To Filter or to Ultrafilter: That is the Question

By William Galary

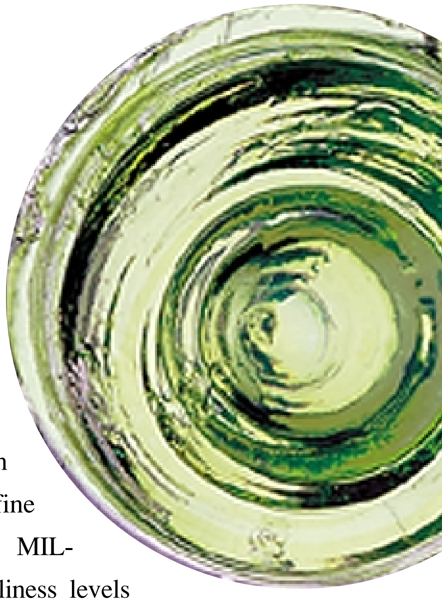
When lubricating small devices, what you can't see can hurt you. Microscopic contaminants in a bearing lubricant can cause vibration that sounds like a sandy bicycle chain. In micro switches, tiny particles can wedge between contacts, keeping the circuit open when it should be closed. In fluid films that coat the surface of a hard disk, particulates can wreak havoc with the recording head that cruises at 10 meters per second, a fraction of a micron above the disk surface.

Unfortunately, many design engineers do not pay enough attention to particulate matter in lubricants. They typically select lubricants for temperature, volatility, corrosion inhibition, and other functional properties. And it is not until there is a high percentage of unexplained rejects or, worse, failures in the field that the spotlight turns toward the lubricant.

Fortunately, however, lubricant contamination problems, with a bit of foresight, can usually be minimized or avoided altogether.

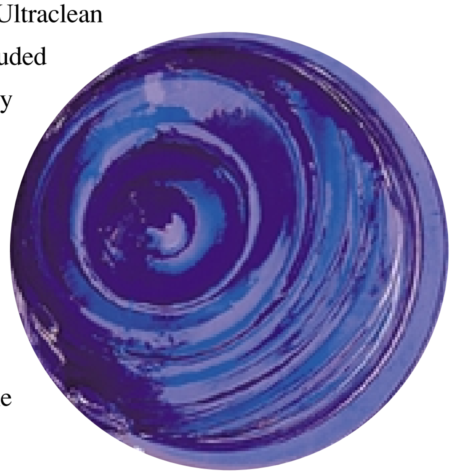
CLEAN VERSUS ULTRACLEAN

Solid particles in lubricants can come from many sources but raw materials, the manufacturing process, and the environment are the three most common culprits. Raw materials — the base fluids, gellants, and additives used to make lubricating oils and grease — may contain paper fiber, plastic debris, iron oxide, and chips from a drum liner. Without stringent process control, all can find their way into a lubricant. During the manufacturing process, lubricants can pick up metal from misaligned machine parts, rubber from gaskets, and carbon from kettles. Undissolved thickener, powders that are combined with oil to make grease, can also damage small parts. Dust particles, fabric fibers, hair, glass, even nuts and bolts are just some of the environmental contaminants I've removed from lubricants during the past 20 years.



What is clean? Basically, the amount of contaminants in a lubricant determines how clean it is. Federal standards define cleanliness for oil and grease. MIL-STD 1246 includes five cleanliness levels for oil: 50, 25, 10, 5, and 1, where each number refers to the largest particle (in microns) allowed in an oil. A rating of Cleanliness Level 1, for example, means that there are no particles greater than 1 micron in that oil. Methods to determine the levels are also standardized.

There are three cleanliness levels for grease: unfiltered, filtered, and ultrafiltered. An unfiltered grease can contain particles larger than 75 microns. The filtered or "clean grease" cannot have any particulate matter larger than 75 microns, and there must be less than 1,000 particles per cubic centimeter between 24 and 74 microns in size (MIL-G-81322, Aircraft Grease). Ultrafiltered or "ultraclean grease" must not have any particles larger than 35 microns, nor may it have more than 1000 particles per cubic centimeter between 10 and 34 microns in size (MIL-G-81937, Ultraclean Instrument Grease). Included in the ultrafiltered category is a new standard for optical gels. They may not contain any particles larger than 25 microns and must have no more than 50 particles per cubic centimeter, none larger than 24 microns.



