

Model3500 Series Dissolved Hydrogen Sensor in Oil User Manual



Hydrogen Sense Limited

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1. Product Overview

1.1 Brief Introduction

The MODEL3500 series hydrogen sensor in transformer oil is based on Pd alloy thin-film hydrogen detection technology. The sensor chip can be directly placed in transformer oil without the need for oil-gas separation. The technology features absolute hydrogen specificity and no cross-response to other combustible gases. The MODEL3500 series sensor chip adopts a Pd alloy thin-film resistor structure, and utilizes key process technologies such as a mature and stable Pd alloy material doping system, alloy thin-film preparation process, and specific composite thin-film preparation technology. These technologies enable the MODEL3500 series sensors to have more excellent long-term stability and detection accuracy, and eliminate the need for periodic maintenance.



Figure 1.1 MODEL3500 Series Hydrogen Sensor in Transformer Oil

1.2 Model and Specification

MODEL3500 Series						
Model	Measuring Range(H ₂)	Minimum Detection Limit(H ₂) ¹	Response Time(H ₂) ²	Accuracy(H ₂) ³	Moisture	Oil Pressure
Model3500	0~10000ppm	15ppm	10min	±10% reading or ±15ppm(whichever is greater)	NA	NA
Model3503	0~10000ppm	15ppm	10min	±10% reading or ±15ppm(whichever is greater)	AVL	NA
Model3504	0~10000ppm	15ppm	10min	±10% reading or ±15ppm(whichever is greater)	AVL	AVL

1. The sensor can only be used for hydrogen measurement in oil with concentration below 10000ppm. Exceeding this range may cause the sensor chip deviation or even failure.

2. The response time is specific to certain hydrogen concentration. As the hydrogen concentration increases, the response rate accelerates and the response time shortens.

3. The accuracy data test is completed under normal temperature conditions.

2. Performance & Characteristics

2.1 Sensor

- Based on our independent intellectual property rights of H2Sense™ solid-state Pd alloy thin-film technology.
- Specific coating technology ensures that then sensor operates reliably in harsh environments containing CO, H₂S, CH etc.
- The sensor can be directly inserted into transformer oil for measurement without the need for oil-gas separation and requiring no maintenance.
- Optimized alloy doping and thin-film preparation processes ensure excellent long-term stability and eliminate the need for calibration.

2.2 External Structure

The housing is made of aluminum alloy, and the probe rod is made of 316L. It

features high mechanical strength, adopts a full sealed structure, and has an IP67 protection rating. It meets the requirements of the C5M corrosion protection grade and can be used in offshore wind power transformers and marine transformers.

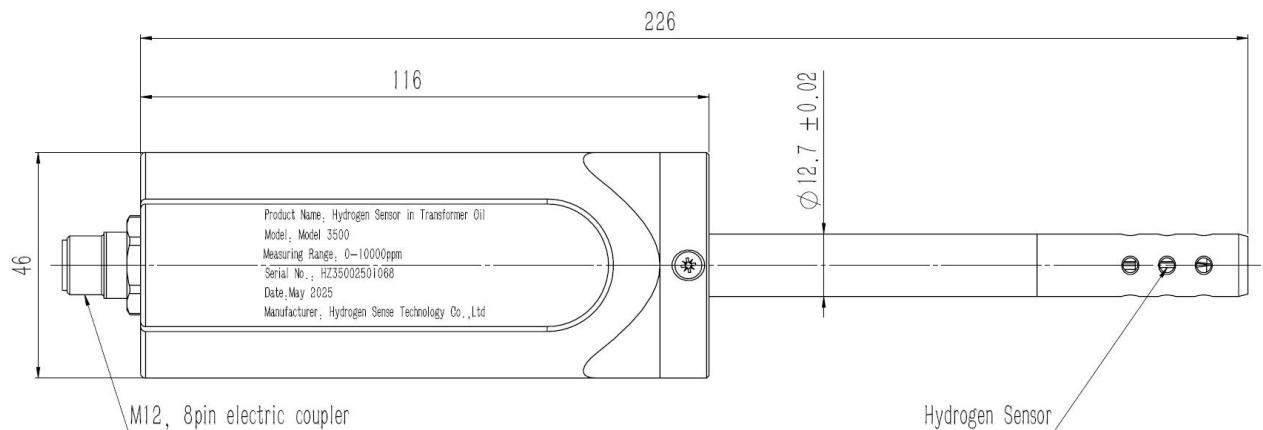


Figure 2.1 Outline Dimension

2.3 Sealing Method

The sensor chip and back-end circuit are connected using metallic glass sintering, combined with laser welding. This connection method achieves electrical connection while meeting the requirement of dielectric isolation, with a maximum pressure resistance exceeding 5Mpa and a leak rate lower than 1×10^{-9} Pa·m³/s. When combined with the metal ferrule seal installation method, it can fundamentally solve the oil leakage problem.

2.4 Adaptability

The general technical requirements of MODEL3500 series hydrogen sensors in transformer oil, including basic functions, communication functions, insulation performance, electromagnetic compatibility performance, environmental adaptability, mechanical performance, shell protection performance, continuous power-on performance, reliability, service life, as well as appearance and structure,

meet the requirements of relevant standards and technical specifications of State Grid and China Southern Power Grid.

3. Parameter Characteristics

3.1 Main Performance Indicators

Main Indicators (H ₂)	Measurement Range	0~10000ppm	
	Measurement Accuracy	±10%or±15ppm (whichever is greater)	
	Repeatability	±5%or±15ppm (whichever is greater)	
	Resolution	1ppm	
	Applicable Oil Temperature	-40~105℃	
	Response Time	<30min	
	Sensor	Pd alloy thin-film hydrogen sensor	
Main Indicators (Moisture)	Measurement Range	(0~1) a _w	
	Measurement Accuracy (20℃)	(0~0.9) a _w	±0.02 a _w
		(0.9~1) a _w	±0.03 a _w
	Response Time (t ₉₀)	<10min	
Main Indicators (Oil Temperature)	Measurement Range	-40~120℃	
	Measurement Accuracy (20℃)	±1℃	
Main Indicators (Oil Pressure)	Measurement Range	0~1MPa	
	Measurement Accuracy	±1%F.S	
	Resolution	0.1kPa	
	Overload Capacity	3MPa	

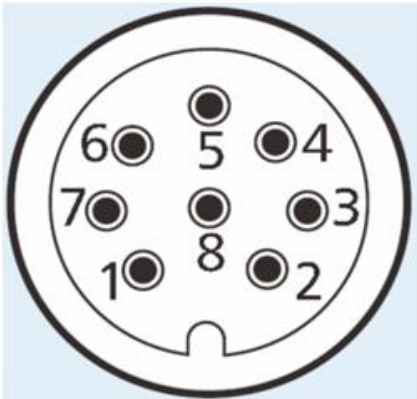
3.2 Electrical Characteristics and Others

Power Supply	24VDC±10%, 0.3A (max)
Digital Output	RS-485
Communication Protocol	Modbus_RTU

IP Rating	IP67
Data Storage	Data Storage Interval: 30s, Number of Data Storage Entries: 109945
Service Life	10 Years

3.3 Power Supply and PIN Definition of Communication Cable

All electrical connections of the sensor are realized through one 8-core M12 connector. The definitions of the connector pins and matching cable cores are as below. When mating the matching cable plug with the sensor socket, it is crucial to ensure that the notch positions are aligned, otherwise, the connector pins may be damaged.

