CONTAMINATION CONTROL

AGENDA

1 What is contamination

2 Sources of Contamination

3 Contaminants and their effects

4 Benefits of Contamination control

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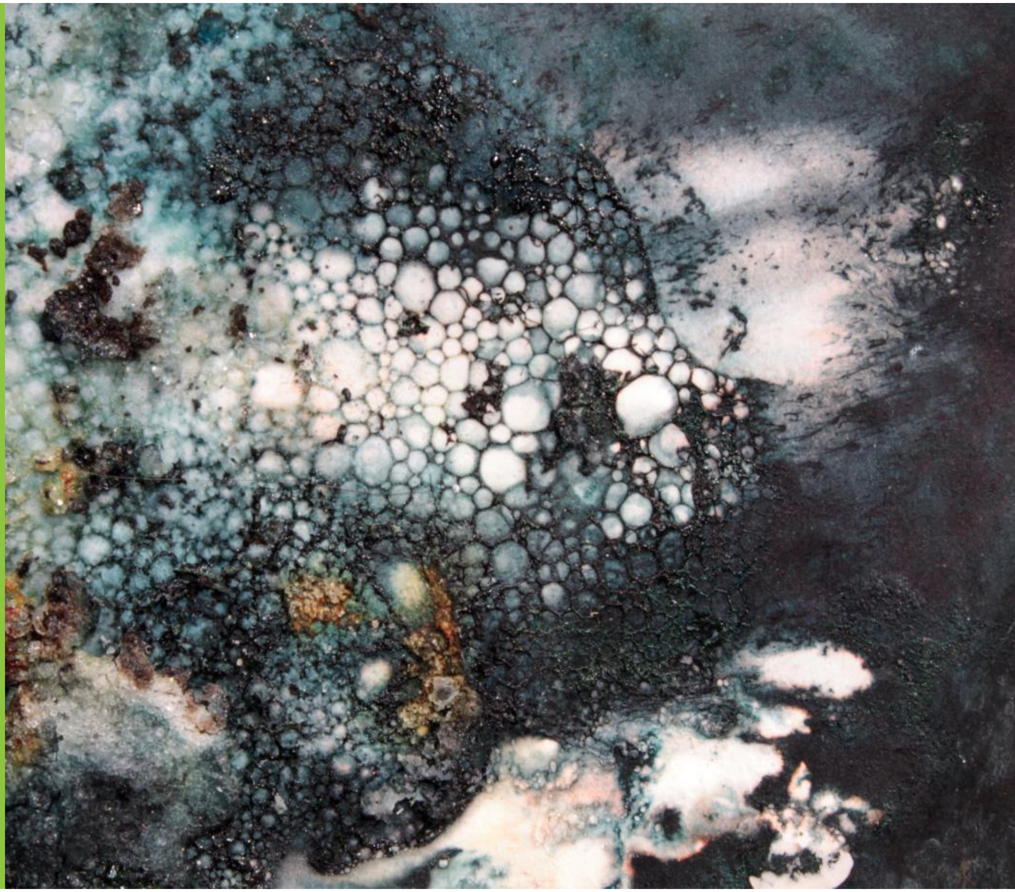
What is contamination?

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.



