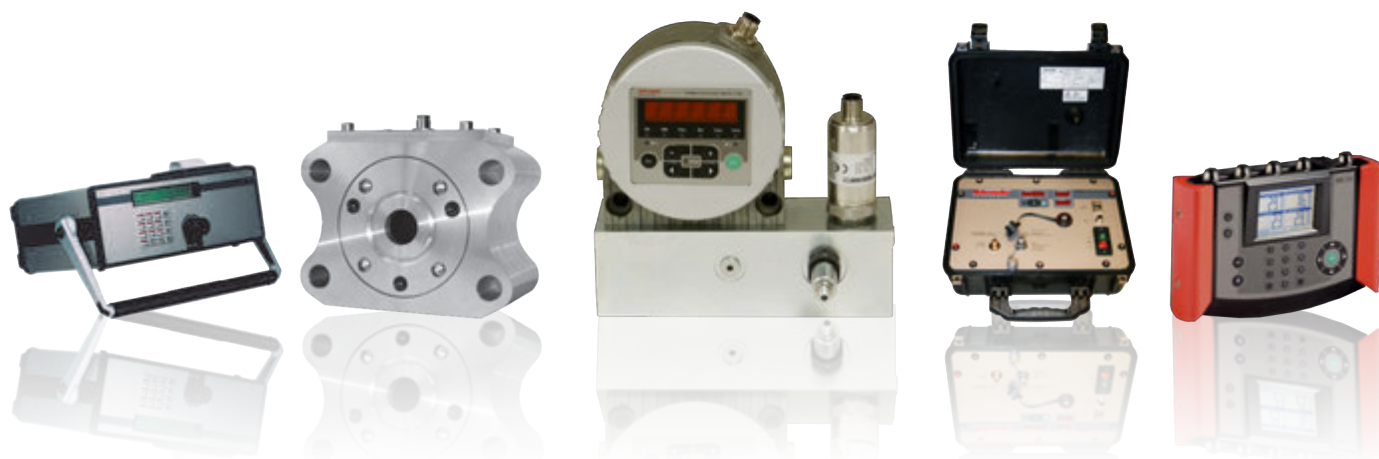


# Contamination Guide for Hydraulic Fluids, Oils and Diesel Fuels



**Schroeder**  
**INDUSTRIES**

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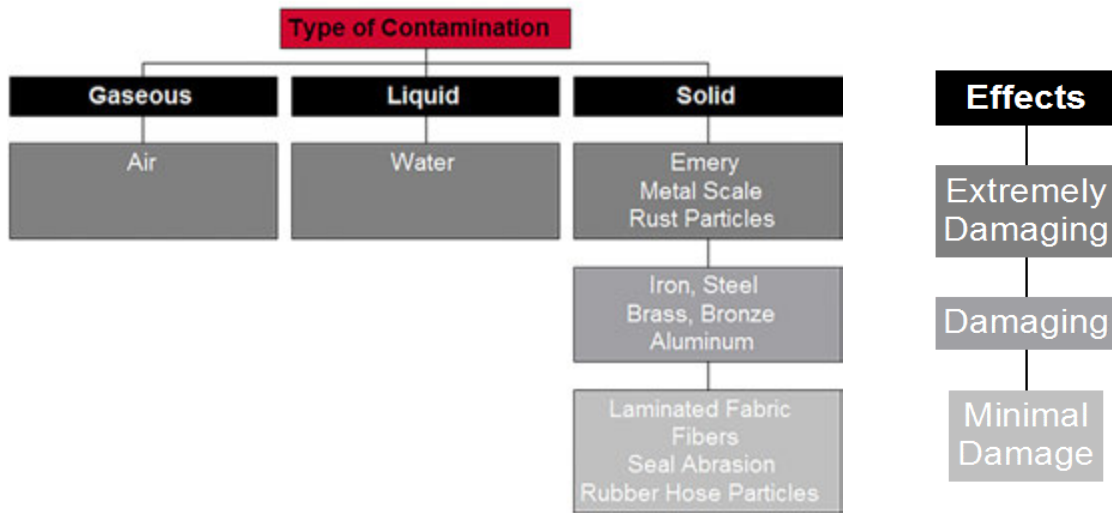
**- TABLE OF CONTENTS -**

<b>Contamination</b>	4
Types of Contamination	4
Sources of Contamination	5
Influence of Contamination	6
<b>Environments</b>	8
Cleanliness in Hydraulic Systems and Diesel Fuel Supply	8
Controlling Contamination	9
<b>Detection of Contamination</b>	10
Particle Counter	10
Water Sensor	11
Lab Report	12
<b>Application of Contamination Sensors</b>	12
Using Particle Counters	12
Installation Guide	14
<b>Hardware and Accessories</b>	17
TCM	17
HY-TRAX®	17
TIM	18
TSU	18
TMU	18
TPM	19
TMS	19
TWS	19
HMG	20
EPK	20
SMU	20
Bottle Samples	21
<b>Data Integration</b>	23
Facility / Equipment Monitoring Systems	23
Individual Sensor Interfacing	23
HY-TRAX®	24
CM-Expert	24
Equipment Management and Validation	26
Roll-off Cleanliness	26
Quality Control and Verification	29
Contamination Monitoring for Preventive Maintenance	29
<b>Glossary</b>	30

## Contamination

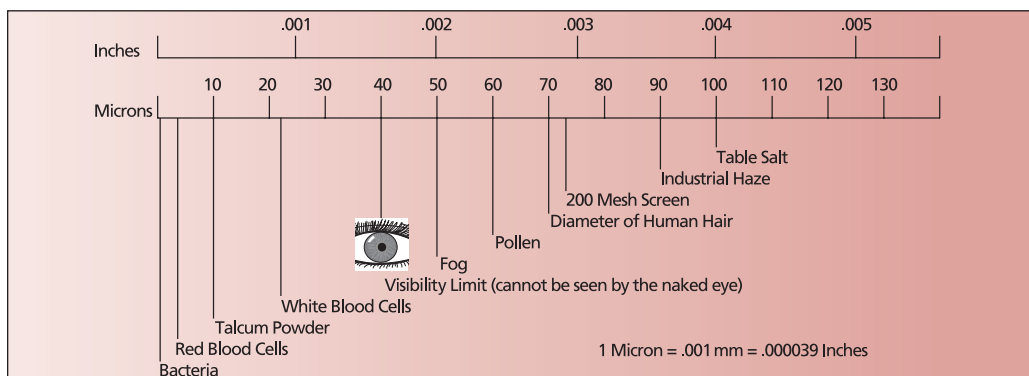
### Types of Contamination

Various types of contamination occur in fluid power systems: gaseous (e.g. air), liquid (e.g. water) and solid contaminants. Solid contamination is subdivided into three groups: extremely hard, hard and soft particles. Extremely hard particles can cause substantial damage in fluid power systems if they are not removed as quickly as possible. Preventive measures can reduce the ingress of contaminants in systems.



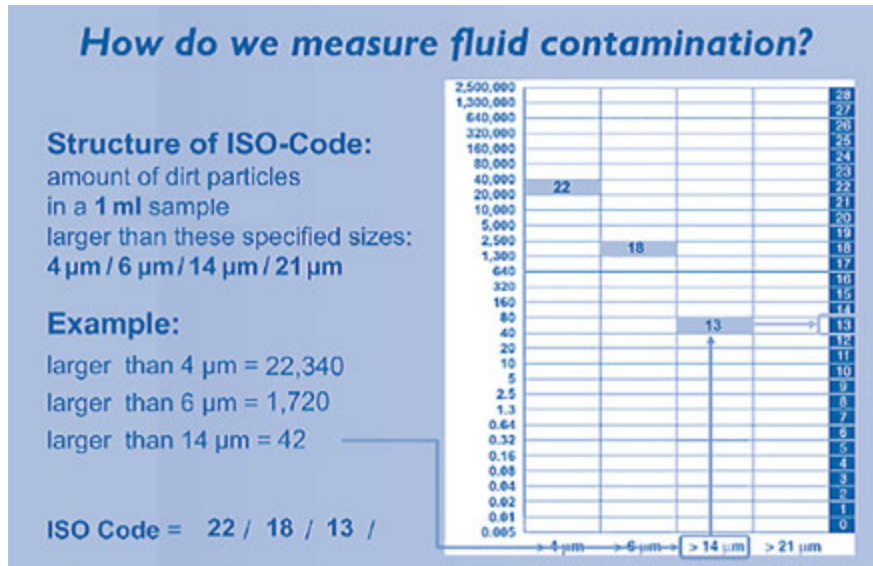
An often overlooked source for premature fluid degradation and consequent system damage is heat. This is especially important if the tank size is small and the fluid does not have enough time to properly cool down. An elevated heat level in the fluid can speed-up the oil aging effects of the fluid and shorten the overall time the fluid can be used in a hydraulic system.

The average healthy human eye can see items down to approximately 40  $\mu\text{m}$  (Microns) in size. In comparison, a human hair is 70 to 80  $\mu\text{m}$  in diameter. Particles that cause problems in high performing, high pressure hydraulic systems are in the range of approximately 5 to 15  $\mu\text{m}$  (1  $\mu\text{m}$  is equal to 0.001 mm or 0.000039 inches).