	Connector Pin No.	Pin Function	Color of the matching cable core
	1	24V power supply positive	Yellow/White
	2	/	Green
	3	/	Green/White
	4	232T/D-	Brown/White
	5	232RXD+	Brown
	6	RS485A	Blue/White
	7	RS485B	Blue
	8	24V power supply negative	Yellow

3.4 Optional Accessories (Non-standard)

Figure 3.1 shows the wiring of the optional power adapter, terminal board and an RS232/RS485 to USB adapter mounted on a DIN rail. It should be noted that the prices of optional accessories can be obtained from sales personnel. Product failures caused by incorrect selection or functional defects of the power adapter or USB adapter are not covered by the warranty.



Figure 3.1 Power Supply and 485 converter

3.4.1 Power Adapter

To ensure the proper operation of the product, it is recommended to use a high-quality 24V DC power adapter for power supply. When multiple products share the same power adapter, it is essential to ensure that the power is sufficient (the peak current of a single instrument is 300mA, and the rated current is 100mA). Overloading will cause abnormal output voltage of the power adapter, and the abnormal supply voltage may result in the product failing to operate normally or even being damaged.

3.4.2 USB Adapter

To minimize the risk of the device damage, when connecting to the RS232 communication interface, it is recommended to use an USB to RS232 protocol converter with an optically isolated interface.

3.5 Serial Communication

3.5.1 RS-485 Connection

The communication protocol adopts the Modbus_RTU mode, and the RS-485 interface requires the following settings to communicate normally with the device.

Baud rate: 19,200
Data bit: 8
Stop bit: 1
Calibration: None
Flow control: None

3.5.2 RS232 Connection

For the command line protocol, RS232 interface requires the following settings to communicate normally with the device.

Baud rate: 19,200
Data bit: 8
Stop bit: 1
Parity: None
Flow control: None

Ensure a secure connection between the communication device and the sensor. The transmission signal (TxD) from the device should be connected to the reception signal (RxD) on the computer, and the reception signal on the device should be connected to the transmission signal (TxD) on the computer.

3.6 Real Time Clock

The sensor's real-time clock is equipped with a backup battery, which can maintain power for approximately one month when external power supply is cut off. After installation, please first use the RS command (Section 6.10) to set the real-time. The real-time data and time will be displayed in the data stream. For more information about these commands, refer to Section 6.

4 Mechanical Installation and Precautions

4.1 Precautions

Warning:  Before installation and using the transmitter, please ensure the installation environment to meet the following conditions and requirements.

1. Avoid the accumulation of foreign objects such as metal fragments near the transmitter chip, as this may affect the sensor's performance in the future.
2. Adopt an appropriate method to remove air bubbles accumulated around the hydrogen sensor chip, ensuring full contact between the sensor chip and the oil.
3. Try to avoid installation during rain to prevent rainwater from entering the installation interface. If water enters the oil through the interface, it will lead to inaccurate measurement of moisture and hydrogen.
4. The hydrogen sensor chip must not be placed in the transformer oil flow; the sensor can only perform its normal working performance when the chip is installed in static oil.
5. Use a standard torque wrench with an approximately 50N•m for 1/2" ferrule fitting, and do not over-tighten the ferrule nut.

4.2 Mechanical Connection

According to the size of the oil sampling port of different transformer ball valves or oil-light equipment, select the appropriate adapter. First, install the adapter on the flange face of the ball valve, then mount the sensor on the adapter. The sensor probe should be as close to the ball valve as possible, but it is not recommended to pass through the ball valve. The sensor is generally installed in a horizontal position to prevent air bubbles from forming around the sensor element, as shown in the

figure below,

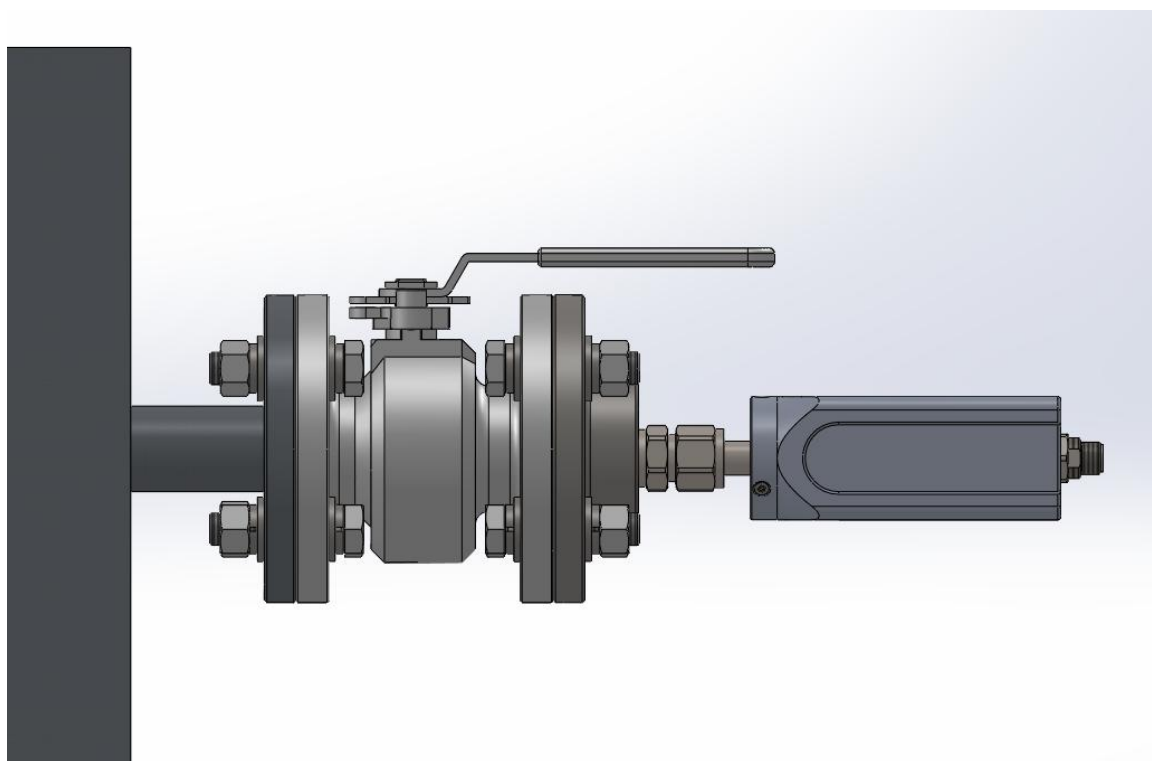


Figure 4.1 Schematic Diagram of Transformer Ball Valve Installation Device Connection

4.3 Installation Steps

(1) Adapter Installation

Close the transformer ball valve. Use a wrench or similar tool to remove the baffle and gasket from the transformer ball valve or bushing oil sampling port, and place them properly. Wipe the sealing surface with a clean cloth. Install a properly sized gasket (flurosilicone material is recommended) between the flange surface or bushing oil sampling port and the adapter. Then install the fixing bolts in sequence, and tighten them one by one with a wrench to compress and deform the gasket, preventing oil leakage.

