Oil Cleanliness & Contamination Reference

POCKET GUIDE

ANDERSON, INDIANA

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Introduction

Contamination Prevention

Our mission is to make our customers as efficient as possible, and we achieve that with the highest quality filtration products and total system cleanliness strategies to maximize uptime, productivity and prevent costly fluid contamination-related failures.

With a Hy-Pro dedicated filtration system, fluid contamination related failures and premature fluid replacement are a thing of the past. Every off-line solution includes sample ports before and after filters, providing accurate reservoir condition and filter performance validation. As with all Hy-Pro systems, your off-line system can be completely customized to provide the best solution for your application.

Particle Contamination

Figure 1

Particle gets trapped between adjacent surfaces.

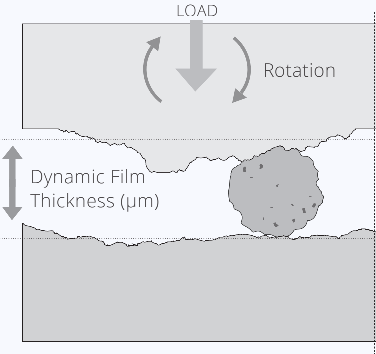
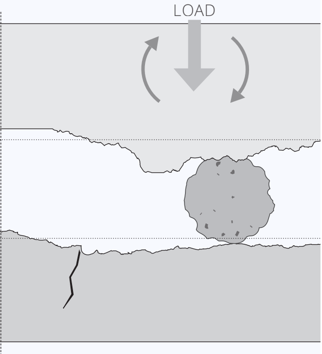


Figure 2

Particle under load damages the outer surface, creating a crack.



Internally Generated Contamination - Bearing Fatigue Wear

‘Clearance Size Particles’ generated from contaminated fluid film between adjacent surfaces (one or both surfaces moving) become work-hardened (Fig. 1). Abrasive wear also causes leakage, dimensional changes, and efficiency loss. The most common result of a decrease in efficiency is an increase in heat. These ‘Clearance Size Particles’ under load damage (fatigue) the outer surface, causing a crack to form (Fig. 2).

Once the crack spreads (Fig. 3), small contaminants break away from the damaged surface that originated from fatigue wear leaving a pit and also releasing particles that will lead to more abrasive wear (Fig. 4).

Particle Contamination

Figure 3

Damage to the outer surface spreads, causing more stress to the crack.

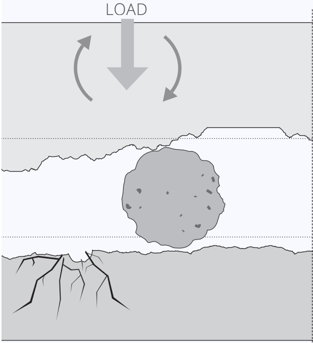
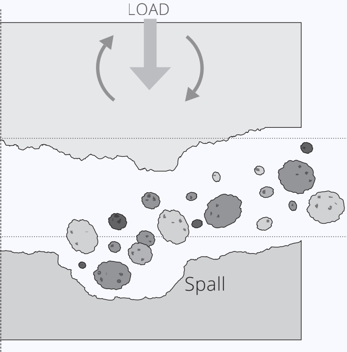


Figure 4

Small contaminantes break away leaving a pit and releasing more abrasive wear.



Servo Valves, Piston Pumps and Gear Pumps

Internally generated contamination can also occur in servo valves, piston pumps, and gear pumps.

Erosive wear in servo valves can cause valve spool movement problems. Soft contamination, such as varnish, can cause these movement problems, resulting in actuator damage or valve damage. Regardless, the control has been lost.

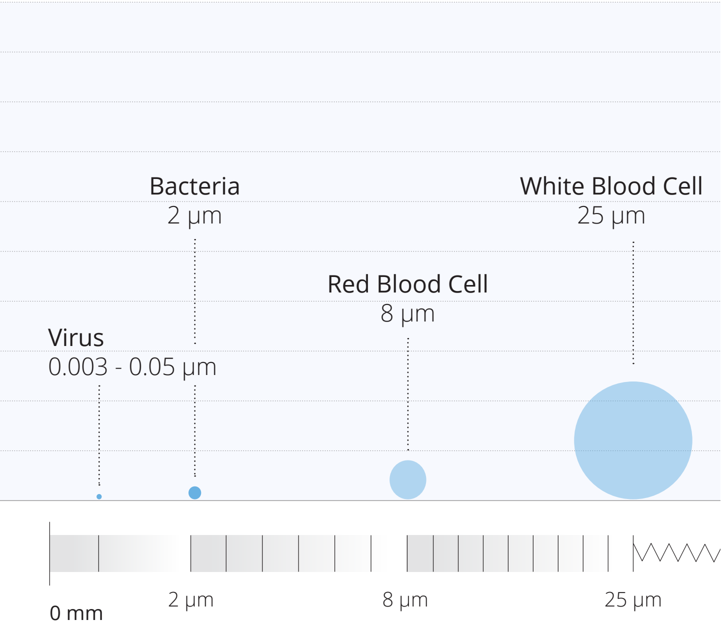
In piston pumps, contamination enters the fluid film then particles are generated by abrasion between the piston show and swash plate.

For gear pumps, changes in pressure cause the gears to come into contact with the housing. This is the main reason that gear pumps should be tested at the operating pressure that they will experience predominately in the system.

Particle Sizes

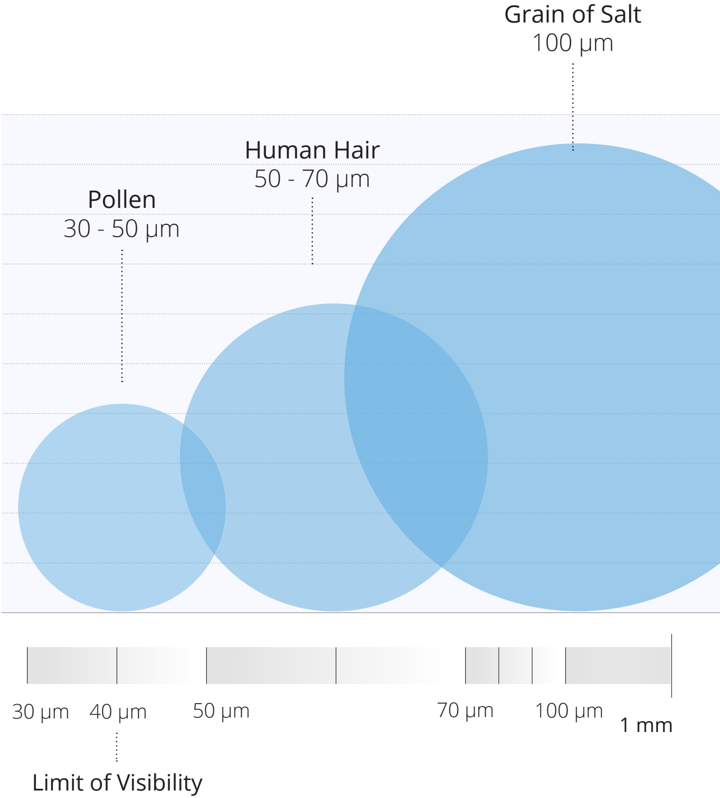
The Micrometer

Particle sizes are measured in “micrometers” (one millionth of a meter). The chart below is meant to put particle sizes into perspective. Hy-Pro manufactures elements every day that can filter contamination the size of white as well as red blood cells out of your body. This includes particles as small as bacteria.



Particle Sizes

1 micron = 0.000039" = 1 micrometer



Understanding ISO Codes

The ISO Cleanliness Code (per ISO4406-1999) is used to quantify particulate contamination levels per milliliter of fluid at 3 sizes - $4\mu_{[C]}$, $6\mu_{[C]}$, and $14\mu_{[C]}$. It is expressed in three numbers (example 19/17/14) where each number represents a contaminant level code for the correlating particle size. The code includes all particles of the specified size and larger.