The objective of the ISO 4406:1999 is to classify particulate contaminants in hydraulic fluids. Particle counts are determined cumulatively (i.e.  $> 4\ \mu\text{m}$ ,  $> 6\ \mu\text{m}$  and  $> 14\ \mu\text{m}$ ) and coded for easy comparison.

The following table explains how the ISO code is determined for a particular fluid sample:



A micron rating in a filter, or element, identifies the size of particles that a particular filtration media will remove. For instance, Schroeder Z10 filter media is rated at  $\beta_{10} \geq 1000$ , meaning that it can remove particles of  $10\ \mu\text{m}$  and greater at 99.9% efficiency.

## Sources of Contamination

The source for Particulate Contamination is often found related to the tank itself; un-cleaned tanks put in use (filled with fluid without cleaning tank), dirt added during maintenance cycles, tank open to the environment and missing or low quality air breathers on tank. New fluid is generally dirtier than what a system, and specific components in the system, would require for proper performance and/or adequate life expectancy. Over time, pipe scale (rust), pump wear and dirt on rods/cylinders add contamination to the fluid.

Water in the hydraulic systems can be caused by moisture from ambient air, leakage of cooling systems or process water, leakage of seals and chemical processes such as combustion, oxidation and neutralization.

Design issues in the hydraulic system can contribute to Air/Gases in hydraulic fluids. If the return line is above the fluid level in the tank, air can be mixed into the fluid. Incorrect motor speeds, unprimed pumps, suction lines too small, suction lifts too high and blocked inlets are among other reasons for air contamination over time.

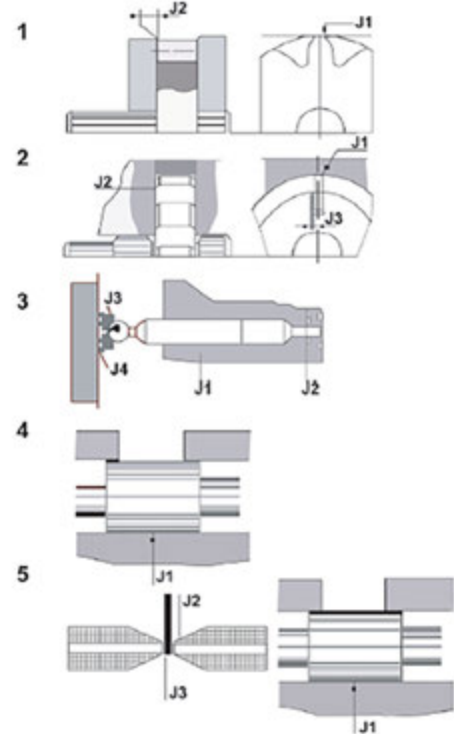
## Influence of Contamination

In hydraulic systems, 70 to 90% of wear and failure is contamination related. Only 10 to 30% can be traced back to misuse, defects or age. **Contamination cannot be stopped, only slowed down!**

System efficiency can drop by up to 20% before an operator even detects a problem, such as cylinder drift, jerky steering, erratic operation or slower performance. Overall, contamination results in shorter service intervals, higher operating costs and lost productivity.

Hydraulic component clearances are critical and require strategic filtration to remove damaging particles. Critical clearances for individual hydraulic components are shown in the table below:

Component	Typical Critical Clearance ( $\mu$ )
1. Gear Pump (J1, J2)	0.5-5
2. Vane-cell Pump (J1)	0.5-5
3. Piston Pump (J2)	0.5-1
4. Control Valve (J1)	1-25
5. Servo Valve (J1)	1-4



Particulate contaminants circulating in fluid power systems cause surface degradation through general mechanical wear (abrasion, erosion, and surface fatigue). This wear causes increasing numbers of particles to be formed, the result being that wear increases if the “chain reaction of wear” is not properly contained (by reducing contamination). Gaps grow larger, leakage oil flows increase in size and operating efficiency (e.g. of pumps, cylinders) decreases.

Free Water causes:

- Corrosion: Corrosion pits, rough surfaces and release of abrasive flakes into the fluid
- Microbial colonization / Bacteria: Odors, acids, slime, and health problems
- Loss of lubricity: Free water enters contact loading zones, allowing opposing surfaces to crash together, results in high friction, wear and seizure
- Additive depletion: Free water retains polar additives

Dissolved Water is responsible for:

- Faster oil oxidation: Accelerates this form of oil degradation, leads to oil acidity, thickening, varnishes, sludge & resins
- Reduced Fatigue life: Propagation of fatigue cracks in metals
- Demolition of Ester-based fluids and additives: Reacting with esters (hydrolysis) results in formation of acids, gels, and loss of additives

Air effects:

- Oil oxidation: Mostly oxygen reacts with oil resulting in premature degradation (oil aging)
- Varnish formation (oil aging)
- Cavitation: Formation and collapse of gaseous oil cavities causes decrease in pump efficiency and damage to pumps
- Noise and increase of temperature result in dynamic operating problems and system stiffness reduction
- Micro-Diesel-Effect
- Change of viscosity

## Environments

### Cleanliness in Hydraulic Systems and Diesel Fuel Supply

#### Hydraulic Systems

Determine TCL (Target Cleanliness Levels) based on most sensitive system components, system pressure and environmental conditions. Refer to the table below for guidance. Keep in mind that the Micron ratings of the filter(s) in the system have a great influence on what ISO Target Levels can be reached:

	Low/Medium Pressure Under 2000 psi (moderate conditions)		High Pressure 2000 to 2999 psi (low/medium with severe conditions <sup>1</sup> )		Very High Pressure 3000 psi and over (high pressure with severe conditions <sup>2</sup> )	
	ISO Target Levels	Micron Ratings	ISO Target Levels	Micron Ratings	ISO Target Levels	Micron Ratings
<b>Pumps</b>						
Fixed Gear or Fixed Vane	20/18/15	20	19/17/14	10	18/16/13	5
Fixed Piston	19/17/14	10	18/16/13	5	17/15/12	3
Variable Vane	18/16/13	5	17/15/12	3	not applicable	not applicable
Variable Piston	18/16/13	5	17/15/12	3	16/14/11	3 <sup>2</sup>
<b>Valves</b>						
Check Valve	20/18/15	20	20/18/15	20	19/17/14	10
Directional (solenoid)	20/18/15	20	19/17/14	10	18/16/13	5
Standard Flow Control	20/18/15	20	19/17/14	10	18/16/13	5
Cartridge Valve	19/17/14	10	18/16/13	5	17/15/12	3
Proportional Valve	17/15/12	3	17/15/12	3	16/14/11	3 <sup>2</sup>
Servo Valve	16/14/11	3 <sup>2</sup>	16/14/11	3 <sup>2</sup>	15/13/10	3 <sup>2</sup>
<b>Actuators</b>						
Cylinders, Vane Motors, Gear Motors	20/18/15	20	19/17/14	10	18/16/13	5
Piston Motors, Swash Plate Motors	19/17/14	10	18/16/13	5	17/15/12	3
Hydrostatic Drives	16/15/12	3	16/14/11	3 <sup>2</sup>	15/13/10	3 <sup>2</sup>
Test Stands	15/13/10	3 <sup>2</sup>	15/13/10	3 <sup>2</sup>	15/13/10	3 <sup>2</sup>
<b>Bearings</b>						
Journal Bearings	17/15/12	3	not applicable	not applicable	not applicable	not applicable
Industrial Gearboxes	17/15/12	3	not applicable	not applicable	not applicable	not applicable
Ball Bearings	15/13/10	3 <sup>2</sup>	not applicable	not applicable	not applicable	not applicable
Roller Bearings	16/14/11	3 <sup>2</sup>	not applicable	not applicable	not applicable	not applicable

1. Severe conditions may include high flow surges, pressure spikes, frequent cold starts, extremely heavy duty use, or the presence of water  
2. Two or more system filters of the recommended rating may be required to achieve and maintain the desired Target Cleanliness Level.

*Remark: Use manufacturer's recommended guidelines for system cleanliness when available.*

#### Diesel Fuel

The Tier 4 engines are built to more stringent specifications than ever before. High operating pressure in excess of 30,000 psi and 2-5 micron injector nozzle tolerances make engine injector systems and fuel pumps vulnerable to contamination levels that were not an issue in the past. While the Common Rail System does provide improved power, better fuel efficiency and lower exhaust emissions, at the same time requires a new level of fuel cleanliness and care. This cleanliness requirement for the fuel is now mission critical to system operation. OEM engine and injection makers are requiring that fuel used in the engine meet tight guidelines before warranty claims are accepted. Today's requirements call for diesel fuel cleanliness at the engines injections of ISO 11/8/6, or better, and a water level of <200 ppm water, both of which are harder to obtain with the surfactants for lubricity found in today's ULSD.



## Controlling Contamination

Determine current fluid conditions based on particle contamination levels (ISO Code), fluid water concentration and fluid health (aging, remaining life and sampling changes over time). Particle contamination and water concentration can be determined by implementing on-line or portable monitoring devices (sensors). Fluid testing in lab settings is recommended for oil aging parameters, fluids chemical composition, to see changes over time and as control measurements (in addition to sensors).