(2) Sensor Installation

Insert the sensor probe into the 1/2" ferrule nut of the adapter. Ensure that the two metal conical rings inside the ferrule nut are in the correct position and state. Slowly push the sensor all the way toward the ball valve or bushing oil sampling

port, then pull it back 5mm-10mm. Tighten the ferrule nut with a torque wrench, taking care that the torque does not exceed 50N.m.

(3) Venting

Loosen the sealed vent screw on the adapter by 2-3 turns using an Allen wrench to release the internal air until transformer oil flows out slightly. After ensuring all air is exhausted, tighten the sealed screw. Wipe off any leaked oil around the sensor with a clean cloth and anhydrous ethanol.

(4) Debug the Sensor

Insert the dedicated cable plug into the sensor socket, power on and debug the sensor to ensure that the sensor collects data normally.

(5) Leakage Inspection

24 hours after installation, check whether there is oil leakage at the interface.

5 Operation

5.1 Startup

I. Please confirm the following before starting:

1. For cables not connected to the sensor, refer to the wiring of section 3.3.
2. Ensure the correct power supply voltage (24V DC).
3. Connect the RS232 serial cable (if used) to the PC and be sure to calibrate

the current time using the Command RS (Section 6.10).

II. After connecting the cable and turning on the power supply, the sensor will warm up for a few minutes. The following actions are performed during the warm-up process:

1. The power-on reset message is sent to the serial port.
2. Perform system self-test.
3. Restore the configuration settings from flash memory.

4. Start the sampling system to measure the hydrogen and oil temperature.
- III. When re-powering the sensor, the power cable must be disconnected for at least 15 seconds to ensure that the internal backup power is exhausted.
- IV. For newly mounted monitor or when replacing monitor to a new transformer, Command IS (Section 6.9) should be used to initialize the sensor. The previous data will be deleted and the previous settings will be restored to the factory defaults at this time.
- V. To ensure the normal operation of the sensor, the following command should be executed:
- Type D 1 ↵ to display device information.
- VI. If conditions permit, it is recommended that the user perform online calibration of the sensor according to the calibration method of hydrogen in oil specified in Section 7.1.1 of Chapter 7.

5.2 Data Display

The measured hydrogen is displayed in the 'H2DG.ppm' column of the command line (via the RS232 port). During hydrogen measurement, a data line containing hydrogen and several other measured values is transmitted every 10 seconds.

The main columns that users use most often are: TimeDay, H2DG.ppm, OilTemp, WeekROC and Messages. Below is a description of all columns and other available columns.

TimeDay: Time and date in 24-hour format: yy-mm-dd hh:mm:ss

PcbTemp: The surface temperature of internal circuit board recorded in degrees Celsius.

H2AG.ppm: The measured hydrogen value relative to nitrogen, in ppm.

H2DG.ppm: The average dissolved hydrogen measurement, in ppm.

OilTemp: The oil temperature measured by the sensor, in degrees Celsius.

H2G.ppm: The instantaneous dissolved hydrogen measurement in oil, in ppm.

H2SldAv: The hourly average value from H2DG.ppm in ppm/hour.

DayROC: The daily rate of change of hydrogen in oil in ppm/day.

WeekROC: The weekly rate of change of hydrogen in oil in ppm/week.

MonthROC: The monthly rate of change of hydrogen in oil in ppm/month.

The information displayed in the 'Messages' column is the measurement status:

rpt: indicates that the line contains the reported hydrogen value.

wait: indicates that the system is waiting for the measurement time.

woff: indicates that the system is waiting for the heater to shut down.

avg: indicates that several samples have been averaged.

OVT: indicates that the oil temperature is above the calibration range.

htr_off: indicates that the heater is turned off to measure the oil temperature or a fault occurs.

warmup: indicates that the sensor is warming up to measure hydrogen.

ramp_up: indicates that the sensor temperature is rising to the operating temperature.

ramp_down: indicates that the sensor temperature is decreasing.

PF: indicates a power failure.

R1: indicates that relay 1 is enabled.

R2: indicates that relay 2 is enabled.

R3: indicates that relay 3 is enabled.

error_xxxxxxx: indicates a detected error status, displayed as a hexadecimal value of xxxxxxxx. If an error code is displayed, it indicates that the sensor failed, please contact customer service.

The product has the following four operating characteristics:

1. Commands DA and DB (Sections 6.4, 6.5) can be used to calibrate hydrogen in oil. Command DX (Section 6.6) can be used to clear the calibration data.
2. The built-in data log memory can store up to 109945 sensor data entries. More details about using the data log can be obtained by using Command T in Section 6.11.
3. Information about the rate of change will be displayed in the diagnostic serial output. The daily, weekly and monthly hydrogen change rates will be shown in

ppm units.

4. Real-time clock log with date and time.

5.3 User Configuration

There are no special requirements for product operation and output settings. The default is factory setting. Users can also make adjustments via the host computer or the following commands:

Commands H: Modify the hydrogen concentration range (Sections 6.8)

Command A: Modify the relay trip point (Section 6.2)

Command RS: Modify the real-time clock (Section 6.10)

6 Command Line Debugging Interface

6.1 Command Summary

Entering any character or command must be confirmed with the 'Enter key'. If no command string is entered, the result of pressing any keys is invalid and an error message will be returned.