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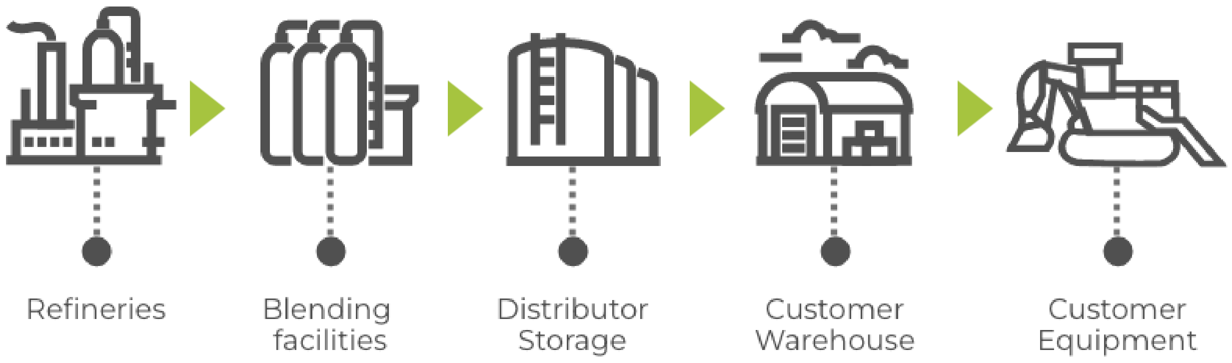
Sources of contamination

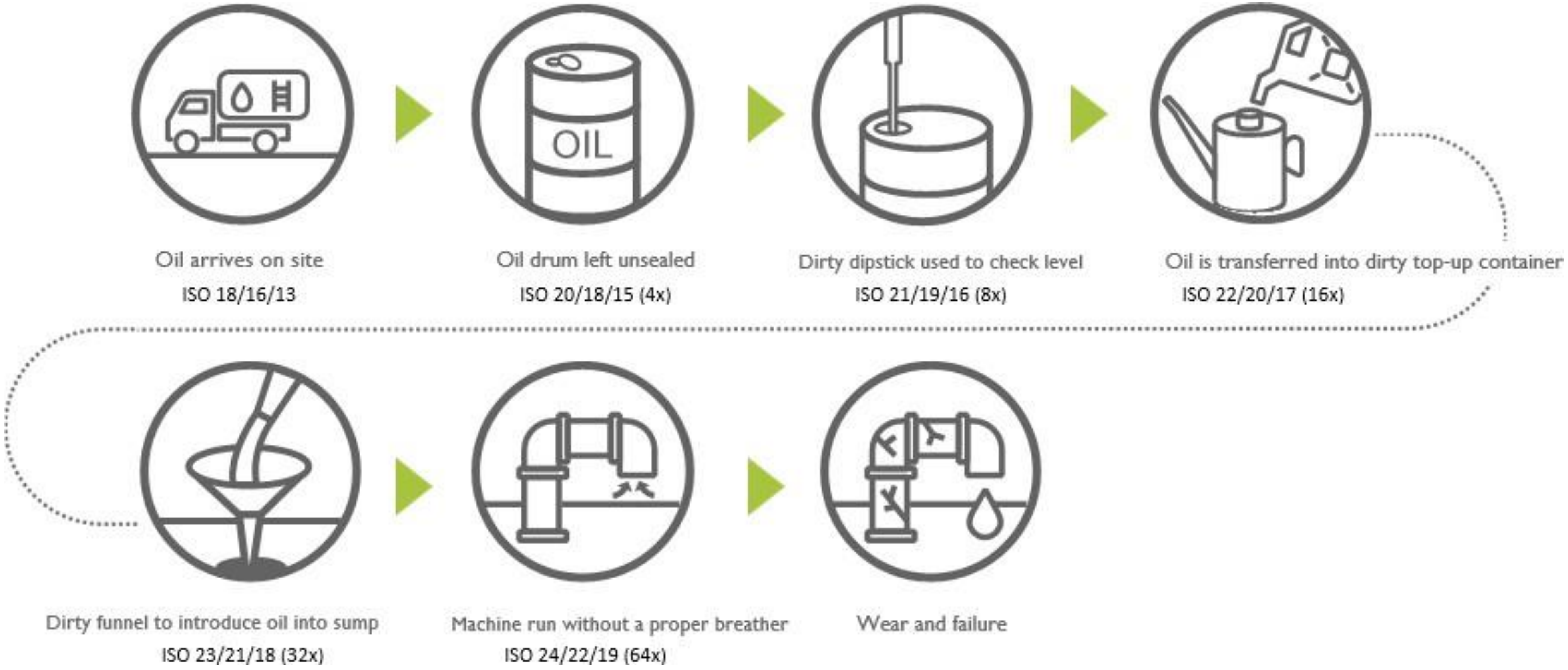
Main sources of contamination

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



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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