After evaluating all sources of contamination such as Dirt, Metal Particles, Water, Gases/Air and Heat, evaluate the current protection in place:

- Pressure and return line filters
- Off-line filtration loops (Kidney loop systems)
- Breathers – High integrity and desiccant types
- New oil protection – Treatment, transfer, polishing
- Monitoring (sampling) and change-out schedule

Recommend optimum components for performance and longevity. Use high efficiency depth filter elements for optimized and efficient filtration of hydraulic fluids. When choosing a filter, and specifically an element, look for:

- High  $\beta_x$ -values
- High  $\beta_x$ -value stability
- High dirt holding capacity
- Low long term pressure drop
- High collapse stability

Bottom Line: Use high quality filters in Filter Carts, Kidney Loop Systems, Pressure/Return Line Filters, Dehydrators, etc., for best results!

All openings on the hydraulic fluid tank must be covered and high performance breathers should be added. Air Breathers come in a wide variety, such as spin-on types for easy replacement, with filler basket and most importantly, desiccant types for water vapor removal of the outside air being drawn-in.



For monitoring and maintaining fluid characteristics, cleanliness and water content use contamination monitoring devices:

- **Portable & In-Line Contamination Sensors:** Portable Particle counters are ideal for plants with many small machines or for field service of mobile equipment. Contamination Sensors permanently installed are perfect for larger, critical systems where constant monitoring is required.
- **Water Content Sensor:** Measures water saturation in %. A reading of 100% indicates the presence of free water in the fluid/system and must be avoided. For fluids in hydraulic tanks with normal temperature ranges (fluid cooled down), a water saturation below 40% should be maintained.

Supplement monitoring techniques, like regular fluid sampling and lab analysis provide additional information beyond contamination:

- Additive depletion
- Contamination > Check in-plant readings
- Water content (ppm) > Check in-plant readings
- Viscosity
- Wear metals
- Trending from periodic sampling



## Detection of Contamination

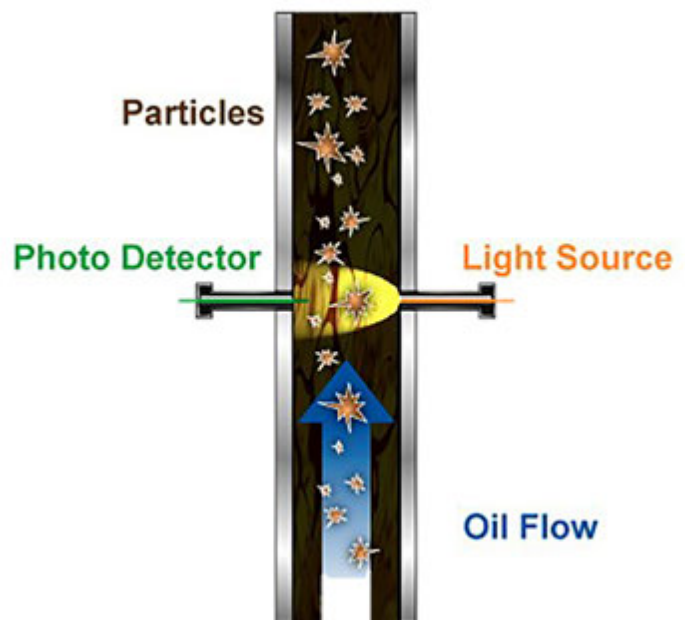
### Particle Counter

The most accurate way to measure fluid contamination (ISO Code) is by applying the use of the Light Obscuration Principle (optical sensor with light barrier):

On-line or portable particle counters apply the same light obscuration principle for measuring solid particles in hydraulic fluids and for determining the ISO code.

The fluid passes through a light barrier. The light source is either an Infrared LED or a laser (mostly used for laboratory equipment). A shadow is created on the photodiode if a particle comes between the light source and the photo detector. This shadow causes the electric signal emitted by the sensor to change. This change can be used to determine the size of the shadow cast by this particle and thus the particle size to be determined. This procedure enables the cleanliness classes according to ISO 4406:1987, ISO 4406:1999, and NAS 1638 or SAE AS 4059 if required, to be accurately determined.

The “noise” involved in this measurement principle is extraneous liquids and gases which cause the light beam to be interrupted and thus be counted as particles. Proper fluid conditioning before particle counting is very important (e.g. use of a manifold block with flow control or an independent pump-driven TestMate® Sensor Unit | TSU). The particle counter should be calibrated according to ISO 11943 (for ISO 4406:1999).



## Water Sensor

A specially designed capacitance sensor is used in the TestMate® Water Sensor (TWS) series. Water molecules are moved into and out of the sensor by changes in the saturation level of the fluid. The capacity value of the sensor changes with the population of water molecules in the sensor and is directly related to the saturation level. The change in capacity value is electronically converted and displayed as the saturation level in percent.

The driving force is the water vapor pressure. The water vapor pressure of the water in the fluid is confronted by the water vapor pressure of the water in the sensor. Water is moved into and out of the sensor until a pressure equilibrium is reached. If the equilibrium is disturbed by adding water (increasing the water vapor pressure of the oil) or drying the oil (decreasing the water vapor pressure), water again starts to move into or out of the sensor.

When adding water to dry oil, the water vapor pressure increases until the oil is saturated with water. This point is called the saturation point. The corresponding pressure is the saturated water vapor pressure and is the point where the oil cannot dissolve any more water. When this point is exceeded, free or emulsified water is the result. Although different oils can dissolve different amounts of water (in ppm) at the saturation point, the saturated water vapor pressure has the same value for all oil types at a given temperature. The saturation level is 100% at this point.

Example:	<b>Oil A</b>	<b>Oil B</b>
Temperature	20°C	20°C
Saturation Level	100%	100%
Saturated water vapor pressure	2,3 kPa	2,3 kPa
Water concentration at saturation	78 ppm	358 ppm

Technically speaking, the Water Sensor measures the saturation level of oil by looking at the water vapor pressure. The simple relation between water vapor pressure and saturation level is:

$$\text{Saturation level}[\%] = \frac{\text{measured water vapor pressure}}{\text{saturated water vapor pressure}} * 100$$

Using readings in ppm to ascertain a harmful level of water is difficult due to differences in fluid properties which include oil age, fluid type and additive levels. For example, a water content of 300 ppm in a synthetic ester would be ideal, but the same water content in a mineral based oil could have disastrous consequences. Furthermore, this only gives a quantitative measure and does not answer the question whether or not the water content is still acceptable.

The saturation level does provide a clear indication of the fluid's condition as it is directly relates to the oils saturation concentration (Saturation Point).

## Lab Report

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Customer Information: NAME, ADDRESS, CITY, STATE, ZIP, PHONE, FAX, E-MAIL, WEBSITE

Sample Information: SAMPLE TYPE, SAMPLE QUANTITY, SAMPLE DATE, SAMPLE TIME, SAMPLE LOCATION, SAMPLE ID, SAMPLE DESCRIPTION

Test Results Table:

TEST	UNIT	RESULT	STATUS
1			
2			
3			
4			

THF Sample Report Form

Schroeder offers two types of sample kits: one for hydraulic fluid (P/N THF) and one for water glycol (P/N TWG). Refer to the next section for tests performed for each of these kits. Upon receipt of order for any of these part numbers, a sample kit containing a clean sample bottle, blank form, and mailing container is shipped to the customer. After the sample has been taken, the customer simply completes the form and encloses it along with the sample in the mailing container provided. Kits are packaged and sold in lots of 10.

For each sample submitted, a lab report will be generated and forwarded directly to the user via e-mail or postal mail (per the user's request). It is strongly recommended that a MSDS (Material Safety Data Sheet) and a base line (unused) fluid sample be submitted with the initial sample to be analyzed. In addition to serving as a baseline for comparison to subsequent results, the sample of new oil will be used to determine warning limits for viscosity and TAN (Total Acid Number).

Customers can create their own personal login and password to view all of their reports in one easy to use interface at: <http://eoilreports.com/>

Information gained by using this service can help identify potential problems in a hydraulic system at minimal cost to the user. Fluid analysis can provide answers to important questions such as:

- Do I have the right filtration system in place for efficient contamination control?
- Is the fluid in my system experiencing changes that could negatively impact component life or system performance?