User command	
Command	Function description
A	Alarm setting
D <page number> (There is a space between D and page number)	Display product information. Enter page number 0-3 and the default page is 1.
DA	0– Product Information
DB	1– User Configuration
DX	2– Production Information
G	3– Product Configuration
H	Step A for the calibration of hydrogen in oil

IS	Initial installation command (storage data will be cleared)
RS	Set date/time
T	Display or clear the alarm data log
X	Restore factory parameter settings
MI	Set Modbus monitor ID
MS	Switch user mode and lab mode
DATA	Read historical data
CL	Program upgrade
CT	Oil temperature, pressure, moisture calibration
LOG	Historical event information

6.2 Command A

Modify the alarm set point to monitor the following conditions:

1. Hydrogen concentration
2. Daily change rate of hydrogen concentration
3. Transformer oil temperature

Example:

```

a
Relay #1 Select mode:
0 - Disable
1 - Hydrogen level
2 - Rate of Change
3 - OilTemp level
Select function: 1
Enter Trigger (ppm H2): 400          (Press Enter to new line)
Relay #1 Trigger (ppm H2): 400
...Wait...SAVED Done.....

Relay #2 Select mode:
0 - Disable
1 - Hydrogen level
2 - Rate of Change
3 - OilTemp level
Select function: 2
Enter Trigger (ppm H2/day): 400      (Press Enter to new line)
Relay #2 Trigger (ppm H2/day): 400
...Wait...SAVED Done.....

Relay #3 Select mode:

```

```

0 - Disable
1 - Hydrogen level
2 - Rate of Change
3 - OilTemp level
Select function: 3
Enter Trigger (Oil temperature): 80      (Press Enter to new line)
Relay #3 Trigger (Oil Temperature): 80
...Wait...SAVED Done.....

```

6.3 Command D

Display product information. Enter page number 0-3, and the default page is 1

0 – Product information

1 – User configuration

2 – Production information

3 – Product configuration

Example:

```

D 0
Product information:
Model Number : 3200
Serial Number: D0004
Sensor model : 4WRes
Firmware Rev : 1.83
Hardware Version: V3
Latest Calibration
  Factory: 20190322
  Field: 2019-3-22

D 1
User configuration is:
Hydrogen reporting range(in oil LowH2Range-HighH2Range): 0.00 - 5000.00ppm H2
Voltage Output is disabled
Isolated Output is enabled: 4.0mA to 20.0mA (LowH2Current-HighH2Current)
Error output is: 3.5mA
Not-Ready output is 2.0mA
Relays#1:enable
Relays#2:enable
Relays#3:enable
(relays#1) threshold is 400 ppm Hydrogen
(relays#2) threshold is 400 ppm Hydrogen/Day
(relays#3) threshold is 80 degrees Celsius
Pressure compensation is disabled
Gas Pressure is 1.0 atm
LabTest:enable

D 2

```

```
Manufacturing information is:  
Sensor Serial Number: S2.3.01539  
Sensor Board Serial Number: 200V4  
Interface Board Serial Number: 17A20SV301141  
Date Built: 20190322
```

```
D 3  
Product Configuration:  
Sample rate is 0:0:30/sample (times/sample)
```

6.4 Command DA

Step A for calibration of hydrogen in oil: This command will save the current sensor's hydrogen concentration reading, which is used by the Command DB to adjust the sensor's readings.

Example:

```
DA  
Current H2 value is 0 ppm H2
```

6.5 Command DB

Step B for calibration of hydrogen in oil: This command uses the information saved by Command DA and the actual hydrogen concentration in oil to adjust the sensor's readings. This Command will immediately adjust the current hydrogen readings.

Example:

```
DB  
Enter actual hydrogen in ppm: 200  
Set hydrogen to 200 ppm (Y/N)?Y  
Calibration Gas finished  
Cal. date is: 2018-1-1 (Y/N)?Y  
Enter Year: 2019  
Enter Month: 3  
Enter Day: 22  
Cal Message:.....  
Cal. date : 2019-3-22  
Calc function is quited.....
```

6.6 Command DX

This command will immediately clear the calibration data of hydrogen in oil.

Example:

```
DX
Returns to last factory Calibration data (Y/N)?y
Cal Message:.....
Returns to last factory Calibration data
Cal. date : 2019-3-22
```

6.7 Command G

Display the sensor's data column headers.

Example:

```
G
TimeStamp      PcbTemp  H2AG.ppm  OilTemp  H2DG.ppm  H2G.ppm  H2SldAv
DayROC  WeekROC  MonthROC  ;Message
2019-3-22 10:00:00 33.86    12      18.58    1        0.8      0
0         0         0          ;wait
```

6.8 Command H

Modify the hydrogen concentration report range. The hydrogen concentration in this command is expressed as % H2. The conversion relationship between % H2 and ppm H2 is as follows:

$$\% \text{ H2} = \text{ppm H2} / 10,000.$$

Example:

```
H
Hydrogen reporting range(in oil LowH2Range-HighH2Range): 0.00 - 5000.00ppm H2
Change (Y/N)?Y
Enter new LowH2Range: 100
Enter new HighH2Range: 4000
New hydrogen reporting range(in oil LowH2Range-HighH2Range): 100.00 - 4000.00ppm
H2
...Wait...SAVED - Done
```

6.9 Command IS

Initial installation command (storage data will be cleared)

Example:

```
IS
Erase All Data Log
...wait...          (Wait for a few seconds)
System time is 2018-1-1 0:0:0 Change (Y/N)?Y
Enter Year: 2019
Enter Month: 3
Enter Day: 22
Enter Hour: 10
Enter Minute: 0
Enter Second: 0
Change time to 2019-3-22 10:0:0
...Wait...SAVE TO RTC - Done
```

6.10 Command RS

Set the sensor's date and time.

Example:

```
RS
System time is 2018-1-1 0:0:0 Change (Y/N)?Y
Enter Year: 2019
Enter Month: 3
Enter Day: 22
Enter Hour: 10
Enter Minute: 0
Enter Second: 0
Change time to 2019-3-22 10:0:0
...Wait...SAVE TO RTC - Done
```

6.11 Command T

Display or clear the alarm data record.

Example:

```
T
Trace Functions:
c = clear log
d = display log
e = exit
Select function: D
Enter Number of entries to show (max.999 alarm log): 888
0:
Begin Log Data - RS232

TimeStamp          H2DG_ppm  OilTemp  DayROC_ppm  Msg
```

```
End Log Data - RS232

T
Trace Functions:
c = clear log
d = display log
e = exit
Select function: C
Erase the Data Log (Y/N)?Y
All clear

T
Trace Functions:
c = clear log
d = display log
e = exit
Select function: E
exit
```

6.12 Command X

This command can restore the sensor's parameter settings to factory defaults, including the hydrogen concentration range, excluding modifications to the calibration of hydrogen in oil.

Example:

```
X
Clear field calibration values (Y/N)?Y
Returns to last factory calibration data
Done - Wait.....
```

6.13 Command MI

Set ID for Modbus products. The default ID is 1, and it can be modified via setting internet communication protocol register 150 or using Command MI.

Example:

```
MI
Modbus ID is 1 Change (Y/N)?Y
Set Modbus ID to: 2
New Modbus ID is 2
Saved - Done
```

6.14 Command MS

Command MS is used to switch between user mode and lab mode. After using

Command MS, the sensor need to be powered off and on again for the command to take effect.

Using Command D1 to check the current mode, if 'LabTest' shows 'enable', it indicates that the current mode is 'Test Mode'; if it shows 'disable', it indicates that the current mode is 'operating Mode'.

