease rises to the top of the reactor, and the water and solids sink to the bottom. The grease is drawn off, filtered, and is ready for market. Again, the residue is ground and sold as a feed supplement. Due to the high requirements for heat and the problems of separating the water from the grease, the steam method is less efficient than the dry method of rendering. However, wet rendering often is used to refine edible fat.

A final method of rendering is the digestive method, where the fat is digested with enzymes or chemicals, such as a solution of alkali. The connecting tissue holding the fat is dissolved and the fat then can be separated easily from the

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TABLE I

Characteristics of Animal Fats

Property	Grease	Tallow
Origin	Hog	Cattle
Titer (C)	Below 40	Over 40
Lard content	High	Low
Stearine content	Low	High
Olein content	High	Low
Iodine value	Higher	Lower

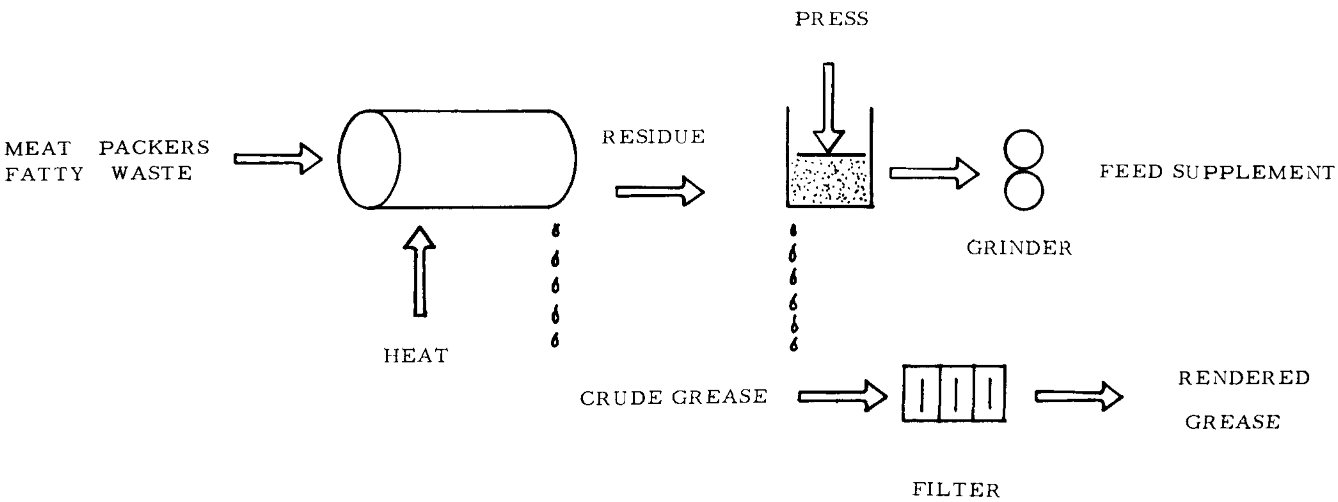

FIG. 1. Dry rendering process.

aqueous liquid.

These rendered greases are used extensively to manufacture soaps, fatty acids, and lubricants. In addition to the ground residue, the largest usage for rendered grease is in the animal feed industry. The National Renderers Association estimates that the rendered greases and the bone meal derived from the ground residue are consumed at the rate of over one billion lb/year in the U.S. alone. The soap and fatty acid manufacturers each consume between 500 and 600 million lb rendered grease. An additional 100 million lb is used to manufacture lubricants and similar oils (7). Ca. 300 million lb rendered greases are used to manufacture lard oils and are used for other purposes.

Refinery Process

The most common method of refining animal greases into lard oils is the cold pressing method (Fig. 2). This involves the treatment of the grease with an alkali, such as soda ash, caustic soda, or sodium bicarbonate. Impurities, such as color bodies, solids, or particulate matter, are removed easily by water washing or the introduction of live steam. These techniques will hydrolize the impurities for ease of removal. The color of the lard oil stream is improved further by treatment with decolorizing carbon or bleaching earth and filtered to obtain a specified color level. The oil then is chilled to a specific temperature, at which the higher melting stearines begin to crystallize. Filter presses remove these stearines from the lard oil, and the finished fat then is graded according to color, free fatty acidity (as oleic acid) and MIU.