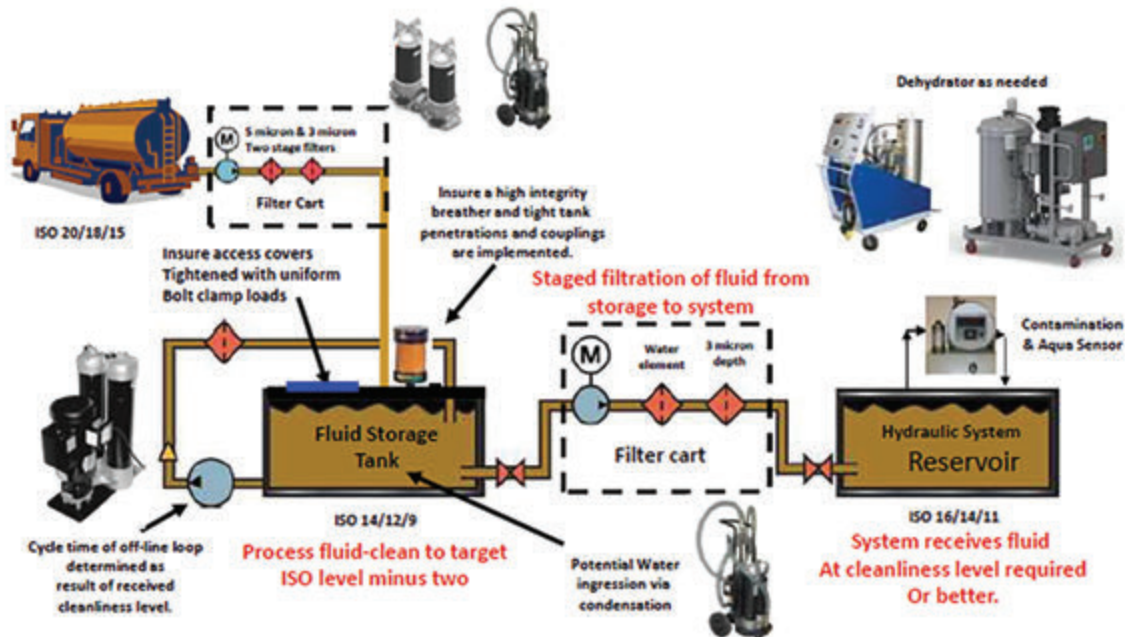
## Application of Contamination Sensors

### Using Particle Counters

New fluid, delivered by the supplier, is generally not clean enough for immediate use without prior filtration and treatment. In general, modern hydraulic systems demand fluid cleanliness of ISO 16/14/11. New fluid delivered in barrels could be as dirty as ISO 23/21/18. If the fluid is delivered in a tanker truck, the cleanliness might be ISO 20/18/15. The best cleanliness levels can be expected if the fluid is delivered in a mini-container with an ISO 17/15/13. Even this fluid is one ISO class above the target cleanliness level required.

Handling of new fluid in a plant involves several points of contact between receiving and hydraulic reservoir (point of use). At each step in the process, the fluid should be filtered either by permanently installed filters or by filter carts using high efficiency filter elements. If the system requires ISO 16/14/11 cleanliness levels, then the fluid should be filtered to ISO 14/12/9 in the fluid storage tank.

As a general rule, the fluid should be processed to target level minus two ISO levels. This can be achieved by adding a Kidney Loop System on the fluid storage tank that will polish the fluid to required ISO levels:



Filter systems with dual filters, so called Staged Filtration, are preferred. It allows removal of larger particles in the first filter and smaller particles in the second filter. E.g. a 10 Micron element in the first filter and a 5 Micron element in the second filter prevents the first filter from filling-up prematurely and allow element change intervals to be aligned more closely on both filters. In addition, the first filter can be equipped with a water absorbing element if the fluid has free water content.

Finally, the hydraulic system reservoir (or hydraulic system itself) should be monitored with particulate and water contamination sensors, and dehydrators should be used to maintain a low water saturation level at all times.

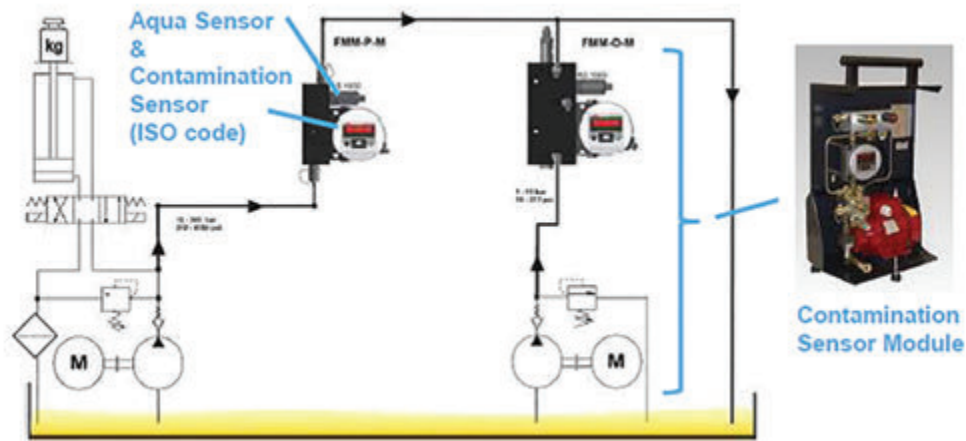
In many cases, only a single pressure filter is used in a hydraulic circuit to protect the equipment and to clean the fluid. This one filter is responsible for 100% of the work and there is no back-up of any kind. **If the filter is filled-up, and consequently goes into by-pass, the fluid is not filtered and the system is no longer protected.** A balanced approach would be adding a Kidney Loop System on the fluid reservoir and, in the best case, a system return filter as well.

A Kidney Loop System is continuously working 24/7 with constant flow and is not influenced by pressure and flow variations that are present in a typically hydraulic system. Therefore, the filter works very efficiently in removing particles and ends up providing about 75% of the work (removing of particles), while the pressure/system filter now handles about 25%.



On hydraulic systems, Contamination Monitoring involves a Contamination Sensor that measures the cleanliness of the fluid and determines the corresponding ISO Code along with a Water Sensor that measures the water concentration of the fluid in % saturation (relative humidity).

The diagram below shows the placement of two sensor combinations placed in a hydraulic system. The one to the left monitors the fluid condition coming from the pump and detects improper fluid filtration (return filter) or problems with the pump (wear and tear). The system pump provides the flow for the sensors while the system is in use.



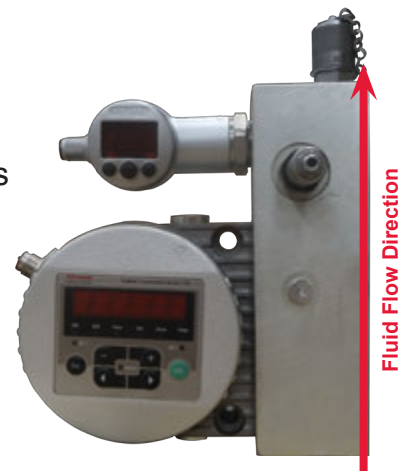
On the right, the same sensor combination is shown, but this time in combination with an independent pump. This system (TestMate® Sensor Unit | TSU) does not depend on the hydraulic system to supply fluid for monitoring, but works consistently and independently. It monitors the fluid in the tank directly.

## Installation Guide

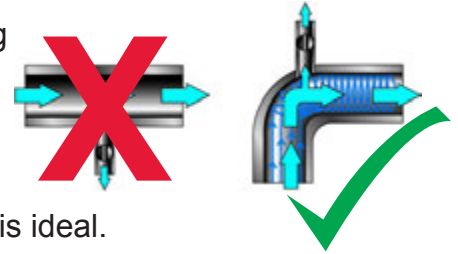
The TestMate® Contamination Monitor (TCM) measures the particular contamination of fluids by taking a sample out of the main stream and measuring the particulate size, the particulate count in the individual size class and the fluid flow (ml/min) to determine the corresponding ISO code (and SAE Code, optional NAS code available as well). Therefore, it is important to connect the lines on the system and to place the sensor correctly for accurate readings.

### A few rules should be followed:

- It is highly recommended to use the optional manifold block with the TCM (shown in picture). This allows for flow control and assures back pressure through the measuring cell. In addition, the manifold block allows placement of an optional TestMate® Water Sensor (TWS) that measures the fluid temperature and water saturation.



- A pressure differential (pressure difference between inlet and outlet) of 70-100 psi is recommended to generate sufficient fluid flow through the sensor.
- Install the sensor in a vertical position, so that the fluid flows from bottom to top (south to north, as shown in picture) through the sensor. **Never install the TCM (or TIM) as a high point in a system!**
- Keep close distances, short line lengths, by installing the TCM close to the measuring point. The face of the TCM, with the display, can be rotated by 270° degrees. If the display would end up in an inconvenient place, or difficult to read, use a Sensor Monitoring Unit (SMU) or remote display.
- When using flex hoses, avoid kinking of the hoses. Use Minimesh (2 mm ID) hoses, max. 25 inches long, or Minimesh (4 mm ID) hoses at inlet when 2 mm ID produces an overly large pressure drop. The hose should be kept as short as possible (not to exceed 25 inches). The use of elbows prevents the kinking of hoses.
- Assure that you have turbulent flow at the point of extraction in the system. Avoid placing Tee's in long hydraulic lines that have laminar flow, in order to get the particulates into the sensor and not by-passing it. Using an elbow, or a Tee turned by 90 degrees is ideal.



For a TCM with Manifold, high pressure is defined by any application with pressure in excess of 150 psi and less than the max allowable working pressure of 3,500 psi. Proper installation requires inlet flow through one of the two High Pressure SAE 4 thread inlets and return flow through one of the two SAE 4 thread outlets. The flow through the TCM is controlled by adjusting the flow control valve to achieve a differential pressure of minimum 70 psi. While the manifold block is designed for use with low pressure/flow situations, an optional needle valve can be placed immediately following the sensor, especially when returning fluid direct to reservoir/tank, to create a back/differential pressure across the sensor. Two gauges can be attached to the SAE 4 Test Points, allowing the operator to see the pressure at the inlet and outlet.