It is important to note that each time a code increases, the quantity range of particles is doubling. Inversely, as a code decreases by one, the contaminant level is cut in half.

ISO 4406:1999 Code Chart

Particles per Milliliter (PPM)

ISO Code	Lower Limit	Upper Limit
24	80,000	160,000
23	40,000	80,000
22	20,000	40,000
21	10,000	20,000
20	5,000	10,000
19	2,500	5,000
18	1,300	2,500
17	640	1,300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	0.64	1.3
6	0.32	0.64

Sample Values Before Filtration

Particle Size	PPM	ISO 4406 Code Range	ISO Code
$4\mu_{[C]}$	151773	80,000-160,000	24
$4.6\mu_{[C]}$	87210		
$6\mu_{[C]}$	38363	20,000-40,000	22
$10\mu_{[C]}$	8229		
$14\mu_{[C]}$	3339	2,500-5,000	19
$21\mu_{[C]}$	1048		
$38\mu_{[C]}$	112		
$68\mu_{[C]}$	2		

Sample Values After Filtration

Particle Size	PPM	ISO 4406 Code Range	ISO Code
$4\mu_{[C]}$	69	40-80	13
$4.6\mu_{[C]}$	35		
$6\mu_{[C]}$	7	5-10	10
$10\mu_{[C]}$	5		
$14\mu_{[C]}$	0.4	0.32-0.64	6
$21\mu_{[C]}$	0.1		
$38\mu_{[C]}$	0.0		
$68\mu_{[C]}$	0.0		

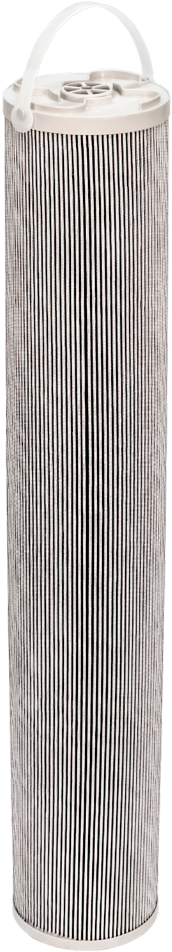
Fluid Cleanliness Code Comparisons

ISO/DIS 4406 BS 5540/4 Codes	NAS 1638	SAE 749	Defence Standard 05/42	
			Table A	Table B
25/23/17			100,000	
24/22/15			21,000	
23/21/18	12			
23/21/14			15,000	
22/20/17	11			
22/20/13			6,300	
21/19/16	10			
21/19/13			4,400	6,300F
20/18/15	9	6		
20/18/13				4,400F
20/18/12			2,000	
19/17/14	8	5		
19/17/11			1,300	2,000F
18/16/13	7			
18/16/11				1,300F
18/16/10			800	
17/15/12	6	3		
17/15/10				800F
17/15/09			400	
16/14/11	5	2		
16/14/09				400F
15/13/10	4	1		
14/12/09	3	0		
13/11/08	2			

ISO Code Limits

Hydraulic component and bearing manufacturers set ISO fluid cleanliness code limits that are the maximum tolerance for fluid contamination under which predictable performance and life can be maintained. These limits often become fluid cleanliness targets at the mill or plant level. Using the upper limit as a target means that you are operating on the absolute edge with no room for error. But there is a better way.

We want to make our customers as efficient as possible. To do this we recommend and help implement operating ISO Codes that are well below OEM upper limits. Our focus is not to hit a valve manufacturer's ISO Code limit but to help our customer reduce servo valve replacements from 220 in one year to six in the next by implementing lower operating ISO Codes and drastically reducing component wear/failure. And since that customer could prove that their oil was cleaner than required by spec, those six servos in year two were replaced under warranty by the manufacturer. Lower operating ISO Codes can extend component life by triple, quadruple and beyond, resulting in huge reliability, profitability and efficiency gains.



ISO Code Limits

How clean is my fluid?

Identifying proper sampling ports and locations, taking accurate samples and correctly interpreting results are critical to success. That's why our training and support are based on knowing and understanding the importance of fluid cleanliness and sampling. Hy-Pro is on the front line with on-line particle counters, expertise and strategies to achieve lower operating ISO Codes.

Setting Operating ISO Codes

The table on the following page represents Hy-Pro's recommendations for operating ISO Code by component and pressure. These are lower than typical industry standard target ISO Codes and are based on our experience of extending component life and reliability. Other considerations in setting lower operating ISO Codes include:

- Component criticality (turbine hydraulic controls)
- Safety (amusement park hydraulics)
- Excessive shock or vibration (mining excavator)
- High frequency duty cycle (high-speed stamping press)

Total System Cleanliness

Upgrading to Hy-Pro DFE rated filter elements, Hy-Dry breathers and adding off-line contamination solutions where needed are a small expense compared to the cost of contamination-related component repair and replacement, premature fluid replacement, increased maintenance demands and, worst of all, downtime.
By taking these small steps and becoming proactive in preventing contamination, you're setting yourself and your plant up with the best possible chance for success.

Recommended* Upper Limit ISO Cleanliness Codes per Component by Pressure Rating

	Pressure <2000 psi (138 bar)	
	Industry Standard	Hy-Pro Recommended
Pumps		
Fixed gear	20/18/15	≤ 17/15/12
Fixed piston	19/17/14	≤ 16/14/11
Fixed vane	20/18/15	≤ 17/15/12
Variable piston	18/16/13	≤ 16/14/11
Variable vane	18/16/13	≤ 16/14/11
Valves		
Cartridge	18/16/13	≤ 16/14/11
Check valve	20/18/15	≤ 17/15/12
Directional (solenoid)	20/18/15	≤ 17/15/12
Flow control	19/17/14	≤ 17/15/12
Pressure control (modulating)	19/17/14	≤ 17/15/12
Proportional cartridge valve	17/15/12	≤ 15/13/10
Proportional directional	17/15/12	≤ 15/13/10
Proportional flow control	17/15/12	≤ 15/13/10
Proportional pressure control	17/15/12	≤ 15/13/10
Servo valve	16/14/11	≤ 14/12/9
Bearings		
Ball bearing	15/13/10	≤ 15/13/10
Gearbox (industrial)	17/16/13	≤ 15/13/10
Journal bearing (high speed)	17/15/12	≤ 15/13/10
Journal bearing (low speed)	17/15/12	≤ 15/13/10
Roller bearing	16/14/11	≤ 15/13/10
Actuators		
Cylinders	17/15/12	≤ 16/14/11
Vane motors	20/18/15	≤ 17/15/12
Axial piston motors	19/17/14	≤ 16/14/11
Gear motors	20/18/14	≤ 17/15/12
Radial piston motors	20/18/15	≤ 17/15/12
Other		
Test stands	15/13/10	≤ 15/13/10
Hydrostatic transmissions	17/15/13	≤ 16/14/11
High pressure fuel injector	18/16/13	≤ 16/14/11

*Depending upon system volume and severity of operating conditions a combination of filters with varying degrees of filtration efficiency might be required (I.e. pressure, return, and off-line filters) to achieve and maintain the desired fluid cleanliness.

