HYDAC FILTERTECHNIK

Particle Measurement Technology in Practice.

From Theory to Application.

E 7.605.2/05.08

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1 Introduction to Particle Counting

1.1 Physics Fundamentals

1.1.1 Light Obscuration

In optical contamination sensors, a beam of light is transmitted through the oil flow.
On the reception side, the light is obscured by the particles.

Fig. 1
No obscuration of the light beam

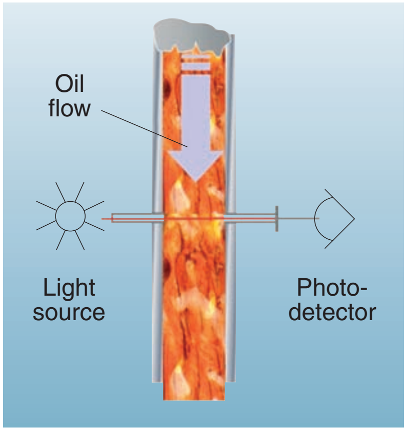
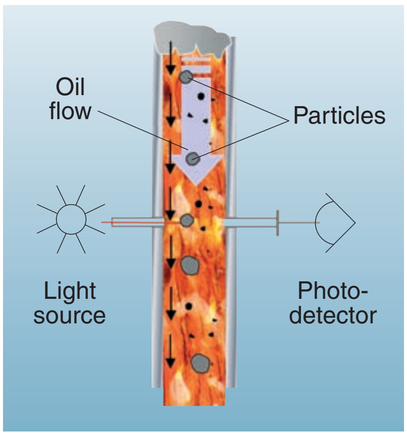
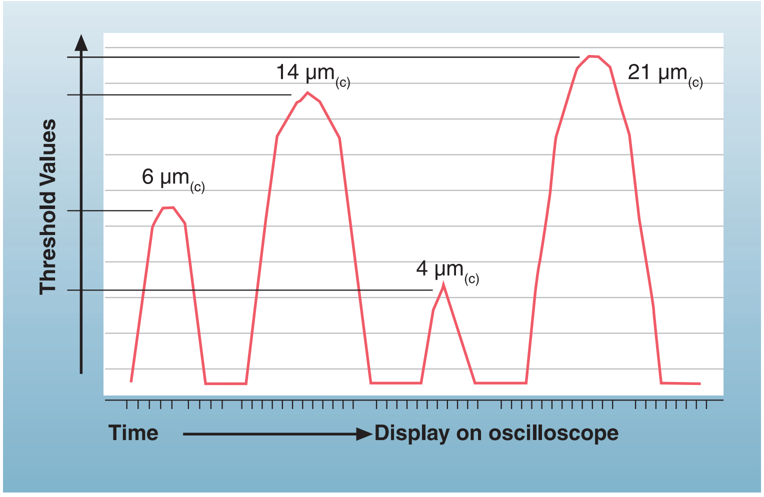


Fig. 2
Obscuration of the light beam by particles



The reception signal looks like this on an oscilloscope:

Fig. 3
Reception Signal



Signal conversion:

- Each of the signal peaks corresponds to obscuration by a particle.
- The signal height or amplitude reflects the particle size.
- The breakdown into 2, 5, 15, 25 µm and 4, 6, 14, 21 $\mu m_{(c)}$ is determined via the threshold values.

The principle of particle counting via light obscuration is used in the sensors presented in section 2.

1.1.2
Mesh Blocking Process

The fluid flow is conveyed through one or more meshes. In so doing, the particles contained in the fluid are retained by the mesh, thus generating a pressure differential (Δp) at the site of the mesh inlet and outlet.

Increases in Δp over time (t) provide information about particle loading.

Fig. 4
MeshBlockage Sensor MBS 1000

Advantages:
Mesh Blocking Process can be used for

- emulsions
- high particle loading
- opaque fluids

Disadvantages:

- only trend monitoring is possible
- no information on particle counts possible
- no particle distribution measurement possible
- no traceability to a calibration standard offered

1.1.3
Process Limits

When measuring particulate contamination using the sensors described in section 2, the oil cleanliness may not be above or below specific limits.

If the oil is “too clean” no particle readings can be captured. The lower process limit is approximately ISO 9/8/7.

Excess contamination leads to coincidence (= temporal meeting of two or more signals caused by several particles aligned in the same plane), rendering particle measurement no longer possible. This problem is encountered with cleanliness classes over ISO 25/24/23.

Particle counting in emulsions is not possible employing optical methods. The principle of light obscuration is limited to particles over 1 $\mu m_{(c)}$ in size.

For oil cleanliness classes of less than ISO 14/12/10, the direct comparison of an online measurement with an oil sample is not always possible. Additional error sources when taking oil samples:

- contamination of environment
- altered flow conditions at sampling point
- variable contamination at different sampling points (tank, pressure line, offline circuit)
- procedure for oil sampling (e.g. cleanliness of sampling adapter, fluid volume, machine cycle)

1.2
Test Dust

1.2.1
ACFTD / ISO MTD

Until 1992 ACFTD (Air Cleaner Fine Test Dust) was valid as test dust.

Starting in 1997, a new test dust, ISO MTD (ISO Medium Test Dust) was stipulated in ISO 12103-A3. ISO MTD forms the basis for the SRM 2806 (Standard Reference Material) developed by the NIST (National Institute of Standards and Technology, USA).