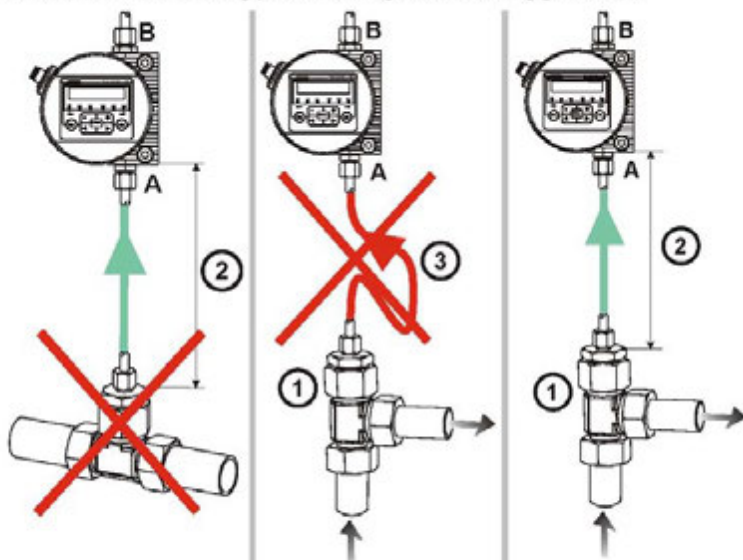
To achieve ideal operating conditions, the TCM should be installed following the factory recommended procedure outlined below and noted in the TCM Series User Manual:

1. Install TCM in a vertical position, either the in-line version or the manifold mount version (preferred)
2. Direction of flow: from IN (bottom) to OUT (top)
3. Select hydraulic hose
  - Minimesh DN2 (2mm ID) at IN, max. 630 mm
  - Minimesh DN4 (4mm ID) at IN (when DN2 produces an overly large pressure loss)
  - The hose should be kept as short as possible (630 mm); when measuring three virtually identical ISO values (e.g. 16/16/15 = air in oil) the hydraulic hose at IN can be extended to 2 m in length or try to increase the system pressure to reduce air bubbles.
4. Connect the TCM via Minimesh hose to IN
  - Shut system off
  - First, connect return line ( $\geq 4$ mm ID) (OUT)
  - Then connect IN

As outlined earlier, the hose length should be the shortest possible run and in a straight line avoiding bends in the line:

### Selecting the measurement point

In order to obtain cleanliness values that are continuous and coherent in real time, select a suitable measuring point according to the following guidelines:



- ① **WRONG** Select the measurement point so that the sample measured comes from a turbulent location, with a good flow. For example: on a pipe elbow, etc.
- ② **WRONG** Install the sensor near the measurement point to achieve as timely results as possible.
- ③ **OK** During installation, avoid creating a "siphon" trap for particle deposits in the line (sedimentation).

In general, Most errors in TCM (or TIM) readings are due to installation errors which can be corrected with simple system/hook-up changes!



## Hardware and Accessories

### TCM



Schroeder's TestMate® Contamination Monitor (TCM) is the newest generation of particle monitors that continuously measures solid contamination in fluid. Enclosed in a 4-inch diameter case, the TCM utilizes an optical sensor and measures particles in four sizes: >4, >6 and >14 microns. Measurement results can be output as a contamination code according to ISO 4406:1999 or SAE AS 4059 (D).

The TCM is designed for connection to hydraulic and lubrication lines with pressures up to 4,350 psi (300 bar) and viscosities up to 4,635 SUS (1,000 cSt). The unit requires that a small flow of oil (between 30 mL/min and 300 mL/min) is diverted for measurement purposes. TCM is shown with optional manifold for flow and pressure control and optional water sensor (TWS-C).

The TCM provides the user with a small, tough, and more versatile stationary sensor. It provides instantaneous readings and is able to self-diagnose continuously with error indication via the status LED. The attractive cost-to-performance ratio makes it especially applicable for OEM applications. Online "real-time" condition monitoring allows to practice total predictive maintenance. The TCM can be programmed with a critical ISO code, and if reached, an output signal can be used as a warning or to control the equipment (e.g. shut down a pump).

### HY-TRAX



HY-TRAX® is a sampling system that integrates Micro-VSD gear pump and flow control into our TCM manifold block. The TCM monitors fluid ISO codes and an optional water sensor measures fluid temperature and water saturation levels. The VSD Pump, designed for continuous duty operation and the very small compact footprint, is ideal for mobile applications. Designed for monitoring fluid conditions in reservoirs or low pressure lines.

It is available in two versions, a manual controlled unit where pump speed is manually adjusted for proper flow through TCM and a telematics version with a Communication Module where pump speed is automatically controlled by the module (TCM signal adjusts motor/pump speed), and TCM & TWS data is sent via GSM cellular to a secure web based dashboard. The fluid condition data is archived on the website and stored for up to one year. This provides true remote access to Fluid condition and allows to set warning levels by the user. If the warning levels are reached, a message (by cell or e-mail) will be sent immediately.

**TIM**

The TestMate® In-line Monitor (TIM) from Schroeder is an in-line contamination counter capable of transmitting information regarding fluid cleanliness in various formats to a wide variety of devices in real time. Software is included to transmit data to a PC. Alternative user-supplied output devices include PLCs, individual display units, and warning lights via trigger points. This unit is intended for critical systems where continuous contamination monitoring is a must and for fluids with higher viscosity ranges (up to 2,000 cSt). A TIM version is Ethernet capable for easy in-plant system integration.

**TSU**

The TestMate® Sensor Unit (TSU) combines the TCM, or TIM contamination sensors, with a pump/motor group for independent operation where system pressure is insufficient or non-existing (e.g. tank) and for test stand applications where air is introduced into the fluid due to a high circulation rate. It includes an air suppression system to counter act the influence of air during the particulate contamination monitoring.

**TMU**

The TestMate® Monitoring Unit (TMU) series combines the advantages of the portable contamination measurement units with the measurement technology of the TCM and TWS. The TMU is a portable service unit and is designed for temporary measurement of solid particle contamination, water saturation and fluid temperature in hydraulic systems. The integrated pump and the hoses with test point connections, which are included with the TMU, allow operation on reservoirs, control circuits, and high pressure circuits. The tests are stored inside the unit and can be downloaded to a PC or onto a USB drive.

**TPM**

The TestMate® Particle Monitor (TPM) is a portable particle counter with, or without an integrated pump that can be used independently or in-line to measure contamination levels of hydraulic fluids. Particles are measured at the 4, 6, and 14 micron sizes, with results available in ISO 4406 (1999) and SAE AS 4059. Various programming options are available, including the ability to activate or deactivate system functions when contamination reaches a user-specified level. It is equipped with a built-in printer to provide instant documentation and an RS-232 serial port for data transfer. A custom software package is also included for trend analysis on a PC. The unit's robust packaging includes a folding handle which doubles as a stand to provide optimal viewing.

## TMS



The TestMate® Metallic Sensor (TMS) detects metallic solid particle contamination in lubrication fluid. The particles are determined according to the inductive measurement process, in which a coil system is the key element of the sensor. Metallic particles (ferromagnetic Fe and non ferromagnetic nFe) in the > 70, 100 or 200 µm size range are detected (particle range depends on MTS sensor size). The TMS is a full flow sensor and is available in sizes of ¼", ½" and 1" bore diameter.

The TMS continuously monitors the status of the fluid condition in regards to larger particulates and allows prediction on imminent system damage. This makes the sensor a reliable instrument for status-oriented, predictive maintenance.

## TWS



The TestMate® Water Sensors (TWS) are online saturation and temperature sensors for the monitoring of hydraulic and lubrication fluids accurately and continuously. They measure the water content relative to the saturation concentration (saturation point) and outputs the degree of saturation (saturation level) in the range of 0 to 100% as a 4 to 20 mA signal. A reading of 0% would indicate the absence of water, while a reading of 100% would indicate that a fluid has free water.

The TWS-D has a 4-digit display that shows “real-time” measured values and allows for parameter adjustments. It can also be rotated/aligned on two axis. The TWS-D can be programmed with a temperature and a %-value water saturation, and if reached, an output signal can be used as a warning or to control the equipment (e.g. shut down a pump).

The special capacitance sensor used in the TWS absorbs water molecules from the fluid and changes its capacity value that is directly related to the saturation level in the fluid. An integrated thermoelement on the sensor measures the temperature of the fluid in the range of -13°F to 212°F (-25°C to 100°C) and outputs it as a 4 to 20 mA signal.

## HMG



The HMG 2500/4000 data recorder is a portable unit for measurement and data capturing tasks involving hydraulic and pneumatic systems. Applications extend primarily to maintenance and servicing, troubleshooting, test stands, and quality inspecting. The HMG 3010 can concurrently evaluate signals from up to 10 sensors. The unit features 5 input jacks for connecting the sensors. If necessary, this number can be doubled using a Y adapter for measurement operations involving more than 5 sensors. Schroeder offers HSI sensors (HSI = Hydraulic Sensor Interface) for pressure, temperature and flow rate, which are automatically recognized by the HMG. Standard, and third party analog sensors can also be used, but these sensors must be manually configured. CAN bus capable sensor can be hooked-up as well with the help of a CAN Adapter.

## EPK



The new Patch Test Kit from Schroeder provides the necessary tools to determine levels of both water and solid particulate contamination present in a particular fluid sample. The kit is named for the patch method used to visually assess the amount of solid contaminants. Using the vacuum pump contained in the kit, the fluid sample is drawn through a membrane patch. The residual dirt left on the patch is viewed under a microscope and compared to photos of known contamination levels in the Schroeder Contamination Handbook (included) for a visual assessment. The handbook also provides photos of various contaminants for use in identifying the type of particulate and its possible source(s).