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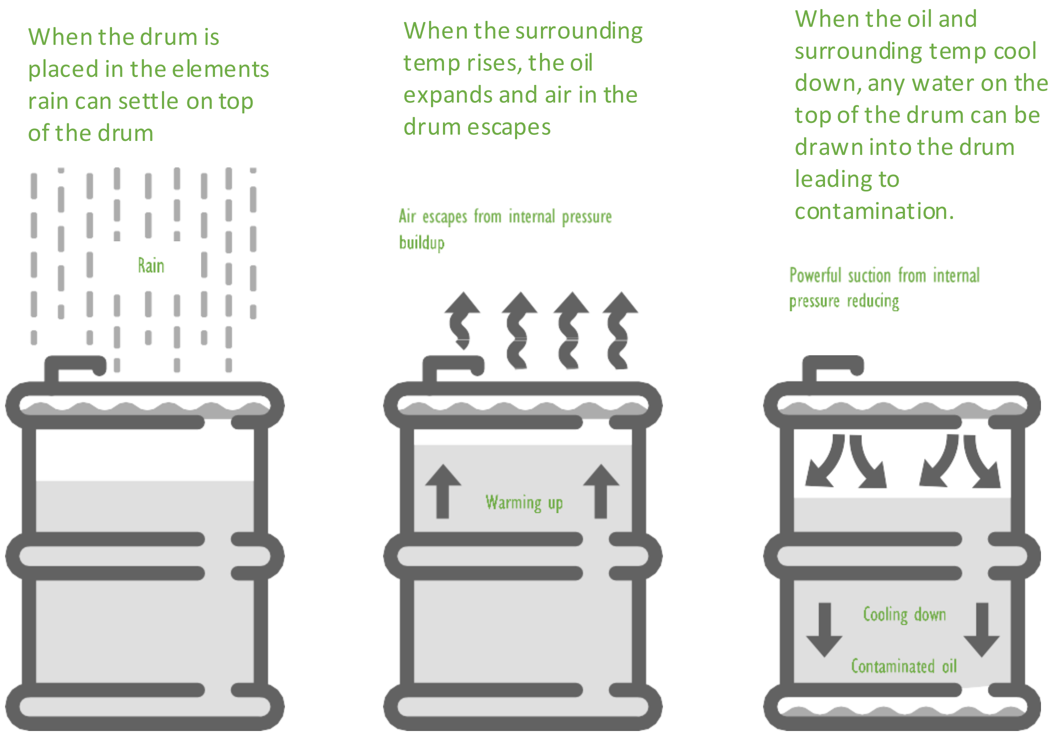
Contamination during transportation and storage

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



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

2

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.

