CRACKING THE ISO CODE TO LUBRICANT CLEANLINESS

DES-CASE

INTRODUCTION

So what does it really mean to increase lubricant cleanliness? We read various articles and textbooks that talk about how increasing the cleanliness of an in-service oil will increase the life of a component and the lubricant, but how do we make that happen? The path to increased cleanliness may not always be clear, and sometimes it may seem that major tasks must be undertaken to increase lubricant cleanliness. Fortunately, that is not necessarily the case. A systematic approach and investment in the right products and tools can show a significant return on investment, more uptime on your factory floor, and less money spent on equipment repairs.

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WHAT IS CLEANLINESS?

When we speak in terms of cleanliness, we often refer to the ISO particle count of the oil. According to the ISO 4406:99 standard, the ISO particle count is a measure of the number of particles greater than 4, 6, and 14 microns in every milliliter of fluid. The number of particles is then converted to what is referred to as the ISO Code or Range Code. The range code represents the number of particles of a given size in one milliliter of sample. Results from an oil cleanliness testing are typically reported in a three number format such as 20/15/11, where 20 represents the range code representing the number of particles that are 4 microns and larger, 15 the range of particles that are 6 microns and larger, and 11 represents particles 14 microns and larger.

Table 1 – Snippet of the ISO Code Table.

# OF PARTICLES PER MILLILITER		CODE NUMBER
MORE THAN	EQUAL TO OR LESSER THAN	
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	2,500	18
640	1,300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11

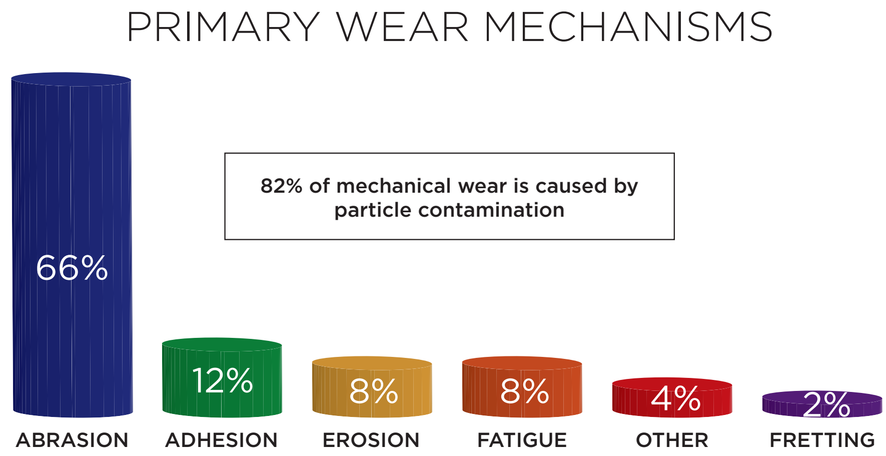
While the process of converting the raw particle count data to a range code is simple, there are a couple of key takeaways that should be noted:

1. For each one unit increase in the code number, the number of particles in the range on average doubles. For example, code 11 has a range of 10-20 particles or span of 10, but code 12 has a range of 20-40 or span of 20. As a result, an oil that is one range code different is potentially twice as dirty, two range codes means four times dirtier, three range codes, eight times dirtier and so on.

2. While the average increase in particles for one ISO Code is double, depending on the actual number of particles present one range code increase could potentially be equivalent to doubling or quadrupling the amount of contaminant in the lubricant. For example, if the number of particles went from 641 to 2,499, the number of particles has almost quadrupled but the ISO Code only changed from 17 to 18. For this reason, it's important to look at the actual number of particles as well as the ISO range code when interpreting particle count data.

WHY IS CLEANLINESS IMPORTANT?

Using the correct lubricants and making sure they are in suitable chemical condition is a prerequisite for success, but the big changes in component service life are achieved by the aggressive management of lubricant contamination. In most cases, the amount of particle contamination in the oil is the single biggest factor that determines how long a lubricated component will last. Many maintenance professionals don't even realize that they have a problem with lubrication related failures, because they don't properly characterize the failures or at least the root cause. The fact is that for mechanical equipment, 60-80% of failures are typically lubrication related. The normal way in which most machine fail is to "wear out" but wear rates can be controlled and the primary purpose of lubrication is to do just that.