In addition to the caustic wash procedure described, there are several other methods of manufacturing lard oils, which include acid treatment and solvent extraction.

The specifications of lard oils typically manufactured by the lard oil industry are shown in Table II. The major differences between the various grades of lard oil are the free fatty acid content, the color, and the MIU. In general, as the free acid content is reduced, the overall quality of the lard oil increases. Note that color, pour point, and MIU also improve as the quality of the lard oil increases. Acidless tallow oil is essentially the stearines removed from the production of prime burning lard oil.

Industrial Usage

Straight grades of lard oils and stearines have many uses, including their application in petroleum lubricant formulation, textile lubricants, manufacturing of antibiotics and pharmaceuticals, the feed industry, and the metalworking industry.

In lubricants, fatty oils are compounded into a variety of oils for light duty and fine precision equipment. Other oils, such as sperm oil, also are used in these applications, which include textile spindle lubricants, sewing machine oils, and instrument oils. It is imperative that these oils be nondrying and will not form a gum or varnish-like deposit (8). Compared to plain mineral oils, fatty oils are less subject to being washed away with water. This makes them ideal for compounding into steam cylinder lubricants and other lubricants which might be subjected to water washing or used in a wet environment.

Lard oils also are used as a fiber lubricant for textile fibers during the process of spinning and weaving. These oils can be used as is; they can be emulsified, or they can be sulfonated for ease of scourability. In general, lard oils are more easily removed from textiles than mineral oils.

In the area of lubricating greases, the greases and tallow oils defined earlier sometimes are used as raw materials for manufacturing soap for lubricating greases. Although today's modern methods for manufacturing lubricating greases are more involved and complex and utilize more

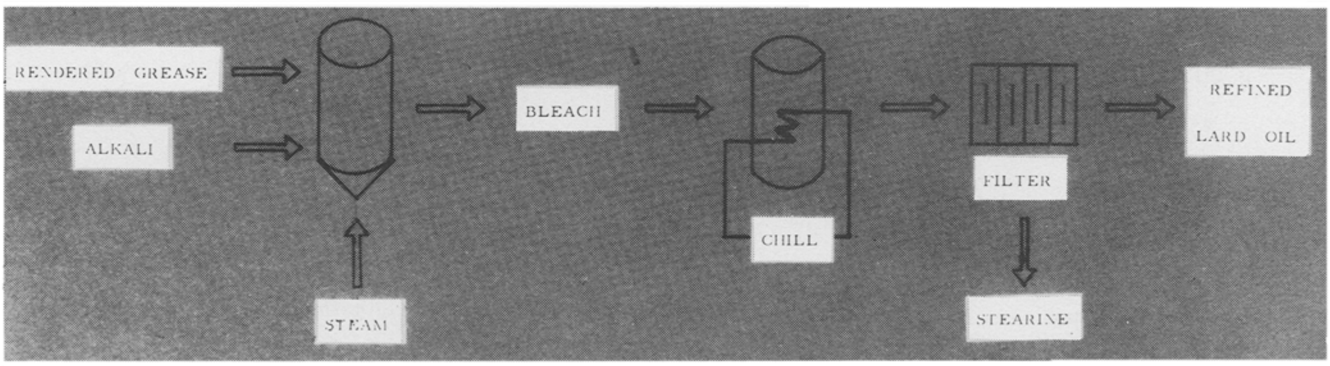

FIG. 2. Lard oil manufacturing process.

TABLE II

Typical Properties of Lard Oils[a]

Designation	Free fatty acid	Color (NPA)[c]	Pour point (ASTMD-97), F[d]	Flash point COC (F)[e]	Fire point COC (F)	MIU[f]
Prime burning	0.2-0.5%	1½-2	40-45	600-625	665-680	0.2 -1.0%
Prime	1.0-2%	2-2½	40-45	550-575	665-680	0.2 -1.0%
Extra winter strained	2.0-4%	2-3	40-45	510-550	650-680	0.2-1.0%
Extra	4-5%	2-3½	40-45	490-520	640-665	0.2 -1.0%
Special extra	6-9%	2½-4	40-45	460-480	540-585	0.3 -1.2%
Special no. 1	8-12%	3-4½	45-50	450-470	520-550	0.4 -1.4%
Extra no. 1	10-13%	4-5	45-50	440-465	500-535	0.5 -1.5%
No. 1	13-16%	4½-6	45-50	430-450	480-510	0.5 -1.5%
No. 2	18-23%	4½-7½	45-50	430-450	480-510	0.75-2.0%
Acidless tallow oil	0.2-0.5%	1½-2	Titer (ASTM) 41-43	600-625		0.2 -0.8%