Example:

```
MS
LabTest mode is disabled Change (Y/N)?Y
Save as Default (Y/N)?
Y
Saved - Done
D 1
User configuration is:
Hydrogen reporting range (in oil LowH2Range-HighH2Range): 0.00
- 5000.00ppm H2
Voltage Output is disabled
Isolated Output is enabled: 4.0mA to 20.0mA
(LowH2Current-HighH2Current)
Error output is: 3.5mA
Not-Ready output is 2.0mA
Relays#1:enable
Relays#2:enable
Relays#3:enable
(relays#1) threshold is 200 ppm Hydrogen
(relays#2) threshold is 100 ppm Hydrogen/Day
(relays#3) threshold is 55 degrees Celsius
Pressure compensation is disabled
Gas Pressure is 1.0 atm
LabTest:enable
```

6.15 Command DATA

Command DATA is used to read the sensor's historical data. The stored data mainly includes the timestamps, hydrogen concentration and oil temperature. The default storage interval is 30s, and a maximum of 109945 entries can be stored. When the number exceeds 109945, the oldest data will be overwritten automatically.

Example:

```
DATA
Trace Functions:
c = clear log
l = display log to rs232
m = display log to rs485
e = exit
Select function: L
Enter Number of entries to show (Max.109945 Record Log): 5
```

```
(Space Under Full)Total number of records: 11500, Display: 5
Begin Log Data - RS232
```

TimeStamp	H2DG_ppm	OilTemp	DayROC_ppm	Msg
2025-05-17 11:09:57	0	29.33	0	;
2025-05-17 11:09:33	0	29.29	0	;
2025-05-17 11:08:57	0	0.00	0	;
2025-04-23 14:32:30	13	31.41	0	;
2025-04-23 14:32:00	13	31.45	0	;

```
End Log Data - RS232
```

6.16 Command CL

Command CL is used to upgrade the program.

```
CL
Download new firmware (Y/N)?Y
Ready.... Flash Magic ...Send Hex file... >
```

6.17 Command CT

Command CT is used to calibrate oil temperature, pressure and moisture:
 Command 2 is for oil temperature calibration, Command 3 for pressure calibration,
 and Command 4 for moisture value calibration.

```
CT
Out temperature or pressure Select calibration:
0 - Hydrogen Sensor TempCL
1 - Pressure Sensor TempCl
2 - Water Sensor TempCl
3 - Pressure Sensor ValueCl
4 - Moisture ValueCl
5 - Delete All Calibration Data
6 - Exit
Select function: 2
Water Sensor Temperature : 29.15C
Enter Actual Water Sensor Temperature : 29.15
Water Sensor Temperature Adi: -0.07C
...Wait...SAVED Done.....
Select function: 3
Pressure Sensor Value : 111.00Kpa
Enter Actual Pressure Sensor Value : 111
Pressure Sensor Value Adi: -0.03Kpa
...Wait...SAVED Done.....
Select function: 4
Moisture value : 42.23C
Enter Actual Moisture value : 42.23
Moisture Value Adi: 0.00C
...Wait...SAVED Done.....
```


6.18 Command LOG

Command LOG is used to read the historical event information of the sensor, including the events such as power cycling, abnormal status, and over-threshold alarms.

```
log
Trace Functions:
c = clear log
d = display log
e = exit
Select function: d
Enter Number of entries to show (Max. 779 Log): 50
Total number of records: 33, Display: 33
Begin Log Data - RS232
TimeStamp      Event
2025-05-17 11:14:17 Power-On RST
2025-04-22 16:32:09 Power-On RST
2025-04-22 16:25:10 Power-On RST
2025-04-22 13:25:40 Power-On RST
2017-05-01 18:38:58 Power-On RST
2017-04-30 16:59:49 Error_10
2017-04-30 15:09:08 Power-On RST
2017-04-27 22:04:29 Power-On RST
2017-04-27 22:02:50 Power-On RST
```

7 Maintenance

7.1 Calibration

By comparing the sensor's readings with off-line DGA samples, the measurement accuracy of the sensor can be checked and adjusted.

Warning:  Entering an incorrect value or using an incorrect DGA result with Command DB may cause the output errors in the hydrogen reading, and may also result in failure to detect dangerous hydrogen readings timely.

7.1.1 Calibration for Hydrogen in Oil

Sending Command DA under the sensor's normal operation status, the sensor will save the current state for subsequent calibration. Meanwhile, collect transformer oil sample surrounded the hydrogen sensor chip, and the DGA oil sample analysis

must be comply with the ASTM D3612 Standard (Standard Test Method for Analysis of Gases dissolved in Electrical Insulating Oil by Gas Chromatography). After obtaining the result of DGA sample analysis, compare the sensor's reading with the DGA result. If the deviation exceeds 15%, the sensor accuracy can be calibrated via using Command DB, which will adjust the current hydrogen reading immediately.

The input of Command DA, DB and standard value can be implemented via the Command line RS232 or Modbus protocol RS485.

7.1.2 Oil Temperature Calibration

Oil temperature calibration can only be implemented via Command line RS232, for specific methods, refer to Section 6.17 Command CT.

7.1.3 Oil Pressure Calibration

Oil pressure calibration can only be implemented via Command line RS232, for specific methods, refer to Section 6.17 Command CT.

7.1.4 Moisture Calibration

Moisture calibration can only be implemented via Command line RS232, for specific methods, refer to Section 6.17 Command CT.

7.1.5 Factory Calibration

If necessary, please contact with manufacturer to return the product to the factory for calibration. A corresponding service and material fee is required for this service.

7.2 Servicing/Repair

There are no user-serviceable parts in the product. If the device is damaged or can not work, please contact the manufacturer's after-sales service. Any repair costs

arising from issues not related to the product's own quality shall be borne by customer.

7.3 Warranty Period

The warranty period for the MODEL3500 series products is 1 year. From the date of the user's receipt of the goods, within 1 year, our company shall be responsible for free repair or replacement of new products for product problems caused by material, component or software faults.

8. Modbus_RTU Protocol

8.1 Brief Introduction

Modbus-RTU communication protocol adopts RS-485 master-slave half-duplex communication in terms of hardware. The master calls the slave address, and the slave responds to the communication.

Baud Rate	19200bps	Default baud rate. If modification is required, please contact the manufacturer.
Parity bit	N	
Data bit	8	
Start bit	1	
Stop bit	1	
Maximum response time	10 seconds	It integrates a pressure or moisture sensor, and the host timeout setting must be no less than 10 seconds.

8.2 Supported Function Codes

Function Codes

Function Code	Function	Access Instructions
---------------	----------	---------------------

0x03	Read register	byte、short、float
0x06	Set single register	byte、short

8.3 MODBUS Protocol Format

8.3.1 Reading Registers and Its Response

The request information specifies the slave address to be read, function code, starting address of holding registers, number of holding registers, and CRC check. The starting address for holding register addressing is 0000H.

