

Planning for Destruction: The Problem of Grease Contamination

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It is widely recognized that grease lubricated bearings don't last as long as oiled bearings. In this session you'll learn how grease contamination is measured and how to specify grease products so that a clean product is purchased for your critical equipment.

Dirt and solid debris kill bearings! Grease contains dirt and solid debris! Grease kills bearings! And this has been the case for many years.

Given the concentrated focus that top quartile performers have applied to improving machine reliability over the last 10 years, how is it possible that manufacturers with otherwise very high standards have missed the fact that the greases currently in use are likely to be heavily contaminated with manufacturing and raw materials debris.

It is likely that a combination of strategic and tactical issues is at the heart of the issue. At the same time, it is not difficult to identify key strategic reasons for why this failed condition is also the default condition, as follows:

1. Lack of understanding of the grease contamination problem.
2. Lack of appreciation for 'Lubrication Excellence'.
3. Money.

Lack of understanding the problem

The US military has long understood that lubricant contaminants should be controlled. Military Oil and Grease Specifications (MilSpec) clearly define allowable contaminant levels for several classes of products, including greases.

MIL-G-81322 is used to rate aircraft grease and MIL-G-81937 is used to rate (ultra-pure requirement) instrumentation grease. The MilSpec for aircraft grease is less than 1,000 contaminant particles per cubic centimeter between 25 and 74 microns, and no particles larger than 75 microns. Assuming the particle distribution (and density) in the grease is similar to ACFTD (test dust), this would mean that the total amount of particulate contained in each milliliter of aircraft grease would be similar to an oil with an ISO Cleanliness code of 22/19.

The specification for the ultra clean instrument grease is less than 1,000 particles per cubic centimeter between 10 and 34 microns, and no particles larger than 35 microns. This would roughly equal an ISO Code of 19/16.

These contaminant levels may seem high versus the types of lubricant cleanliness standards that manufacturers set for in-plant sump contaminant control. However, at least there are standards.

Manufacturers that build sensitive electronic components (computer storage disk drives, linear and swivel drives for read/write heads, printer motors, other micro-motors, other precision components) also take a proactive role in defining the amount of allowable contaminants in the greases used to lubricate moving parts. The central issue for these applications is reducing noise (particularly for audio and computerized electronic drives), reducing time for final quality control, and extending bearing life.¹

While noise is not a particular concern for heavy manufacturing, the dirt that creates noise is, and the purity that supports the low noise objective would fit strategically within the industrial reliability engineering plan. When applied to general bearing lubrication, the cost implications are measurable and significant.

Stefan Daegling with Shell Research noted in 1999 that there were approximately 18 billion bearings in operation somewhere in the world, and the majority, perhaps 90 percent as noted by Bill Herguth of Herguth Laboratories, is grease-lubricated.²

Bearing manufacturers have done a good job of demonstrating to bearing users how vitally important contamination control is in achieving L₁₀ bearing lifecycles. However, until now, there has not been a great demand for super pure or quiet greases outside of hi-tech applications such as computer hard drive reader motor bearings.

Lack of appreciation for 'Lubrication Excellence'

Large machinery operators in automotive, steel, paper and power generation industries put a significant amount of effort and money into purifying bearing lubricants to achieve better reliability. Given the prevailing evidence, it appears that the same machine that may be lubricated with oil operating in the ISO 15/12 range would be lubricated with grease having cleanliness ratings in the range of ISO 23/19.³

That alone is irrelevant. However, once the implication to reliability is recognized then the potential economic impact begins to resolve as well.