Studies show that approximately half of lost machine life is due to mechanical wear and approximately 80% of mechanical wear is caused by particle contamination in the oil. It therefore stands to reason that when particle contamination is reduced, wears rates go down and component service life goes up.

WHAT DOES IT REALLY MEAN?

A Cleanliness Code is great, but why do these numbers really matter? It seems like a lot of contaminant, so surely this should be visible in the oil? The reality is that 4, 6 and 14 micron particles simply cannot be seen with the naked eye. In fact, it's not until particles get as large as 40-50 microns that we can see them without a microscope. By comparison, a red blood cell is around 8 microns. To put that into perspective, the life expectancy of your equipment is being compromised by red-blood cell sized particles!

By the time you can see contaminants in your oil, the oil cleanliness has well exceeded what the oil laboratories particle counter can count. This effectively means your oil is not meeting standards and is TOO DIRTY.

HOW CAN WE MEASURE HOW MUCH PARTICLE CONTAMINATION IS IN AN OIL?

Particle contamination is measured using the ISO 4406:99 (c) standard.

PARTICLE COUNT DATA

Size in Microns	Number of Particles Larger than Size per mL
4	1654
6	495
10	122
14	52
20	21
50	1.3
75	0.22
100	0.05

NUMBER OF PARTICLES / ML

More Than	Less Than or Equal To	Range Number
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,00	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	2,500	18
640	1,300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10

R4/R6/R14
ISO 18/16/13

The ISO 4406:99 (c) standard gives a range code corresponding to the number of particles per milliliter in three difference size ranges:

particles > 4 micron
particles > 6 micron
particles >14 micron

To understand how little dirt we're talking about, consider that a teaspoon of dirt in a 55 gallon drum will yield an effective particle count of 19/17/14; way too dirty for most critical applications. On a gravimeric basis, an oil with a cleanliness code of 19/15/12 would have a level of contamination equivalent to roughly 3 grams (0.1 oz) of dirt within a 100 gallon reservoir. At 19/15/12, a hydraulic system would be considered to be highly contaminated and pump life could potentially be cut in half. 3 grams may not seem like much and is not even visible in an oil sample, but what if we are circulating this oil through a 50 gpm pump? 3 grams of contaminant is now equivalent to running approximately 1,500 pounds of contaminant through the system on an annual basis!

Effectively controlling contamination requires among other things, a good strategy. Implementing a contamination control policy may take a lot of time and effort, but developing the strategy is fairly simple and involves a simple three step process:

1. Set appropriate targets
2. Take specific actions to achieve the target
3. Use ISO particle counting to ensure compliance with the target.

HOW CLEAN SHOULD THE OIL BE? SET YOUR TARGETS.

The first step is to identify goals in the form of target lubricant cleanliness. Targets should be based on equipment type, sensitivity to contamination induced failure, criticality, and operating environment.

The more sensitive a component is to contamination, the cleaner the system should be. Likewise, the more critical a system is from a production, safety or environmental standpoint, the cleaner it should be kept. Table 2 outlines some target cleanliness levels for common component types. Notice that certain types of hydraulic valves, such as servo valves, require cleaner oil than cartridge valves. This stands to reason since servo valves have tighter clearances and are typically used where higher pressure and more precise motion control are required. Similarly, pumps or bearings that typically operate at a higher RPM require a greater cleanliness level (lower ISO code) than a slower moving gearbox. System pressure also has an effect. As pressures increase, tolerances typically decrease making higher pressure hydraulic systems more sensitive to contamination induced failures than lower pressure systems.

Table 2 – Target Particle (ISO Code) Levels

Machine Type		Particle Level Target
Hydraulics 1500-2500psi	With servo valves	15/13/11
	With proportional valves	16/14/12
	Variable volume piston pump	17/15/12
	With cartridge valves or fixed piston pump	17/16/13
	With vane pump	18/16/14
Gearbox		19/16/13
Paper Machine		18/14/11
Steam Turbine		18/14/11
Pumps		17/14/12

While these are good starting points, the targets listed in Table 2 are really just guidelines. The targets should be adjusted up or down depending on criticality and appetite for risk. In essence, how much reliability do you want to buy? Just like exceeding the speed limit on a highway doesn't guarantee a crash, the further away from the limit you stray the higher your risk of a crash or getting a speeding ticket!