[a]All grades have a viscosity of 190-210 saybolt universal seconds and saponification no. 192-198.
[b]As oleic acid.
[c]NPA = National Petroleum Association.
[d]ASTM = American Society for Testing and Materials.
[e]COC = Cleveland Open Cup.
[f]MIU = moisture, insoluble, and unsaponifiable matter.

exotic materials, basically a fat and caustic soda or caustic potash is reacted to form a soap. Mineral oil then is dispersed within the structure of the soap, forming the lubricating grease. The final characteristics of the grease depend upon the type of fat used to make the soap, the amount and type of oil cutback, and the method or procedure for manufacturing the grease. Lard oils sometimes are added to the grease formulation to give it certain desirable properties.

The metal processing industry represents one of the larger markets for the use and application of straight grades of lard oil. In particular, cutting, metalworking, and rolling oils often are formulated with lard oil. Straight lard oil can be used as a cutting and cooling medium or can be compounded with mineral oil. In general, no. 1 or no. 2 lard oil with an approximate free fatty acidity level of 13-23% is used in many of these cutting oil applications. Other applications that demand a low free fatty acid content or light color will require the use of the higher quality grades of lard oil, such as prime burning or extra winter strained lard oil.

TABLE III

Types of Extreme Pressure Additives

I. SULFURIZED COMPOUNDS
- A. Sulfurized fats, greases, and oils
- B. Sulfurized synthetic additives
- C. Polysulfides

II. CHLORINATED ADDITIVES
- A. Chlorinated paraffins
- B. Chlorinated fats
- C. Chlorinated synthetic additives

III. SULFOCHLORINATED ADDITIVES
- A. Sulfochlorinated animal fats, greases, and oils
- B. Sulfochlorinated synthetics

IV. PHOSPHOROUS CONTAINING COMPOUNDS
- A. Phosphate esters
- B. Phosphated synthetic additives

V. COMBINATION OF ABOVE

The pharmaceutical industry is another large volume user of lard oil. During the fermentation of various antibiotics, considerable quantities of foam are generated. Lard oil sometimes is used as a defoaming agent; and, at the same time, the oil serves as a nutrient for culture growth and production of a particular type of antibiotic. The various pharmaceutical manufacturing companies use all types of lard oil, from the top grade, prime burning lard oil to no. 2 lard oil. The quality of the lard oil can have a great effect upon the yield of the fermentation batch.

There is one other minor application of lard oil in the pharmaceutical industry: that is in the area of cosmetics. Although not a glamour oil, such as almond, coconut, palm, olive, turtle, etc., hydrogenated lard oil has been used as a base for various creams, ointments, lotions, and emolients. Compared to mineral oils, all these oils are absorbed more readily into the skin.

Earlier it was noted that the ground residue from the rendering process, as well as rendered greases, are used as supplements for animal feeds. Stearines derived from the production of the lower grades of lard oils also are used in this application. All of these fats have a high calorie/lb density, when compared to starches and proteins. Animal fats also contain linoleic acids and other polyunsaturated fatty acids which are essential in the diet of most animals (9). Fats, not only lower the cost of the feed itself, but also increase the production of quality livestock. As an example, the National Renderers Association has calculated that as much as 20% of cost of feed can be saved by the addition of animal fat (10). The results should be more meat at a lower cost for the average consumer.

LARD OIL

Role of Lard Oil in Theory of Lubrication

So that the application of lard oils in the petroleum industry may be properly visualized, a review of the basic types of lubrication is included. These are hydrodynamic, boundary, and extreme pressure lubrications (Fig. 3). Consider the meshing of gears in a gear box, two bearing surfaces, or the metal-to-metal contact found in any metalworking operation, such as cutting, drilling, drawing, etc. A good lubricant, not only acts as a coolant which draws the frictional heat away from the parts, but also

