

OIL CLEANLINESS

The effectiveness of lubricants in preventing wear can be seriously compromised by the presence of contaminants such as particulates and water in the lubricant.

Where sliding surfaces are separated by an oil film (hydrodynamic lubrication), wear rates of the two surfaces arising from the presence of particulate contaminants increase rapidly when the sizes of the particles exceed the running clearances between sliding surfaces.

The quantity and size of particulates in the lubricant is therefore one of the most important factors affecting the service life of the lubricated components of all machinery. (For the purposes of this article, and in keeping with common industry practice, the terms "clean" and "cleanliness" refer to the amount and size of particulate contamination in a lubricating or hydraulic fluid). The effect of particulate contamination varies with the type of system and lubrication environment, in that some environments are more sensitive to particulate contamination than others. In hydraulic systems, for example, clean fluid is absolutely essential for successful long-term operation. Also, machines equipped with rolling element bearings are especially sensitive to particulate contamination, although machines using fluid-film bearings are not immune to such damage. Many sources cite dramatic improvements in expected machine life resulting from even modest improvements in lubricant cleanliness.

QUANTIFICATION OF PARTICULATE CONTAMINATION.

The question of quantification of oil cleanliness raises a number of issues such as

- How clean is "new" oil?
- How clean does the oil need to be?
- What improvements in machine life can you expect from cleaning up your oil?
- What about other types of contamination?
- What steps can you take to clean up your oil?

The standard test procedure for assessing the cleanliness of hydraulic fluids is ISO 4406, which establishes the relationship between particle counts and cleanliness. Although originally developed for application to hydraulic fluids, common practice has now extended the application of the standard to many other types of lubricants. This international standard uses a code system to quantify contaminant levels by particle size in micrometers (μm). Using ISO 4406, a machine owner/operator can set simple limits for excessive contamination levels, based on quantifiable cleanliness measurements.

Table 1. ISO 4406 fluid cleanliness codes (particles per ml).

ISO Code	Minimum	Maximum
10	5	10
11	10	20
12	20	40
13	40	80
14	80	160
15	160	320
16	320	640
17	640	1300
18	1300	2500
19	2500	5000
20	5000	10000
21	10000	20000
22	20000	40000
23	40000	80000

Table 1 illustrates the ISO 4406 cleanliness codes. (The ISO standard calls the codes "scale numbers." They may also be referred to as "range numbers" and represented as R_5/R_{15} for 2-part codes and $R_2/R_5/R_{15}$ for 3-part codes.) This standard allows the quantification of current particulate cleanliness levels and also to set targets for

required cleanliness levels. The current standard provides a 3-part code to represent the number of particles per millilitre (ml) of fluid greater than 2 μm , 5 μm , and 15 μm , respectively. The current standard is ISO 4406:1987(E). The ISO is now circulating a draft proposal, ISO/DFIS 4406:1999(E), for contamination levels measured with automatic particle counters calibrated in accordance with ISO 11171. In the proposed standard, the three parts signify the number of particles/ml greater than 4 μm , 6 μm , and 14 μm respectively (scale or range numbers $R_4/R_6/R_{14}$.) Many laboratories will report either a 2-part code, or a 3-part code, as specified by the user. The 2-part code refers to particle counts in the 5 μm and 15 μm size ranges. A 3-part code of 17/14/12, for example, would indicate 640 to 1,300 particles/ml greater than or equal to 2 μm , 80 to 160 particles/ml greater than or equal to 5 μm , and 20 to 40 particles/ml greater than or equal to 15 μm . Notice each step in the ISO code represents either double or half the particle count relative to an adjacent code. It is important to note the "/" character in the written form of the code is merely a separator, and does not signify a ratio of the scale numbers.

Studies of "new" turbine oils, crankcase oils, hydraulic fluids, and bearing oils delivered to customers indicate varying degrees of cleanliness, with ISO codes from a low of 14/11, to as high as 23/20. Drum-delivered products were generally found to be cleaner than bulk-delivered products. Referring to Table 1, one might think twice before putting "new" oil with an ISO 23/20 measurement in a machine. Improper storage procedures can contribute additional contamination to new oil. Poor handling practices are another source of new oil contamination. It is important to identify all vessels are used in the plant for transporting and adding makeup oil, and to ensure that they are in an adequate state of cleanliness. After implementing cleanup programs, many users find the dirtiest oil in their plant is incoming "new" oil. It is clear that proper filtering of new oil during or before filling is a prudent and highly desirable practice to extend machine life. Each machine class should be evaluated for cleanliness levels appropriate to the application. In general, machines with tight clearances and/or anti-friction (rolling element) bearings benefit greatly from very clean oil. Turbine electro-hydraulic control (EHC) systems and many aero-derivative gas turbines are examples of industrial machines that require extremely clean oil for proper performance and long life. Filter systems rated to remove particles as small as 3 μm to 7 μm are commonly used in such applications. Hydraulic systems' targets should also be adjusted to cleaner levels for higher system operating pressures.

Table 2 presents some typical base lubricating oil cleanliness targets for common machines and machine elements. Like most guidelines, these targets are suggested as starting points. It may be necessary to make adjustments to these levels once the response of machinery on a particular site has been evaluated.

Table 2. Typical base cleanliness targets.

Machine/element	ISO Target
Roller bearing	16/14/12
Journal bearing	17/15/12
Industrial gearbox	17/15/12
Mobile gearbox	17/16/13
Diesel engine	17/16/13
Steam turbine	18/15/12
Paper machine	19/16/13

Studies performed in many industries all show dramatic extensions in expected machinery life by improving lubricant cleanliness. In one example, a reduction of particles larger than 10 μm from 1000/ml to 100/ml resulted in a 5-fold increase

(Continued on Page 11)