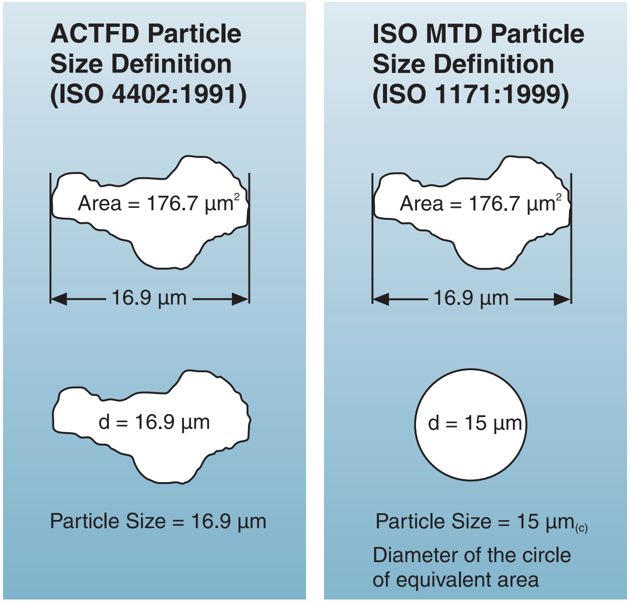
The ISO MTD dust is used for calibrating automatic particle counters subject to calibration standards ISO 11171:1999 and ISO 11943:1999.

1.2.2
Particle Sizes

In ACFTD dust the longest particle dimension is used to specify size.

With the introduction of ISO 11171:1999, a new definition of particle sizes was stipulated. The standard defines the diameter of an area-equivalent particle of ISO MTD dust as the particle size.
Particle size specifications according to ISO 11171:1999, the new calibration standard, contain the index $_{(c)}$, example: 4 µm$_{(c)}$, designating the calibration material used, certified and traceable to a national standard.
This notation is also used in the revised ISO 4406:1999 and the new ISO 11943:1999.

Fig. 5
Particle size definition



1.2.3
Calibration standard ISO 11171:1999

The ISO 11171:1999 calibration standard covers the calibration of automatic particle counters for fluids. This standard is applied in the primary calibration of laboratory particle counters. A suspension containing ISO MTD contamination is used for calibration.

The reference particle counters used by HYDAC and the ALPC Automated Laboratory Particle Counter are calibrated on the basis of ISO 11171:1999.

Fig. 6
ALPC Automated Laboratory Particle Counter

1.2.4
Calibration standard ISO 11943:1999

The ISO 11943:1999 calibration standard covers the calibration of automatic online particle counters for fluids.
This standard is applied in the secondary calibration of online laboratory particle counters.

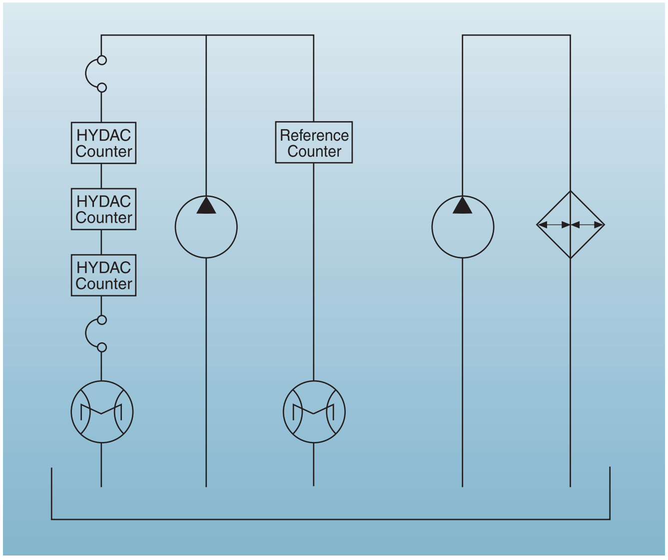
Fig. 7
FluidControl Unit FCU 2000

Fig. 8
ContaminationSensors CS 1000 and CS 2000

The same ISO MTD contamination is used as in ISO 11171:1999.

ISO 11943:1999 stipulates that online particle counters are connected in a hydraulic circuit with reference particle counters calibrated according to ISO 11171:1999.

Fig. 9
Schematic of a Calibration Test Rig



1.3 Contamination Classification

For a concise reference containing reference photographs, please refer to our Contamination Handbook on fluid monitoring (stock no. 349339).

1.3.1 ISO 4406

In ISO 4406, particle counts are determined cumulatively, i.e. > 4 µm$_{(c)}$, > 6 µm$_{(c)}$ and > 14 µm$_{(c)}$ (manually by filtering the fluid through an analysis membrane or automatically using particle counters) and allocated to measurement codes.
The goal of allocating particle counts to codes is to facilitate the assessment of fluid cleanliness ratings.
In 1999 the "old" ISO 4406:1987 was revised and the size ranges of the particle sizes undergoing analysis redefined.

The counting method and calibration were also changed. This is important for the user in his everyday work:

Even though the measurement codes of the particles undergoing analysis have changed, the cleanliness code will change only in individual cases. When drafting the "new" ISO 4406 care was taken to ensure that not all the existing cleanliness provisions for systems had to be changed (Lit. © HYDAC, "Filters- Power Fluid Technology, New Test Dust, New Calibration, New Filter Testing Methods – How This Impacts Everyday Work").

