



CONTAMINATION CONTROL

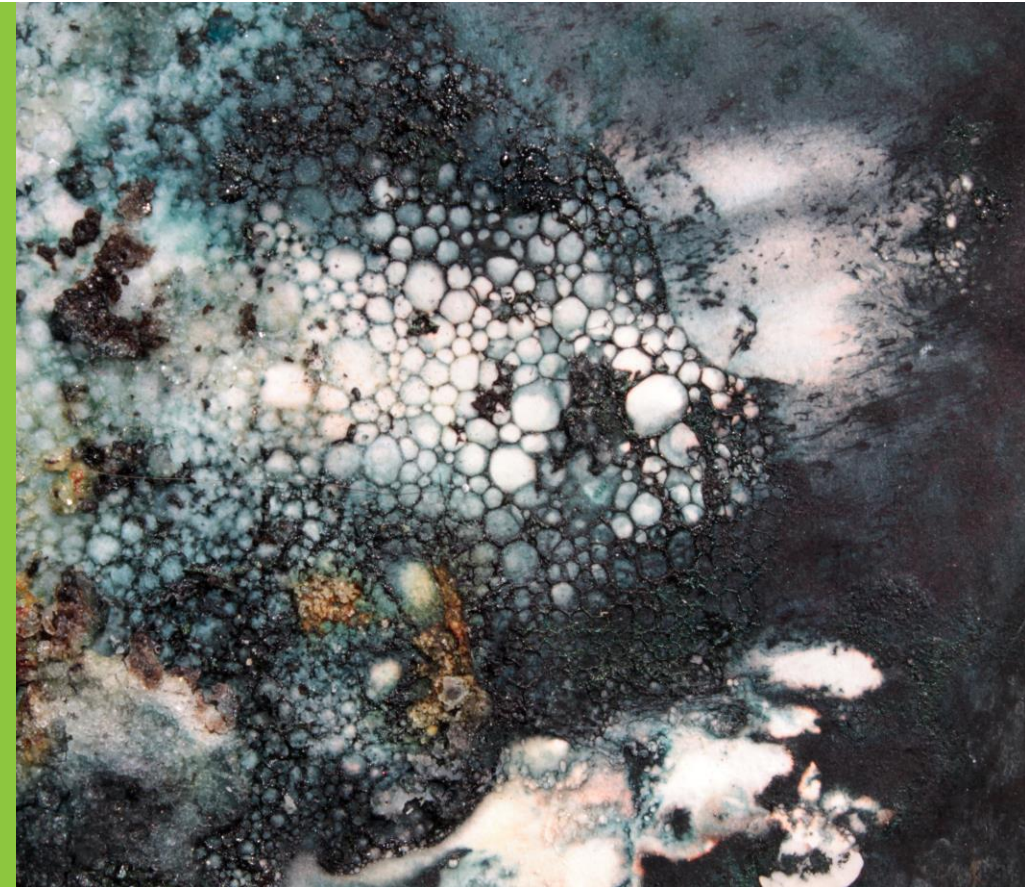
AGENDA

- 1 What is contamination
- 2 Sources of Contamination
- 3 Contaminants and their effects
- 4 Benefits of Contamination control

I What is contamination?

Contamination

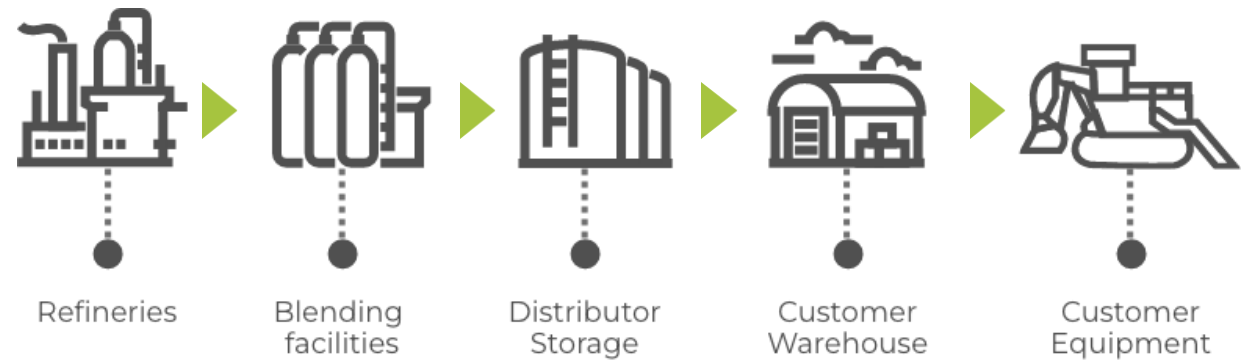
- Any material in the lubricant or fuel that may cause harm to equipment or affect the its performance negatively
- Contamination may be particulate matter (solids) or liquids (such as water), present in the fuel of lubricant but are not part of the formulation of the same.