HOW IS CLEANLINESS ACHIEVED?

Cleanliness can be an abstract thought and is not achieved through any one simple practice. When thinking in terms of a lubrication system, the tendency is to think only in terms of the in-service components. However, typical oil handling methods will have a big impact on the amount of contamination in equipment. Because of this, most plants will need to revise and upgrade lubricant storage and handling methods and equipment as part of a holistic contamination control strategy.

Preventing contamination in lubricated equipment starts with new oil. New oil from drums or bulk deliveries usually contains anywhere from 2 to 20 times the amount of particles that is acceptable for most lubricated equipment. There are a number of reasons for this and this is not an indictment of lubricant suppliers, but it is a fact and it has to be addressed before cleanliness targets in machinery can be met. In general, it is a good practice to maintain the cleanliness of new oil at least two ISO codes cleaner than the targets for the in-services oil. This will allow for modest amounts of contamination to be introduced during transfer and application while still meeting the targets.

While the concept that new oil is not clean may be shocking to some, it stands to reason when you consider the number of times a lubricant is transferred before it's put into a machine. For example, when a lubricant is delivered to a bulk tank it may be dispensed from a tanker truck. If the transfer process is not a closed system, then airborne particulate may enter the lubricant and storage tank. The same concept applies when a lubricant is dispensed from the bulk storage tank to a transfer container or satellite storage area. To minimize this risk of contamination, an enclosed transfer system is desirable. This is achieved through addressing storage and handling practices, component modifications, and transfer protocol at every point in the Plant Lubrication System.