0x03 Reading Registers Format:

Byte	Parameter	Range	Definition
1	Slave Address	1-247	*Slave ID Address
2	Function Code	03	Read the binary data of holding registers
3	Starting Address of Holding Register Hi	0x00-0xFF	Holding register address High byte
4	Starting Address of Holding Register Lo	0x00-0xFF	Holding register address Low byte
5	Number of Holding Registers Hi	0	Number of Holding Registers High byte
6	Number of Holding Registers Lo	1-125	Number of Holding Registers Low byte
7	CRC Lo	0x00-0xFF	CRC Low byte
8	CRC Hi	0x00-0xFF	CRC High byte

* Slave ID Address: The MODBUS 8-bit RTU specifies that the slave address range is 0~247, where 0 is the broadcast address, and 248~255 are reserved.

0x03 Reading Registers Response Format:

Byte	Parameter	Range	Definition
1	Slave Address	1-247	Slave ID Address
2	Function Code	03	Return the binary data of holding registers
3	Total number of bytes	7-255	*Number of returned data bytes
4	DATA1 Hi	0x00-0xFF	First data value High byte
5	DATA1 Lo	0x00-0xFF	First data value Low byte
6	DATA2 Hi	0x00-0xFF	Second data value High byte
7	DATA2 Lo	0x00-0xFF	Second data value Low byte

...	...		
...	...		
2N+4	CRC Lo	0x00-0xFF	CRC Low byte
2N+5	CRC Hi	0x00-0xFF	CRC High byte

* Number of returned data bytes: If the number of holding registers queried is N, the number of returned bytes will be $2*N + 5$.

8.3.2 Writing a Single Register and Its Response

0x06 Writing a Single Register Format:

Byte	Parameter	Range	Definition
1	Slave Address	1-247	Slave ID Address
2	Function Code	06	Writing holding register
3	Holding Register Address Hi	0x00-0xFF	Holding Register Address High byte
4	Holding Register Address Lo	0x00-0xFF	Holding Register Address Low byte
5	DATA Hi	0x00-0xFF	Data value High byte
6	DATA Lo	0x00-0xFF	Data value Low byte
7	CRC Lo	0x00-0xFF	CRC Low byte
8	CRC Hi	0x00-0xFF	CRC High byte

0x06 Writing a Single Register Response Format:

Byte	Parameter	Range	Definition
1	Slave Address	1-247	Slave ID Address
2	Function Code	06	
3	Holding Register Address Hi byte	0x00-0xFF	Holding Register Address High byte
4	Holding Register Address Lo byte	0x00-0xFF	Holding Register Address Low byte
5	DATA Hi byte	0x00-0xFF	Data value High byte
6	DATA Lo byte	0x00-0xFF	Data value Low byte
7	CRC Lo	0x00-0xFF	CRC Low byte
8	CRC Hi	0x00-0xFF	CRC High byte

8.3.3 Exception Response

Exception Response Format

Command

Byte	Parameter Description
1	Slave Address
2	Function Code 0x80
3	Exception Code
4, 5	CRC Check

Exception Code

Code	Name	Description
01	Illegal function code	Invalid function code
02	Illegal data address	Address not allowed by slave
03	Illegal data value	Invalid data length

Applicable to MODEL3500 series						
Register Address (Decimal)	Register Address (Hexadecimal)	Register Description		Data Format	Unit	Read/Write
0	0x00	Instantaneous Dissolved H2 in Oil(1)	High Byte	32-bit integer	PPM	R
1	0x01		Low Byte			
2	0x02	Average Dissolved H2 in Oil(1)	High Byte	32-bit integer	PPM	R
3	0x03		Low Byte			
4	0x04	H2(2)	High Byte	32-bit integer	PPM	R
5	0x05		Low Byte			
6	0x06	Sensor Temperature	x100-100, $T=(V/100-100)$	16-bit integer	°C	R
7	0x07	Circuit Board Temperature	x100-100, $T=(V/100-100)$	16-bit integer	°C	R
8	0x08	Temperature in Oil(1)	x100-100, $T=(V/100-100)$	16-bit integer	°C	R
9~10	0x09~0x0A	Reserved				
11	0x0B	1-hour Average Value of Dissolved Hydrogen in Oil/(1)	High Byte	32-bit integer	PPM	R
12	0x0C		Low Byte			
13	0x0D	Daily Change Rate of Dissolved Hydrogen in Oil(1)	High Byte	32-bit signed integer	PPM	R
14	0x0E		Low Byte			
15	0x0F	Weekly Change Rate of Dissolved Hydrogen in Oil(1)	High Byte	32-bit signed integer	PPM	R
16	0x10		Low Byte			
17	0x11	Monthly Change Rate of Dissolved Hydrogen in Oil(1)	High Byte	32-bit signed integer	PPM	R
18	0x12		Low Byte			

19~30	0x13~0x1E	Reserved				
31~40	0x1F~0x28	Product Model		ASCII String		R
41~50	0x29~0x32	Product Number		ASCII String		R
51~60	0x33~0x3C	Sensor Serial Number		ASCII String		R
61~70	0x3D~0x46	Core Batch		ASCII String		R
71~80	0x47~0x50	Circuit Board Number		ASCII String		R
81	0x51	Production Date	Month & Day			R
82	0x52		Year			
83	0x53	Manufacturer's Calibration Date	Month & Day			R/W
84	0x54		Year			
85	0x55	On-site Calibration Date	Month & Day			R/W
86	0x56		Year			
87	0x57	Calibration Date of Dissolved H2 in Oil(1)	Month & Day			R/W
88	0x58		Year			
89~98	0x59~0x62	Software Version Number		ASCII String		R
99	0x63	Setting of Historical Data Reading Count	High Byte	32-bit integer		R
100	0x64		Low Byte			
101	0x65	Start Flag of Historical Data Reading	Output starts after writing 1001.	16-bit integer		W
99~110	0x63~0x6E	Reserved				
111	0x6F	Device Status Bit	See Table 8.1	16-bit binary flag bit		R
112~120	0x70~0x77	Reserved				
121	0x79	Command Line DA(1)	Record the current	16-bit integer		R/W

			hydrogen measurement value after writing 1001. See Table 8.3 for details.			
122	0x7A	Command Line DB(1)	First, write the hydrogen concentration detected by the laboratory chromatograph into registers 126~127, write the calibration date into registers 128~129, and then execute the hydrogen concentration calibration after writing 1001 into this register.	16-bit integer		R/W
123	0x7B	Command Line DX	Write 1 to clear calibration data, and write 2 to restore factory settings.	16-bit integer		R/W
124~125	0x7C~0x7D	Reserved				
126	0x7E	Current concentration detected by the lab chromatograph ⁽¹⁾ or standard gas concentration with N ₂ as the background gas ⁽²⁾	High Byte	32-bit integer	PPM	W
127	0x7F		Low Byte			
128	0x80	Current	High Byte	32-bit		W