		New Cleanliness Level (ISO Code)																								
		2011/5	18/16	15/15	17/14	16/13	15/12	14/11	13/10	12/9	11/8	10/7														
Current Machine Cleanliness (ISO Code)	26/23	5	3	7	2.5	9	4	>90	5	>90	6	>16	7.5	>16	8	>50	>16	>16	>16	>16	>16	>16	>16	>16	>16	
	25/22	4	2.5	4.5	3	6	3.5	8.5	4	7.5	5	6.5	8.5	16	7	>50	9	>16	16	>16	>16	>16	>16	>16	>16	
	24/21	3	2	3.5	2.5	4.5	2	5	3.5	6.5	4	8	5	9	8	16	7.5	>16	9	>16	>16	>16	>16	>16	>16	
	23/20	2	1.5	3	2	4	2.5	5	3	7	3.5	6	4	>16	6	>16	7	>16	9	>16	16	>16	>16	>16	>16	
	22/19	1.7	1.2	2.3	1.5	3	2	3.7	2.5	5	3	6	3.5	7	4	8	5	10	8.5	>16	8.5	>16	16	>16	>16	
	21/18	1.5	1.1	1.8	1.2	2.3	1.7	3	2	3.5	2.5	4.5	3	5.5	3.5	7	4	8	5	10	5.5	>16	8.5	>16	>16	
	20/17	1.3	1.2	1.5	1.5	2	1.7	3	2	4	2.5	5	3	7	3.5	4	>16	5	>16	8	>16	7	>16	16	>16	
	19/16	1.2	1.1	1.5	1.3	1.8	1.4	2.3	1.6	3	2	3.5	2.5	4.5	3	5	3.5	7	4	9	5.5	16	6	>16	>16	
	18/15					1.3	1.2	1.8	1.5	3	2	4	2.5	5	3	7	4	8	5	>16	7	>16	7	>16	>16	
	17/14					1.2	1.1	1.5	1.3	1.9	1.5	2.3	1.7	3	2	3.5	2.5	5	3	6	4	8	5.5	3.7	8	5
	16/13									1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4	9	4	4
	15/12									1.2	1.1	1.5	1.3	1.9	1.5	2.3	1.7	3	2	3.5	2.5	5	3.5	3.7	3	3.2
	14/11													1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	3	3	3
13/10																	1.3	1.2	1.6	1.4	1.9	1.5	2.3	1.8	1.8	

Hydraulic and Diesel Engines
Rolling Element Bearings
Journal Bearings and Turbo Machinery
Gear Boxes and Other

Consider the impact on bearing life and replacement cost that may be realized from selecting the more stringent MilSpec grease standard instead of the less strenuous standard.

Using the Noria Machine Life Extension chart for lubricant cleanliness, it would be possible to improve bearing lifecycles by a factor of 1.6 strictly through requiring that the least contaminated of these two products be specified for use. The left axis shows the allowable contaminant level for MilSpec 81322, and the top axis shows the allowable contaminant level for MilSpec 81937. The line intersection denotes the relative lifecycle improvement that can be attained through meeting the more rigorous cleanliness standard.

For any given manufacturing facility, the potential economic improvement derived from extending the life of grease lubricated bearings by 60% would flow right to the bottom line. Indirect impacts could be reduced MRO inventory, reduced MRO floor space, shorter scheduled outages, fewer scheduled outages, improved quality (through improved machine repeatability), less demand on scarce maintenance resources.

Money

Producing greases that can meet tight MilSpec requirements is not a tall requirement. At the same time, unless there is a tangible recognition of the benefit for improved quality, and some tangible return for implementing new processes and manufacturing systems, there would be no real reason for the grease manufacturer to devote precious resources to this endeavor.

Solid particles in grease lubricants can come from many sources; the three most common culprits are formulation raw materials, the grease manufacturing process and the environment. Raw materials - the base fluids, additives and thickeners 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.⁴

Most grease manufactures exercise appreciable caution to assure that they do not inflict solid debris contamination abuse on the grease products they manufacture. Selection of basic materials is based on the belief that their supplier is exercising caution to maintain a high level of product purity, for base oils, additives and thickener components.

From this starting point the grease manufacturer visually inspects raw materials before and as they are blended together. The materials are loaded into the blending kettles by hand and through material hoppers. Screens are used to catch unwanted materials (paper, cloth, handling utensils, etc.) that could fall in during this process.