Overview of the changes:

	"Old" ISO 4406:1987	**"New" ISO 4406:1999**	
Size ranges	> 5 µm > 15 µm	> 4 µm$_{(c)}$ > 6 µm$_{(c)}$ > 14 µm$_{(c)}$	
Dimension determined	Longest dimension of a particle	Diameter of the area-equivalent circle ISO 11171:1999	
Test dust	ACFTD-dust	1-10 µm ultrafine fraction	ISO 12103-1A1
		SAE Fine, AC-Fine	ISO 12103-1A2
		SAE 5-80 µm ISO MTD Calibration dust for particle counters	ISO 12103-1A3
		SAE Coarse Coarse fraction	ISO 12103-1A4
Comparable size ranges	Old ACFTD-Calibration	Comparable ACFTD dusts	New NIST calibration
		< 1 µm 4.3 µm 15.5 µm	4 µm$_{(c)}$ 6 µm$_{(c)}$ 14 µm$_{(c)}$

Allocation of particle counts
to cleanliness classes:

No. of particles / ml		Clean-liness class
Over	**Up to**	
2,500,000		> 28
1,300,000	2,500,000	28
640,000	1,300,000	27
320,000	640,000	26
160,000	320,000	25
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
2.5	5	9
1.3	2.5	8

The reproducibility of the results in cleanliness class 8 depends on the concentration of particles in the sample undergoing analysis. If the number of particles counted in the sample is fewer than 20, the result has to be reported with ≥.

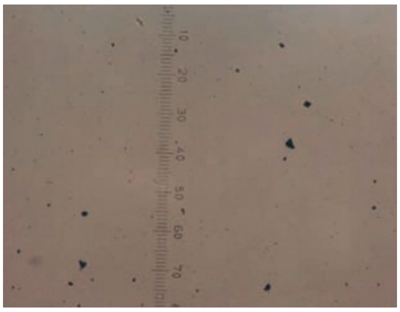
Example: 14/12/≥8

Note: increasing the measurement code by 1 causes the particle count to double.

Example: ISO class 18 / 15 / 11 says that the following are found in 1 ml of analyzed sample:

1,300 - 2,500 particle > 4 µm $_{(c)}$
160 - 320 particle > 6 µm $_{(c)}$
10 - 20 particle > 14 µm $_{(c)}$

Fig. 10
Microscopic Examination
of an Oil Sample (100 ml),
Magnification 100x
(ISO 18/15/11)



1.3.2 SAE AS 4059

Like ISO 4406, SAE AS 4059 describes particle concentrations in liquids. The analysis methods can be applied in the same manner as ISO 4406:1999 and NAS 1638.

The SAE cleanliness classes are based on particle size, number and distribution.
The particle size determined depends on the measurement process and calibration, consequently the particle sizes are labeled with letters (A - F).

The following table shows the cleanliness classes in relation to the particle concentration determined:

		Maximum particle Concentration [particles/100 ml]					
Size ISO 4402 Calibration or optical counting*		> 1 µm>	5 µm	>15 µm	> 25 µm	> 50 µm	> 100 µm
Size ISO 11171, Calibration or electron microscope**		> 4 µm (c)	> 6 µm (c)	> 14 µm (c)	> 21 µm (c)	> 38 µm (c)	> 70 µm (c)
Size coding		A	B	C	D	E	F
Classes	000	195	76	14	3	1	0
	00	390	152	27	5	1	0
	0	780	304	54	10	2	0
	1	1,560	609	109	20	4	1
	2	3,120	1,220	217	39	7	1
	3	6,250	2,430	432	76	13	2
	4	12,500	4,860	864	152	26	4
	5	25,000	9,730	1,730	306	53	8
	6	**50,000**	**19,500**	**3,460**	**612**	**106**	**16**
	7	100,000	38,900	6,920	1,220	212	32
	8	200,000	77,900	13,900	2,450	424	64
	9	400,000	156,000	27,700	4,900	848	128
	10	800,000	311,000	55,400	9,800	1,700	256
	11	1,600,000	623,000	111,000	19,600	3,390	1,020
	12	3,200,000	1,250,000	222,000	39,200	6,780	

* Particle sizes measured according to the longest dimension.

** Particle sizes determined according to the diameter of the projected area-equivalent circle.

The SAE cleanliness classes can be represented as follows:

1. Absolute particle count larger than a defined particle size

Example:

Cleanliness class according to AS 4059:6

The maximum permissible particle count in the individual size ranges is **bold-faced** in the above table.

Cleanliness class according to AS 4059:6 B

Size B particles may not exceed the maximum number indicated for class 6.

6 B = max. 19,500 particles of size of 5 µm or 6 µm (c)

2. Specifying a cleanliness class for each particle size

Example:

Cleanliness class according to AS 4059: 7 B / 6 C / 5 D

Size B (5 µm or 6 µm (c)):
38,900 particles / 100 ml

Size C (15 µm or 14 µm (c)):
3,460 particles / 100 ml

Size D (25 µm or 21 µm (c)):
306 particles / 100 ml

3. Indication of the highest cleanliness class measured

Example:

Cleanliness class according to AS 4059:6 B - F

The 6 B - F specification requires a particle count in size ranges B - F.

The respective particle concentration of cleanliness class 6 may not be exceeded in any of these ranges.

1.3.3 NAS 1638

Like ISO 4406 and SAE AS 4059, NAS 1638 describes particle concentrations in liquids.

This standard is now obsolete but often used in practice.
The analysis methods can be applied in the same manner as ISO 4406:1999.

In contrast to ISO 4406, certain particle size ranges are counted in NAS 1638 and allocated to these measurement codes.