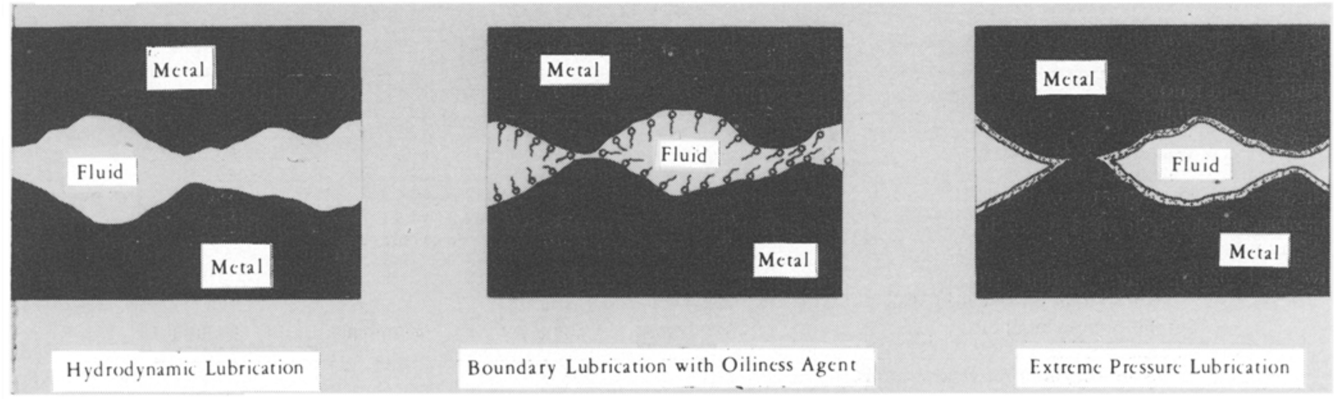

FIG. 3. Basic types of lubrication.

lubricates the parts by providing an oil film, thus preventing intimate metal-to-metal contact. If this condition went unchecked, it could lead to plastic deformation, wear, galling, or welding of the metallic part. All of these would lead to the eventual destruction of the gear teeth, bearing surfaces, or metal workpiece.

All liquids or gases will provide some lubrication, but some will be better than others. For example, if mercury were used as a lubricant, it would be found that it lacks the adhesion or metal wetting characteristics necessary to keep the two metal surfaces separated. Alcohol, on the other hand, wets the metal surface readily but under conventional applications is too thin to maintain a lubricating film of adequate thickness to prevent metal-metal contact of the parts being lubricated.

Petroleum products, both with and without additives, have been found to excel as lubricants. They not only possess the proper metal wetting characteristics but also the body necessary to maintain a substantial lubrication film.

As an example, under conditions of a lightly loaded bearing, a thin, continuous film of oil will suffice to form a barrier against metal to metal contact. The use of such a lubricant is called fluid or hydrodynamic lubrication (Fig. 3), i.e., sliding lubrication (11).

Suppose the load placed upon the lubricant is increased greatly. What happens is: (A) the oil film is squeezed out from between the bearing surfaces, (B) more surface asperities make contact with each other, and (C) hydrodynamic lubrication fails and boundary lubrication (Fig. 3) must be used to limit or reduce the severe galling and welding of the parts being lubricated.

Effective boundary lubrication (12) is achieved by adding a polar organic molecule to the lubricating oil. The polar molecule extends the life of the bearing by helping to prevent the metal surfaces from touching. Consider the chemical structure of the principal component of lard oil—the fatty acid ester of glycerol. The ester portion of the molecule is polar in nature and exhibits an affinity toward the metal surfaces to be lubricated. The long fatty acid tail tends to remain more soluble in the oil phase of the system. There is also some interaction between the molecules causing lateral cohesive forces which further strengthen the film (13). This film helps to prevent the penetration of the asperities of the metal surfaces and limits the metal-metal contact.

A third type of lubrication, actually an extension of boundary lubrication, is called extreme pressure additive lubrication (Fig. 3). Consider the condition in which a cutting tool is biting through a metal surface, where there is shock loading of a bearing or where two gears are meshing. In these instances, there is a point of intimate contact between the metal surfaces. Hydrodynamic lubrication is impossible under such conditions, and boundary lubrication is likewise ineffective. It is necessary to add an extreme pressure additive to the lubricant. Sulfurized or chlorinated lard oils often are used in this area (14-17). The chemically bound sulfur or chlorine is activated by temperature and pressure and reacts chemically with the metal surface at the point of metal-metal contact. The inorganic salt that is formed then is removed by sluffing away, rather than the metal being removed by galling, scoring, etc. In a sense, this can be considered to be a condition of limited or controlled wear.

