OilWear®

User and operation Handbook

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1 Introduction

This handbook describes the key features of the OilWear 2.0 system, whose primary function is to monitor existing particles in the lubricating oil for industrial equipment. The core of the system is the measuring module, which is based on the patented technology of digital image and video processing. It quantifies particles greater than 4 microns present in fluids and classifies them related to the ISO, NAS or SAE standards.

The OilWear 2.0 (OW2.0) system is prepared to be installed as a bypass onto the lubrication circuit. Thus a small hydraulic subsystem is required to prepare the oil flow so that the measurement can be taken.

This sensor is offered in two different setups. The measurement module can be installed as a stand-alone device, or it can be fitted in a housing, as shown in Figure 1.

Figure 1. OilWear Sensor 2.0.

The OilWear 2.0 device is in the process of being protected through the following patents:

- European Patent n. 16382179.6
- US Patent n. 15/496,430

2 Measuring principle

Atten2 OW2.0 sensors measure fluid contamination and condition using optical acquisition systems and digital image processing algorithms.

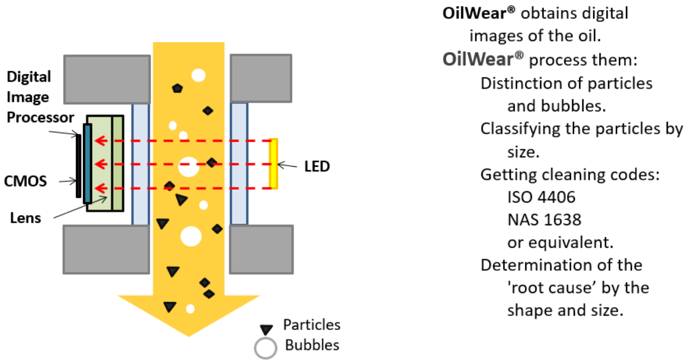


Figure 2. The measurement principle of Atten2 OilWear2.0.

Periodical images are obtained, processed in the sensor and the information collected is delivered via Modbus to the customer acquisition system.

3 OILWEAR 2.0 INTERFACES

The OW system is designed to be fitted as a bypass onto the industrial machine's lubrication circuit. Via one of its digital outlets, the OW is designed to deliver a value of the cleanliness codes of the measurement (related to the selected standard – ISO, NAS or SAE) of the oil sample that it receives through the bypass, without interfering with the regular operation of the machine. Also, this equipment is capable of offering information about wear particle root cause and particles pictures.

So, the system has two distinct interfaces: a hydraulic one plus an electrical/electronic one.

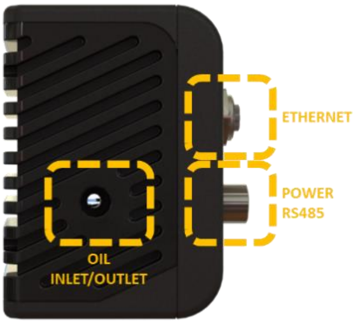


Figure 3. Interfaces of the OilWear 2.0. System. Stand-alone sensor (left) and housing (right).

Currently, the system provides all communications based on Modbus protocol indicated in the table below. The end-user is capable of modifying sensor parameters to choose between each type, with the configuration app.

REFERENCE	COMMUNICATIONS	
OilWear 2.0 A	Modbus RTU	RS485-2W
OilWear 2.0 B	Modbus TCP/IP	Ethernet

Table 1: OW2.0 System Communication Protocols.

Also, upon request the hydraulic hoses and electric cords are provided so that the device can be correctly fitted onto the machine. Only the necessary hoses and patch cords should be selected, and only of the length that is needed. Listed below are the hoses/patch cords for all the electrical and hydraulic interfaces.

A Patchcord for connecting the OW2.0 to the electrical panel that provides 24VDC power and RS485-2W communication. There are different length options. For other options, please contact Atten2. The OW2_Wire_A is designed to keep the system sealed (IP65).

- OW2_Wire _A-5: 5 meters long
- OW2_Wire _A-10: 10 meters long
- OW2_Wire _A-15: 15 meters long

An OW Ethernet connection patch cord to an Ethernet port that provides TCP/IP communication. There are different length options. For other options, please contact Atten2. The OW2-ETH is designed to keep the system sealed (IP65).