A final filter at the outlet of the kettle catches any remaining large debris from the batch prior to milling the product. These filters are designed to catch items that represent a hazard to milling machinery, and consequently target items in the 3 to 7 thousandths of an inch range, which is equivalent to filtering particles 75 microns and larger. Final filtration may be applied to remove any agglomerated thickener particles following the grease milling procedure.

However, final filtration is not likely to be performed at appreciably tighter tolerances (that is, to less than 75 microns) unless there is a specific customer requirement.⁵

Modifying the methods and procedures alone requires an investment in the effort to see the change through to a newly stabilized set of 'standard operating conditions. The cost to implement the changes should transfer to the price of the product, which should be considered a reasonable trade for the improved value.

Ordering Grease to a Specific Standard

There are a few readily recognized cleanliness standards that are sufficiently quantitative to meet the needs of purchasing by technical specification. The selected cleanliness standard should be added to a generic grease purchase specification that includes other key criteria (Base Oil Viscosity, Base Oil Viscosity Index, Thickener Type, Load Wear Index, Weld Load Point, Designation of Solids (Y/N), Oxidation Stability, Worked Stability, etc.).

How are Solid Contaminant Levels Measured in New Greases?

The ISO Solid Contaminant Code (ISO 4406:99) rating system is the measure of choice for rating the amount of solid material in either a new or used (in-service) oil lubricants.

Similarly, there are a few approaches designed to provide a solid contaminant rating for grease. The measures are not part of an ISO designated method, but are still useful to the practitioner. There are both direct measures that look for and measure quantities of solid particles and indirect measures that observe the effect of solid particles and characterize the results. Whether the lab selects a direct or indirect measure depends on the product's technical requirements as defined by the reliability goals of the user with respect to machine design and application.

Direct Measures

In addition to the US Military MilSpec requirements, there are several other useful test methods that would make useful contamination limit standards.

1. The European DIN standard 51-825 is a recognized standard for rating solid contaminants in lubricating greases. This method seeks only to quantify the amount of solids larger than 25 microns per kilogram of grease.

2. The DIN 51-813, provides a score (pass / fail). It is performed by pressing 500 grams of grease through a 25-micron mesh screen, capturing the remains from the screen, dissolving the grease portion and then draining this portion through a filter. The filter is weighed and compared to the original filter weight to determine the quantity of particles 25 microns and larger that were captured. A successful test result would be less than 20 mg of particles

greater than 25 microns per kilogram of grease. ⁶ (This test result limit would be equivalent to an ISO Cleanliness code of 23/19).

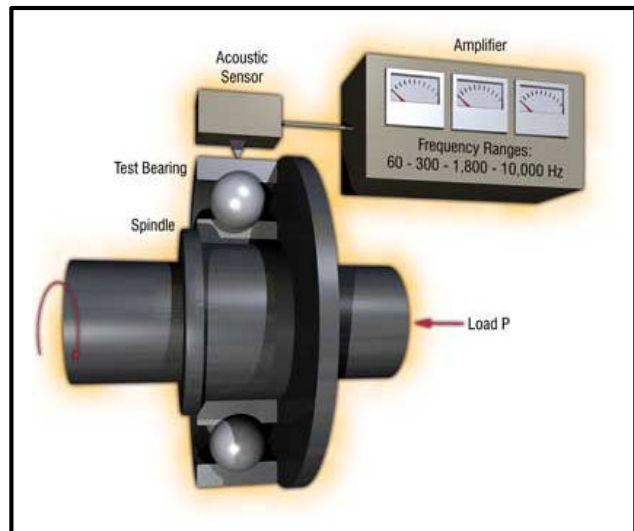
3. The Kluber Lubricants Company modified version of DIN 51-813 will provide greater clarity and certainty, with a correlation to a gravimetric reference.

The Kluber test method requires that the tester dissolve 20 grams of grease and filter the solution through a 1.2-micron filter. The effective mesh size would be smaller than 1/20th of the standard 25-micron mesh size. The filter would be weighed before and after the test.