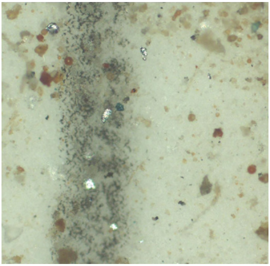
Pressure **2000-3000 psi (138-207 bar)**		Pressure **>3000 psi (207 bar)**	
Industry Standard	Hy-Pro Recommended	Industry Standard	Hy-Pro Recommended
Pumps			
19/17/15	≤ 16/14/11	-	-
18/16/13	≤ 15/13/10	17/15/12	≤ 15/13/10
19/17/14	≤ 16/14/11	18/16/13	≤ 15/13/10
17/15/13	≤ 15/13/10	16/14/12	≤ 15/13/10
17/15/12	≤ 15/13/10	-	-
Valves			
17/15/12	≤ 15/13/10	17/15/12	≤ 15/13/10
20/18/15	≤ 17/15/12	19/17/14	≤ 16/14/11
19/17/14	≤ 16/14/11	18/16/13	≤ 15/13/10
18/16/13	≤ 16/14/11	18/16/13	≤ 16/14/11
18/16/13	≤ 16/14/11	17/15/12	≤ 15/13/10
17/15/12	≤ 15/13/10	16/14/11	≤ 14/12/9
17/15/12	≤ 15/13/10	16/14/11	≤ 14/12/9
17/15/12	≤ 15/13/10	16/14/11	≤ 14/12/9
17/15/12	≤ 15/13/10	16/14/11	≤ 14/12/9
16/14/11	≤ 14/12/9	15/13/10	≤ 13/11/8
Bearings			
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
Actuators			
16/14/11	≤ 15/13/10	15/13/10	≤ 15/13/10
19/17/14	≤ 16/14/11	18/16/13	≤ 15/13/10
18/16/13	≤ 15/13/10	17/15/12	≤ 15/13/10
19/17/13	≤ 16/14/11	18/16/13	≤ 15/13/10
19/17/14	≤ 16/14/11	18/16/13	≤ 15/13/10
Other			
15/13/10	≤ 15/13/10	15/13/10	≤ 15/13/10
16/14/11	≤ 15/13/10	16/14/11	≤ 15/13/10
18/16/13	≤ 15/13/10	18/16/13	≤ 15/13/10

Bearing & Component Life Extension

Improving fluid cleanliness means reduced downtime, more reliable equipment, longer fluid life, and fewer maintenance hours. In addition, it also means reduced component replacement and repair expenses.

By improving the cleanliness of your fluid by only a few ISO Codes, you can directly increase the lifespan of your components and equipment. The tables on the following page demonstrate the life extension for both roller contact bearings and hydraulic components given a reduction in ISO Codes.

How clean is your ***new*** oil?



As it turns out, new oil can be one of the worst sources of particulate and water contamination.

The picture on the left was taken from a patch test at 10x magnification on a new oil sample direct from the manufacturer and shows the level of contamination present in seemingly clean oil.

A good upper limit for new oil cleanliness is 16/14/11. However, a commonly seen ISO Code for new oil reaches an ISO Code of 25/22/19, which is not only unsuitable for hydraulic or lubrication systems but can actually be a major cause of degradation and premature component failure.

Hy-Pro will help you develop a plan to achieve and maintain target fluid cleanliness. Arm yourself with the support, training, tools and practices to operate more efficiently, maximize uptime and save money.

Hydraulic Component Life Extension

Current ISO Code	New ISO Code			
	2 x Life	3 x Life	4 x Life	5 x Life
28/26/23	25/23/21	25/22/19	23/21/18	22/20/17
27/25/22	25/23/19	23/21/18	22/20/17	21/19/16
26/24/21	23/21/18	22/20/17	21/19/16	21/19/15
25/23/20	22/20/17	21/19/16	20/18/15	19/17/14
24/22/19	21/19/16	20/18/15t	19/17/14	18/16/13
23/21/18	20/18/15	19/17/14	18/16/13	17/15/12
22/20/17	19/17/14	18/16/13	17/15/12	16/14/11
21/19/16	18/16/13	17/15/12	16/14/11	15/13/10
20/18/15	17/15/12	16/14/11	15/13/10	14/12/9
19/17/14	16/14/11	15/13/10	14/12/9	13/11/8
18/16/13	15/13/10	14/12/9	13/11/8	–
17/15/12	14/12/9	13/11/8	–	–
16/14/11	13/11/8	–	–	–
15/13/10	13/11/8	–	–	–
14/12/9	13/11/8	–	–	–

Roller Contact Bearing Life Extension

Current ISO Code	New ISO Code			
	2 x Life	3 x Life	4 x Life	5 x Life
28/26/23	25/23/19	22/20/17	20/18/15	19/17/14
27/25/22	23/21/18	21/19/16	19/17/14	18/16/13
26/24/21	22/20/17	20/18/15	18/16/13	17/15/12
25/23/20	21/19/16	19/17/14	17/15/12	16/14/11
24/22/19	20/18/15	18/16/13	16/14/11	15/13/10
23/21/18	19/17/14	17/15/12	15/13/10	14/12/9
22/20/17	18/16/13	16/14/11	14/12/9	13/11/8
21/19/16	17/15/12	15/13/10	13/11/8	–
20/18/15	16/14/11	14/12/9	–	–
19/17/14	15/13/10	13/11/8	–	–
18/16/13	14/12/9	–	–	–
17/15/12	13/11/8	–	–	–
16/14/11	13/11/8	–	–	–
15/13/10	13/11/8	–	–	–
14/12/9	13/11/8	–	–	–

Fluid Analysis Reference Guide

The table below and on the next page outline the viscosity measurements per ISO 3448 along with common minimum and optimum viscosities for various systems you'll likely find operating in your facility.

Viscosity Range	ISO 3448 Viscosity Class	Kinematic Viscosity Mid-point cSt @ 40°C	Kinematic Viscosity Minimum cSt @ 40°C	Kinematic Viscosity Maximum cSt @ 40°C
	ISO VG 32	32	28.8	35.2
	ISO VG 46	46	41.4	50.6
	ISO VG 68	68	61.2	74.8
	ISO VG 100	100	90	110
	ISO VG 150	150	135	165
	ISO VG 220	220	198	242
	ISO VG 320	320	288	352
	ISO VG 460	460	414	506
	ISO VG 680	680	612	748

Industrial Oil Viscosities - ISO 3448

ISO 3448 establishes common viscosity classifications for industrial lubricants that are widely accepted and used across the globe. Each of your oils fall under a specific category of ISO VG classification, which you can obtain from the manufacturer and are often listed on test reports you will receive from fluid sample analyses.

Fluid Analysis Reference Guide

On the following pages are contaminants found on fluid analysis test reports listed according to their chemical symbol (often how they'll be listed on the reports) and the various sources from which they are known to occur.

Minimum Viscosities

Application	Viscosity cSt @ 40°C
Gearbox Reducers	33
Gear Pumps	30
Spherical Roller Bearings	21
Other Roller Bearings	13
Hydraulic Systems	13
Plain Bearings	13
To Support Dynamic Load	4

Optimum Viscosities (at Operating Temp)

Application	Viscosity cSt @ 40°C
Hydraulic Systems	25
Plain Bearings	30
Spur & Helical Gears	40
Hypoid Gears	60
Worm Gears	75

Fluid Analysis Reference Guide

Oil Analysis Test Categories

Xx Name	**Wear Metals**	**Xx** Name	**Additives**	**Xx** Name	**Contaminants**

Al Aluminum	🟦 Bearings 🟦 Blocks 🟦 Blowers 🟦 Bushings 🟦 Clutches 🟦 Cylinders 🟦 Housings 🟦 Pistons 🟦 Pump Bearings 🟦 Motor Housings 🟦 Rotors 🟦 Thrust Bearings 🟦 Thrust Washers	🟥 Alumina 🟥 Bauxite 🟥 Catalyst 🟥 Coal 🟥 Fly Ash 🟥 Foundry Dust 🟥 Granite 🟥 Grease Thickener 🟥 Paint 🟥 Road Dust
Sb Antimony	🟦 Alloy Steel	🟥 Ceramic Products 🟥 Paint
Ba Barium	🟦 Fuel Additive 🟦 Grease Thickener	🟦 Oil Additive: Detergent
Be Beryllium	🟦 Alloy Steel	
B Boron	🟥 Coolant Inhibitor 🟥 Oil Additive: Anti Wear	🟥 Oil Additive: Ext Pressure 🟥 Oil Additive: Detergent
Cd Cadmium	🟦 Journal Bearings 🟦 Plating	