129	0x81	Calibration Date	Low Byte	integer		
130	0x82	Month,Day(RTC)		BCD Code		R/W
131	0x83	Year(RTC)		BCD Code		
132	0x84	Hour(RTC)		BCD Code		
133	0x85	Minute, Second(RTC)		BCD Code		
134~140	0x86~0x8C	Reserved				
141	0x8D	Lower Limit Setting of H2 Measurement	High Byte	32-bit integer	PPM	R/W
142	0x8E		Low Byte			
143	0x8F	Upper Limit Setting of H2 Measurement	High Byte	32-bit integer	PPM	R/W
144	0x90		Low Byte			
145~149	0x91~0x95	Reserved(232\485)				
150	0x96	Slave Address Setting		16-bit integer		R/W
151	0x97	Device Operation Mode Setting	See Table 8.2	16-bit integer		R/W
152	0x98	Alarm Value of H2 Concentration in Oil(1)	High Byte	16-bit integer	PPM	R/W
153	0x99		Low Byte			
154	0x9A	Alarm Value for Daily Change Rate of H2 Concentration in Oil(1)	High Byte	16-bit integer	PPM	R/W
155	0x9B		Low Byte			
156	0x9C	Alarm Setting for Oil Temperature Upper Limit(1)	x100, T=(V/100)	16-bit integer	℃	R/W
157~160	0x9D~0xA0	Reserved				
161	0xA1	Integrated Pressure Sensor: Pressure in Oil(3)	High Byte	32-bit Floating-point Type (Storage Order:	KPa	R
162	0xA2		Low Byte			

				CDAB)		
163	0xA3	Integrated Moisture Sensor: Temperature in Oil(3)	High Byte	32-bit Floating-point Type (Storage Order: CDAB)	℃	R
164	0xA4		Low Byte			
165	0xA5	Integrated Moisture Sensor: Water Content in Oil(3)	High Byte	32-bit Floating-point Type (Storage Order: CDAB)	PPM	R
166	0xA6		Low Byte			
167	0xA7	Integrated Moisture Sensor: Water Content in Oil Relative Humidity in Oil(3)	High Byte	32-bit Floating-point Type (Storage Order: CDAB)	%	R
168	0xA8		Low Byte			
169~174	0xA9~0xAE	Reserved				
175	0xAF	Operating Time	The highest Byte	64-bit integer	Second	R
176	0xB0		High Byte			
177	0xB1		Low Byte			
178	0xB2		The Lowest Byte			
179~200	0xB3~0xC8	Reserved				
201~210	0xC9~0xD2	User ID		ASCII String		R
211~220	0xD3~0xDC	Substation ID		ASCII String		R
221~230	0xDD~0xE6	TransformerID		ASCII String		R
231~255	0xE7~0xFF	Reserved				

Remark: (1)Registers provided by Model3500 series sensors
 (2)Registers provided by Model5000 series sensors
 (3)Registers provided by Sensors integrating pressure or moisture.

Table 8.1 Device Status Bit

Bit Number	Function Description	Status Description
15	Device ready	1: Ready 0: Not ready
14	Reserved	
13	Reserved	
12	Sensor abnormal and cannot self-recover	1: Abnormal 0: Normal
11	Sensor hydrogen sensitivity (fault) – Status 1 indicates activation	1: Fault 0: Normal
10	Sensor thermal sensitivity (fault) – Status 1 indicates activation	1: Fault 0: Normal
9	Sensor heating (fault) – Status 1 indicates activation	1: Fault 0: Normal
8	Sensor pressure (fault) – Status 1 indicates activation	1: Fault 0: Normal
7	Reserved	
6	Relay 3 (ambient temperature) – Status 1 indicates activation	1: Alarm 0: Normal
5	Relay 2 (daily change rate) – Status 1 indicates activation	1: Alarm 0: Normal
4	Relay 1 (hydrogen) – Status 1 indicates activation	1: Alarm 0: Normal
3	Reserved	
2	Sensor status information: 0 - Sensor unavailable	Sensor status information: 000 - Sensor unavailable
1	1 - Operating normally and measuring 2 - Measuring ambient temperature 3 - Calibration mode	001 - Measuring hydrogen concentration 010 - Measuring ambient temperature 011 - Calibration mode
0	4 - Circuit board temperature exceeds the sensor's operating temperature 5 - Ambient temperature exceeds the sensor's operating temperature 6 - Measurement data unavailable or self-locked	100 - Circuit board temperature overrun 101 - Ambient temperature overrun 110 - Data self-locked (can be automatically unlocked and restored)

Table 8.2 Device Mode Setting Read

Read operation		
Register Value	Default(Power on again)	Current
0x0000	On-site	On-site
0x0100	Lab	On-site
0x0001	On-site	Lab
0x0101	Lab	Lab

Write Operation		
Register Value	Default(Power on again)	Setting
0x0000	Lab	On-site
0x1000	On-site	On-site
0x0001	On-site	Lab
0x1001	Lab	Lab

Enclosure: Hydrogen Calibration Method of Model 3500 Series Sensors

Calibration Condition: The dissolved hydrogen concentration in the oil sample, as measured by the hydrogen sensor, remains balanced and stable. This can be determined by historical data or measured response curves.

Step 1: Check Calibration Readiness

After writing 1001 into Register 121, record the current measured value of dissolved hydrogen in the oil. After a 1-second delay, read Register 121:

If the Register content is still 1001, the read operation is successful and the sensor is in a calibration state.

If the Register content is 403 or 404, the read operation fails and the sensor is not in a calibration state.

Step 2: Perform Hydrogen Concentration Calibration

1. Obtain the hydrogen concentration of the current oil sample (detected by a lab chromatograph) and write 126~127 into Registers. For example:

If the dissolved hydrogen concentration is 100ppm, its hexadecimal equivalent is 0x00000064.

2. Write the calibration date into Registers 128~129. The calibration date shall be in the format of a continuous year-month-day timestamp (e.g., 20180920),

whose hexadecimal equivalent is 0x0133EFB8.

- After writing 1001 into Register 122, execute the hydrogen concentration calibration. After a 1-second delay, read Register 122:

If the register content is 0, calibration is successful.

If the register content is 403 or 404, calibration fails.

Step3: If calibration fails, retry the calibration by repeating Step 1. To clear calibration data: Write 1 into Register 123. After executing the calibration data clearing, a register content of either 0 or 1 indicates successful data clearing.

Detailed Register usage is as shown in the Table below.