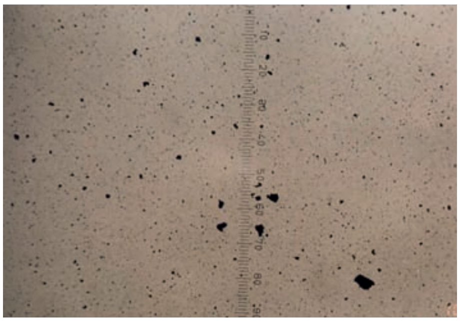
The following table shows the cleanliness classes in relation to the particle concentration determined.

		Particle size [µm]				
		5-15	15-25	25-50	50-100	>100
		No. of particles in 100 ml sample				
Cleanliness class	00	125	22	4	1	0
	0	250	44	8	2	0
	1	500	89	16	3	1
	2	1,000	178	32	6	1
	3	2,000	356	63	11	2
	4	4,000	712	126	22	4
	5	8,000	1,425	253	45	8
	6	16,000	1,850	506	90	16
	7	32,000	5,700	1,012	180	32
	8	64,000	11,600	2,025	360	64
	9	128,000	22,800	4,050	720	128
	10	**256,000**	**45,600**	**8,100**	**1,440**	**256**
	11	512,000	91,200	16,200	2,880	512
	12	1,024,000	182,400	32,400	5,760	1,024

Increasing the class by 1 causes the particle count to double on average.

The maximum particle counts of class 10 are **bold-faced** in the above table.

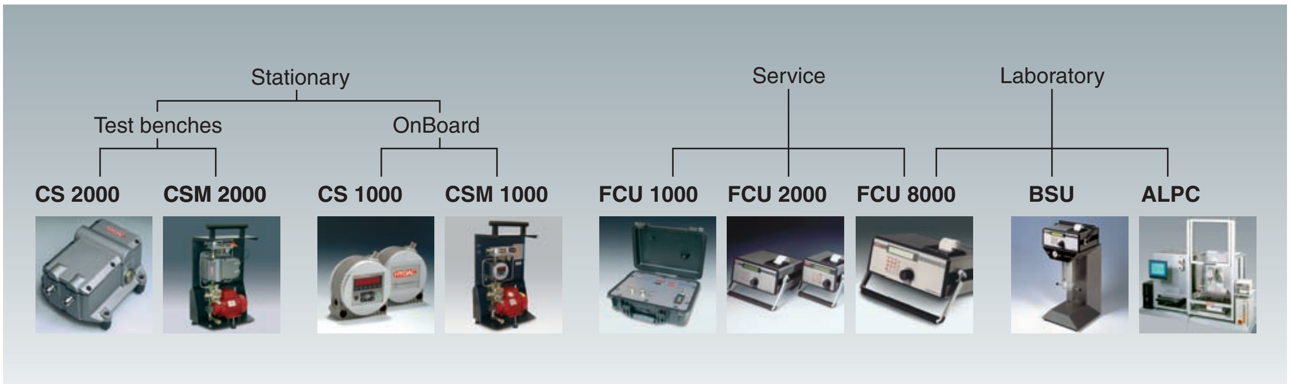
Fig. 11
Microscopic Examination of an Oil Sample (100 ml), Magnification 100x (NAS 10)