Predictor Source of Spectrometry Metals

🟦 **Wear Metals** 🟥 **Contaminants & Abrasives**

Ca
Calcium

- 🟥 Cement Dust
- 🟥 Fuller’s Earth
- 🟥 Grease Thickener
- 🟥 Gypsum
- 🟥 Hard Water
- 🟥 Lignite
- 🟥 Hard Rock Dust
- 🟥 Oil Additive: Detergent
- 🟥 Oil Additive: Rust Inhibitor
- 🟥 Road Dust
- 🟥 Rubber
- 🟥 Salt Water
- 🟥 Slag

Cr
Chromium

- 🟦 Exhaust Valves
- 🟦 Sleeve Liners
- 🟦 Low Alloy Steel
- 🟦 Oil Coolers
- 🟦 Rings
- 🟦 Rods
- 🟦 Roller Bearings
- 🟦 Stainless Steel
- 🟦 Taper Bearings

- 🟥 Water Treatment
- 🟥 Paint

Cu
Copper

- 🟦 Babbitt Bearings (Underlay)
- 🟦 Bearing Cage
- 🟦 Brass
- 🟦 Bronze
- 🟦 Cam Bushings
- 🟦 Clutches
- 🟦 Governors
- 🟦 Guides
- 🟦 Oil Coolers
- 🟦 Oil Pumps
- 🟦 Pump Piston & Thrust Plate
- 🟦 Steering Disc
- 🟦 Valve Train Bushings
- 🟦 Wear Plates
- 🟦 Wrist Pin Bushings

- 🟥 Oil Additive: Anti Wear
- 🟥 Paint

Fe
Iron

- 🟦 Bearings
- 🟦 Blocks
- 🟦 Brake Pads
- 🟦 Cam Shaft
- 🟦 Cast Iron
- 🟦 Crankshafts
- 🟦 Cylinders
- 🟦 Hydraulic Pump
- 🟦 Vanes
- 🟦 Gears
- 🟦 Pistons
- 🟦 Liners
- 🟦 Oil Pump
- 🟦 Power Take Off (PTO)

Fluid Analysis Reference Guide

Oil Analysis Test Categories

🟩 **Xx** Name	**Wear Metals**	🟨 **Xx** Name	**Additives**	🟪 **Xx** Name	**Contaminants**

🟩 **Fe** Iron	🟦 Discs 🟦 Gears 🟦 Housings	🟦 Rings 🟦 Screws 🟦 Shafts
🟩 **Pb** Lead	🟦 Babbitt 🟦 Journal Bearing (Overlay) 🟦 Bronze Alloy 🟦 Solder 🟦 Balancing Weights	🟥 Gasoline Additives 🟥 Paint 🟥 Road Dust
🟨 **Mg** Magnesium	🟦 Turbine Metallurgy	🟥 Hard Water 🟥 Oil Additive: Detergent 🟥 Road Dust 🟥 Sea Water 🟥 Fuller's Earth
🟨 **Mo** Molybdenum	🟦 Alloy Steel 🟦 Ring	🟥 Oil Additive: Ext Pressure 🟥 Grease
🟩 **Ni** Nickel	🟦 Hardened Steel 🟦 Stainless Steel 🟦 Plating	
🟨 **P** Phosphorous	🟥 Oil Additive: Anti Wear 🟥 Oil Additive: Ext Pressure	
🟪 **K** Potassium	🟥 Coolant Inhibitor 🟥 Fly Ash 🟥 Fuel Element	🟥 Granite 🟥 Paper Dust 🟥 Road Dust

Predictor Source of Spectrometry Metals

🟦 **Wear Metals** 🟥 **Contaminants & Abrasives**

Si Silicon	🟦 Alloy Steel 🟥 Asbestos 🟥 Cement Dust 🟥 Fly Ash 🟥 Road Dust 🟥 Glass	🟥 Granite 🟥 Grease 🟥 Limestone 🟥 Oil Additive: Antifoam 🟥 Synthetic Lubricant 🟥 Sealant
Ag Silver	🟦 Bearing (Overlay) 🟦 Needle Bearings	🟦 Oil Cooler (Solder) 🟦 Wrist Pin Bushings
Na Sodium	🟥 Activated Alumina 🟥 Coolant Inhibitor 🟥 Dirt 🟥 Fly Ash	🟥 Grease 🟥 Oil Additives 🟥 Paper Mill Dust 🟥 Road Salt
Sn Tin	🟦 Bearing Cage 🟦 Babbitt 🟦 Bearing Flashing	🟦 Piston Overlay 🟦 Solder
Ti Titanium	🟦 Gas Turbine Bearings 🟦 Turbine Blades	🟥 Paint
V Vanadium	🟦 Turbine Blades 🟦 Valves	🟥 Bunker Oil
Zn Zinc	🟦 Brass 🟦 Plating	🟥 Cathodic Protection 🟥 Galvanizing 🟥 Grease 🟥 Oil Additive: Anti Wear

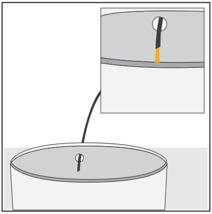
Oil Sampling Procedure

Upstream vs. Downstream Sample Ports

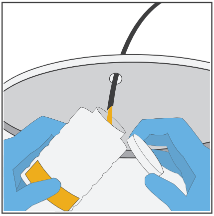
Locate a sample port upstream of the pressure filter so reservoir or barrel contamination levels can be analyzed to determine if system is operating under its limit or if top off oil is clean enough to be added to the system.

An upstream sample port provides reservoir information, while a downstream sample port provides filter element performance information and will confirm if a bypass valve is leaking. For system trend analysis, an upstream sample port is preferred.

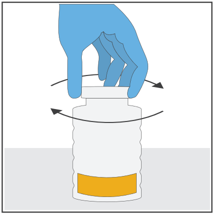
Step 1 & 3



Step 4

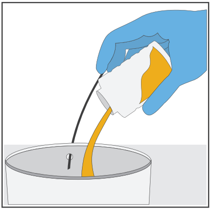


Step 5

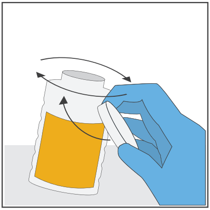


Step 6

Step 7



Step 9 & 10



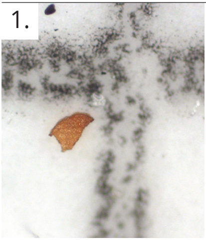
Steps for Acquiring a Proper Oil Sample

1. Place a bucket below the sampling valve. *(Use an assistant to help in this process. If no assistant is available, drill a hole slightly smaller than the size of the tube in the top of the bucket and stick the tube into it at a downward angle.)*
2. Open/shut sample valve several times to dislodge any contaminants from internal surfaces.
3. Create an acceptable flow rate through the sample valve line into the bucket. *(Not fast enough to splash, but enough to continue flushing the line. Maintain oil flow through entire sample procedure.)*
4. Fill bottle 1/4 to 1/3 Full. (*While filling, hold the cap facing downward. Do not hold cap in mouth or breath onto surface, as this can add up to 200 ppm water content to sample, invalidating results.*)
5. Recap the bottle.
6. Agitate vigorously.
7. Dump oil back into bucket. *(Make sure not to splash in order to avoid contamination potential.)*
8. Repeat steps 4-7 two additional times for three rounds of agitation to remove contaminants from bottle and cap.
9. Fill sample bottle up to the neck/sample line.
10. Cap the bottle.
11. Shut off flow from the sample valve and discard oil collected in bucket according to your company's policies.

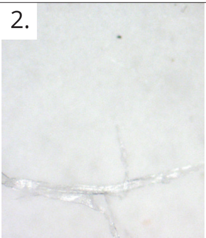
After all steps for acquiring a proper oil sample have been completed, all four components (hose, valve, bottle and cap) have been flushed and trend data is now accurate for solid particle contamination.