Sources of contamination

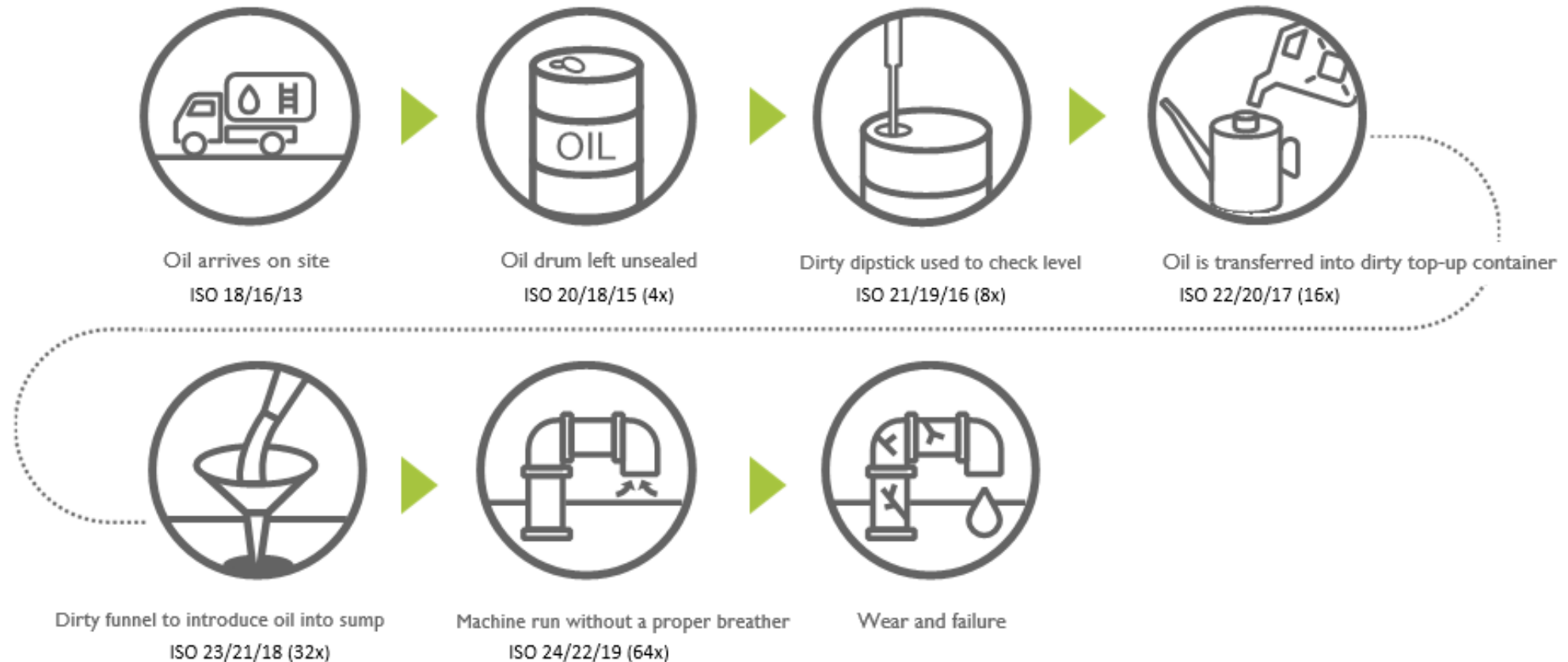
Main sources of contamination

1. Contamination during production
2. Contamination during transportation, storage.
3. Contamination during application and dispensing
4. Contamination while the lubricant is in use (internally generated)



How lube oil contamination happens prior to use

Contamination control is everyone's responsibility



Contamination during production

Production contamination

- From pipes, hoses and storage tanks during production
- Water condensation in holding tanks
- Different lubricants are also produced using the same vessels. If proper blending procedures are not in place or followed, cross-contamination may occur



