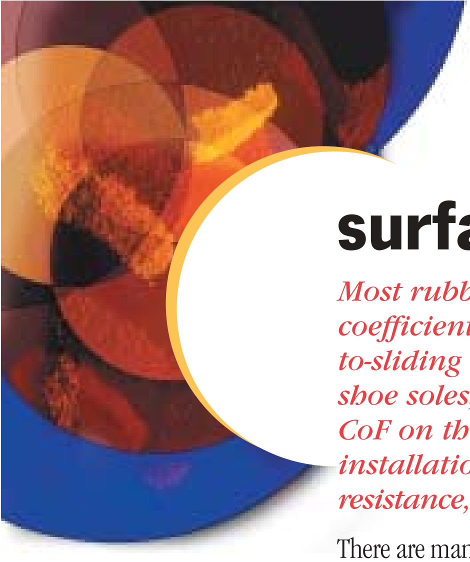


surface lubricants

Most rubber products have a good-to-outstanding surface coefficient of friction (CoF). While this drag or resistance-to-sliding is an important feature of products like tires, shoe soles, and golf grips, certain products need a low CoF on the part surface. This surface results in easy part installation or assembly, increased abrasion and scratch resistance, and reduced sticking of the parts to other surfaces.

There are many ways to create a low coefficient of friction (CoF) on a rubber sample. Most compounders have (usually much to their chagrin) unintentionally created a low CoF on their rubber surface by adding an incompatible material that bled to the surface. A few examples would be liquid chlorinated paraffin in EPDM, naphthenic process oil in polychloroprene or nitrile, or silicone fluid in almost anything except possibly EPDM. These exude an exceedingly oily film; the severe incompatibility of these oils can cause non-knitting and other molding problems. Cured properties like compression set resistance are usually adversely affected.

Certain fillers like PTFE or graphite will provide some surface lubricity in abrasive applications but there are drawbacks: only that material at the surface at the time of molding has any immediate effect and thus large quantities must be added to the compound to get enough present at the surface. This may be a problem in cost and/or viscosity increases. PTFE and graphite may be useful in severe abrasion applications where a fresh surface of rubber is constantly being exposed. However, until the molded surface is abraded to expose these filler-type internal lubricants, there is minimal slippage on the rubber surface. This prevents using these fillers as assembly aids or easing the movement of another product (wires, for example) through the rubber part.

Akrochem offers a complete line of Proaids that act as rubber surface lubricants. These materials are bipolar in nature so that one end of the molecule is compatible enough with rubber compounds to not bloom from raw stock but the other end is incompatible enough to stick out from the rubber surface. As the pictorial representation shows below, the surface lubricants are mixed into a rubber compound where they act as process aids prior to and during molding. After molding, the lubricant's polar end migrates to the part surface over a day or two. The molecule then orients itself (polar end to polar end) so the fatty acid, or slippery portion, is exposed on the surface. The two most popular forms that bloom and provide surface lubricity are esters and amides.

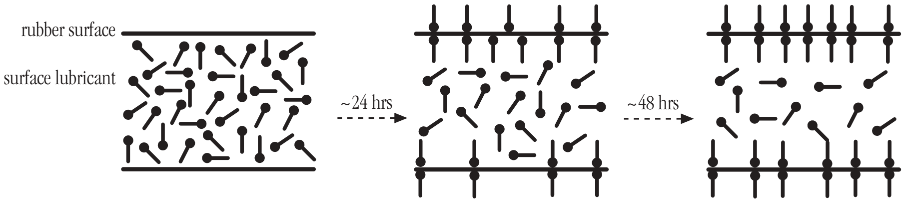
Here are a few examples of actual applications where a surface lubricant has been used:

- Grommets in an auto firewall had wires passed through them. Dragging the long wires through the grommet caused the wires to catch, chafe, and in some cases cut or tear the grommet until a surface lubricant reduced the coefficient of friction.
- An O-ring in a hose had to be repeatedly forced over a male connector. A surface lubricant eased this connection.
- A hospital IV pole with rubber stoppers had to slide up and down but still maintain typical rubber sealing abilities.

- To be used, parts shaped like little umbrellas were forced through holes in a sheet of metal. This was a daunting task until a slip agent was introduced into the compound.
- A small vibration-dampening mount in an auto glove compartment worked fine except for an annoying "squeak" as it moved. A surface lubricant stopped the squeak.
- A rubber part had to go through a production step of having a light coating of grease applied to allow further assembling. Addition of a CoF reducer allowed elimination of this step.