- OW2-ETH-5: 5 meters long
- OW2-ETH-10: 10 meters long
- OW2-ETH-15: 15 meters long

ELECTRICAL patch cords		
OW2_Wire_A-5	Main Connector Patch Cord	5 M
OW2_Wire_A-10	Main Connector Patch Cord	10 M
OW2_Wire_A-15	Main Connector Patch Cord	15 M
OW2-ETH-5	Ethernet Connector Patch Cord	5 M
OW2-ETH-10	Ethernet Connector Patch Cord	10 M
OW2-ETH-15	Ethernet Connector Patch Cord	15 M

Table 2: Additional Interface Components

Hydraulic hose (INLET and OUTLET) for the bypass connection with the machine's lubrication system. There are different lengths available. If a different length is needed, please contact Atten2.

HYDRAULIC HOSES		
OW-OIL-A (OIL INLET)	Hydraulic Hose	2 M
OW-OIL-A (OIL INLET)	Hydraulic Hose	3 M
OW-OIL-A (OIL INLET)	Hydraulic Hose	5 M
OW-OIL-B (OIL OUTLET)	Hydraulic Hose	2 M
OW-OIL-B (OIL OUTLET)	Hydraulic Hose	3 M
OW-OIL-B (OIL OUTLET)	Hydraulic Hose	5 M

Table 3: Additional Hydraulic Components

Upon request, a set of hose adapters (BSP type) are also provided to ensure correct fitting onto the threads, with male/male reducers for the following thread sizes: ½", 3/8", ¼". Screws are also provided to assist in the mechanical installation of the OW 2.0 onto the machine, and a mechanical clamping solution is also provided.

MECHANICAL INSTALLATION		
OW-MEC-B	Screws for fixing brackets in place	(x4)

Table 4: Additional fixing accessories

Extended information can be found in the "Installation and commissioning handbook".

4 GENERAL SPECIFICATIONS

ELECTRICAL				UNIT.
	Nominal	Minimum	Maximum	
Power supply*	24 VDC	20	28	V
Consumption	50 mA	40	600	mA
*Reverse Voltage Protection				
Electrical Inlets/Outlets				
Modbus RTU over (RS485-2W)*	Reading/Configuration			
Modbus TCP over Ethernet*	Reading/Configuration			
* Independent use. Selection depending on user.				
Dimensions				
Height	80			mm
Width	45			mm
Depth	45			mm
Weight				
When circuit empty	0.5			Kg
Operating temperature		0	60	ºC
Humidity RH		0	95	%
Minimum/Maximum Temperature		-10	90	ºC
Operating pressure		0.1	5	bar
Maximum pressure			150	bar
Operating oil flow	0.2	0.1	0.5	l/min
Housing	IP 65			
MATERIALS				
Wettable Material	BK7, Aluminum, VITON Other materials upon request			
External Material	Aluminium, Nylon			
Connections	1/8" BSP female			
Certifications	CE, UL			
Branding	Serial Number, Logo, Patent info, certifications.			
Lifetime	3 years (80% of sensitivity)			
Calibration	Following ISO 11171 standards			
Viscosity	460 (max)			cST

Table 5: OW2.0 General Specifications

Results (depending on the sensor selected)	
Resolution	>4um
Results	ISO4406, NAS 1638, AS 4059
ISO Code Range	6-27
Precision	±1 ISO Level at normal conditions ±2 ISO Level, not favourable conditions (i) presence of water,(ii) presence of air,(iii) low opacity,(iv) High flow range
Output	>4, >6,>10, >14, >21, >38, >70um particle counts per ml Wear-related Shaped particles (>20um) per ml Number of Bubbles per ml Oil degradation index (%) Image (1 per test)
Error Log	Last 200 errors
Data Log	Last 1000 measurements
Test time Adjustable	60-3600 seconds

Table 6: OW2.0 Results specifications.

5 Connecting the sensor

The OW 2.0 system has various electrical/electronic interfaces to control its operation.

Figure 4. Interface Details of the OilWear 2.0 System.

OW2.0 Wire is based on M12 5-pins male connector. This connector groups together the Power Supply and Modbus RTU Interface lines. The pins are distributed as follows.

PIN	FUNCTION	OH-WIRE_A COLOUR CODE
2	VDC IN	White
3	GND IN	Blue
5	D– (RS485)	Gray
4	D+ (RS485)	Black

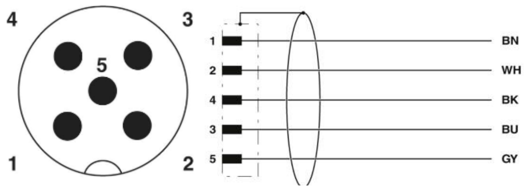


Figure 5. OW2.0 Pin-out Connector

Please refer to the Modbus section of the Users Handbook for the description of the analogue Modbus (RS485 D+/D-) access and output. An OW2-Wire_A-NN patch cord is provided for connection to the electrical panel. OW2-ETH-NN is the input connector to the internal TCP/IP server of the OilWear 2.0 system. For the description of the Modbus TCP/IP access, please refer to the Modbus Section.