The water sensing device included in this kit is an aluminum mixing vessel with a small LCD display and microprocessor built into the lid. When the two reagents supplied in the kit (one liquid and one powder) are mixed with the sample fluid in the cell, the resulting chemical reaction causes an increase in pressure within the vessel. This change in pressure is converted into water content and displayed on the screen in terms of parts per million (ppm) or % by volume.

## SMU



The Sensor Monitoring Unit (SMU) is a display unit for fluid sensors and is designed to display and store measured data. The following combinations of fluid sensors can be connected directly:

- Contamination Sensor (TCM) and Water Sensor (TWS-C/D)
- Metallic Contamination Sensor (TMS) and Water Sensor (TWS-C/D)

The SMU allows simple installation parallel to a customer system using the magnetic holder or top hat rails. The housing has a high protection class IP67. Therefore, installation in a switch cabinet is not necessary. It is Plug & Play ready with simple keypad operation.

Bottle Samples (Hydraulic fluids & Diesel Fuel)



Schroeder offers Troubleshooting and Quality test packages. All packages include pre-paid testing and the required number of fuel containers for sample.

Schroeder also offers sample kits for hydraulic fluid (P/N THF) and kits for water glycol (P/N TWG). The bottles are 4 oz in size:

	Total Conditioning Analysis Kit (P/N THF)	Water Glycol Kit (P/N TWG)
Particle Count	✓	Patch Test
ISO 4406 Cleanliness Code	✓	Estimated
Water Content	✓	
Viscosity	✓	✓
TAN	✓	✓
Spectrographic Analysis	✓	

**Fuel analysis** can identify potential causes for fuel filter plugging, smoking, loss of power, poor injector performance, malfunctioning throttle position sensors and sticking valves. Testing also confirms a diesel fuel’s sulfur content, biodiesel content and compliance with manufacturer specifications and standards for cleanliness that could affect equipment warranty requirements. Total sample volume of 32 oz is required for all tests listed on the next page:

Complete Diesel Fuel Analysis    Schroeder P/N: 02098012		Includes	
<ul style="list-style-type: none"><li>Complete fuel quality, fuel filter-ability, fuel stability and bio content test (8 critical ASTM tests with a single comprehensive relational summary)</li></ul> NOTE: Test 0209812 only can be run with as little as 14 oz. (402 mL) sample		Filter Plugging Free Contamination	Computability   Loss of Power
		Filter Plugging   Injector Scoring   Corrosion	Flowability   Filterability   Di or Tri Glyceride Fall Out
		All Cultures of Microbes	Microscopic Composition
		Filter Plugging   Injector Scoring   Microbial Promoting   Cause of Water	Biodiesel Content
Contamination Tests    Schroeder P/N: 02098006		Includes	Sample Amount
<ul style="list-style-type: none"><li>Identifies contamination from external sources - oil, biological growth, water, sediment</li><li>Identifies contamination to be the result of a change in the fuel's physical properties - low thermal stability may require use of an asphaltene conditioner</li></ul>		ICP	2mL
		Flash Point	200mL
		Thermal Stability	120mL
		Water and Sediment	200mL
		Bacteria, Fungi, Mold	120mL
Smoking Tests    Schroeder P/N: 02098007		Includes	Sample Amount
<ul style="list-style-type: none"><li>Identifies low cetane index or water contamination - loss of power, white smoke</li><li>Identifies excessive sulfur content - black smoke</li></ul>		Sulfur	50mL
		Cetane Index	100mL
		API Gravity	400mL
		Distillation	200mL
		Water and Sediment	200mL
Filter Plugging Tests    Schroeder P/N: 02093395		Includes	Sample Amount
<ul style="list-style-type: none"><li>Identifies contamination from external sources specific to filter plugging - high particle count, biological growth</li><li>Identifies contamination due to a change in the fuel's physical properties - low thermal stability or insufficient cold weather capability for operating environment</li></ul>		Thermal Stability	120mL
		Bacteria, Fungi, Mold	120mL
		Pour Point	100mL
		Cloud Point	100mL
		Cold Filter Plug Point	100mL
		Particle Count	80mL
Cleanliness Tests    Schroeder P/N: 02098008		Includes	Sample Amount
<ul style="list-style-type: none"><li>Identifies water contamination - can lead to smoking, biological growth and corrosion</li><li>Identifies particulate contamination - can result in extreme wear in high pressure fuel systems which may cause premature injector failure</li></ul>		Karl Fischer	10mL
		Particle Count	80mL
Wear Prevention Tests    Schroeder P/N: 02098009		Includes	Sample Amount
<ul style="list-style-type: none"><li>Identifies cause of wear - water contamination, excessive particles or insufficient lubricity</li></ul>		Karl Fischer	10mL
		Particle Count	80mL
		Lubricity	20mL



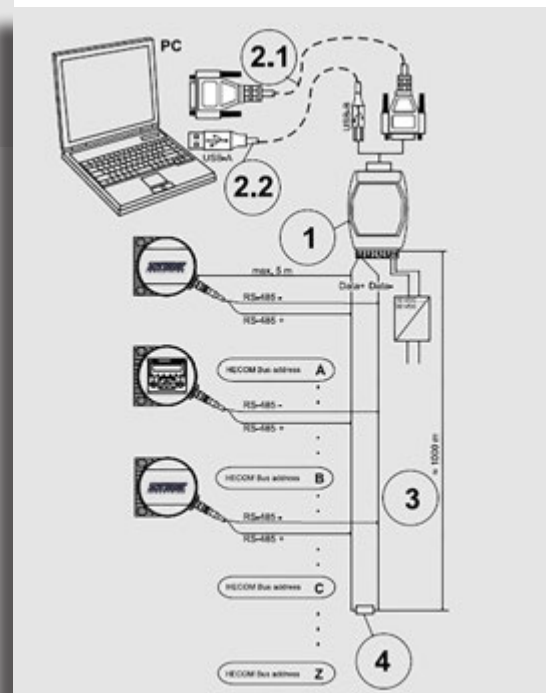
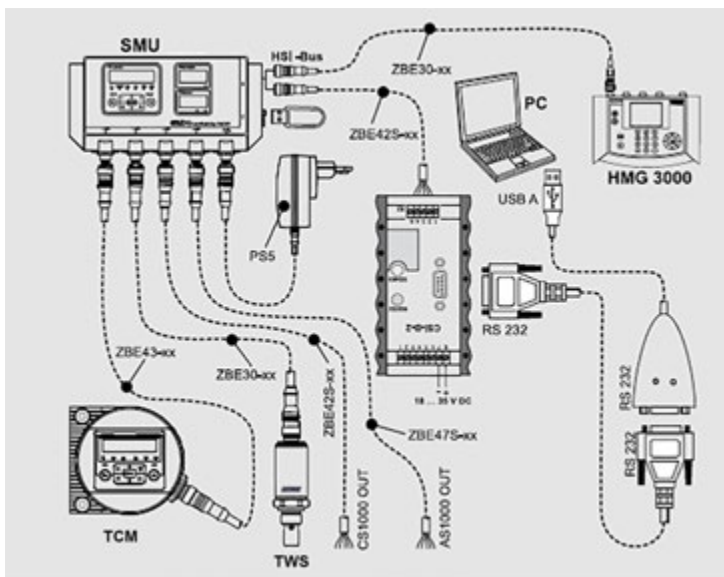
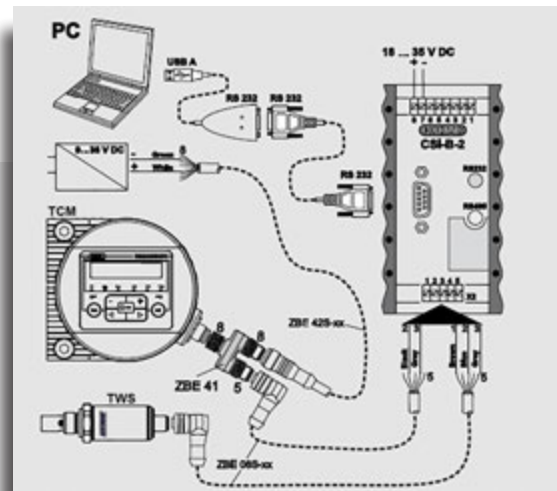
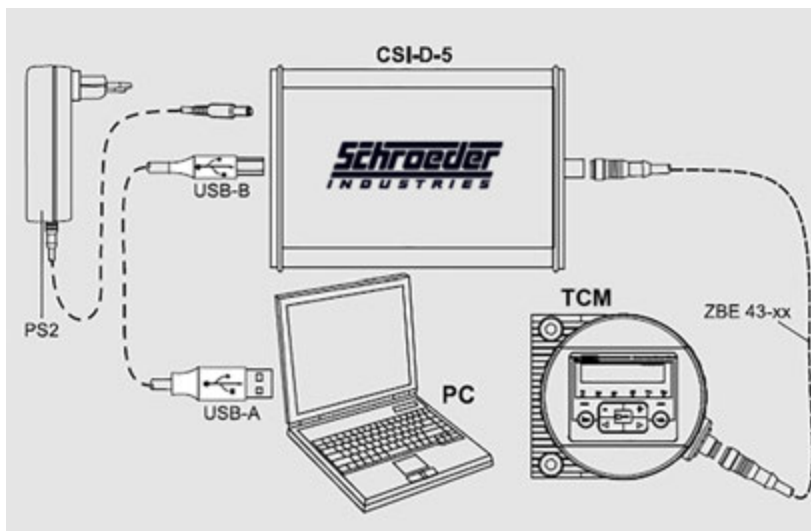
## Data Integration

### Facility / Equipment Monitoring Systems

#### Individual Sensor Interfacing

The Schroeder Contamination Sensors have output signals that can be used in different ways. The signals can be fed into a PC (desktop or laptop computers) for monitoring and data collection, or into existing systems (e.g. PLC) for monitoring, data collection and decision making. Some, like the TCM or TWS-D, can be programmed with a threshold value. If the threshold value is reached, the sensor will provide an output signal that can be used for warnings and/or controls (e.g. shut down a pump).