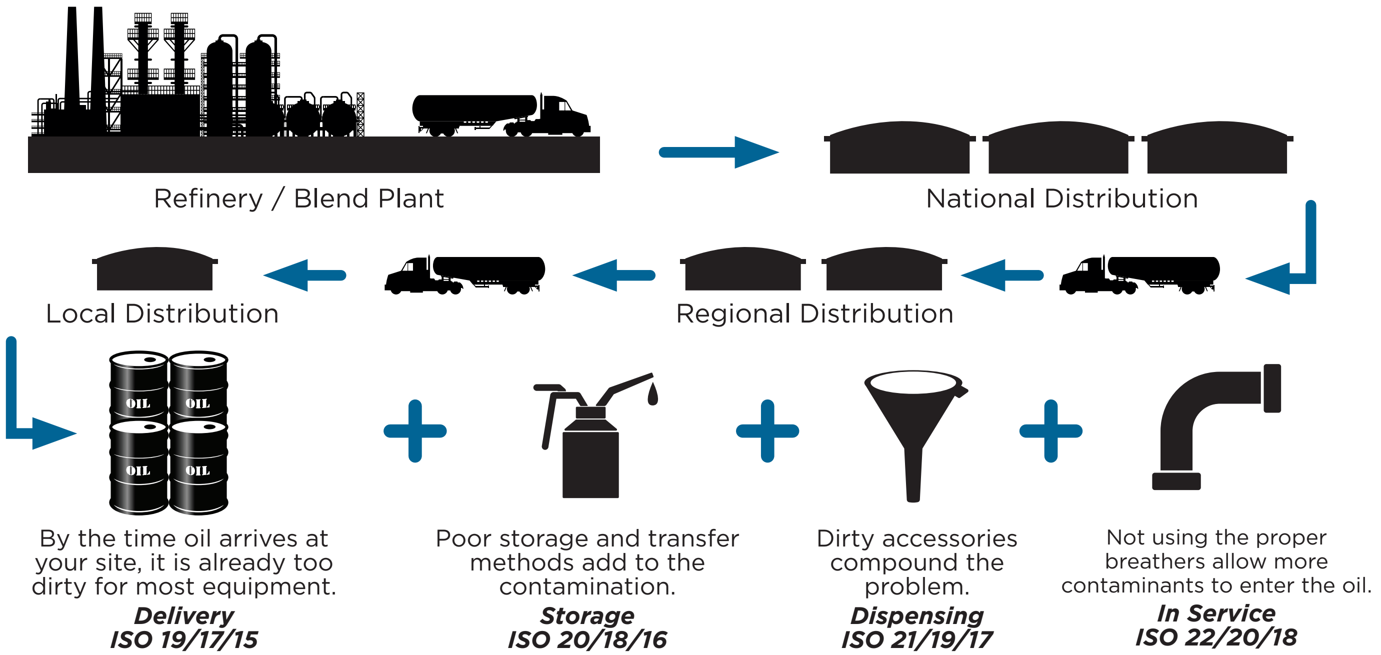


Figure 1 – Demonstrates the Lubrication System from the Refinery/Blend Plant through the dispensing into a component. From the point of delivery to each subsequent lubricant transfer, the ISO code potentially increases by at least one grade which is equivalent to doubling and in some cases tripling the amount of contaminant in the oil. As an end user, control over the lubrication system starts at the point of delivery into the plant and extends all the way through to point of use at the machine.

PREVENTION

As stated earlier, it is important to stop airborne contaminants from entering tanks, drums, or machine reservoirs. The good news is that this is one of the easiest problems to address through high quality desiccant breathers that strip particles and moisture from the air. Whenever there's an exchange of air, either due to volume changes or thermal siphoning, a desiccant breather should be used. This includes on bulk and tote storage tanks, drums, transfer containers and all critical in-service equipment.

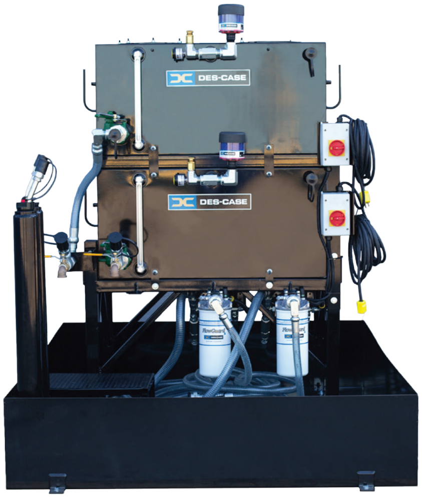
BULK STORAGE

Preventing contamination in lubricated equipment starts with new oil from drums or bulk deliveries. As mentioned earlier, new oil is not clean. The first step in ensuring the cleanliness of new oil is to filter the oil to an acceptable level.

The most effective technique used to filter new oil depends on the oil's method of delivery. If it comes in drums, each drum can be filtered using portable compact filtration units (Figure 2). If the volume is sufficiently large, the oil can be filtered as it is transferred.

Figure 2 – Prefiltration of new oil using a portable filtration system

Another popular technique, which covers a wider range of storage and handling issues, involves the use of a comprehensive lubricant management system (Figure 3). These systems can be configured with a wide range of options, including separate pumps and filters for each lubricant, high-quality desiccant breathers to prevent subsequent contamination to the fluid, fittings and spigots that minimize contamination, and even flowmeters to measure and track the amount of oil dispensed.



Whether you filter oil in the barrel prior to use, hard pipe from bulk storage to the machine or dispense using transfer containers, all new oils should be pre-filtered a minimum of 5-7 times prior to use.

Figure 3 - Tote storage systems such as these allow new oil to be stored in 80-300 gallon quantities before dispensing to smaller transfer containers. Each tote has a dedicated transfer pump and filter to allow oil the be pre-filtered prior to use.

SATELLITE STORAGE

Satellite storage often refers to cabinets located throughout the plant or facility for the purpose of storing lubricants. These cabinets house a variety of containers utilized to transfer lubricants from bulk storage to the component itself. To minimize contaminant ingression, storage cabinets should be kept closed when not being accessed, kept clean or orderly, and should have a place designated for any lubricants or tools stored in it.

OIL TRANSFER CONTAINERS

For small sumps that are filled from oil cans, the oil transfer containers should be made of plastic, sealable, color-coded or marked for product type, and easy to clean on a regular basis. The use of funnels should be avoided whenever possible and separate handling equipment should be maintained for different lubricants. Ideally, transfer containers should come with quick connects so they can be filled without exposing the container to the outside environment while the trigger should be self closing so that the container is always sealed when not in use (Figure 4).