These are just a few specific applications that found the surface lubricants to ease part assembly, improve movement of parts, and improve abrasion resistance under mild, sliding-type abrasive conditions.

Things to consider when choosing a surface lubricant include: polymer from which the material must bloom; cure effects; cosmetic appearance; FDA status of part; type of film (too much bloom can cause a build-up that can get dry and flake off. Optimizing the lubricant will create a smooth, semi-solid bloom that has better staying power); and finally cost. Thickness of the bloomed, lubricating film is directly related to the loading. The speed at which a lubricant blooms is both polymer-related as well as loading-related.



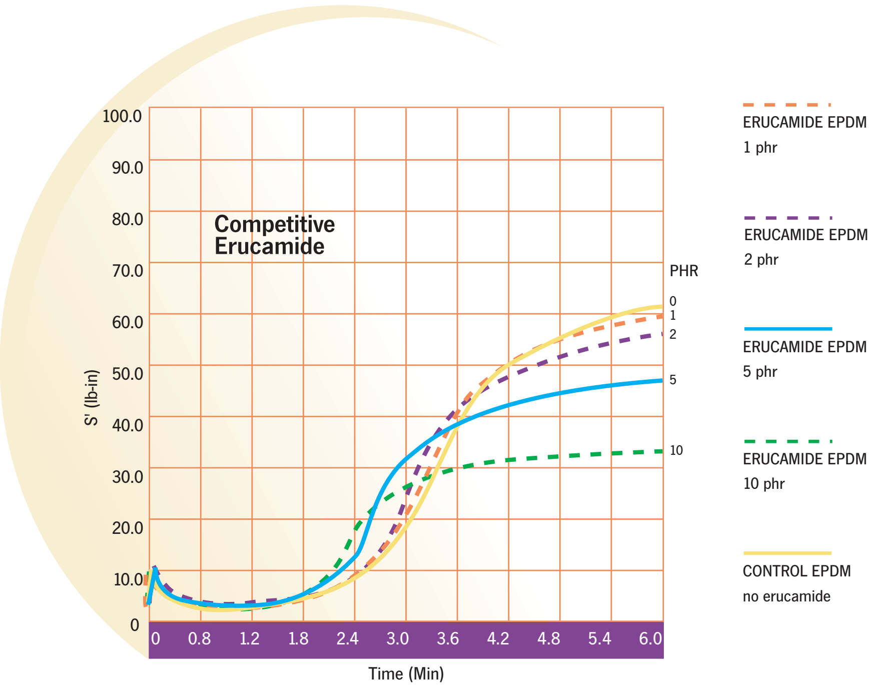
Rubber after curing — Rubber with mild bloom — Cured rubber with slippery film

Materials Available from Akrochem	Chemistry	
Proaid LCF	hydroxystearate (fatty ester)	$CH_3\,(CH_2)_{16}C{=}O$ with /OH /OCH$_3$
Proaid AC-18-E	(E) erucamide	$CH_3\,(CH_2)_9CH{=}CH\,(CH_2)_9\text{-}C{=}O$ with /NH$_2$
Proaid AC-18-O	(O) oleamides	$CH_3\,(CH_2)_7CH{=}CH\,(CH_2)_7\text{-}C{=}O$ with /NH$_2$
Proaid AC-18-S	(S) stearamide	$CH_3\,(CH_2)_{16}C{=}O$ with /NH$_2$