Identifying Types of Contamination

1.



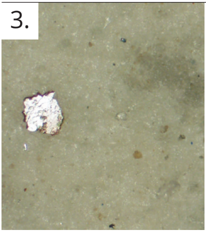
2.



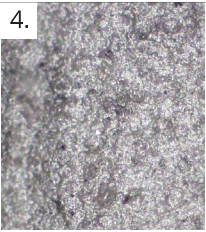
1. Rust or gel.

2. Large fiber.

3.



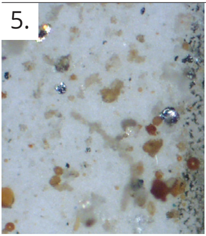
4.



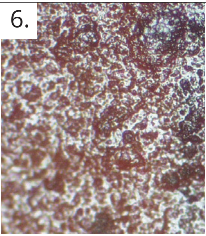
3. Bright metal particle typically from internal contaminant generation.

4. Oxidized fine metal.

5.



6.



5. Combination bright metal, silica, rust, gel and fiber materials.

6. Fine rust or gel particles.

Examples of Contamination

Particle Size	Particles per ml	ISO 4406 Code Range
4µm$_{[C]}$	492	320~640
6µm$_{[C]}$	149	80~160
14µm$_{[C]}$	15	10~20

Xµm$_{[c]}$ denotes particle counter calibration per ISO 11171 using NIST traceable contaminant.

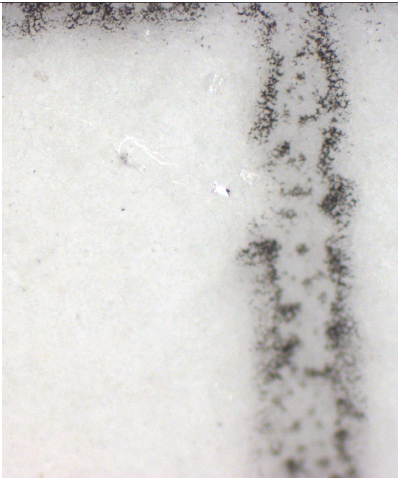
Scope scale division (mm): 1 = 10µm$_{[C]}$
Scope scale division (IN): 1 = 14µm$_{[C]}$

Slide Magnification: 100x
Fluid Volume: 25ml

ISO Code: 16/14/11

Photo Analysis:

Fine metallic and oxidized metallic particles.



Examples of Contamination

Particle Size	Particles per ml	ISO 4406 Code Range
$4\mu m_{[C]}$	3169	2500~5000
$6\mu m_{[C]}$	1283	640~1300
$14\mu m_{[C]}$	109	80~160

$X\mu m_{[c]}$ denotes particle counter calibration per ISO 11171 using NIST traceable contaminant.

Scope scale division (mm): 1 = $10\mu m_{[C]}$

Scope scale division (IN): 1 = $14\mu m_{[C]}$

Slide Magnification: 100x

Fluid Volume: 25ml

ISO Code: 19/17/14

Photo Analysis:

Silica, metallic and some rust particles.

Examples of Contamination

Particle Size	Particles per ml	ISO 4406 Code Range
4µm$_{[C]}$	6361	5000~10000
6µm$_{[C]}$	1200	640~1300
14µm$_{[C]}$	79	40~80

Xµm$_{[c]}$ denotes particle counter calibration per ISO 11171 using NIST traceable contaminant.

Scope scale division (mm): 1 = 10µm$_{[C]}$

Scope scale division (IN): 1 = 14µm$_{[C]}$

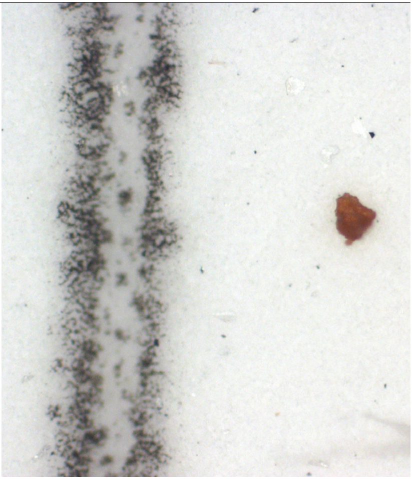
Slide Magnification: 100x

Fluid Volume: 25ml

ISO Code: 20/17/13

Photo Analysis:

Silica and some metallic particles.



Examples of Contamination

Particle Size	Particles per ml	ISO 4406 Code Range
4µm[C]	14358	10000~20000
6µm[C]	3110	2500~5000
14µm[C]	596	320~640

Xµm[c] denotes particle counter calibration per ISO 11171 using NIST traceable contaminant.

Scope scale division (mm): 1 = 10µm[C]
Scope scale division (IN): 1 = 14µm[C]

Slide Magnification: 100x
Fluid Volume: 25ml

ISO Code: 21/19/16

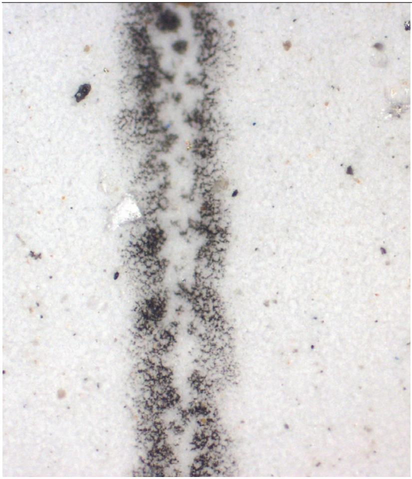


Photo Analysis:

Silica, metallic and some rust particles.

Examples of Contamination

Particle Size	Particles per ml	ISO 4406 Code Range
4µm[C]	151773	80000~160000
6µm[C]	3863	20000~40000
14µm[C]	3339	2500~5000

Xµm[c] denotes particle counter calibration per ISO 11171 using NIST traceable contaminant.

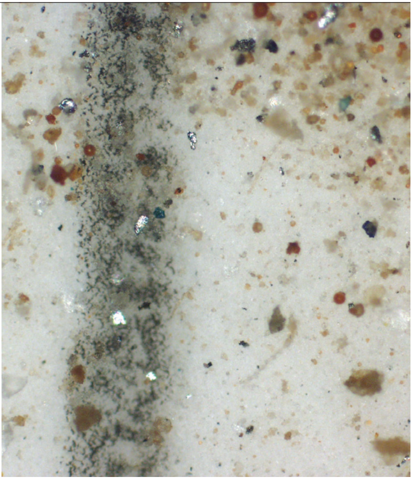
Scope scale division (mm): 1 = 10µm[C]
Scope scale division (IN): 1 = 14µm[C]

Slide Magnification: 100x
Fluid Volume: 25ml

ISO Code: 24/22/19

Photo Analysis:

Silica, rust, gel, metallic particles, and fibers.



Examples of Contamination

Particle Size	Particles per ml	ISO 4406 Code Range
$4\mu m_{[C]}$	286480	160000~320000
$6\mu m_{[C]}$	100541	80000~160000
$14\mu m_{[C]}$	615	320~640

$X\mu m_{[c]}$ denotes particle counter calibration per ISO 11171 using NIST traceable contaminant.

Scope scale division (mm): 1 = $10\mu m_{[C]}$
Scope scale division (IN): 1 = $14\mu m_{[C]}$

Slide Magnification: 100x
Fluid Volume: 25ml

ISO Code: 25/24/16

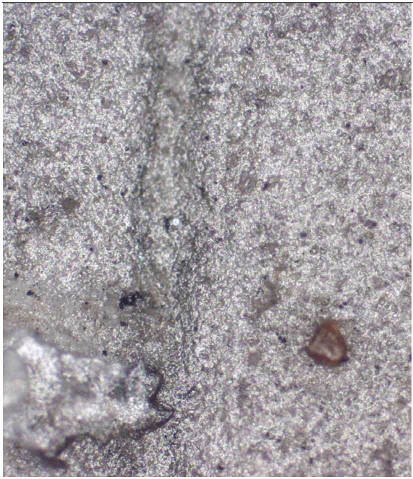


Photo Analysis:

Oxidized metal particles with a high concentration of fine contaminant.