The OW is designed to start working automatically with the default setting. Sensor led provides information about sensor power condition and TCP/IP communication.

Colour	Status	Information
Red	Stable	Powered up
Orange	Stable	TCP/IP communication
Orange	Blinking	TCP/IP data transmission

Figure 6. OW2.0 LED information.

The system's measuring principle does not require OW to be calibrated for the oil type being used in the target system, except for the OilHealth degradation measurement.

On all its interfaces the OW displays the latest measurement of the Oil Cleanliness (related to the selected cleanliness standard), particle counting (compared to standard), shape detection, as well as fault origin detection.

The result of the measurement is shown through the various channels fitted onto the OW sensor.

6 Modbus communication

6.1 Introduction

Modbus is a communications protocol located at levels 1, 2 and 7 of the OSI Model, based on the master/slave (RTU) or client/server (TCP/IP) architecture, designed in 1979 by Modicon for its range of programmable logic controllers (PLCs). Having become a de facto industry standard communications protocol, it is the most widely available for the connection of industrial electronic devices.

Modbus allows the control of a network of devices and communicates the results to a computer. Modbus is also used for the connection of a supervisory computer with a remote unit (RTU) in supervisory systems data acquisition (SCADA). There are versions of the Modbus protocol for serial port and Ethernet (Modbus/TCP). Information from this section has been obtained from the Modbus organisation reference documentation.

Each device in the Modbus network has a unique address. Any device can send Modbus commands, although usually only one master device is allowed. Each Modbus command contains the address of the device to which the command is sent. All devices receive the frame, but only the recipient executes it. Each of the messages includes redundant information that ensures its integrity at reception. The basic Modbus commands allow an RTU device to be controlled to modify the value of one of its registers or to request the contents of those registers.

Modbus is based on an approach of coils, registers and functions. The Modbus data model distinguishes between digital inputs (discrete input), digital outputs (coils), input registers, and holding registers. The digital inputs and outputs occupy one bit, while the registers, both input and holding, occupy two bytes. MODBUS uses a ‘big-Endian’ representation for addresses and data items. This means that when a numerical quantity larger than a single byte is transmitted, the most significant byte is sent first.

Primary tables	Object type	Type of	Comments
Discretes Input	Single bit	Read-Only	This type of data can be provided by an I/O system.
Coils	Single bit	Read-Write	This type of data can be alterable by an application program.
Input Registers	16-bit word	Read-Only	This type of data can be provided by an I/O system
Holding Registers	16-bit word	Read-Write	This type of data can be alterable by an application program.

Figure 7. Types of data registers in the Modbus protocol.

Each device defines its coils and registers in their physical memory where information is stored, and the master sends or extracts this information. To extract the information, the master requires to send information regarding the function and the value.

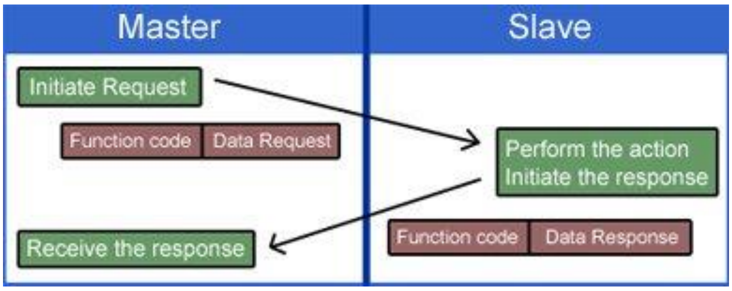


Figure 8. Modbus communication schema.

6.2 Modbus address definition

Depending on the communication protocol selected, Modbus address information is different.

Type	Modbus TCP/IP	Modbus RTU
Interface	Ethernet	RS485-2W
Address	IP address*	COM Port
Port	502	-
Baud rate*	-	57600
Slave ID*	10	10
Modbus configuration*		Data bits: 8 Stop bits: 1 Parity: Even
*configurable upon request		

6.3 Results data registers

In the next table OilWear 2.0´s results, Modbus map can be found. The Modbus map shown below it is defined equally for both communication modes, Modbus RTU-RS4852W and Modbus TCP/IP. Two definitions of the map are shown.