Examples of sensor interfacing:

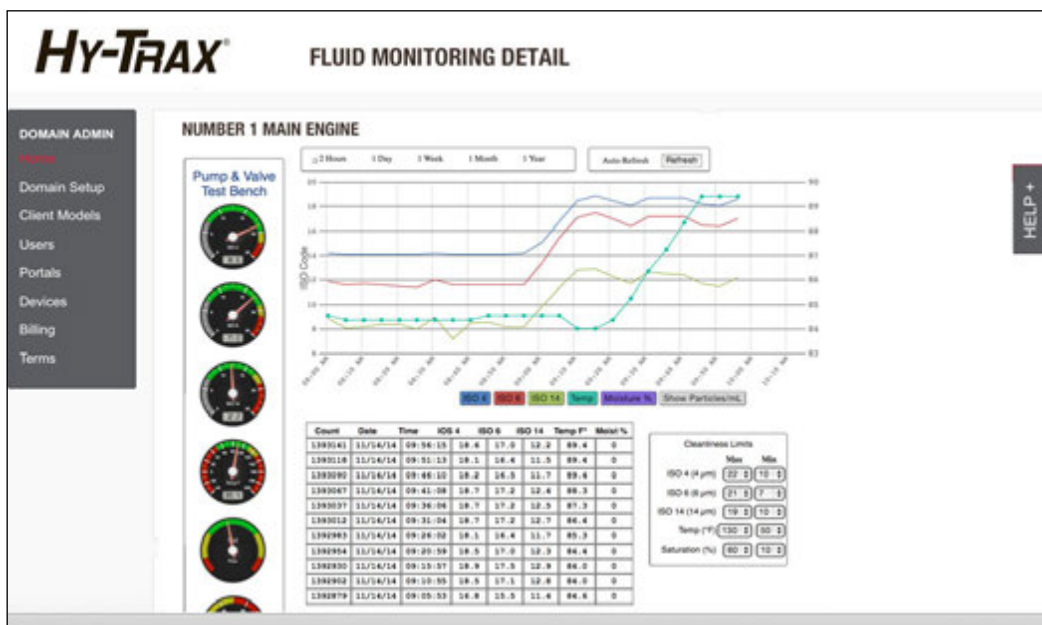


## HY-TRAX

The HY-TRAX® system provides an independent fluid contamination monitoring ability. It is pump/motor driven with a TCM Contamination Sensor and optional TWS Water Saturation Sensor. Because of its small build, compact size, it is ideal for on-board applications.

The HY-TRAX® Telematic Communications Module with Remote Controlled Sampling System adds great flexibility to the end user. The VSD pump is automatically adjusted by the Communication Module to provide optimal flow to the TCM particle counter. The fluid sampling system collects data and the Communications Module transmits this data, via GSM cellular communications, at scheduled intervals. All data is transmitted through a secure VPN and is archived in a protected database. The information is displayed on a custom dashboard with user selectable parameters. HY-TRAX® will even send alert emails when programmed thresholds are reached. This will provide maintenance managers with the visibility and information to pro-actively schedule preventative maintenance on local and remote equipment.

Example of **HY-TRAX** Communication Module Dashboard Contamination Chart:

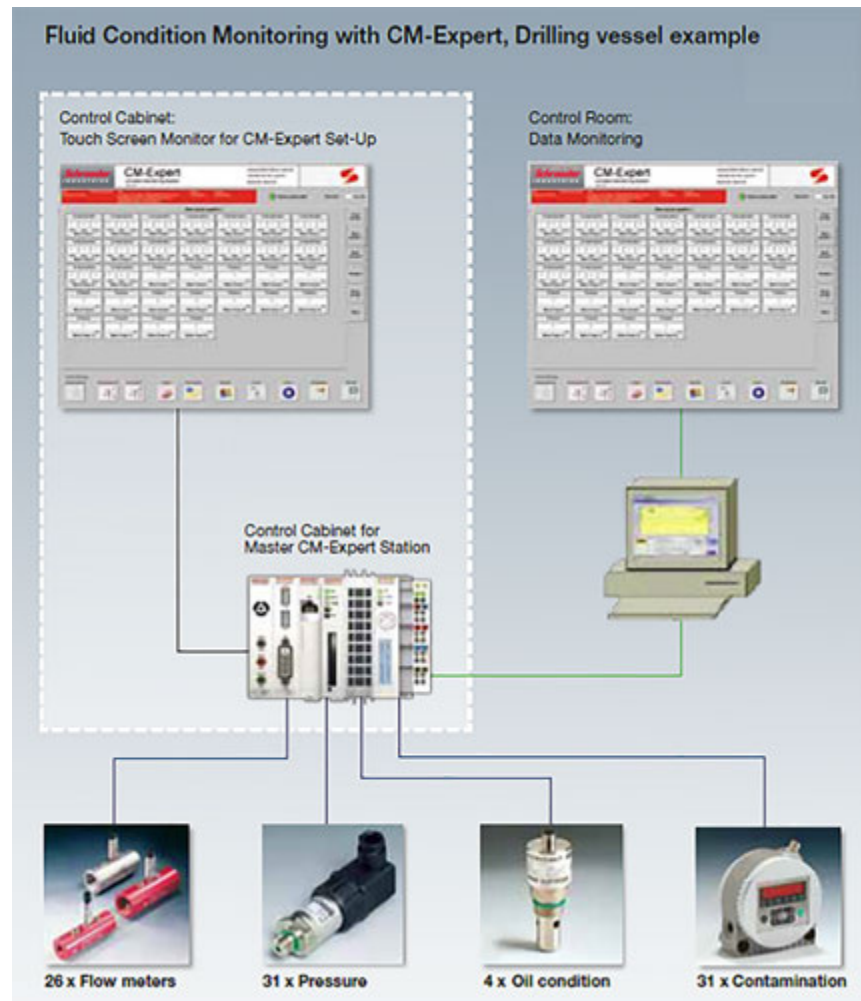


## CM-Expert

CM-Expert is a powerful monitoring and control system for use with any standard PC. Its decentralized configuration makes the system extremely reliable and flexible for use in fluid power systems. Since the controller is specific to the particular purpose, there is no limit to the number/type of sensors, actuators, operating and signal components which can be connected, or to the control tasks and data exchange with other systems. All common physical parameters can be recorded by the data acquisition unit and processed: temperature, pressure, differential pressure, viscosity, water content, particles, flow rate, etc.



CM-Expert monitors and stores the data recorded by sensors and detects changes emerging in the system of machines and within systems. Experience developed over decades and the reference data accumulated enable analyses and forecasts for production-relevant parameters, such as remaining service life, service intervals and risks, to be made and evaluated – in good time and long before a standstill threatens. The CM-Expert software does not just work with Schroeder sensors but also of course with other third-party sensor without restriction.



## Equipment Management and Validation

### Roll-off Cleanliness

More and more manufacturing firms discover the high cost of warranty claims after the products have been delivered. A significant reason has been insufficiently cleaned hydraulic systems and fluids, which caused failure within the warranty time. By addressing the fluid cleanliness of new oils, appropriate fluid processing in the plant, fluid filtering and flushing of the systems during assembly and/or final testing, the warranty costs can be substantially lowered. Besides cleaning the fluids to recommended ISO levels, the monitoring with contamination sensors and recording of data for quality control play an important role.

Roll-off Cleanliness is commonly referred to as the overall contamination level of the hydraulic fluid in the equipment at the time of release from an assembly line or re-build line, after testing and before shipping to customers and/or end users.

Roll-off Cleanliness deals with contamination (particulates) that is “Built-In” the equipment at the time of assembly:

- Due to contamination that already exists in the new fluid
- Due to contamination that is already in supplied components
- Due to contamination introduced during the build process

This can be considered ‘Initial Contamination’, present even before the equipment has been running at all.

The objective is to reduce this **Initial Contamination Level**. The investment in time and equipment is worthwhile because of a reduction of costly warranty claims and for quality control and tracing purposes of products. Incoming warranty claims can be investigated and connected to maintenance activities at the customer location. If the fluid was not maintained to recommended cleanliness standards during use, e.g. what was achieved when the equipment left manufacturing, a warranty claim could be denied based on this info. Overall, manufacturers have found that clean hydraulic systems will reduce the occurrence of failure during the warranty period, resulting in:

- Happy Returning Customers
- As well as a Healthier Bottom Line

### Benefits of Condition Monitoring:

The breakdown rate is high during the start-up phase of equipment. Problems can often be detected while machinery is in the testing phase after assembly or in the beginning after installations have been started-up and commissioned. Those immediate failures are often caused by defective parts, but defects due to contamination might not show up in the start-up phase, but some time in use and often during warranty period.