FROM MILITARY TO MAINSTREAM

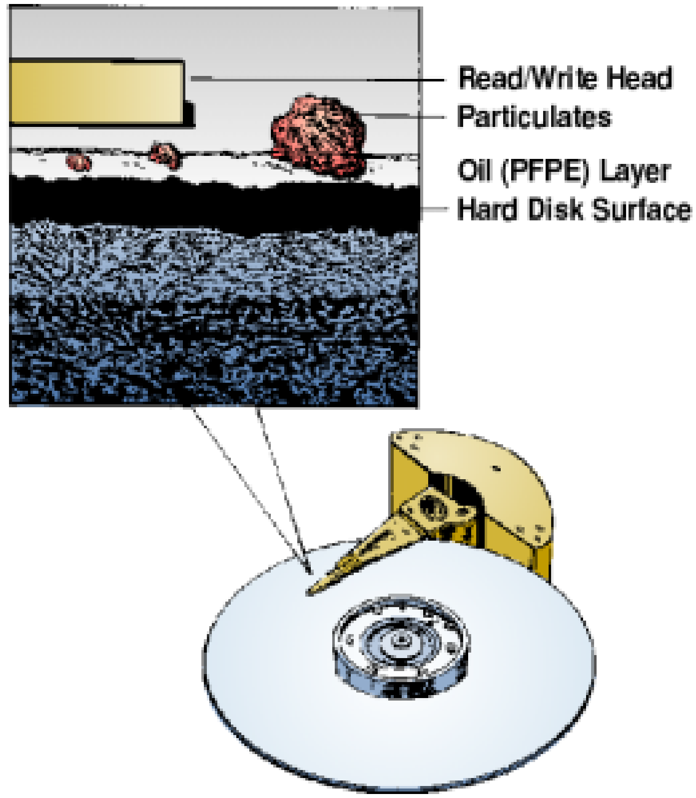
While ultraclean lubricants were first developed for the military, applications today are multiplying in several arenas — driven by more stringent demands for quality, reliability, and long operating life.

Miniature precision bearings have relied on ultraclean greases for many years. Found in such devices as disk drives, spacecraft gyros, high speed dental drills, or positioning equipment used in vacuum chambers, the bearings can contain balls as small as 350 microns — which means that 75-micron particulates (found in an unfiltered grease) can pose a serious threat to the life and operation of these bearings.

The life of a bearing depends on a micro-thin film of lubricant that separates the ball and the raceway. The rotation of bearings creates this elastohydrodynamic (EHD) film. Any solid contaminant greater in diameter than the EHD film can result in "debris denting," where the contaminate jams between the two surfaces, damaging one or both surfaces. Further, the denting sometimes creates additional debris, which causes bearing "noise." Repeated denting action can eventually lead to "peeling" or microspalling, a very shallow chipping of the surface caused by metal fatigue. Using ultrafiltered lubricants bypasses these problems.

In the fiber optics industry, contamination plays a more passive, but nonetheless harmful role. It does not gouge or dent. It just blocks the light — typically in fiber optic connectors, one of the few junctures on this information highway where light waves can be interrupted.

Connectors are used in lieu of a physical splice. Fiber optic strands are inserted and secured into opposite ends of the connector. A small gap in the center of the connector prevents the strands from touching. The gap is filled with a crystal clear optical gel formulated to have the same Refractive Index as the fiber. Hence, instead of being impeded by the air, the light travels through the gel to the fiber on the other side. The gel, however, must be ultrafiltered, otherwise particles in the gel will cause reflection or absorption, which may increase bit error rates. Connector manufacturers — and designers of the growing number of sophisticated opto-electronic devices that require the matching of dissimilar plastics and glasses — rely on ultraclean optical gels to act as a "light bridge" in their devices.



Collision Course. This exploded view of the head/disk surface interface shows the collision course that the head has with contamination in the film of oil that protects the disk surface. Not only are the large particles knocked around and into the surface, the smaller particles below the film surface can cause damage during the occasional bump that happens between the head and the surface layer.

Another application for ultraclean lubricants is disk drives — where size really does matter. Hard disks are good examples. Manufacturers are continually shrinking the distance between the flying head and the disk surface as one way to speed the transfer of data. The head now cruises about 500 angstroms above the disk. On the surface of the disk is a 20-angstrom layer of lubricant film. The film provides protection for the occasional bump that happens between the head and disk. Without lubrication, the surface would wear and fail rapidly. Solid contaminants in the oil, however, jeopardize the protective film. The flying head could, in fact, become a golf club hitting particles of debris across the surface of the disk — or driving them into the surface of the disk. In either case, disk reliability and data integrity are jeopardized. By removing the particles, ultraclean fluids significantly reduce that risk.