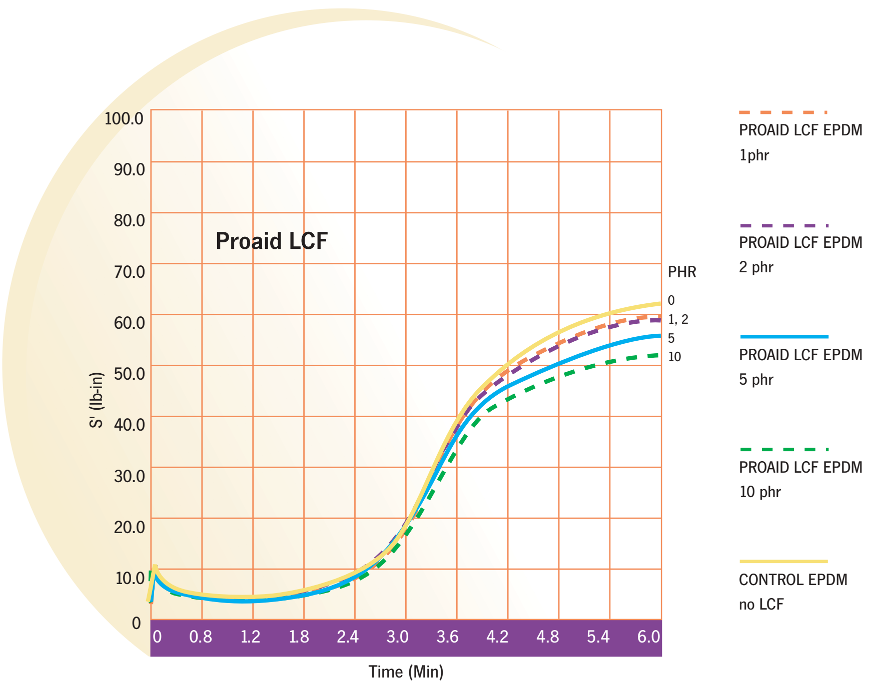
PROAID LCF: Proaid LCF has been found to be Akrochem's most effective all-around rubber surface lubricant. It will bloom from virtually all polymers (one customer has found it useful in silicone – much cheaper than liquid phenyl silicone that was normally used). Proaid LCF can be used at higher levels than most surface lubricants due to its saturated (no double bonds in the molecule) nature. Erucamides and oleamides have double bonds in them that dilute the state-of-cure (see rheographs to the right).

LCF provides a remarkably effective slippage with few drawbacks other than a bloomed appearance that may not be cosmetically acceptable in some parts. LCF has not been seen to bloom in raw stock so there are no molding problems. LCF will also act as an efficient mill and mold release (for outstanding mill release without bloom, ask for Proaid AC-18-DSA). Metal bonding and adhesion to other surfaces should be evaluated on an individual part basis. Proaid LCF also resists abrading from a rubber surface due to its bloom having a creamy texture (some slip agents tend to ball up and roll off with mild abrasion). Because of the excellent retention of the state-of-cure, good results in all polymers, low cost and easy mixing, Proaid LCF is Akrochem's primary surface lubricant recommendation.

EPDM Compound with 1, 2, 5, and 10 phr Proaid LCF or erucamide



Notice how the state-of-cure severely declines as the loading increases with a erucamide.



LCF state-of-cure barely declines – no more than a normal dilution effect.

Proaid LCF Summary:

- Outstanding reduction in surface coefficient-of-friction in all tested elastomers.
- Minimal effect on cure.
- For good lubrication and quick bloom, 4 to 5 phr has been shown to work well in most compounds. The typical process aid loading of 2 phr will be very slow to bloom, if at all. Some stocks may require more than 5 phr if the formula is highly extended (up to 10 phr still shows little detriment to state-of-cure). The tendency to remain soluble at low loadings prevents LCF from blooming from raw rubber and interfering with molding.
- Melt point is just 50 °C (122 °F) so dispersion is easy and mill addition is possible.
- Because LCF migrates to the cured rubber surface so well, the bloomed film is a strong off-white color similar in appearance to many rubber chemical blooms. Certain applications may find this cosmetically unacceptable. The amides tend to have a less obvious bloom.
- Cost effectiveness is excellent (amides will cost more).

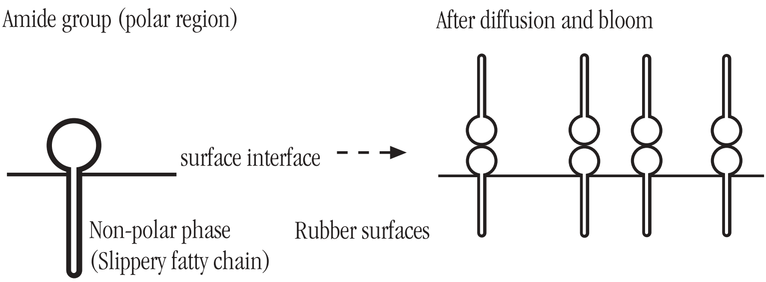
Proaid AC-18-E: "E" stands for erucamide, a 22-carbon hydrocarbon chain with an amide group on the end. The amide group provides a polar end to go along with the long, "fatty," non-polar hydrocarbon chain. The amide group diffuses well to the surface of elastomers, TPEs, and olefinic plastics like PE and PP. A double bond is present in the hydrocarbon chain. This double bond alters certain properties, which will be looked at in the summary below. The "E" lubricant is the second best blooming surface lubricant Akrochem supplies. Erucamides are used extensively in plastics to provide "slip properties." Slip properties are those needed when two surfaces move horizontally against one another. Those amides with double bonds (18-E and 18-O) tend to be used as slip promoters. We'll see later that the saturated (no double bonds) stearamide (18-S) is used for "anti-block" applications. Anti-block is defined as the right angle separation of two surfaces (a vertical force rather than the horizontal force of a slip agent).