Contamination during transportation and storage

Bulk Lubricants

- Moisture and particulate matter.
- Changes in Oil level in the tank during drawing or filling causes the tank to “breathe”

Packed Lubricants

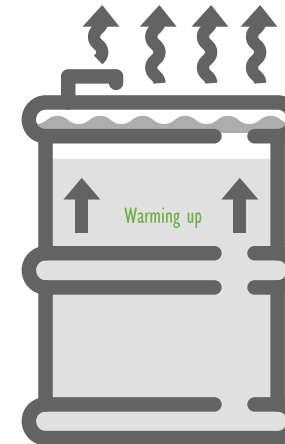
- Moisture ingress as the drums “breathe”.
- Water ingress if the drums are stored in an improper manner
- Some lubricants like greases and Transformer oils must be kept under roof

When the drum is placed in the elements rain can settle on top of the drum



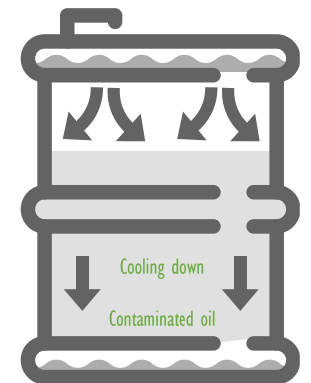
When the surrounding temp rises, the oil expands and air in the drum escapes

Air escapes from internal pressure buildup



When the oil and surrounding temp cool down, any water on the top of the drum can be drawn into the drum leading to contamination.

Powerful suction from internal pressure reducing



Contamination during application



Contamination during application

Improper handling of the lubricants at the point of application may introduce particulate contamination

- Improper and inadequate lubes dispensing equipment
- Human factors
 - Lube lids left open
 - Dirty tools being used to dispense the lubricants
 - Lack of knowledge in the lubricants and application
 - Improper drainage during changeover
 - Improper flushing procedure
- Communication between different chambers with different lubricants due to seal failure

Contamination while the Lubricant is in service

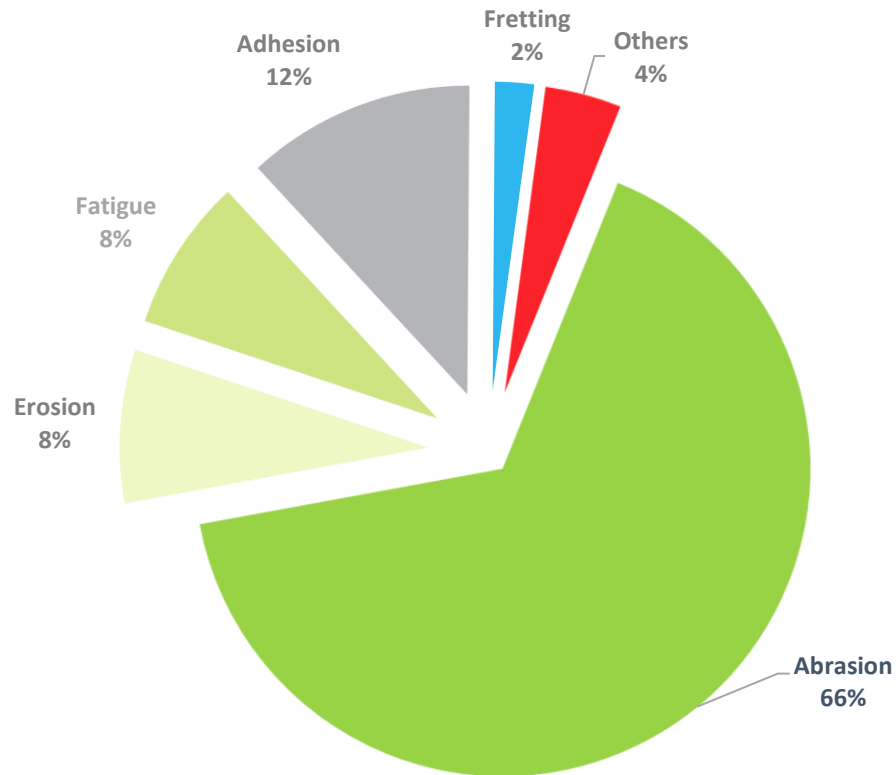
Internally generated contamination

- Wear debris
- Soot contamination in diesel engine oils
- Dust and moisture ingress through breathers
- Moisture condensation in reservoirs
- Hydraulic cylinders and rods in operation.