Figure 4 – the transfer container on the left has been left open and the lid has to be removed to fill it. The container on the right is completely sealed and can filled using quick connects

COMPONENT MODIFICATIONS

The last link of defense is to properly modify components to allow for routine lubrication tasks to be completed without opening the lubricated sump. These include visual oil condition and level checks, oil sampling, oil top offs, and even an oil change (Figure 5).

TRANSFER PROCEDURES

Once the physical points of ingression have been addressed, it is necessary to address the personnel charged with maintaining the lubrication system. Procedures for storage, handling, and transferring lubricants must be made available along with proper training. It's not just a matter of modifying the equipment but also modifying behaviors to ensure the storage tanks, transfer containers, and modifications are properly utilized.

Figure 5 – This gearbox has been properly modified with quick connects on the drain and fill port for oil changes, top offs and offline filtration, a column sight glass for level checks, an oil sampling valve, and a proper desiccant breather.

YOU'VE CRACKED THE CODE – NOW ENJOY YOUR TREASURE

Increasing system cleanliness has multiple benefits to the component and the lubricant, but the number one benefit is increased component life. In terms of damage, hard particle contaminants can be brutal to internal moving components. Under rolling contacts, particles are often the precursor to premature fatigue failure, while in high pressure systems, particles can "sandblast" a component from the inside out. In other systems, particles enter the dynamic clearances between moving surfaces and wear components through a three-body abrasion.