Proaid AC-18-E Summary:

- 18-E will develop a less-offensive looking bloom than LCF. The surface is not pristine but the bloom is less noticeable than Proaid LCF. The bloom can be made even less noticeable when there is a matted finish on the part. A slightly roughened surface will break up the bloom and make it almost invisible yet it will still function as a lubricant.
- 18-E has extensive use in FDA applications. It is commonly used in direct food contact articles like wax paper. See the discussion on FDA status of surface lubricants in rubber later in this brochure.
- Used extensively in plastics like PE, PP, and PVC for slip and antiblock properties. As little as 0.1% will aid high-speed plastic packaging operations.
- The unsaturated nature of erucamides means some of the sulfur cure will be siphoned-off resulting in a lower state of cure than would be expected from simple dilution. Additional cure can be added (for example, 0.5 phr sulfur for every 5 phr of Proaid AC-18E) or minimize the amount of Proaid used. The

double bond does cause the geometry of the lubricant to cover a greater area than its saturated counterparts, so less can be used with the same result.

- Proaid AC-18-E will bloom slower than the 18-O (oleamide). This is an advantage if printing or sealing must be done to a product shortly after production. Its heat stability finds use in high-temperature-processed polyolefins.



Proaid AC-18-O: "O" stands for oleamide. Oleamides are 18-carbon fatty chains with a double bond present in the chain similar to erucamides. Oleamides are used in most of the same applications where erucamides are used. Oleamides will bloom faster than erucamides in polyethylene films. The oleamide is less heat stable than the erucamide but also is inherently less costly. The 18-O is a high quality oleamide (based on amide content and low acid value) of excellent color. It comes in a pelleted form for ease of handling. Like the erucamide (E), the oleamide's (O) bloom is less noticeable compared to Proaid LCF.

Proaid AC-18-S: "S" stands for stearamide, an 18-carbon saturated (no double bonds) fatty chain with a polar amide group on the end. Stearamides have found use in unplasticized Hypalon where calendar sheets are rolled up on themselves without liners. The stearamide is the most efficient anti-block lubricant among the amides. This allows sheets to separate from one another when a calendar roll is ready to be used.

Lab Study of Reduction in Coefficient of Friction:

One method to measure coefficient of friction (CoF) is ASTM D-1894 where a weighted "sled" is dragged across the surface of a rubber or plastic part. Kinetic CoF is the unit-less measure of the relative force to keep the sled in motion once it starts. Most rubber stocks have a CoF above 0.70 without lubricant. Soft rubber with minimal plastic content will have CoF's above 1.30. A rubber CoF below 0.40 indicates excellent slip (below 0.30 for plastics). Here are a few typical results:

	Kinetic CoF
NBR without lubricant (control)	0.728
NBR with 5 phr Proaid LCF	0.337
NBR with 10 phr Proaid AC-18-E	0.367
NBR with 10 phr Proaid AC-18-O	0.643
NBR with 10 phr Proaid AC-18-S	0.702
CR without lubricant (control)	1.382
CR with 5 phr Proaid LCF	0.322
CR with 10 phr Proaid LCF	0.242
CR with 10 phr Proaid AC-18-E	0.369
CR with 10 phr Proaid AC-18-O	0.398
CR with 10 phr Proaid AC-18-S	0.525
EPDM without lubricant (control)	1.183
EPDM with 5 phr Proaid LCF	0.341
EPDM with 10 phr Proaid LCF	0.303
EPDM with 10 phr Proaid AC-18-E	0.432
EPDM with 10 phr Proaid AC-18-O	0.502
EPDM with 10 phr Proaid AC-18-S	0.514

In our testing, LCF at 5 phr or more is consistently under 0.4 CoF. Other slip agents vary with polymer. "S" is not as useful for slip lubrication but more for anti-blocking in calendared sheets and reduction of tack in cured parts.