Desiccant filter breathers installed on an industrial gearbox to prevent dust and moisture ingress into the gearbox oil.



Contaminants and their effect



TYPES OF SURFACE DEGRADATION

- The most common contaminants are particulate matter and water
- Over 80% of mechanical wear can be attributed to particulate contaminants in the oil.
- Some particulate contaminants are chemically active also impact the performance of the lubricant by negatively altering some properties such as resistance to foaming and air release
- Water may also change the physical and chemical properties of lubricants

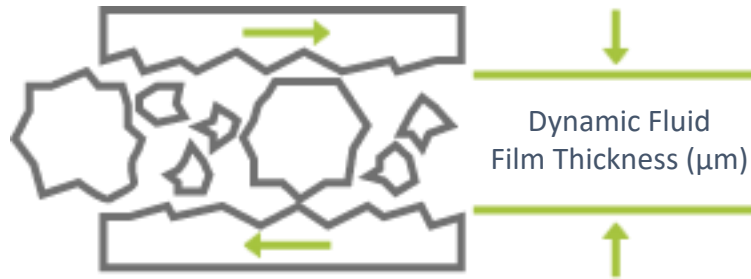
Particulate contamination

- Various studies have pointed out that 70% of component replacements or 'loss of usefulness' is due to surface degradation.
- In hydraulic and lubricating systems, 20% of these replacements result from corrosion, and the remaining 50% results from mechanical wear.
- Particulate matter in lubricants are the key contributors to abrasion, erosion, and fatigue failures.

Particulate contamination in oils is monitored through fluid cleanliness. The most common measure of cleanliness is the ISO 4406 numeric code, XX/YY/ZZ, which represents the allowable levels of different sized particles in the oil.



Dynamic oil film



| Dynamic oil film | |
|--|--|
| Component | Oil film thickness in micron (μm) |
| Journal, slide and sleeve bearings | 0.5 - 100 |
| Hydraulic cylinders | 5 - 50 |
| Engines, ring/cylinder | 0.3 - 7 |
| Servo and proportional valves | 1-2 |
| Gear pumps | 0.5 - 5 |
| Piston pumps | 0.5 - 5 |
| Rolling element bearings / ball bearings | 0.1 - 3 |
| Gears | 0.1 - 1 |
| Dynamic seals | 0.05 - 0.5 |

Figure 2: Dynamic oil film | Source: Noria Corporation

- Large particles can't enter the working clearance, but can block ports, orifices and jam moving parts.
- Very small particles pass through the clearance and can cause erosive wear..
- Clearance-sized particles cause the highest risk.
- They cause abrasive wear and surface fatigue reducing component life.
- It is important to know the most vulnerable component in the system.
 - Use it to set the cleanliness requirement of the lubricant or hydraulic fluid.

To prolong component life clearance-size and particles must be removed from the system.

ISO 4406 fluid cleanliness coding

How can we measure how much particle contamination is in an oil?

Particle contamination is measured using the ISO 4406 (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 | | Range Number |
|--------------------------|-----------------------|--------------|
| More Than | Less Than or Equal To | |
| 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 |
| 5 | 10 | 10 |

R4/R6/R14
ISO 18/16/13

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

Particles > 4 micron
Particles > 6 micron
Particles > 14 micron

Fluid (oil) cleanliness

- The measure of particulate contaminants in the oil.
- Most Original Equipment Manufacturers OEMs now specify the acceptable level of oil cleanliness for their equipment/components.
- Where OEMs have not indicated any cleanliness level, then industry best practice may be adopted
- Where a customer has mixed OEM fleet, the most stringent cleanliness level requirement may be adopted for the entire fleet for the same application.
- Different components have different typical cleanliness requirements based on the internal clearances of their internal components.

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 μ m from 1000/ml to 100/ml resulted in a 5-fold increase

Charts have been developed by different OEMs and Institutions to demonstrate the effect of fluid (oil) cleanliness on component life.