According to the referenced paper by Helmut Miller, ⁷ most lubricating greases manufactured for low-noise applications test out by the Kluber-modified method at more than 300 grams of solid particles per kilogram. This represents a gravimetric equivalent of approximately 80 mg/L, (calculation based on a nominal grease weight of 7.2 lbs. per gallon), which translates into an ISO cleanliness rating of roughly 23/19.

Indirect Measures

4. The ASTM D 1404 measures the amount of solid abrasive material in a quantity of grease by using a scratch test. The rating is a subjective evaluation of the number of arc-shaped scratches that would appear on highly polished acrylic plates after 0.25 grams of grease is compressed between the plates and stressed in a circular motion under 200 PSI force. The plates are graded as $1 \geq 10$; $2 \geq 10$ and < 40 , and $3 \geq 40$ scratches. This does not correlate well to other known industrial contaminant measures.



5, 6. Both FAG and SKF have devised internal test methods to rate the contaminant levels in grease by observing the indirect effect of contaminants in the grease on a closely monitored system. Both approaches measure the noise or decibel (dB) of a bearing under a set of test conditions. The SKF approach automatically injects grease into a bearing in a test stand.

Figure 1. Principle of Solid-borne Sound Measurement. Courtesy SKF, Germany

7. The SKF noise rating method is designed to assess particle effects on rolling and grease damping characteristics. Called the “Be Quiet +” rating method, the test uses an automated test stand that injects grease into a deep groove ball bearing (type 608 @ 1800 RPM), operates the bearing for 15 seconds before testing, operates the bearing for an additional 30 seconds after testing and then dispels the grease and repeats the exercise. An acceleration

transducer measures energy readings in three windows: Low, Medium and High, as shown in Table 1.

The high bands reflect shortwave disturbances, which can be caused by particles in the lubricant.⁸ A peak value is also recorded in all frequency bands to record unique or irregular disturbances that are mainly due to the lubricant.

Low	50 - 300 Hz	Typical running noises for the class of bearing
Medium	300 - 1,800 Hz	Grease noise characteristic measurement range
High	1,800 - 10,000 Hz	Grease noise characteristic measurement range

The FAG ‘MGG’ and Shell ‘GMN’ test methods use similar techniques, including the same bearing, bearing load and energy range measures. The FAG-MGG method requires the test results to be based on readings from five bearings vs. just two bearings for SKF and three bearings for the Shell - GMN method.⁹

Figure 2. Noise Recording on Dirty Lubricant

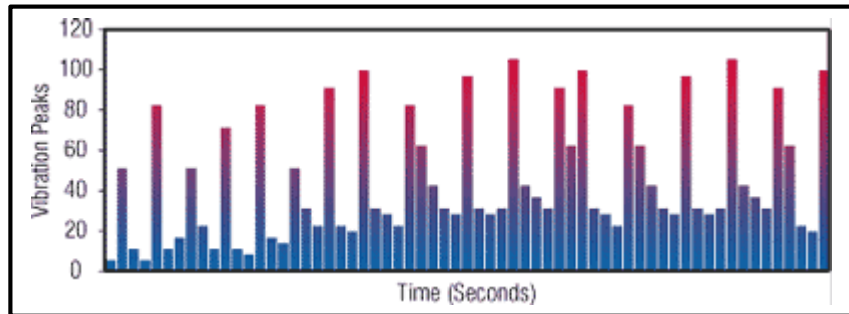
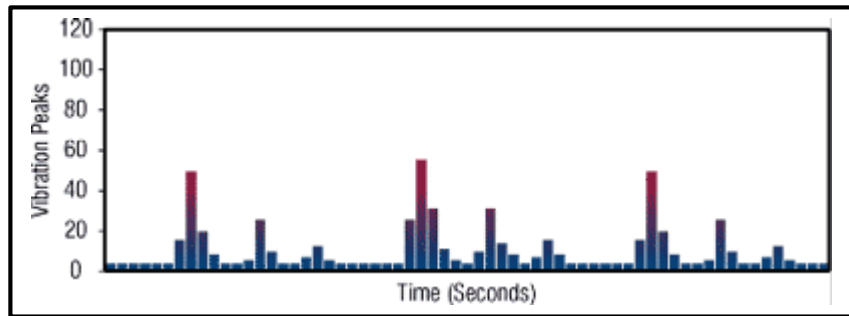