A Kidney Loop Systems can flush a system during assembly. E.g. a Kidney Loop Compact System is used to clean-up fluid reservoirs on tractors while the tractor moves through the assembly line, and a portable Particle Counter is used to document the ISO cleanliness level before shipping.



Kidney Loop Compact System KLC



Mobile Particle Counter TPM  
(with Printer included)

Filter carts can be used to flush a system after assembly (in testing). Use a Filter Cart to flush the system at the end of assembly and during functional testing, with high efficiency, high capacity elements for particulate and/or water removal. This is a simple time based method for Roll-off Cleanliness. After the designated filtration time has passed (based on experience), the ISO code is checked with a mobile Particle Counter Unit for verification.

A better practice is the use of a filter cart after assembly that includes a Contaminating Sensor that measures the ISO level continuously and stops the filtration after the preselected, target cleanliness level has been reached. The Filtration Station® is an off-line system with integrated motor/pump group that includes dual stage filtration for water removal and/or staged filtration for fast cleanup of fluids. It comes with a Contamination Sensor and Water Sensor standard, with a fixed flow rate of 9 gpm or variable of 3-8 gpm (optional).



Filtration Station® with integrated  
TCM® Particle Counter and  
TWS® Water Sensor

Pump-less versions of this type of cart have been successfully applied on systems that allow external hook-up to the hydraulic system (e.g. 3,000 psi systems) while the equipment to be cleaned is running. The fluid is then circulated through the filter cart until the target cleanliness level is reached.

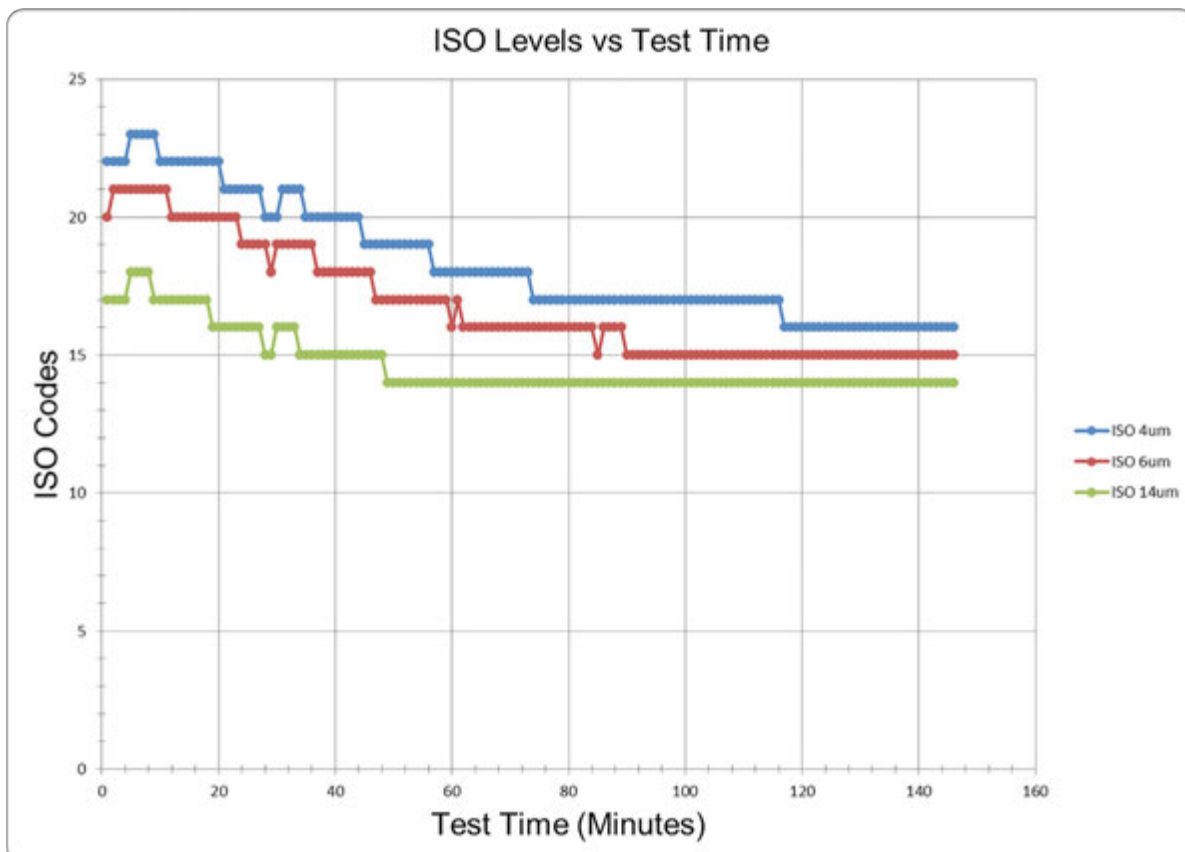
While the Filtration Station is collecting the ISO data, it still needs to be handled by personnel for evaluation and storage. The next generation Filtration System is the Asset Management Filtration Station® that combines the filter and sensor technology with state of the art data collection by means of an on-board computer system.



Asset Management Filtration Station®

The Touch Screen terminal allows for easy user interface, continuous monitoring and progress display of cleanliness levels and programmable cleanliness levels and automatic switch-off. The data is stored in an MS Excel file for data management (e.g. by S/N), record keeping and quality control.

Example of a filter cycle from 23/21/18 to 16/15/14 with automatic shutdown:



## Quality Control and Verification

Besides cleaning the fluids to recommended ISO levels, the monitoring with contamination sensors and recording of data for quality control play an important role.

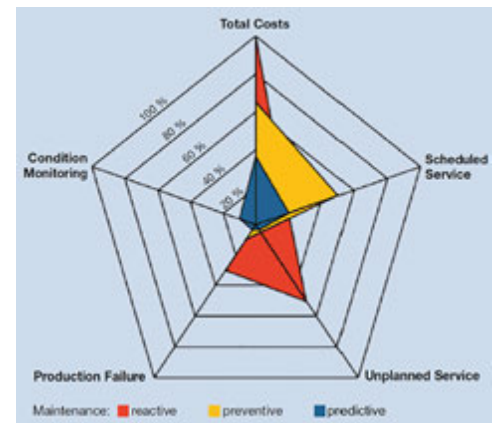
During assembly and/or final testing of new products (e.g. OEM's) the hydraulic fluid is filtered and the cleaning process is documented and recorded for Quality assurance. The OEM can claim that they produce 'clean' products. In addition, warranty claims can then be verified with the records, customer treatment of fluid and use of equipment for appropriate responses and actions because the quality data was collected and stored.

The same importance must be applied to in-plant hydraulic systems used for production. Condition monitoring of fluid contamination reduces unscheduled downtime, repair and maintenance costs and allows a pro-active, preventive maintenance approach.

## Contamination Monitoring for Predictive Maintenance

The real world approach to contamination control involves fluid diagnostics and treatment. The objective of diagnostics, or Condition Monitoring, is measuring and determining the status of system components and fluid health to prevent failure, optimize maintenance practices and fluid processing and/or replacement intervals. It allows moving the maintenance procedure in a plant from a reactive (failure oriented) to a predictive (status oriented) one.

Reactive maintenance (failure oriented) has high overall associated costs, mainly due to production failure and unplanned services. Preventive maintenance (time oriented) reduces the overall costs by focusing on scheduled services. These scheduled services might be premature and not yet needed, adding unnecessarily to the costs. This is where Condition Monitoring comes in. An investment in Condition Monitoring equipment allows the monitoring of equipment and fluid to determine the status and schedule maintenance accordingly.



### Benefits of Condition/Contamination Monitoring:

- Reduced unscheduled downtimes
- Reduced loss of production
- Reduced consequential damage

## Glossary

<b>Contamination Monitoring</b>	Extends to checking the cleanliness status of all manufacturing and assembly processes considered relevant in this connection
<b>Contamination Sensor</b>	A device that continuously measures contaminants in fluid
<b>Emulsified Water</b>	A particular example of a dispersion comprising a continuous and a dispersed phase
<b>Fluid</b>	Any liquid or gas
<b>Free Water</b>	Water that will settle from oil rapidly
<b>Initial Contamination Level</b>	The starting contamination level of the fluid being treated
<b>Laminar Flow</b>	In fluids, a smooth, layered flow
<b>Laser</b>	Light Amplification by Stimulated Emission of Radiation, which is high-intensity coherent light
<b>Liquid</b>	A fluid that is not gaseous or solid
<b>µm, micrometer</b>	Unit of measure equal to 10 <sup>-6</sup> meter (1/1000 of a millimeter)
<b>Particle Counter</b>	A device that counts particles
<b>Particles</b>	Very small pieces made of diverse substances
<b>ppm</b>	Unit of measurement; parts per million
<b>Pressure Differential</b>	Pressure difference from the inlet to the outlet
<b>Saturation</b>	The state or process that occurs when no more of something can be absorbed, combined with, or added
<b>Turbulent Flow</b>	Non-smooth movement of air or fluid
<b>TAN</b>	Total Acid Number
<b>Vacuum</b>	The absence of gas or liquid in a given volume
<b>Water Sensor</b>	A device that continuously measures water levels in fluid