CLEAN FLUID IS GOOD FOR BUSINESS



Component life extension by reducing moisture

| | | New Moisture Level (ppm) | | | | | | | | | | | | | | | |
|------------------------|--------|--------------------------|---------|-----------------|---------|-----------------|---------|-----------------|---------|-----------------|---------|-----------------|---------|-----------------|---------|-----------------|---------|
| | | 10,000 | | 5,000 | | 2,500 | | 1000 | | 500 | | 250 | | 100 | | 50 | |
| | | Rolling Element | Journal | Rolling Element | Journal | Rolling Element | Journal | Rolling Element | Journal | Rolling Element | Journal | Rolling Element | Journal | Rolling Element | Journal | Rolling Element | Journal |
| Current Moisture Level | 50,000 | 2.3 | 1.6 | 3.3 | 1.9 | 4.8 | 2.3 | 7.8 | 2.9 | 11.2 | 3.5 | 16.2 | 4.3 | 26.2 | 5.5 | 37.8 | 6.7 |
| | 25,000 | 1.6 | 1.3 | 2.3 | 1.6 | 3.3 | 1.9 | 5.4 | 2.4 | 7.8 | 2.9 | 11.2 | 3.5 | 18.2 | 4.6 | 26.2 | 5.5 |
| | 10,000 | | | 1.4 | 1.2 | 2.0 | 1.5 | 3.3 | 1.9 | 4.8 | 2.3 | 6.9 | 2.8 | 11.2 | 3.5 | 16.2 | 4.3 |
| | 5,000 | | | | | 1.4 | 1.2 | 2.3 | 1.6 | 3.3 | 1.9 | 4.8 | 2.3 | 7.8 | 2.9 | 11.2 | 3.5 |
| | 2,500 | | | | | | | 1.6 | 1.3 | 2.3 | 1.6 | 3.3 | 1.9 | 5.4 | 2.4 | 7.8 | 2.9 |
| | 1000 | | | | | | | | | 1.4 | 1.2 | 2.0 | 1.5 | 3.3 | 1.9 | 4.8 | 2.3 |
| | 500 | | | | | | | | | | | 1.4 | 1.2 | 2.3 | 1.6 | 3.3 | 1.9 |
| | 250 | | | | | | | | | | | | | 1.5 | 1.3 | 2.3 | 1.6 |
| | 100 | | | | | | | | | | | | | | | 1.4 | 1.2 |

Source: Noria Corporation

Fluid cleanliness impact on hydraulic system component life

| Final | */20/17 | */19/16 | */18/15 | */17/14 | */16/13 | */15/12 | */14/11 |
|---------|---------|---------|---------|---------|---------|---------|---------|
| Initial | | | | | | | |
| */26/23 | X 5 | X 7 | X 9 | X >10 | X >10 | X >10 | X >10 |
| */24/21 | X 3 | X 4 | X6 | X 7 | X9 | X >10 | X >10 |
| */22/19 | X 1.6 | X 2 | X 3 | X 4 | X 5 | X 7 | X 8 |
| */20/17 | -- | X 1.3 | X 1.6 | X 2 | X 3 | X 4 | X 5 |
| */19/16 | -- | -- | X 1.3 | X 1.6 | X 2 | X 3 | X 4 |

Potential useful life extension of hydraulics based on improving the lubricant cleanliness from the initial to the final cleanliness codes. (Source: Noria Corporation)

Caterpillar fluid cleanliness recommendation

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SEBU6251

Contamination Control
Contamination Control

Table 46

| ISO 4406 Code | Number of particles in 1 milliliter of fluid | | |
|----------------|--|-------------|-------------|
| | 4µm and up | 6µm and up | 14µm and up |
| "ISO 18/16/13" | 1300 - 2500 | 320 - 640 | 40 - 80 |
| "ISO 21/19/17" | 10000 - 20000 | 2500 - 5000 | 80 - 160 |

Note: Several factors affect the results of particle counts. The factors include the cleanliness of the equipment used to obtain the sample, sample techniques, the cleanliness, and type of sample container, particle counter accuracy (calibration, maintenance, and process), and the environment where the sample is procured. Samples should be taken at representative locations in the fluid circulation system or the fluid distribution system when possible. The sample should be protected adequately from contamination during transport to the lab for analysis.

In addition, particle counters may count water droplets and air bubbles as particulate contamination.