Examples of Contamination

Particle Size	Particles per ml	ISO 4406 Code Range
4µm[C]	314475	160000~320000
6µm[C]	266087	160000~320000
14µm[C]	39129	20000~40000

Xµm[c] denotes particle counter calibration per ISO 11171 using NIST traceable contaminant.

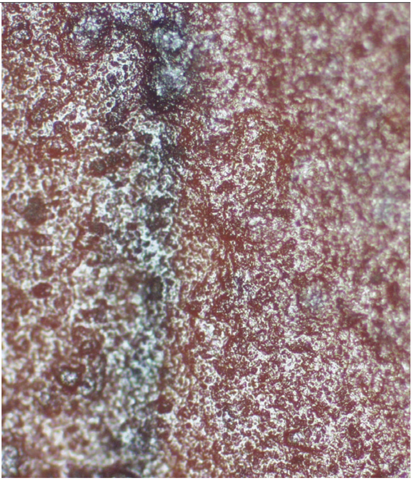
Scope scale division (mm): 1 = 10µm[C]
Scope scale division (IN): 1 = 14µm[C]

Slide Magnification: 100x
Fluid Volume: 25ml

ISO Code: 25/25/22

Photo Analysis:

Silica, metallic and some rust particles.



Water Removal

Remove Water: Protect Your System

Emulsified water, very small droplets of water dispersed through oil, will often cause oil to appear cloudy or milky along with increasing its viscosity. Hy-Pro Water Removal filter elements pull free and emulsified water from your industrial oils to leave them clean and dry and ensure your system is operating at its peak efficiency.

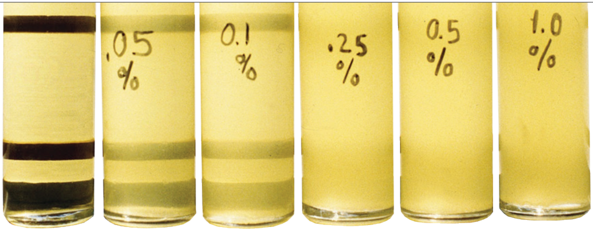
Harmful Effects of Water in Oil

Water is one of the most common and most damaging contaminants found in a lube or hydraulic system. Continuous or periodic high water levels can result in damage such as:

- Metal Etching (Corrosion)
- Abrasive Wear in Hydraulic Components
- Dielectric Strength Loss
- Fluid Breakdown
- Additive Precipitation and Oil Oxidation
- Reduction in Lubricating Properties

Appearance of Water in Oil

In dissolved water, oil appears bright and clear and the water can only be removed by vacuum dehydration. In emulsified water, very small droplets are dispersed in the oil and the viscosity may go up, making it appear cloudy and milky. Tiny amounts of detergent engine oil can contaminate industrial oils as well.



Types of Water Contamination

Dissolved Water

Dissolved water is the state at which individual water molecules (not visible to the naked eye) are dispersed throughout a fluid. Dissolved water accrues below the fluid's saturation point. Fluid with only dissolved water in it will have a bright, clear appearance.

Emulsified Water

Once the dissolved water's concentration has exceeded the saturation point of the fluid, microscopic water droplets will start to form an emulsion which is suspended within the fluid. Fluid samples containing emulsified water will have a cloudy, hazy appearance.

Free Water

Free water is formed once the emulsified water has reached a concentration at which it starts a separation phase and large water droplets begin to fall out of solution. Fluid samples containing free water will have a cloudy, hazy appearance. As the sample settles, the free water will fall out to form a separated layer on the bottom of the sample.

Upgrading from Cellulose to Glass

Figure 1: Filter Efficiency Equation

$$\beta x_{[c]} = \frac{\text{quantity particles} \geq X\mu_{[c]} \text{ upstream of filter}}{\text{quantity particles} \geq X\mu_{[c]} \text{ downstream of filter}}$$

Understanding Media Efficiencies

When a filter element is rated at a particular micron size, it is said to remove particles of that particular size and larger from the fluids it is filtering. However, filter elements of different media with the same micron rating can have substantially different filtration efficiency. Filter efficiency is calculated by taking the ratio of particles upstream of (before) the filter to particles downstream of (after) the filter. The higher the ratio, the more efficient the filter and the less particles it allows to pass. There are two distinct ratings of filter efficiency, classified as nominal and absolute.

Nominal Efficiency

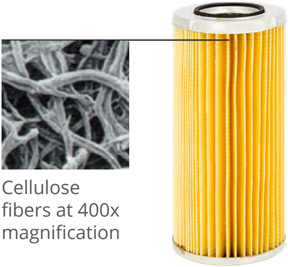
Nominal ratings refer to a degree of filtration at a particular micron by weight of solid particles. Filters rated as nominal (we're looking at you cellulose) have no maximum pore size, meaning while they may remove some 10 micron particles, they can still allow larger particles such as 200 micron to pass through and devastate components in the system.

Absolute Efficiency

Absolute ratings, which most glass media filter elements are classified under, derive their value from the largest size particle which can pass through the pores of the media. Along with much greater efficiencies glass elements have superior fluid compatibility versus cellulose with hydraulic fluids, synthetics, solvents, and high-water based fluids.

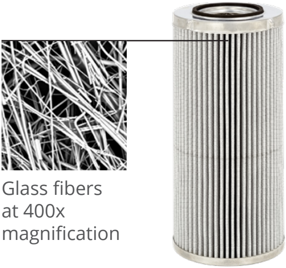
Upgrading from Cellulose to Glass

Figure 2: Cellulose Filter Media



Cellulose fibers at 400x magnification

Figure 3: Glass Filter Media



Glass fibers at 400x magnification

Cellulose vs. Glass Elements

Organic cellulose fibers can be unpredictable in size and effective useful life, while inorganic glass fibers are much more uniform in diameter and much smaller than cellulose fibers as seen in the images to the right (Figures 2 and 3).

The illustrated elements on the following pages provide a visual representation of the efficiencies of both a cellulose and glass element at their respective efficiency ratings.

The cellulose element would typically achieve a code no better than 22/20/17. Runaway contamination levels at $4\mu_{[c]}$ and $6\mu_{[c]}$ are very common when cellulose media is applied in which a high population of fine particles exponentially generate more particles in a chain reaction of internally generated contaminants. The illustrated glass element would typically deliver an ISO Fluid Cleanliness Code of 18/15/8 to 15/13/9 or better depending upon the system conditions and ingression rate.

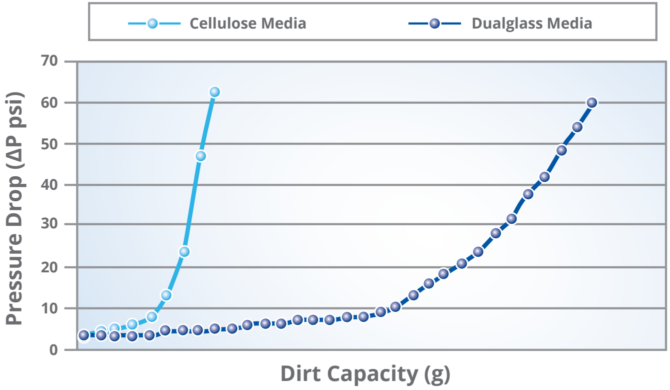
Upgrading from Cellulose to Glass

Upgrading to Hy-Pro G8 Dualglass

When upgrading to an absolute efficiency glass media element, the system cleanliness must be stabilized. During this clean-up period, the glass element halts the runaway contamination as the ISO cleanliness codes are brought into the target cleanliness range. As the glass element removes years of accumulated fine particles, the element life might be temporarily short.