Figure 6 – Particle Effects on Component Life

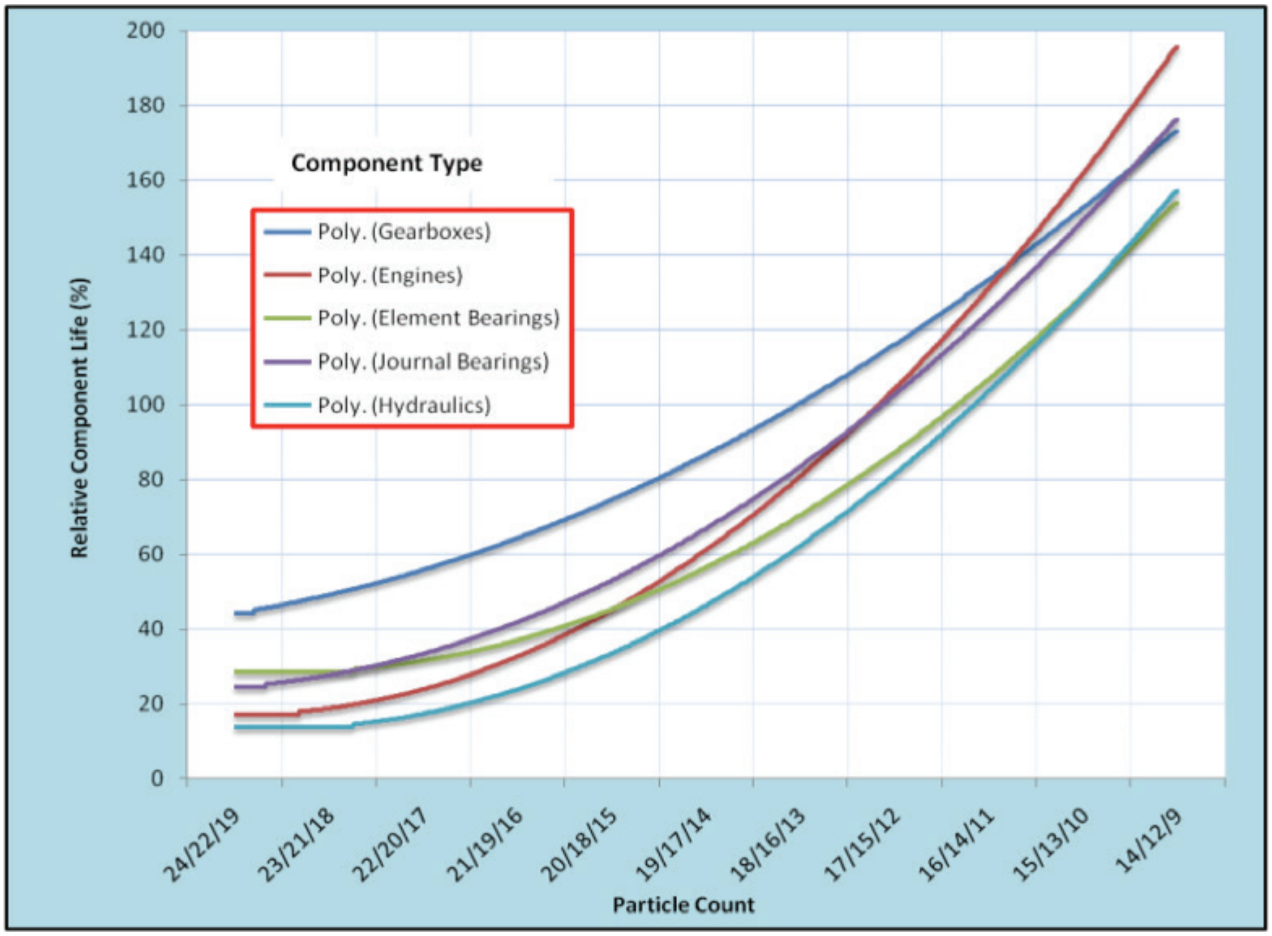


Figure 6 demonstrates the relative life of a component based on its cleanliness level. As an example, if we had a rolling element bearing operating at a cleanliness level of 23/21/18, it would only achieve 30% of its relative useful life. If that relative useful life is 10 years based on operational rated loads and speeds, the bearing would only last 3 years before a potential replacement is needed. Conversely, if the same bearing were operating at a cleanliness level of 16/14/11, 100% of its relative useful life could be achieved, representing a 3-4 fold life extension.

As an added benefit, clean oil typically doesn't have to be changed as frequently. With clean oil and the ability to filter instead of changing oil, oil changes can be done based on oil condition as opposed to simply removing contaminants. Moreover, by removing metals and other contaminants from the oil the rate of oil degradation is slowed, which ultimately makes the oil last longer.

To illustrate just how effective contamination control can be, consider the following example. A mine was operating a number of large haul trucks and recognized that contamination was a major contributing factor to the cost and frequency of rebuilds on their final drives. Historically, the mean-time-between-failure (MTBF) was around 9,000 hours, equating to a estimated cost of $2.11 per operating hour. By installing kidney loop filtration stations in the truck shop, the mine was able to filter the final drives during each routine PM cycle. As a result, maintenance costs dropped to $1.36 per operating hour, a 36% reduction is maintenance costs. As an added benefit, oil drain intervals could be extended from 2,000 hours to 6,000 hours as a result of less contamination induced oil degradation and fewer oil changes to remove contaminants.

ITEM	BEFORE PROGRAM	AFTER IMPROVED FILTRATION
MTBF	90,000 hours	13,000 hours
Average rebuild cost	$19,900	$17,500
Maint. cost/operating hour	$2.11	$1.36
Oil Change interval	2,000 hours	6,000 hours

THE BOTTOM LINE

Equipment life can be greatly extended through proper lubrication maintenance. In today's competitive market, most companies are now realizing that maintaining clean oil is one of the best investments it can make, with contamination at the core of premature machinery failure and diminished lubricant life.

By utilizing options outlined above and implementing several contamination control techniques as a 'best practice', maintaining clean dry lubricants—and gaining the profitability that goes along with it—is easier than ever.

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ABOUT DES-CASE CORPORATION

Des-Case is where the original desiccant breather was invented and now manufactures a wide array of contamination control products for industrial lubricants. Headquartered near Nashville, TN, we market an entire line of products designed to help companies make their equipment investments last longer. Our design features are unparalleled in the marketplace and are used wherever lubricant life and performance are essential to daily operations.

Des-Case has worked with some of the world's largest companies, both directly and through our partners. Founded on innovation to solve lubrication problems, we continue to design enhancements to our current line as well as provide customers with unique products for their particular company or industry.

Des-Case Corporation | 675 N. Main St. | Goodlettsville, TN 37072
D: 615.672.8800 | F: 615.672.0701 | descase.com

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