Note: American Society for Testing and Measurement has developed "ASTM D7619" Standard Test Method for Sizing and Counting Particles in Light and Middle Distillate Fuels, by Automatic Particle Counter". This test procedure was developed in 2010 to count and measure the size of dispersed dirt particles, water droplets, and other particles in 1-D and 2-D diesel

Table 47

| Cat Recommended Fluid Cleanliness Targets ⁽¹⁾ | | |
|--|---|--------------|
| Cat Recommended Cleanliness Targets for Fluids Dispensed into Machine or Engine Fill tanks | Fill oils ⁽²⁾⁽³⁾ | ISO -/16/13 |
| | Dispensed fuels | ISO 18/16/13 |
| | Dispensed DEF | ISO 18/16/13 |
| Cat Recommended Machine Roll-off Cleanliness Targets | Hydraulic systems (Implement & Steering) | ISO -/18/15 |
| | Electronic Transmissions | ISO -/18/15 |
| | Mechanical Transmissions | ISO -/21/17 |
| | Differentials, Wheels, and Axles ⁽⁴⁾ | ISO -/18/15 |

⁽¹⁾ The fluids should meet or exceed the cleanliness requirements of the listed ISO levels.

⁽²⁾ For engine oils, when filtering the oil prior to dispensing into the engine tank, use engine oil filters of 12 micron absolute efficiency and ensure that the oil temperature is 20° C (68° F) or

OEM & Industry Fuel Cleanliness requirement

| Organization | Particulate ISO 4406 | Water |
|------------------------|--|---|
| Bosch | 12/9/6 at injector | <200 ppm |
| CAT | 18/16/13 at storage | <200 ppm |
| Cummins | 18/16/13 at storage 15/13/10 at vehicle tank 12/9/6 at injector | <200 ppm |
| Worldwide Fuel Charter | 18/16/13 at storage | No free, emulsified or dissolved <200 ppm |
| Sector Mining Trends | 16/14/12 at storage | <200 ppm |

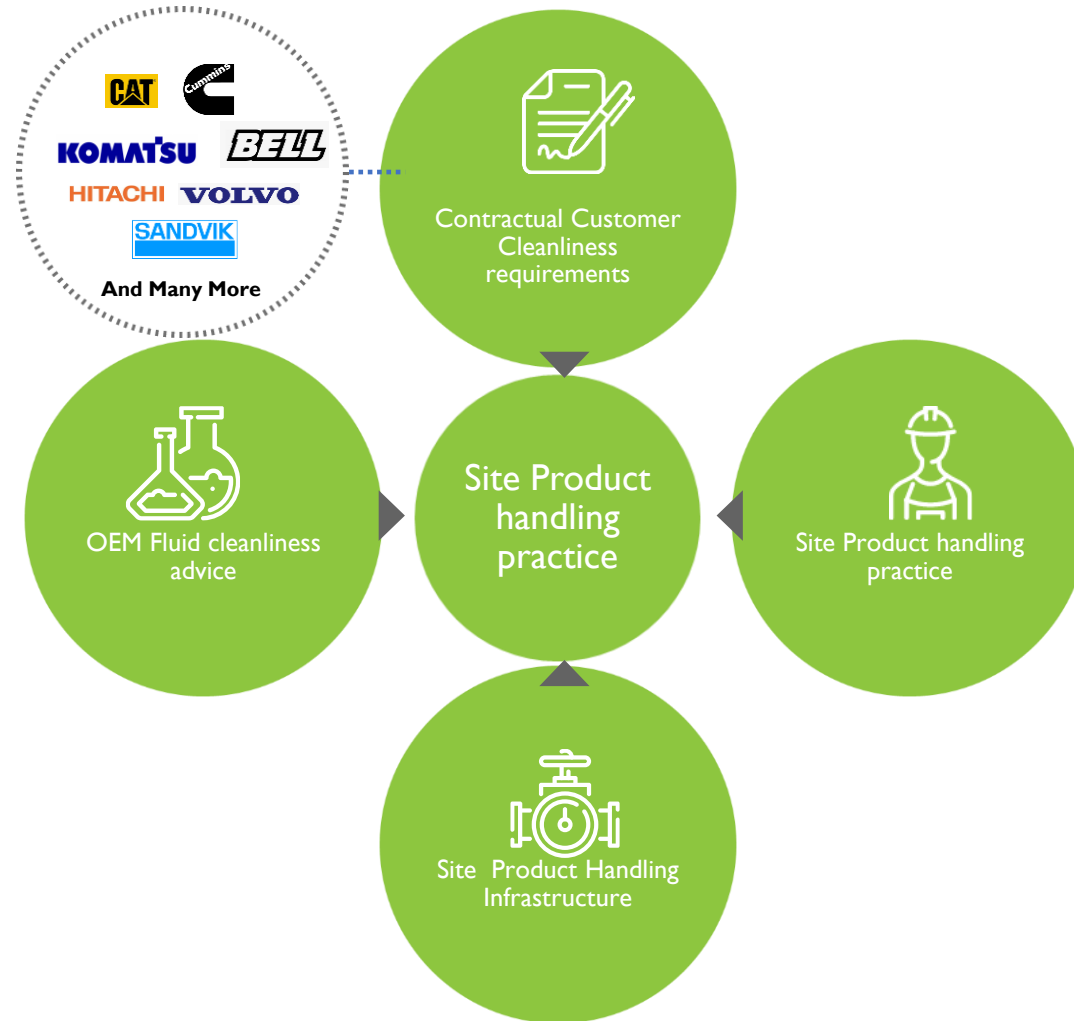
Determination of appropriate filtration medium