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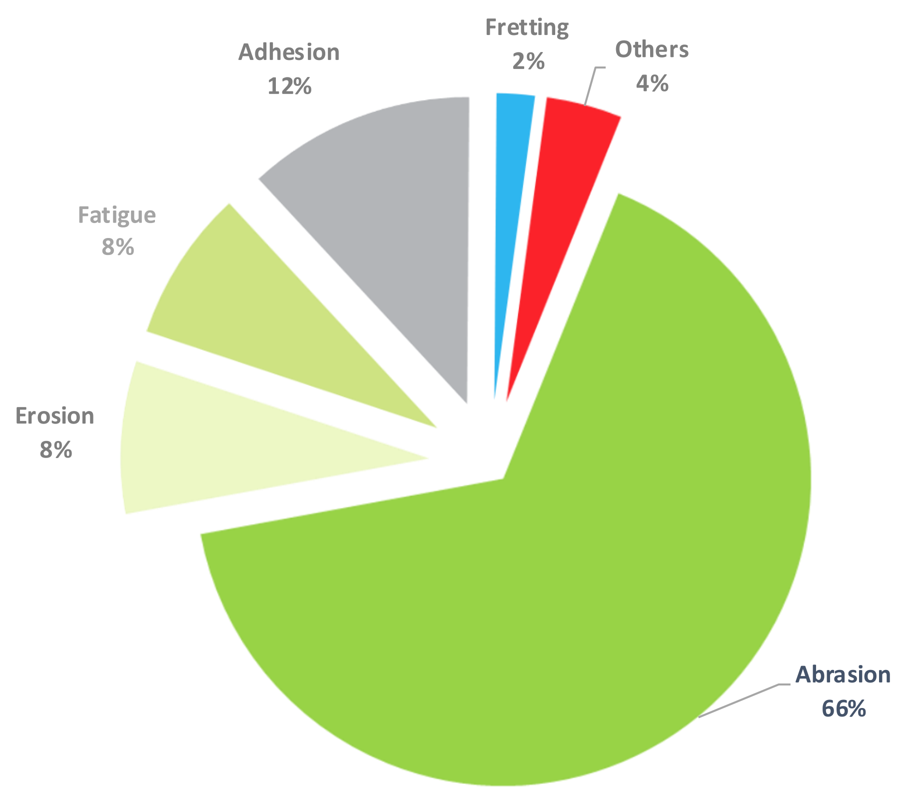
Contaminants and their effect



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

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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 venerable 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 10µm 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

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Component life extension by reducing moisture

New Moisture Level (ppm)

Current 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
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)

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Caterpillar fluid cleanliness recommendation

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

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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	(β_x = 2000)	3000 psi	(β_x = 2000)	>3000 psi	(β_x = 2000)
Valves						
Cartridge	18/16/13	12µ[c] (12µ)	17/15/12	7µ[c] (6µ)	17/15/12	7µ[c] (6µ)
Check valve	20/18/15	22µ[c] (25µ)	20/18/15	22µ[c] (25µ)	19/17/14	12µ[c] (12µ)
Directional (solenoid)	20/18/15	22µ[c] (25µ)	19/17/14	12µ[c] (12µ)	18/16/13	12µ[c] (12µ)
Flow control	19/17/14	12µ[c] (12µ)	18/16/13	12µ[c] (12µ)	18/16/13	12µ[c] (12µ)
Pressure control modulationg	19/17/14	12µ[c] (12µ)	18/16/13	12µ[c] (12µ)	17/15/12	7µ[c] (6µ)
Proportional Cartridge View	17/15/12	7µ[c] (6µ)	17/15/12	7µ[c] (6µ)	16/14/11	5µ[c] (3µ)
Proportional Directional	17/15/12	7µ[c] (6µ)	17/15/12	7µ[c] (6µ)	16/14/11	5µ[c] (3µ)
Proportional Flow Control	17/15/12	7µ[c] (6µ)	17/15/12	7µ[c] (6µ)	16/14/11	5µ[c] (3µ)
Proportional Pressure Control	17/15/12	7µ[c] (6µ)	17/15/12	7µ[c] (6µ)	16/14/11	5µ[c] (3µ)
Servo Valve	16/14/11	7µ[c] (6µ)	16/14/11	5µ[c] (3µ)	15/13/10	5µ[c] (3µ)
PUMPS						
Fixed Gear	20/18/15	22µ[c] (25µ)	19/17/15	12µ[c] (12µ)	-	-
Fixed Position	19/17/14	12µ[c] (12µ)	18/16/13	12µ[c] (12µ)	17/15/12	7µ[c] (6µ)
Fixed Vane	20/18/15	22µ[c] (25µ)	19/17/14	12µ[c] (12µ)	18/16/13	12µ[c] (12µ)
Variable Piston	18/16/13	7µ[c] (6µ)	17/15/13	5µ[c] (3µ)	16/14/12	7µ[c] (6µ)