Further Information on Slip Agents:

- FDA Status: Applying FDA regulations to rubber chemicals can be a slippery business at times. All Akrochem slip agents have FDA status under various regulations (see list below). In fact, the amides are used extensively in direct food contact applications like plastic food wrap. However, none of the surface lubricants appear in the regulation most rubber compounders consider their holy grail: 177.2600, Rubber Articles Intended for Repeated Use. To allow use in an FDA rubber compound, refer to paragraph c (3) under 177.2600 regulations: "Substances that by regulation in parts 170 through 189 of this chapter may be safely used in rubber articles, subject to the provisions of such regulation." As can be seen below, all of Akrochem's surface lubricants meet the provisions of many regulations. Based on paragraph c (3), this would allow their use in rubber. Remember that any other 177.2600 relevant testing must be carried out [such as extraction testing per parts (e) and (f)]. It would be our suggestion that since the amides, Proaid AC-18-E, O, and S, have extensive FDA history and are permitted in numerous products similar to rubber goods (such as adhesives and coatings), they should be the preferred products for FDA applications.

FDA Listings

Proaid LCF:	CFR 21 177.2260, 177.2800, 176.200, and 176.210
Proaid AC-18-E:	CFR 21 175.105, 175.300, 176.180, 177.1200, 177.1210, 177.1350, 177.1400, 178.3860
Proaid AC-18-O:	CFR 21 175.105, 175.300, 175.320, 176.210, 177.1350, 178.3120, 178.3910, 179.45, 181.28
Proaid AC-18-S:	CFR 21 175.105, 175.300, 175.320, 176.210, 177.1210, 178.3120, 178.3910, 179.45, 181.28

- The fatty non-polar chain in each surface lubricant will provide water resistance to the rubber both before and after cure. In raw stocks, water spotting from steam vulcanizers is reduced (a higher molecular weight amide may be best for this – ask about Advawax 280). In cured rubber, the bloomed film forms a barrier to moisture.
- The amount used to develop a consistent lubricating bloom will differ with every compound. Plastics use these materials at levels as low as 0.1%. Crosslinked rubber, with its fillers that absorb active materials and oils that solubilize chemicals, will require more lubricant material to assure a slippery film. Some trial-and-error is needed to optimize the lubricant level. Start at 5 phr and work up or down as needed.
  - One customer used a lubricant to excess. Instead of a creamy haze of a bloom, copious amounts bloomed out until flakes of re-crystallized lubricant built up in the nooks and crannies of the part. While it still functioned, the part "looked wrong." Half as much lubricant solved the problem.
  - Another customer had just enough lubricant to get a satisfactory bloom. Over time he saw occasional variation in the bloom. Sometimes it took only two days; sometimes it took two weeks to develop a good bloom. This difference had occurred in one case within a single box of lubricant, which made it unlikely that the lubricant was the variable. In the end, the customer's other raw materials apparently varied to such an extent that they caused the bloom rate to change. By increasing the loading of lubricating material to a level that would perform properly even when the other raw materials varied, the customer solved the inconsistent bloom issue.
- Abrasion resistant applications may be aided by the presence of a surface lubricant. Mild, sliding abrasives will have a reduced effect on the rubber due to the lower coefficient-of-friction. An O-ring that fails due to rubbing causing enough wear to create a gap can extend its useful life by adding a surface lubricant. Gaskets and seals are prevented from "galling" or chaffing on metal surfaces during service by self-lubrication. However, a lubricant on the surface will not improve rubber's performance with highly abrasive materials or severe impact abrasion.
- The blooming nature of these surface lubricants will help bring chemical antiozonants like p-phenylenediamines to the surface similar to petroleum waxes. The surfactant-like nature can help bring other materials to the surface as well. One example is UV inhibitors that have almost no value when they are buried in an opaque rubber compound. Only when the UV inhibitor is brought to the surface can it serve any purpose. A surface lubricant may help UV resistance in this manner.

Surface lubricants offer a clean, simple, controllable way to reduce the coefficient of friction on a rubber, TPV, or plastic part. Variations on the way the lubricants are used continue to occur to innovative compounders. This is the type of material a rubber lab should keep handy to be available when inspiration strikes. Talk to your Akrochem Technical Sales Representative or Akrochem Technical Service about ways to use surface lubricants.

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