| Example Selection Chart for Target ISO Cleanliness Codes | | | | | | |
|--|-----------|--------------------------|----------|--------------------------|-----------|--------------------------|
| Components | Pressure | Media | Pressure | Media | Pressure | Media |
| | <140 bar | $\beta_x(c) = 1000$ | 212 bar | $\beta_x(c) = 1000$ | >212 bar | $\beta_x(c) = 1000$ |
| | <2000 psi | ($\beta_x = 2000$) | 3000 psi | ($\beta_x = 2000$) | >3000 psi | ($\beta_x = 2000$) |
| Valves | | | | | | |
| Cartridge | 18/16/13 | 12 μ [c] (12 μ) | 17/15/12 | 7 μ [c] (6 μ) | 17/15/12 | 7 μ [c] (6 μ) |
| Check valve | 20/18/15 | 22 μ [c] (25 μ) | 20/18/15 | 22 μ [c] (25 μ) | 19/17/14 | 12 μ [c] (12 μ) |
| Directional (solenoid) | 20/18/15 | 22 μ [c] (25 μ) | 19/17/14 | 12 μ [c] (12 μ) | 18/16/13 | 12 μ [c] (12 μ) |
| Flow control | 19/17/14 | 12 μ [c] (12 μ) | 18/16/13 | 12 μ [c] (12 μ) | 18/16/13 | 12 μ [c] (12 μ) |
| Pressure control modulationg | 19/17/14 | 12 μ [c] (12 μ) | 18/16/13 | 12 μ [c] (12 μ) | 17/15/12 | 7 μ [c] (6 μ) |
| Proportional Cartridge View | 17/15/12 | 7 μ [c] (6 μ) | 17/15/12 | 7 μ [c] (6 μ) | 16/14/11 | 5 μ [c] (3 μ) |
| Proportional Directional | 17/15/12 | 7 μ [c] (6 μ) | 17/15/12 | 7 μ [c] (6 μ) | 16/14/11 | 5 μ [c] (3 μ) |
| Proportional Flow Control | 17/15/12 | 7 μ [c] (6 μ) | 17/15/12 | 7 μ [c] (6 μ) | 16/14/11 | 5 μ [c] (3 μ) |
| Proportional Pressure Control | 17/15/12 | 7 μ [c] (6 μ) | 17/15/12 | 7 μ [c] (6 μ) | 16/14/11 | 5 μ [c] (3 μ) |
| Servo Valve | 16/14/11 | 7 μ [c] (6 μ) | 16/14/11 | 5 μ [c] (3 μ) | 15/13/10 | 5 μ [c] (3 μ) |
| | | | | | | |
| PUMPS | | | | | | |
| Fixed Gear | 20/18/15 | 22 μ [c] (25 μ) | 19/17/15 | 12 μ [c] (12 μ) | - | - |
| Fixed Position | 19/17/14 | 12 μ [c] (12 μ) | 18/16/13 | 12 μ [c] (12 μ) | 17/15/12 | 7 μ [c] (6 μ) |
| Fixed Vane | 20/18/15 | 22 μ [c] (25 μ) | 19/17/14 | 12 μ [c] (12 μ) | 18/16/13 | 12 μ [c] (12 μ) |
| Variable Piston | 18/16/13 | 7 μ [c] (6 μ) | 17/15/13 | 5 μ [c] (3 μ) | 16/14/12 | 7 μ [c] (6 μ) |