Figure 3. Noise Recording on Clean Grease



As figures 2 and 3 demonstrate, there can be an appreciable difference in the amount of contaminant and noise levels a grease can generate in a bearing. Notice that the overall noise level in Figure 2 is gradually rising over the prolonged test cycle. The increased amplitude suggests that as the debris in the grease rolls through the bearing clearances the surface damage increases.. The reading averages will get higher as more damage occurs.

7. SKF offers four classes, and further divides the classes with its “Be Quiet +” quantitative rating division.

The four classes are as follows:¹⁰

Dirty. The particles' hardness and size is such that over-rolling [particles passing through the loaded surfaces] leads to permanent damage giving increased overall noise and reduced bearing fatigue life.

Noisy. The hardness and size of over-rolled particles [generally undispersed thickener] may damage the bearing surfaces which gives a noticeable increase in overall bearing noise but not to the degree that the bearing fatigue life is adversely affected.

Clean. The hardness and size of over-rolled particles will produce noticeable vibration peaks but the bearing surfaces are not permanently damaged.

Quiet. The highest degree of cleanliness due to a minimum number of particles giving vibration peaks.

The more quantitative GN rating system is shown in Table 2.

GN0	Anything worse than GN1
GN1	> 95% of all peaks are ≤ 40 m m/s
GN2	> 95% of all peaks are ≤ 20 m m/s
GN3	> 95% of all peaks are ≤ 10 m m/s
	> 98% of all peaks are ≤ 20 m m/s
	> 100% of all peaks are ≤ 40 m m/s
GN4	> 95% of all peaks are ≤ 5 m m/s
	> 98% of all peaks are ≤ 10 m m/s
	> 100% of all peaks are ≤ 20 m m/s

Table 2. Grease Noise (GN) Classes

The majority of today's greases fall into the clean class. An example of typical clean grease would be a polyurea product that could have large agglomerates of thickener present,

producing large vibration noise peaks but have little influence on bearing and race surfaces.¹¹ For a grease to fit into the quiet category the manufacturer would take extra measures to filter raw materials and final products, manufacture in a clean environment, and ship final products in isolated containers.

Conclusions

There are several methods through which the buyer may choose to designate a limit to the amount of solid contaminant debris that may be included in the product. The effect of any contaminant in the lubricant may be appreciable, and is worth serious consideration as one of several steps in improving the quality of the lubrication program. The buyer may choose to secure some statistical sample and representation of the extent of contaminants in the grease, and incorporate this data into recognized models to characterize and justify additional cost associated with the improved quality.

¹ Galary, W. "To Filter or to Ultrafilter: That is the Question." Nye Lubricants, Inc.

² Galary, W. "To Filter or to Ultrafilter: That is the Question." Nye Lubricants, Inc.

³ Samman, N; Johnson, M. "Is it Time to Buy Quiet". ML Magazine, January 2003.

⁴ Galary, W. "To Filter or to Ultrafilter: That is the Question." Nye Lubricants, Inc.

⁵ Samman, N; Johnson, M. "Is it Time to Buy Quiet". ML Magazine, January 2003

⁶ Galary, W. "To Filter or to Ultrafilter: That is the Question." Nye Lubricants, Inc.

⁷ Galary, W. "To Filter or to Ultrafilter: That is the Question." Nye Lubricants, Inc.

⁸ Galary, W. "To Filter or to Ultrafilter: That is the Question." Nye Lubricants, Inc.

⁹ Daegling, S. "Eurogrease." ELGI Conference. Oslo, June 1999. Shell Research. Shell Global Solutions

¹⁰ Kuhl, R. and Haag, C. "Grease Noise in Roller Bearings." Noise generation in bearings and its effects, influence of the lubricating grease, grease noise tester, test procedures and requirements

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