Clean room, clean grease. Clean air for a 10-foot mini-environment blankets the working surface, where lubricants are ultrafiltered and packaged in a Class 100 environment.

HOW TO CLEAN A GREASE

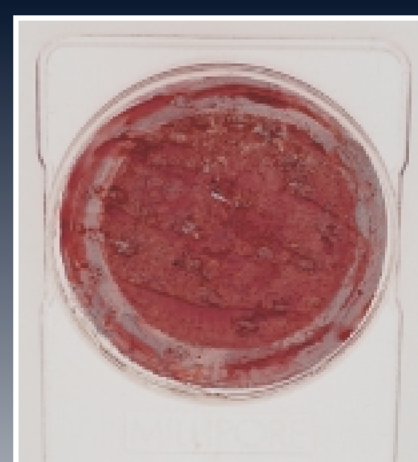
The best way to make an ultraclean grease is to control each step in the manufacturing process. However, most lubricant manufacturers produce large volumes of grease in a single batch. Since only a small percentage of a batch may be earmarked for an ultraclean application, it is not cost-efficient to create an ultraclean process for the entire batch. Many plants do filter their products at the end of the production cycle, but only to remove visible particles (primarily for appearance) before the lubricant is pumped into unwashed containers.

Consequently, many oils, greases, and fluids, especially those destined for miniature devices, have to be cleaned post-production — a niche Nye Lubricants aimed to address when it established its ultrafiltration services 20 years ago. While Nye does use small batch, process control to manufacture all lubricants for ultraclean applications, the ultrafiltration department serves as a fail-safe when packaging our lubricants — and as a venue for cleaning greases from other manufacturers, which is a sizable portion of our operations.

Removing contamination from a grease once it has been gelled requires a thorough knowledge of Rheology, the science of the flow and deformation of matter, a controlled environment, and a vast arsenal of filters. Generally, the filters are either nylon or stainless steel, starting at a rating of three microns. The filters used depend on the composition of the grease and the type of contaminants. Once a set of filters is selected, the lubricant is forced through them with custom-designed, high pressure equipment in a Class 100 mini-environment. This ultrafiltration system can process as little as one ounce of grease, and it deposits the ultrafiltered

Trapped. Potential light-blocking particles from an optical gel were trapped on this 3-micron filter.

Long, quiet life. Contaminates filtered from one pound of bearing grease used in computer applications are displayed next to miniature balls and a bearing. Without ultrafiltration the bearing would have had a short and noisy life. (The paper clip is added for scale)



Unfriendly skies. Without ultrafiltration, this metal sliver would have found its way into an aircraft bearing. Metal is one of the more common contaminates found in grease.

lubricant directly into end-use containers, which range from 1cc syringes to 35 pound pails. Before filling, each container undergoes a multi-cycle cleaning with filtered de-ionized water. They are then dried with HEPA-filtered hot air.