Parameter		OW 2.0 Map - INPUT		OW 2.0 Compatible map - INPUT/HOLDING	
		Data type	Modbus register address	Data type	Modbus register address
Timestamp	-	int	/*1356-1357*/	int	/* 1042-1043 */
ISO 4406 Code	>4 microns	float	/*1402 - 1403*/	short	/* 1030 */
	>6 microns		/*1404 - 1405*/	short	/* 1031 */
	>14 microns		/*1406 - 1407*/	short	/* 1032 */
Big particle count	>21 microns	int	/*1366-1367*/	-	
	>38 microns	int	/*1362-1363*/	-	
	>70 microns	int	/*1358-1359*/	-	
Total particles	-	int	/*1378-1379*/	short	/* 1029 */
Total bubbles	-	int	/*1380-1381*/	short	/* 1028 */
OD	-	unsigned char (2nd byte)	/*1416*/	short	/* 1018 */
Shape	Timestamp	int	/*63000-63001*/	int	/* 1042-1043 */
	Cutting	short	/*63003*/	short	/* 1035 */
	Cutting [%]	unsigned char (2nd byte)	/*63014*/	-	
	Sliding	short	/*63006*/	short	/* 1036 */
	Sliding [%]	unsigned char (1st byte)	/*63016*/	-	
	Fatigue	short	/*63004*/	short	/* 1037 */
	Fatigue [%]	unsigned char (1st byte)	/*63015*/	-	
	Fiber	short	/*63005*/	short	/* 1038 */
	Fiber [%]	unsigned char (2nd byte)	/*63015*/	-	
	Air	short	/*63002*/	short	/* 1039 */
	Air [%]	unsigned char (1st byte)	/*63014*/	-	
	Unknown	short	/*63007*/	short	/* 1040 */
	Unknown [%]	unsigned char (2nd byte)	/*63016*/	-	
Temperature	[ºC]	float	/*62480-62481*/		
Particle count	>4 microns	int	/*1378-1379*/		
	>6 microns	int	/*1374-1375*/		
	>14 microns	int	/*1370-1371*/		

Figure 9. OW2.0 results in Modbus map.

- OW2.0 Map (orange colour): Both maps contain the same data. This one has extended features, such as ISO 4406 decimal values, and shape percentages.
- OW2.0 Map (Grey colour): Both maps contain the same data. This map is provided for implementation easiness, in terms of data reading and interpreting and INPUT/HOLDING presence.

The Modbus map of OW2.0 contains different features that are not explained in this document.

6.4 Modbus integration

A successful Modbus integration in an acquisition system requires that several topics are considered:

- Register Addresses and Functions: Modbus data is obtained through a combination of functions and registers. Some Modbus acquisition systems require to introduce both function and register in the same area. For example, reading a Modbus INPUT register “1001”, requires to introduce “41001”, that is the combination of function 4 “READ INPUT REGISTERS” plus the register 1001.

				Function Codes			
				code	Sub code	(hex)	Section
Data Access	Bit access	Physical Discrete Inputs	Read Discrete Inputs	02		02	6.2
		Internal Bits Or Physical coils	Read Coils	01		01	6.1
			Write Single Coil	05		05	6.5
			Write Multiple Coils	15		0F	6.11
	16 bits access	Physical Input Registers	Read Input Register	04		04	6.4
		Internal Registers Or Physical Output Registers	Read Holding Registers	03		03	6.3
			Write Single Register	06		06	6.6
			Write Multiple Registers	16		10	6.12
			Read/Write Multiple Registers	23		17	6.17
			Mask Write Register	22		16	6.16
			Read FIFO queue	24		18	6.18
	File record access		Read File record	20		14	6.14
			Write File record	21		15	6.15

Figure 10. Table of public functions in Modbus.

- Modbus offset: In the Modbus/RTU and Modbus/TCP protocols, the addresses are encoded using 16 bits with a number between 0 and 65,535. These are 0-based addresses. Therefore, the Modbus protocol address is equal to the Holding Register Offset minus one. Some acquisition devices have the offset predefined, but others not. So, it is essential to check that the address is pointing the correct register.
- Confusion about Little-Endian vs Big-Endian Word Order: Although Modbus.org standard documents provide some guidance for implementing the Modbus protocol, they do not address the question of word order beyond the register level. Modbus implementers have to make an arbitrary choice as to which address of the register pair contains the most significant word of 32-bit values such as IEEE-754 single-precision floats and signed or unsigned 32-bit integers. Most programs for communicating with Modbus slaves can be configured for either register word order, but the most common default word order today is Little-Endian.
- Register sectioning: Some of the data contained in the sensor Modbus map encapsulates two different data values in the same register, one in each byte. The acquisition system should be able to section this data and interpret this data separately.
- Data type interpretation: Different programming languages offer different names for the variable types available. Once collected, registers have to be interpreted correctly. The following table defines the variables as proposed by the sensor interface, with expected ranges.