2 The Right Tool for the Job

2.1 Product Overview and Applications

Fig. 12
Product Overview

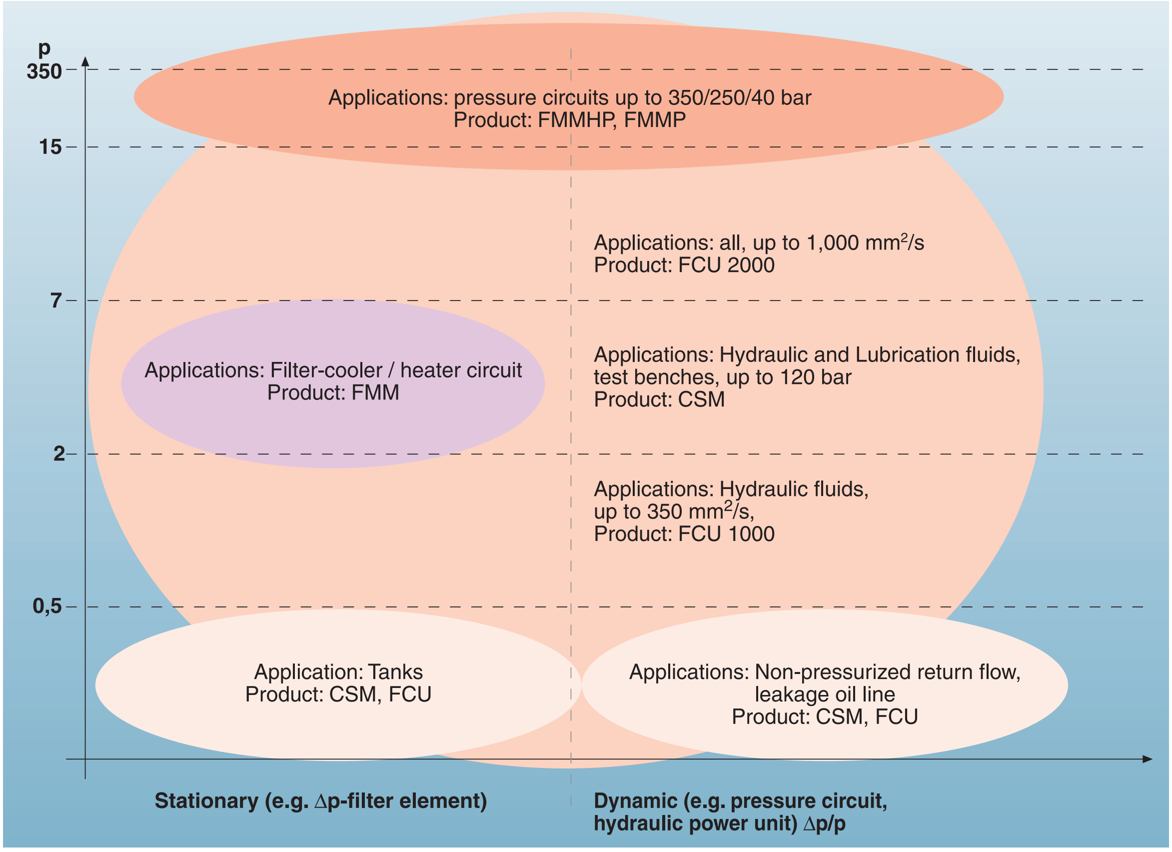


FluidControl Units (FCU) are offered for temporary measurement and fluid service purposes.
The Contamination Sensors (CS) are designed for stationary applications in hydraulic/lube systems and test rigs.
These sensors are also available as units featuring a motor-pump assembly, patented air suppression, and optional installation for the AS 1000 AquaSensor and HYDACLab®.

The Bottle Sampling Unit (BSU) combined with the FCU 8000 is used for analyzing oil samples. Simplified oil sampling can be done with FCU 2000 and FCU 1000.
The Automated Laboratory Particle Counter (ALPC) can be used to analyze up to 500 samples/day.
The following table shows the key differences between the individual units:

	FCU 1000	FCU 2000	FCU 8000	CS 2000	CS 1000	CSM 2000 / CSM 1000
Optical measurement cell	Glass block → higher pressure stability	Glass fiber	Glass plates Lens system	Glass fiber	Glass block → higher pressure stability	Depends on sensor
LED	Infrared	Infrared	Laser	Infrared	Infrared	Depends on sensor
Determination of flow rate via	Particle signal	Integrated flow rate sensor	Integrated flow rate sensor	Particle signal	Particle signal	Depends on sensor
Regulation of flow rate via	Motor-pump assembly	Control knob on the front for setting the flow control valve	Control knob on the front for setting the flow control valve	- Internal hydraulic conditioning selectable in the model/type code - External modules (see 2.4.3)	External modules (see 2.4.3)	Motor-pump assembly

Fig. 13
Typical Applications
and Suitable Products
(and Modules)



The various applications are subdivided below into:

- Temporary Measurement and Fluid Service
- Continuous Online Analysis in Test Rigs for Determining Surface Cleanliness
- Continuous Online Measurement in Hydraulic and Lubrication Systems for Condition Monitoring
- Laboratory Equipment

2.2 Temporary Measurement and Fluid Service

Portable FluidControl Units (FCU) (series 2000) are available for temporary measurement and fluid service purposes.
The FCU is available in various calibrations and models.
All models feature a display with a keypad, a knob for adapting the flow rate, and an integrated miniature dot-matrix printer. Models are also available with/without an internal pump for automatically suctioning fluids from oil samples or the tank. The FluidControl Units are user-friendly and provide for reliable measurement results.

The following table provides a comparison of the various models:

	FCU 1000	FCU 2000	FCU 8000
			
Brief description	- Portable particle counter	- Portable particle counter	- Laser particle counter
Features	- 4 measurement channels - Cleanliness ratings according to ISO 4406, SAE 4059 and NAS 1638 - With internal pump - Data output on display or via connection to a PC - Analysis and storage of measurement data - M12x1 and Bluetooth interface - Rugged design	- 4 measurement channels - Cleanliness ratings according to ISO 4406, SAE 4059 and NAS 1638 - Type with internal pump available - Integrated graphics-capable printer - Data output on display or via connection to a PC - Analysis and storage of measurement data - RS232 or RS485 interface - Continuous online measurement - Rugged design	- 6 measurement channels - Cleanliness ratings according to ISO 4406, SAE 4059 and NAS 1638 - Integrated graphics-capable printer - Data output on display or via connection to a PC - Analysis and storage of measurement data - RS232 interface for data output - Laser particle sensor - Extended measurement range for fluids down to NAS 0
Competitive advantages	- Optical infrared measurement cell - Capturing, analysis and storage of measurement data - Evaluation via HYDAC's own FluMoS software possible (FluMoS light available as freeware)	- Patented fiber optic infrared measurement cell - Capturing, analysis and storage of measurement data - Evaluation via HYDAC's own CoCoS software possible (CoCoS light available as freeware)	- Can be used in the field as a portable measurement unit and in laboratory - Evaluation via HYDAC's own CoCoS software possible (CoCoS light available as freeware)
Applications	- Hydraulic systems - Maintenance and servicing - Tank analysis	- Hydraulic and lubrication systems - Maintenance and servicing - Test rigs - Bottle sampling analysis - Tank analysis	- In laboratories and at service centers - Field applications - Bottle sampling analysis

The following prerequisites apply to using the FCU:

Pressure range	1 - 350 bar (depending on viscosity)
Permissible viscosity range (continuous operation)	5 - 1,000 mm^2/s (pressure port) 5 - 150 mm^2/s (suction port, FCU 2000-4 only)
INLET port (pressure)	FCU 2000: Minimess coupling, type 1604 (including high-pressure inlet hose DN 4 (type 1604 - type 1620, 2 m long)) FCU 8000: Minimess coupling, type 1620 (including high-pressure inlet hose DN 2 (type 1620 – type 1620, 2 m long))
OUTLET port (suction)	Plug connector DN 6.4 with shut-off
OUTLET port	Plug connector (low-pressure outlet hose DN 7 (2 m long))

2.3 Continuous Online Analysis in Test Rigs for Determining Surface Cleanliness

Using online particle counters for checking component cleanliness is described in detail in ISO 18413. In the process, the test oil is analyzed subsequent to component cleanliness analysis. Test rigs possess several factors which render continuous online analysis difficult:

- short measurement cycles
- changing flow rates
- air bubbles
- oil mixtures
- grease
- assembly lubricants

Stationary units, i.e. the Contamination Sensor Modules (CSM), are available for ensuring stable measurement conditions, thus enabling continuous online analysis. The CSM 2000 and CSM 1000 models differ by virtue of the sensors used.
The CSM is a standalone unit featuring a motor-pump assembly and a contamination sensor. This enables the fluid to be suctioned out of lines and non-pressurized tanks and conveyed through the sensor for measurement.

The module also possesses a patented air suppression feature. This causes air present in the oil to be dissolved by applying pressure and thus not counted as particles in the optical contamination sensor. A moisture sensor, the AS 1000, or an oil level sensor, the HYDACLab®, can be integrated in the oil stream. The HYDACLab® is a multi sensor for

- temperature
- moisture
- viscosity changes
- permittivity alterations

Fig. 14
CSM 1000

Fig. 16
CSM 1000 integrated in test rig

Fig. 15
CSM 2000

The following prerequisites apply in order to enable simple integration in the test rig, the CSM is used to suction oil in the vicinity of the return-flow line and convey it through the particle counter.
The CSM 1000 is used for standard hydraulic applications.
The CSM 2000 – combined with a supplementary CM-FS flowmeter – is available for difficult-to-count fluids (gear lubrication fluids, oil mixtures, grease concentrates and assembly lubricants).

The following prerequisites apply to the use of the CSM:

INLET pressure range	-0.4 – 0.5 bar (standard pump) or -0.4 – 120 bar (pump, inlet pressure stability, with leakage oil line)
Pressure OUTLET	5 bar
Permissible viscosity range	10 - 3,000 mm²/s
Permissible viscosity range for measurement operation	10 - 1,000 mm²/s
INLET port (pressure)	Thread G 1/4, ISO 228
OUTLET port	Thread G 1/4, ISO 228

The CSM contains a 400 µm protective mesh (CM-S).

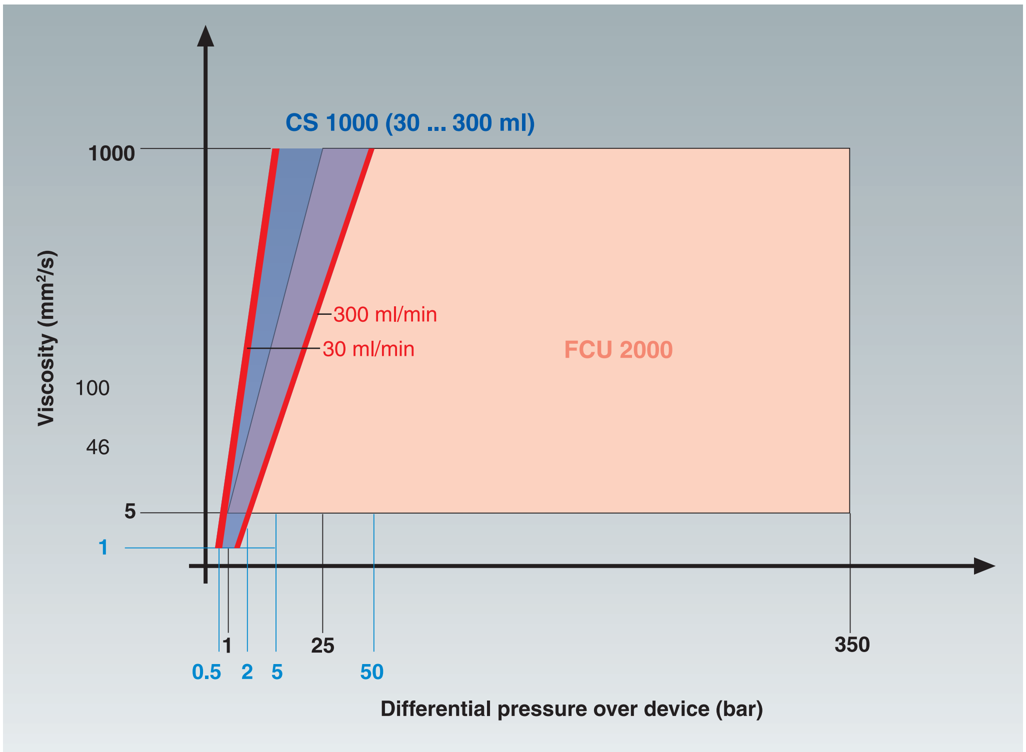
2.4 Continuous Online Measurement in Hydraulic and Lubrication Systems for Condition Monitoring

The series 2000 and 1000 Contamination Sensors (CS) are available for continuous online measurement in hydraulic and lubrication systems, the sensors being integrated permanently in the system. To this end, the flow rate has to be precision-adjusted in the respective measurement range via the sensor.
The Contamination Sensor is an orifice (hydraulically speaking).