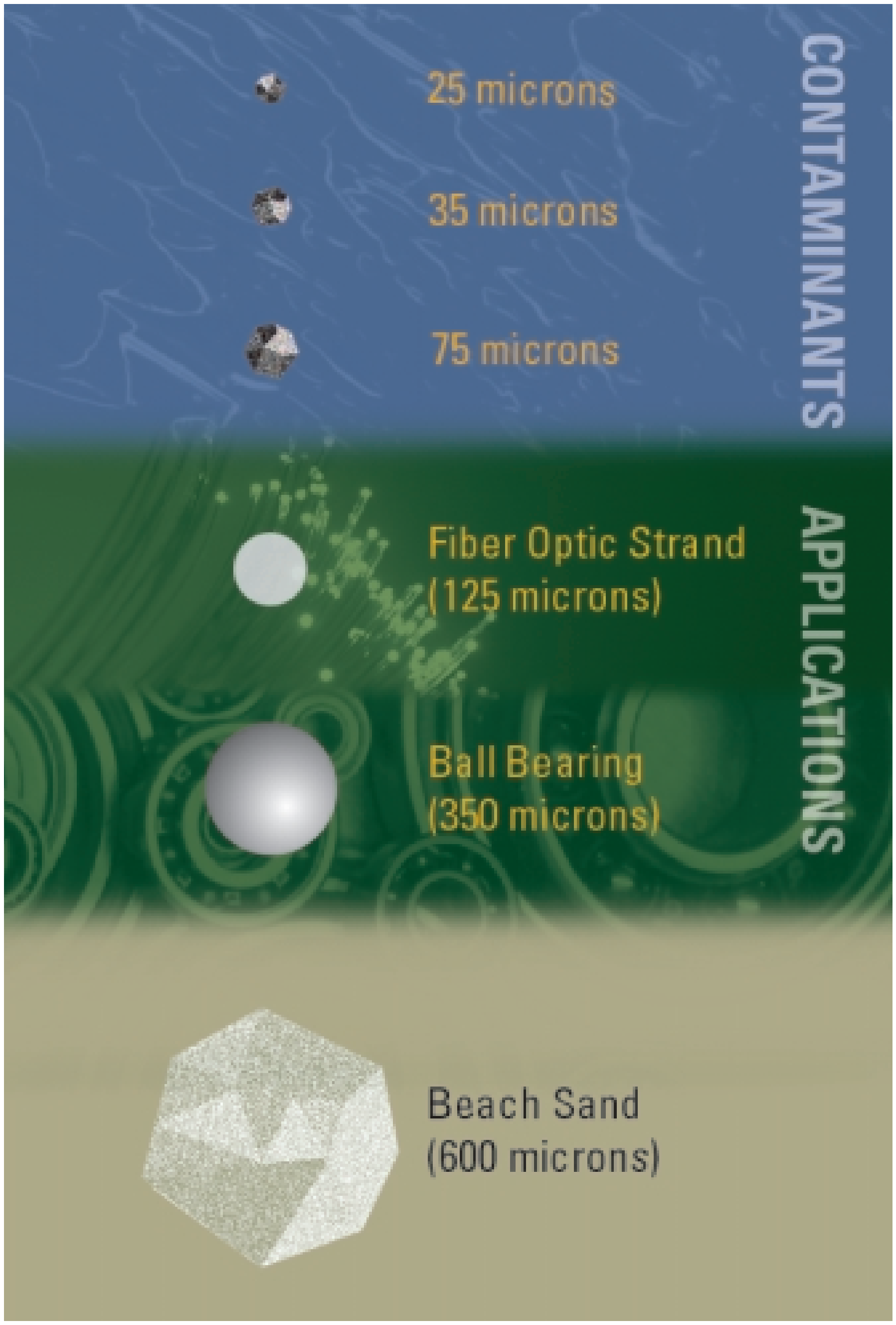
Care is also taken in the selection of containers. Metal and fiber containers are avoided. Plastic is a good choice as long as there are no pressure plug openings. The friction from such openings releases contaminants. Glass is an excellent choice, but must be examined before use. A rough molding flash along the bottle threads can create contaminants when the caps are screwed on and off.

A LITTLE KNOWLEDGE IS AN AUSPICIOUS THING

Contamination control is never complete unless you consider the lubricant. By understanding some basic guidelines, engineers can avoid problems.

First, all filtered lubricants are not equal! There is a difference between a clean and ultraclean grease. Never assume that a filtered grease is a clean grease. It may have been passed through a large membrane filter to remove the "fur, teeth and bones," but problems may lurk beneath the surface. Develop a sense about what size contaminates can be tolerated. As with any special process, the finer you filter something the more expensive it gets. Bearings are quite happy with a clean grease (contaminates less than 75 microns) while miniature bearings need an ultraclean grease (contaminates less than 35 microns). Manufacturers of disk drives, who always push the clean envelope, require an oil with a Cleanliness Level 1. Ask about the containers! Are they cleaned before a lubricant is added? Are the design and material of the container suitable for maintaining a clean product?

As technology continues its march to smaller devices, ultraclean lubricants will play an increasingly larger role in assuring long and defect-free product life. And the important question design engineers must ask is not whether a lubricant has been filtered — but, rather, whether to use a clean or an ultraclean oil or grease. ■



Light Blockade. This diagram compares the maximum size of contaminates allowed in filtered and unfiltered grease to the size of some of the components with which they interact (Ultrafiltered Optical Gel, 25 microns; Ultrafiltered Grease, 35 microns; Filtered Grease, 75 microns) For example, a filtered, not an ultrafiltered, optical gel could have a 75 micron particle in it — more than half the diameter of a fiber optic strand. Less than half the light waves would make it through this blockade. (Note, while the elements in the diagram are enlarged, they are proportionally accurate. The grain of beach sand is added to illustrate scale.)