Variable type	Bytes	Range	Definition
INT	4	0-42949697295	Unsigned 32-bits integer
FLOAT	4	$\pm 1{,}5 \times 10^{-45}$ - $\pm 3{,}4 \times 10^{38}$	Floating number
SHORT	2	0-65535	Unsigned 16-bits integer

CHAR	1	0-255	Unsigned 8-bits integer

Figure 11. Variables definition and range.

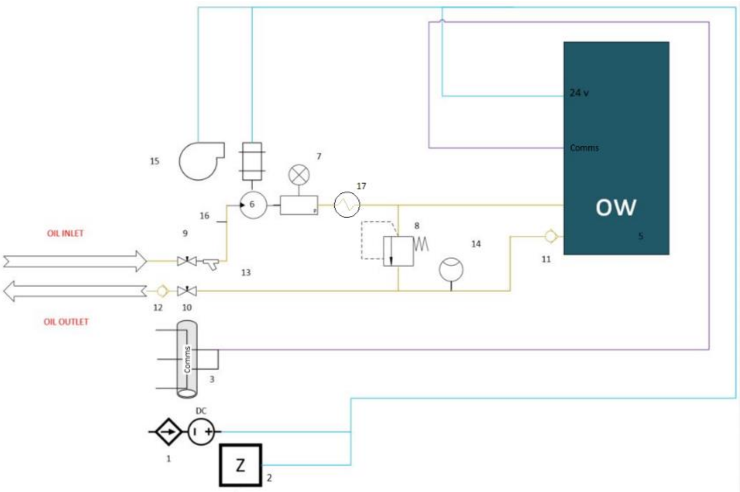
6.5 Quick integration test

- Modbus code reading without lubricant: Base readings for ISO 4406 code are 8/7/6. To confirm offset, a quick test with the three ISO codes to ensure modbus offset.
- Comparison with compatible map: Since data is present in different parts of modbus map, double-acquisition can ensure data correctness.
- Shape simulation function: Atten2 can provide support with shape integration. Please contact our support team to perform a simulated shape data acquisition.

7 Hydraulic subset

The OilWear 2.0 is based on the OW module, but some additional subsets can be added to ensure measuring capabilities. The subsystems comprise all the hydraulic components for fluid conditioning in terms of pressure, temperature and flow adapted to the sensor optimum capabilities.

The next view of the OilWear system presents the scheme of the subsystems. To clarify any doubts about any of them, please contact Atten2.



1	Power supply 24VDC
2	Control module
3	Communications switch
4	Power strip with grip
5	Sensor (OW / OH)
6	Pump
7	Pressure gauge
8	Pressure regulating valve
9 /10	Needle valve
11 /12	Check valve
13	Inlet prefilter
14	Flow indicator
15	24 VDC fan
16	Sampling point
17	Heat exchanger

Figure 12. Components of the hydraulic subsystem of the OilWear 2.0.

The hydraulic subset can include the following items, depending on user equipment oil conditions:

- Pumping and overpressure security system
- Electronic system connected to equipment lubricant status signal
- Communications switch
- Cooling system

Please contact Atten2 for more information of any required subset.

8 Maintenance

OilWear sensor has been designed and manufactured to operate autonomously during equipment lifetime of the machine. Nevertheless, it is strongly recommended to perform a cleaning procedure once a year to enhance sensor response and durability. Please follow this procedure carefully.

1. Please ensure that the lubrication feeding system to the sensor is blocked or stopped. If necessary, the circuit must be depressurised.
2. Remove the sensor power supply.
3. After that, proceed to disconnect the hydraulic hoses connected to the sensor. It should be noted that this action may spill some of the hoses remaining oil. It is strongly recommended to have a drain pan or any other means for containment and cleaning procedures:
4. Plastic plugs hose ends.
5. Use absorbent cloths for containment and area cleaning.
6. Container for oil drain if necessary.
7. Then, a flushing system with petroleum ether is required. If no pump is available, this procedure could be done with the help of a syringe, discharging in the sensor oil inlet, making sure the ether comes out from outlet port. This operation should be performed until the outgoing ether appearance is similar to the fresh ether. Please note that the ether is a volatile product, and check the material safety data sheet before use.
8. After ether cleaning, a similar procedure with flowing air is required through the sensor circuit. Please ensure that the compressed air supply line is filtered and moisture-free.
9. Finally, please connect the hoses back to the system and power the sensor again. Turn on the lubrication system, and please make sure there are no leakages in the circuit. At this point, please check that the sensor is delivering correct readings, according to the installation procedure.