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WHAT VIVO ENERGY WILL DO TO IMRPROVE CONTAMINATION

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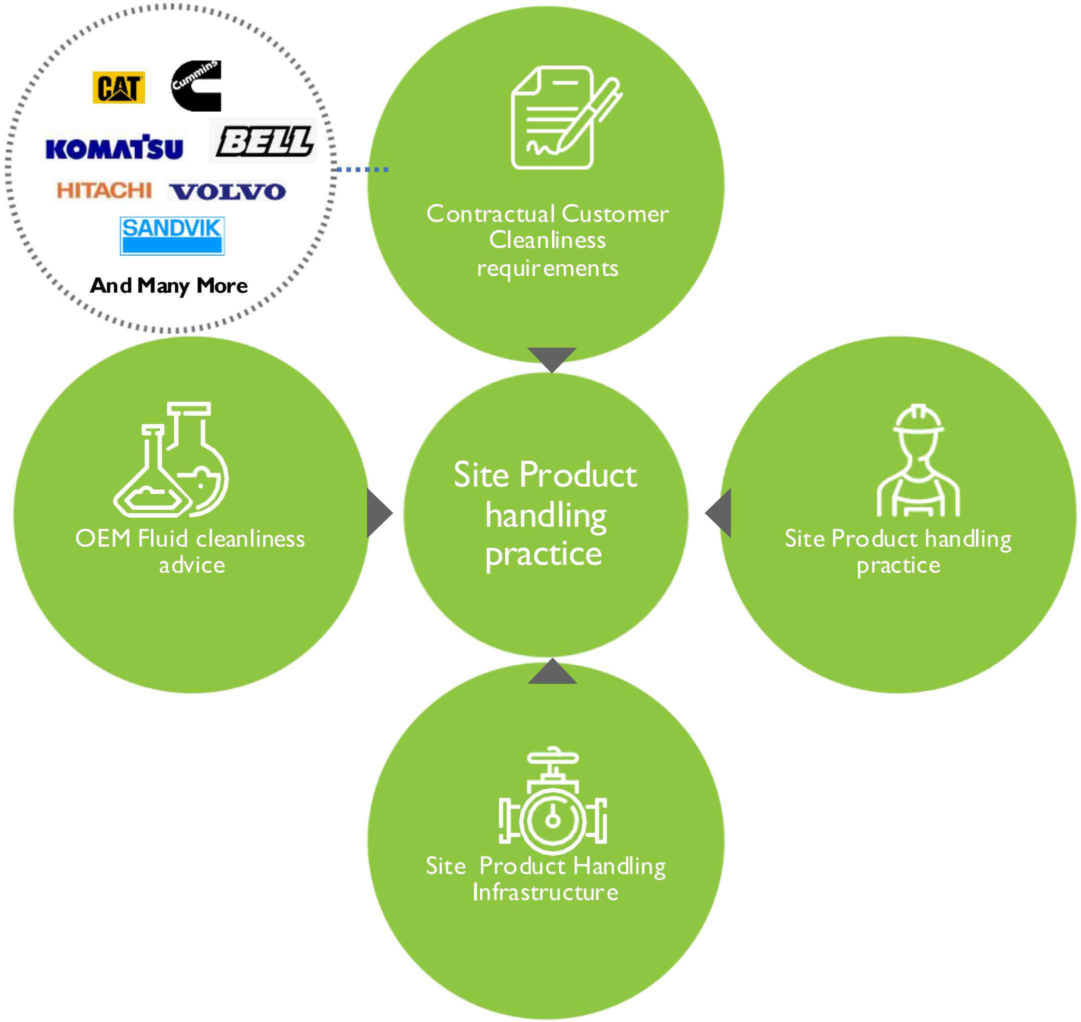