	CS 1000 	CS 2000 
Brief description	- Contamination Sensor for measuring the solid particle contaminants in hydraulic and lubricating fluids	- Contamination Sensor for measuring the solid particle contaminants in hydraulic and lubricating fluids
Features	- Up to 300 bar - No data input - Switching output - Analog output: 4 – 20 mA or 0 – 10 V - RS485 port	- Max. 40 bar - 2 x 4 – 20 mA inputs for AquaSensor (AS) or other sensors - 3 dedicated and 3 optional outputs - RS232 for ISO code display - 2 alarm relays - Universal PLC output - Option: 4 – 20 mA, RS232, RS485 or Ethernet - Can be operated with an external flow sensor
Competitive advantages	- Recalibratable - IP 67 - Shock- and vibration-resistant - Compact design - 3-digit display - Data interfaces integrated in unit	- Recalibratable - Large number of data outputs - Wide range of hydraulic conditioning modules available - Electrical outputs
Applications	- Mobile hydraulics - Industrial facilities, e.g. machine tools, injection moulding equipment, presses, etc. - Filter carts - Scheduled maintenance	- Test rigs

In contrast to the fluid service unit FCU, the flow rate is not subsequently manually readjusted in the permanently integrated Contamination Sensors.
The limited flow range correlates with a restricted working range with regard to pressure and viscosity. The following graph shows the difference in hydraulic working range between the FCU and CS 1000.

Fig. 17
Working Ranges of the CS 1000 and FCU 2000

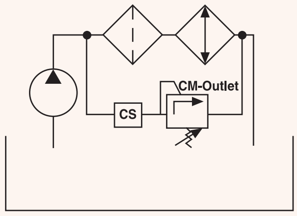
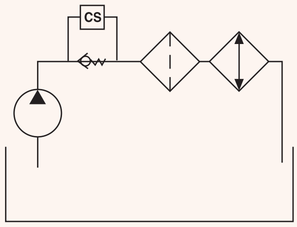
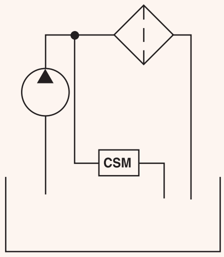


Various ConditioningModules (CM) are available for regulating the flow rate within the permissible range. The ConditioningModules enable the working range of the CS 1000 and CS 2000 to be adapted to the hydraulic conditions. These units are presented in a number of typical installation examples.

2.4.1
Typical Installation Examples

2.4.1.1
Filter-Cooler / Heater Circuit

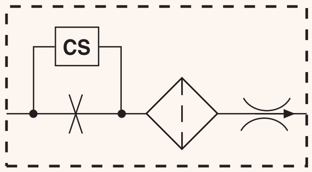
In a hydraulic circuit featuring a filter and cooler / heater unit, the CS can be integrated in the bypass.

Modules Used	Circuit Diagram	Function Description	Significance for the operating point
CS + CM-O **FMM**		- Pressure upstream of the filter-cooler/heater is sufficient for creating a pressure differential (Δp) - Return flow conveyed into tank or downstream of cooler/heater, depending on pressure differential (Δp) - Throttling of (possibly) overly high flow rate through the CM-O	- Clean filter element: setting of the operating point in the lower part of the permissible flow range - Increasing contamination of the filter element → Increase of the pressure differential (Δp) → Shifting of the operating point upwards = increase of the flow rate through the CS - Contaminated filter element: If the flow rate continues to be within the permissible range, the static operating point suffices for regulating the flow rate through the sensor
Check valve **CS + CM-O** **FMM**		- System-specific check valve (2-3 bar) for generating a sufficient Δp via the sensor - Connection of the sensor via Minimess DN4 (minimum line length, inlet: 630 mm, max. 4 m)	- Setting a constant Δp → Working range of the sensor now only dependent on viscosity
CSM 2000 **CSM 1000**		- Pressure upstream of clean filter element is not sufficient for creating a pressure differential (Δp) - Use of a CSM	- Automatic imposition of the operating point by impressing a flow rate in the specified range of the CS

Industries / applications:
- Plastic injection molding machinery (OEM and MRO)
- Automotive / hydraulic presses (OEM and MRO)
- Steel manufacturing / paper manufacturing / power generation

2.4.1.2
Pressure Circuit

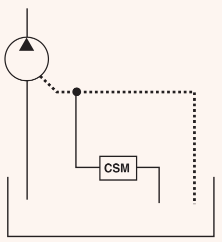
Integration is done via a pressure-compensated flow control valve for medium pressure applications and when good oil cleanliness ratings are present. In high-pressure applications it is recommended that a filter be used for protecting the flow control valve.

Modules Used	Circuit Diagram
FMMP **FMMHP** **CM-S + CM-I** **+ CS + CM-O**	

Industries / applications:
- Plastic injection moulding machinery (OEM)
- Mobile / agricultural machinery, forestry equipment, stackers and lifting trucks, conveying equipment, mining machinery, construction machinery (OEM)

2.4.1.3
Leakage Oil Flow Monitoring

In hydraulic circuits in which large, costly pumps are used it is important that the wear and tear posed to these pumps is measured. The optimal location for performing contamination measurement is the leakage oil line as particle concentrations build up here the fastest.