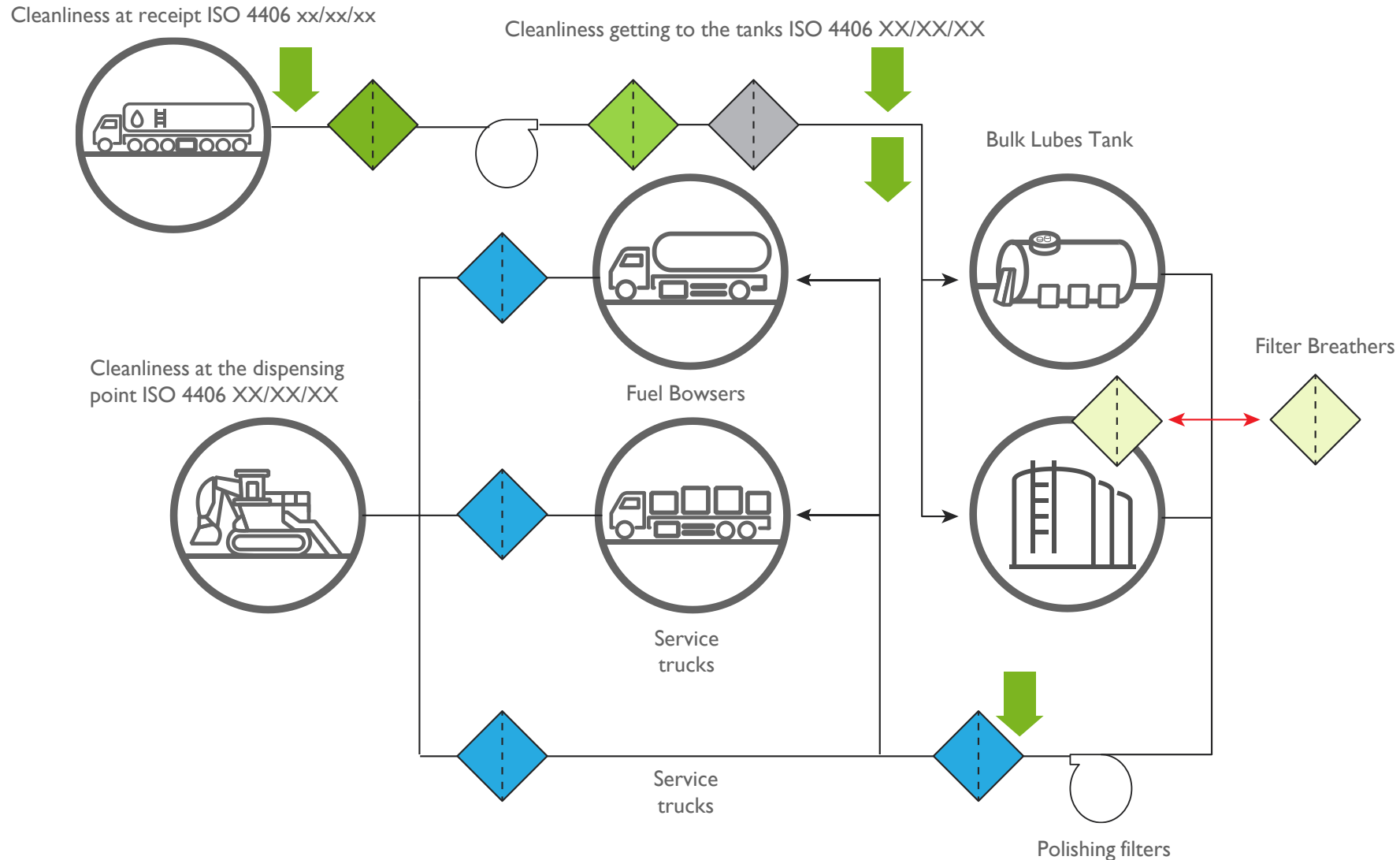
WHAT VIVO ENERGY WILL DO TO IMPROVE CONTAMINATION



Our approach to Contamination Control Implementation



Site Fluid cleanliness management Audit ISO 4406





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