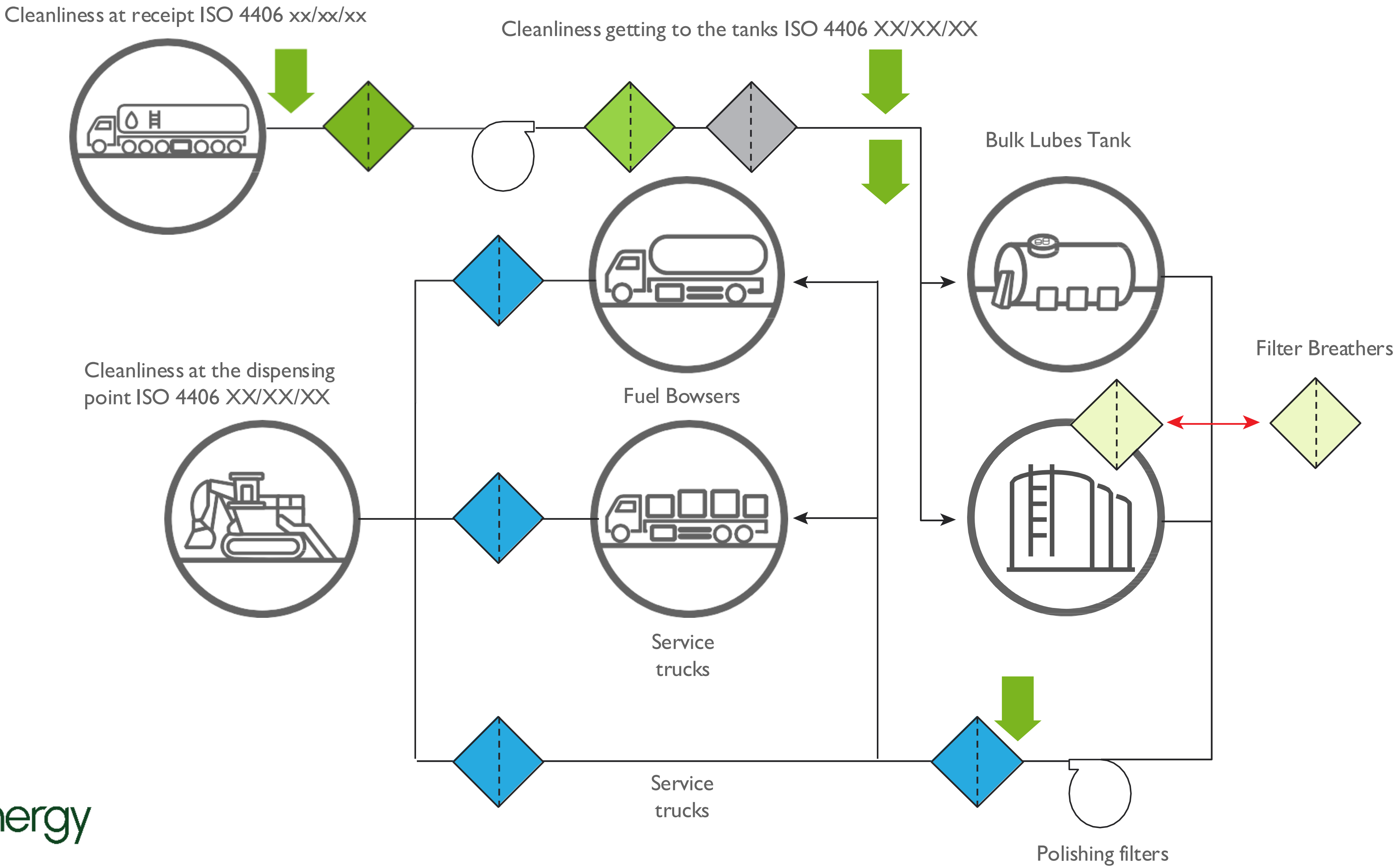
Our approach to Contamination Control Implementation



Site Fluid cleanliness management Audit ISO 4406



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