Once the system is clean the glass element can last up to 4-5 times longer than the cellulose element that was upgraded as shown in Figure 4.

Figure 4: Element Lifespan



Cellulose: $\beta 10\mu_{[C]} = 2$

$$= \frac{50,000 \text{ Particles In}}{25,000 \text{ Particles Out}}$$

Dirt in

50,000 particles $10\mu_{[c]}$ or larger

Dirt out

25,000 particles $10\mu_{[c]}$ or larger

50%
efficiency

Glass: $\beta 10\mu_{[C]} = 4000$

$$= \frac{50,000 \text{ Particles In}}{50 \text{ Particles Out}}$$

Dirt in

50,000 particles $10\mu_{[c]}$ or larger

Dirt out

50 particles $10\mu_{[c]}$ or larger

99.9%
efficiency

HY-PRO

CUT DIRT,
CUT COSTS

Contamination Calculator Mobile App

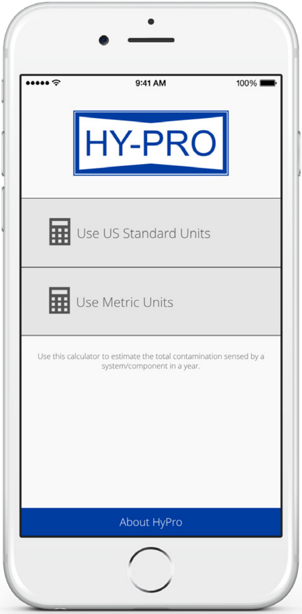
Available on the App Store and on Google Play™

Calculate the amount of contamination that passes through your hydraulic components and bearings annually with the Hy-Pro Filtration Contamination Tool.

Just enter current and target ISO Fluid Cleanliness Codes, flow rate and daily operating hours to understand the impact of dirty vs. clean oil. Raise awareness, improve reliability, and save money by minimizing component repair and replacement costs while extending useful fluid life. Put Hy-Pro on your lube team and let us help you set a target and implement strategies to achieve and maintain your fluid cleanliness goals.

Download on the App Store

ANDROID APP ON Google play

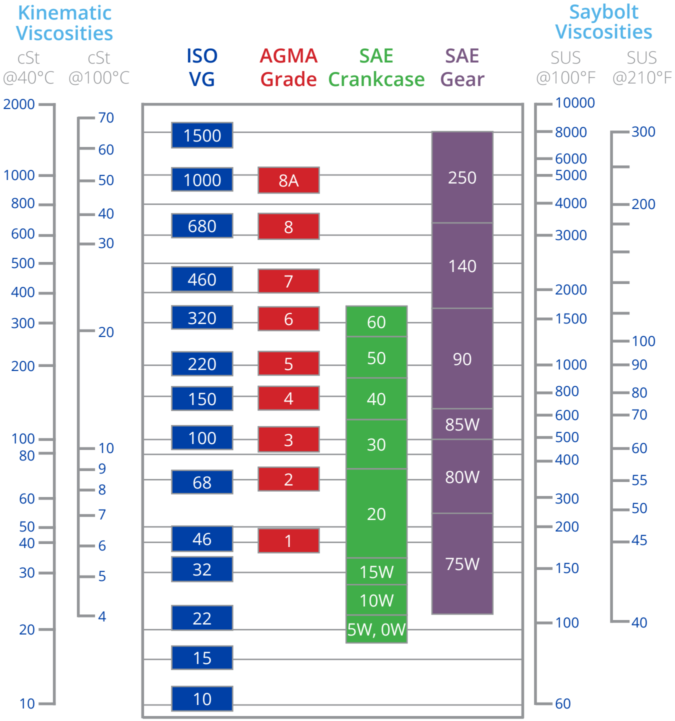


Use this calculator to estimate the total contamination sensed by a system/component in a year.

Viscosity Reference Chart

Viscosity Scale Chart

The chart below provides a quick reference for converting between the four major measures of viscosity. To determine equivalents, draw a horizontal line straight across the page at your known viscosity. All other columns that intersect the line represent equivalents.

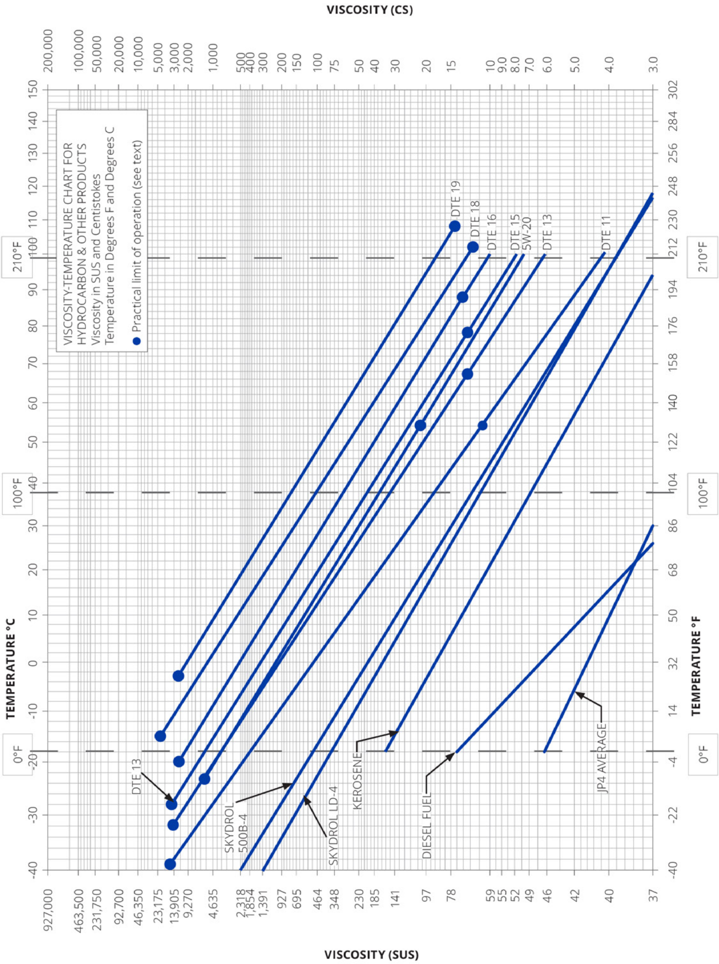


ISO/Temperature Reference

The table below gives viscosity values in cSt for known ISO VG fluids at specified temperatures using the Kinematic midpoint of each classification according to ISO 3448. Values given below are an approximation subject to variation ±10% from the midpoint value used in the calculations and are intended to be used as a reference. For exact value ranges, contact your fluid manufacturer.

To determine viscosity, locate your fluid ISO VG across the top, locate your target/specified temperature in the two left hand columns, and the cell in which the respective column and row intersect is the approximate viscosity value.