Sulfur and Chlorine in Lard Oil

Table III lists some of the types of extreme pressure additives available today. The basic types are sulfurized, chlorinated, sulfochlorinated, and phosphorus containing additives. Among other bases, fatty oils and lard oils are particularly well suited to the first three types of extreme pressure compounds. Fatty oils also can be used in phosphorus containing additives; but, in general, other carriers are used in such products.

Sulfurized fats and greases are made by the exothermic reaction of raw sulfur with fatty oils. The reaction is initiated by heat, and the temperature is controlled carefully throughout the entire reaction period. The reaction should be conducted under constant vacuum so that the reaction by-product, hydrogen sulfide gas, can be drawn off and scrubbed before the effluent gas is vented to the atmosphere. Fatty oils will retain up to ca. 16.5-17.0% sulfur and, under special reaction conditions, can hold more. The sulfur molecule, an S_8 ring, splits and attacks the olefinic groups forming polysulfides, sulfides, and mercaptans. The reaction by-products hydrogen sulfide and some sulfur intermediates, then attack the carbon chain providing more olefinic sites for further sulfurization.

Table IV shows the typical inspections of sulfurized no. 1 lard oil that contain up to 17% sulfur. In addition to the viscosity and the sulfur levels, one of the most important criteria for selecting a sulfurized fat is the copper corrosion test (American Society for Testing and Materials D-130) (17). The copper corrosion is an indication of the sulfur activity, i.e. whether is stains copper. Nonstaining sulfurized lard oils with a 1 a/b copper strip (slight tarnish) can only be obtained with sulfur levels below 12%. Also, additives may be used to deactivate the copper surface and to chelate the mercaptan sulfur group. These corrosion inhibitors usually are based upon benzotriazole or mercaptobenzotriazole.

Sulfurized lard oils with sulfur levels above 12% will stain or darken a copper strip. At these sulfur levels, metal deactivators and corrosion inhibitors are either ineffective or uneconomical. Note also how the viscosity of the sulfurized fat increases correspondingly with the increase in sulfur level.

Sulfurized lard oils are used as extreme pressure addi-

TABLE IV

Typical Inspections of Sulfurized Lard Oils

Test	Typical inspections			
Total sulfur, wt %	10	12	16	17
Viscosity, SUS[a] @ 210 F	250/450	400/600	600/850	800/1000
Pour point, F	55	55	65	65
Flash point, COC[b], F	440	440	450	450
Saponification no.	185	185	185	185
Copper corrosion (ASTM D-130)[c] 3 hr @ 210 F 90/10 dilution w/100 VisPale oil	1 a/b	1 a/b	Positive	Positive
Solubility in mineral oil	Complete	Complete	Complete	Complete

[a]SUS = saybolt universal seconds.
[b]COC =Cleveland Open Cup.
[c]ASTM = American Society for Testing and Materials.

tives in many types of industrial lubricant formulations, to include gear oils, way oils, greases, transmission fluids, and specialized metalworking oils. These oils include formulations for cutting, broaching, tapping, threading, drilling, drawing, reaming, grinding, etc..

Animal fatty oils also can be sulfochlorinated to produce extreme pressure additives with good color and stability. This is accomplished by the controlled addition of sulfur monochloride (S_2Cl_2) to the fatty oil. The sulfur monochloride reacts exothermically with the olefinic sites found in the lard oil. The reaction product contains 100% of the sulfur and 85-90% of the chlorine that was introduced. The chemical by-product of the reaction is hydrogen chloride gas. An organic preserative, generally based upon an amine, usually is added to preserve the chlorine from any further degradation. These additives, when used in cutting oil formulations, will combine the beneficial aspects of two extreme pressure additives, sulfur and chlorine, as well as retaining the polar nature of the lard oil for good metal adhesion.

Finally, lard oils may be chlorinated by the addition of chlorine gas to the lard oil under controlled temperature and pressure condtions. The chlorine is combined to form chlorinated oils containing 8-12% chlorine. Under boundary lubrication or extreme pressure conditions, this type of lubricant additive liberates atomic chlorine, which reacts with the metal surfaces to form ferrous chloride which will be sluffed away in preference to the metal itself (18).

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