Modules Used	Circuit Diagram	Function Description	Significance for operating point
CSM 2000 **CSM 1000**		- Leakage oil line virtually non-pressurized - Pressure generation in the leakage oil line is not possible on account of possible damage to the main pump(s) - CSM used - Possibility of integrating an AS 1000 or HYDACLab® - Note: Maintain temperature range of CSM	- Automatic imposition of the operating point by impressing a flow rate in the specified range of the CS

- Industries / applications:
Large-scale systems (OEM and MRO)

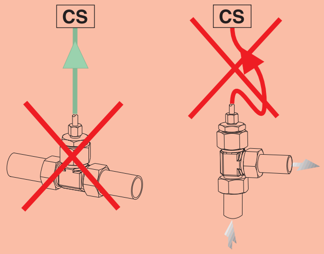
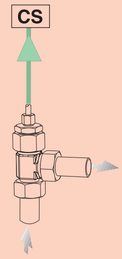
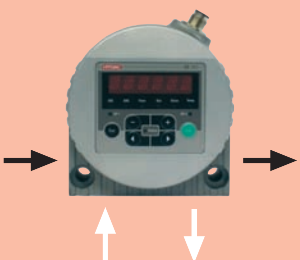
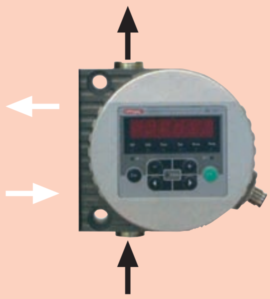
2.4.1.4
Lubrication Oil Monitoring

The ContaminationSensor Module CSM is available for lubrication oil monitoring. The pump provides a sufficient flow rate through the sensor.
The CSM possesses a patented air suppression feature. Hydraulic pressure precharging of 25 bar in the sensor is recommended for lubricating oil.

Industries / applications:
- Wind power generation systems and gear units
- Steel manufacturing / paper manufacturing / power generation

2.4.2 General Installation Recommendations

Certain criteria should be heeded when installing the sensors so that interference is reduced.

Installation recommendation	BAD	GOOD
		
Selection of the measurement point		- The measurement point has to be selected so that the measured volume is taken from a turbulent flow, e.g. at a pipe bend
Spacing with regard to measurement point		- The CS has to be installed in the vicinity of the measurement point in order to obtain precision-timed results - When precharging using the CM-O (recommended: 20 – 25 bar) an intake path of 630 mm (max. 4 m) is advisable between the measurement point and the CS
Prevent siphon trap		- While installing the measurement line, make sure that no "siphon trap" is created so as to prevent sedimentation buildup (formation of particle deposits in the line)
Diameter of connector lines		- INLET: Minimess hose DN4 or pipe with an internal diameter of 6 mm - OUTLET: Minimess hose ≥ DN4 or pipe with an internal diameter ≥ 6 mm - If a high viscosity is present, the cross-sections have to be accordingly larger
Direction of flow Horizontal or vertical?	- A horizontal flow direction is not advisable - Air bubbles may collect, particularly when the CS is installed at the highest point of the hydraulic circuit 	- A vertical flow direction is preferable over a horizontal one as no air bubbles will collect 

2.4.3 Conditioning Modules

For information on the Conditioning Modules, please refer to the brochure “Fluid Monitoring - Technical Information” (when ordering, please state language required: German or English).

2.5 Laboratory Equipment

Sample analysis in the laboratory:
the BottleSampling Unit (BSU), Automated Laboratory Particle Counter (ALPC) and FCU 2000 have been specifically developed for this purpose.
Overview of the key features of these units:

	FCU 2000	FCU 8000	ALPC
			
Brief description	- Portable particle counter	- Laser particle counter combined with a BottleSampling Unit for analyzing hydraulic fluid sampling bottles	- Automatic particle counter for analyzing fluid sampling bottles
Features	- Continuous online measurement - Rugged design - Cleanliness ratings according to ISO 4406, SAE 4059 and NAS 1638 - Type with internal pump available - Integrated graphics-capable printer - Data output on display or via connection to a PC - Analysis and storage of measurement data - RS232 or RS485 interface - Calibrated according to ISO 11943	- 6 measurement channels - Cleanliness ratings according to ISO 4406, SAE 4059 and NAS 1638 - Integrated graphics-capable printer - Data output on display or via connection to a PC - Analysis and storage of measurement data - RS232 interface for data output - Laser particle sensor - Extended measurement range for fluids down to NAS 0	- Automated, controlled measurement and flushing cycles of hydraulic and lubrication fluids - Sample analysis performed quickly thanks to extremely short measurement and flushing times (up to 500 samples/day) - Calibrated according to ISO 11171 and ISO 4402 Consequently, analysis according to NAS1638 possible
Competitive advantages	- Patented fiber optic infrared measurement cell - Capturing, analysis and storage of measurement data - Evaluation via HYDAC's own CoCoS software possible (CoCoS light available as freeware)	- Easy to use - Can be used in the field as a portable measurement unit - Can be used in the laboratory with the BottleSampling Unit (BSU)	- Only small sampled quantity required (approx. 50 ml) - Automated sample feeding via multi-axis robot arm (ALPC 9000-2) - Enables convenient operation - Graphical analysis of measured results via ALPC software
Applications	- Hydraulic and lubrication systems - Maintenance and servicing - Test rigs - Bottle sampling analysis - Tank analysis	- Laboratories and service centers - Field applications	- Laboratories - Up to 500 samples/day

3 Imprint

3rd Edition, April 2008

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E 7.605.2/05.08