Temp °F	Temp °C	ISO 22	ISO 32	ISO 46	ISO 68	ISO 100	ISO 150	ISO 220	ISO 320	ISO 460	ISO 680	ISO 1000	ISO 1500
14	**-10**	315	610	1,130	2,285	4,493	9,277	18,565	36,300	69,775	141,088	283,473	593,291
23	**-5**	218	405	724	1,401	2,646	5,225	10,013	18,790	34,687	67,151	129,188	258,112
32	**0**	155	278	481	893	1,625	3,081	5,672	10,249	18,228	33,901	62,665	119,962
41	**5**	113	196	330	590	1,037	1,893	3,359	5,861	10,072	18,052	32,160	59,188
50	**10**	85	142	233	402	685	1,207	2,071	3,498	5,825	10,088	17,371	30,828
59	**15**	65	106	168	282	467	797	1,324	2,171	3,510	5,890	9,828	16,865
68	**20**	51	80	125	203	327	542	875	1,396	2,196	3,579	5,800	9,648
77	**25**	40	62	95	150	235	379	596	927	1,422	2,255	3,557	5,748
86	**30**	32	49	73	113	173	272	417	633	950	1,468	2,259	3,554
95	**35**	27	39	58	87	130	200	300	445	652	986	1,481	2,274
104	**40**	22	32	46	68	100	150	220	320	460	680	1,000	1,500
113	**45**	19	26	37	54	78	115	165	235	332	481	694	1,018
122	**50**	16	22	31	44	62	89	126	177	245	348	493	709
131	**55**	13	19	26	36	50	71	98	135	185	258	358	506
140	**60**	12	16	22	30	41	57	78	105	142	194	266	369
149	**65**	10	14	18	25	34	46	62	83	110	149	201	275
158	**70**	9	12	16	21	28	38	51	67	87	117	155	208
167	**75**	8	10	14	18	24	32	42	54	70	92	121	161
176	**80**	7	9	12	16	20	27	35	45	57	74	96	126
185	**85**	6	8	11	14	18	23	29	37	47	60	77	100
194	**90**	6	7	9	12	15	120	25	31	39	50	63	81
203	**95**	5	7	8	11	13	17	21	27	33	42	52	66
212	**100**	5	6	7	9	12	15	18	23	28	35	43	54
221	**105**	4	5	7	8	10	13	16	20	24	30	37	45
230	**110**	4	5	6	8	9	12	14	17	21	25	31	38
239	**115**	4	5	6	7	8	10	12	15	18	22	27	32
248	**120**	3	4	5	6	8	9	11	13	16	19	23	28
257	**125**	3	4	5	6	7	8	10	12	14	17	20	24
266	**130**	3	4	4	5	6	8	9	11	12	15	18	21
275	**135**	3	3	4	5	6	7	8	10	11	13	15	18
284	**140**	3	3	4	4	5	6	7	9	10	12	14	16
293	**145**	2	3	3	4	5	6	7	8	9	11	12	14
302	**150**	2	3	3	4	4	5	6	7	8	10	11	13


VISCOSITY (CS)
200,000
100,000
50,000
20,000
10,000
5,000
3,000
2,000
1,000
500
400
300
200
150
100
75
50
40
30
20
15
10
9.0
8.0
7.0
6.0
5.0
4.0
3.0
TEMPERATURE °C
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
TEMPERATURE °F
302
284
256
248
230
212
194
176
158
140
122
104
86
68
50
32
14
-4
-22
-40
210°F
100°F
0°F
VISCOSITY-TEMPERATURE CHART FOR
HYDROCARBON & OTHER PRODUCTS
Viscosity in SUS and Centistokes
Temperature in Degrees F and Degrees C
● Practical limit of operation (see text)
DTE 19
DTE 18
DTE 16
DTE 15
5W-20
DTE 13
DTE 11
DTE 13
SKYDROL 500B-4
SKYDROL LD-4
KEROSENE
DIESEL FUEL
JP4 AVERAGE
VISCOSITY (SUS)
927,000
463,500
231,750
92,700
46,350
23,175
13,905
9,270
4,635
2,318
1,854
1,391
927
695
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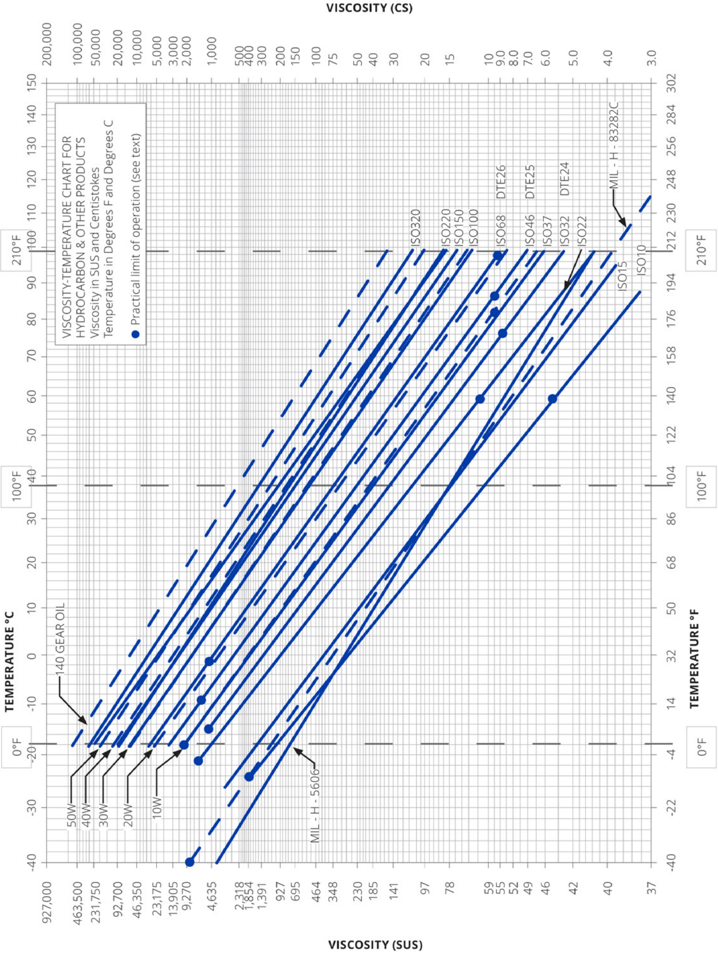
141
97
78
59
55
52
49
46
42
40
37


VISCOSITY (CS)
200,000
100,000
50,000
20,000
10,000
5,000
3,000
2,000
1,000
500
400
300
200
150
100
75
50
40
30
20
15
10
9.0
8.0
7.0
6.0
5.0
4.0
3.0
TEMPERATURE °C
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
VISCOSITY-TEMPERATURE CHART FOR
HYDROCARBON & OTHER PRODUCTS
Viscosity in SUS and Centistokes
Temperature in Degrees F and Degrees C
● Practical limit of operation (see text)
210°F
100°F
0°F
140 GEAR OIL
50W
40W
30W
20W
10W
MIL - H - 5606
ISO320
ISO220
ISO150
ISO100
ISO68
ISO46
ISO37
ISO32
ISO22
ISO15
ISO10
DTE26
DTE25
DTE24
MIL - H - 83282C
TEMPERATURE °F
302
284
256
248
230
212
194
176
158
140
122
104
86
68
50
32
14
-4
-22
-40
927,000
463,500
231,750
92,700
46,350
23,175
13,905
9,270
4,635
2,318
1,854
1,391
927
695
464
348
230
185
141
97
78
59
55
52
49
46
42
40
37
VISCOSITY (SUS)

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The world's largest selection of critical filter elements.

With over 250,000 filter element crosses, Hy-Pro's Interchange offers the most extensive and comprehensive selection of critical hydraulic and lube oil filter elements anywhere. And it's only growing larger. Each year, we catalog thousands of filter elements in our efforts to provide our customers with the best contamination solutions, service and support possible.

ISO Certification

ASR

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REGISTRAR
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Wyoming, MI 49509 USA
www.asrworldwide.com
616-942-6273

ANAB
ANSI National Accreditation Board
ACCREDITED
MANAGEMENT SYSTEMS
CERTIFICATION BODY

American Systems Registrar, LLC, a provider of third-party system registration and accredited by the ANSI National Accreditation Board attests that:

HY-PRO CORPORATION
6810 LAYTON ROAD
ANDERSON, IN 46011

with a scope of:

DESIGN AND MANUFACTURE OF FLUID FILTRATION COMPONENTS AND SYSTEMS

has established a quality management system that is in conformance with the International Quality System Standard

ISO 9001:2015

ASR Certificate Number:	**1459**
Date of Certification:	**July 17, 2021**
Date of Certification Expiration:	**July 16, 2024**
Revision:	
Re-Issue Date:	

President

CERTIFICATE OF REGISTRATION

Want to find out more? Get in touch.

hyprofiltration.com
info@hyprofiltration.com
+1 317 849 3535

CUT DIRT, CUT COSTS

HY-PRO