Table 8.3 Calibration Method

Hydrogen Calibration Method of Model 3500 series Sensors					
Register Address (DEC)	Register Address (HEX)	Register Description		Data Format	Unit Read /Write
121	0x79	DA Command Line	After write 1001 into Register 121, make record for current measured H2 value in oil.	16-Bit integer	R/W
122	0x7A	DB Command Line	First write the hydrogen concentration detected by laboratory chromatograph into Registers 126~127, write the calibration date into Registers 128~129, then execute hydrogen concentration calibration after writing 1001 into Register 122.	16-Bit integer	R/W
123	0x7B	DX Command Line	Write 1 into Register 123 to clear calibration data, and write 2 to restore factory settings.	16-Bit integer	R/W

126	0x7E	Current H2 concentration detected by lab chromatograph	High Byte	32-Bit integer	PPM	W
127	0x7F		Low Byte			
128	0x80	Current calibration date	High Byte	32-Bit integer		W
129	0x81		Low Byte			

Remark: For all series of sensors, if the contents of calibration registers 120~123 are set to 403 or 404, it indicates a calibration failure.

Table 8.4 Reading Method of Historical Data

Instructions for Reading Historical Data Stored in Sensors via RS485 Interface						
Reading Protocol						
Register Address (DEC)	Register Address (HEX)	Register Description	Data Format	Unit		Read/Write
99	0x63	Historical data read count setting	High byte	32-bit integer		R
100	0x64		Low byte			
101	0x65	Historical data read start flag	Output starts after writing 1001	16-bit integer		W

Table 8.5 Historical Data Parsing Method

Data Parsing						
Start Character (1 Byte)	Timestamp (7 Bytes)		Hydrogen in Oil (4 Bytes)	Oil Temperature (2 Bytes)	Daily Change Rate of Hydrogen in Oil (4 Bytes)	End Character (1 Byte)
0x5A	BCD Code (Order: Year/Month/Day/Hour/Minute/Second)		32-bit Integer	x100 Scale, +100 Offset, 16-bit Integer	32-bit Integer	0xA5

Example: Sensor ID1 reads 1000 (0x000003E8) entries of internal historical data. Perform write

operations sequentially on individual registers as follows: 01 06 00 63 00 00 79 D4, 01 06 00 64 03 E8 C8 AB, 01 06 00 65 03 E9 58 AB.

Response data: 5A 20 25 01 22 11 45 07 00 00 01 88 36 8F 00 00 00 0A A5.

Time: 11:45:07 on January 22, 2025

Dissolved hydrogen concentration in oil: 392 ppm

Oil temperature: 39.67 °C

Daily change rate of dissolved hydrogen in oil: 10 ppm

9 Serial Port Debugging Tool FoxTerm

9.1 FoxTerm Installation

1. Create a folder named "H2sense" in "My Documents" on the computer.
2. Download the FoxTerm software from the website: www.foxterm.net. Click the download option and save the latest file to the "H2sense" folder.
3. Unzip the FoxTerm file and save it to the "H2sense" folder.

9.2 FoxTerm Settings

1. Launch **FoxTerm** and close the default session window if necessary.
2. Click "**File-New COM Port Connection**" to open a new session window.
3. Select the correct **port** and **baud rate**. In this example, use **COM2**. The settings are as shown in Figure 9.21.
4. The "**Newline Behavior**" must be set to "**CRLF**".
5. Click "**OK**".

- For data saving, right-click in the blank interface, a session window as shown in Figure 9.22 will pop up. Select "**Logging Setup**", and choose the storage path.

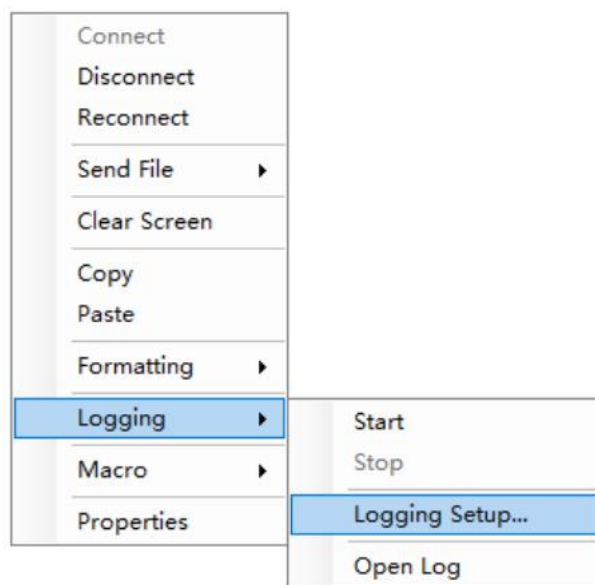
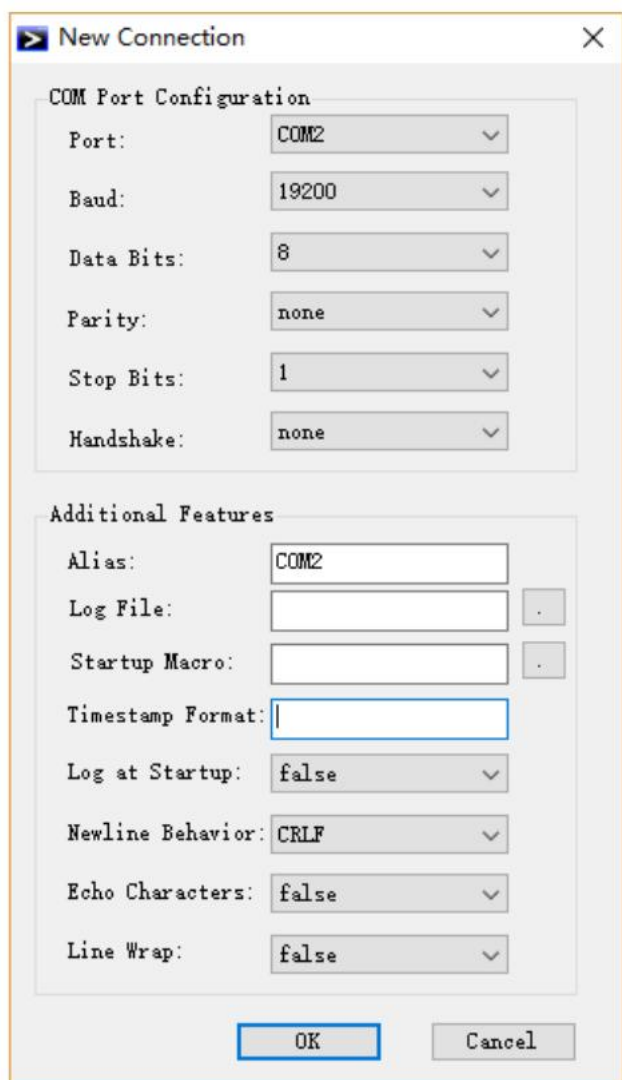


Figure 9.21 Foxterm Settings dialog box

Figure 9.22 Foxterm Data Storage Settings Diagram

10. Program Upgrade

10.1 Upgrade Preparation

Prepare the software and hardware required for program upgrade

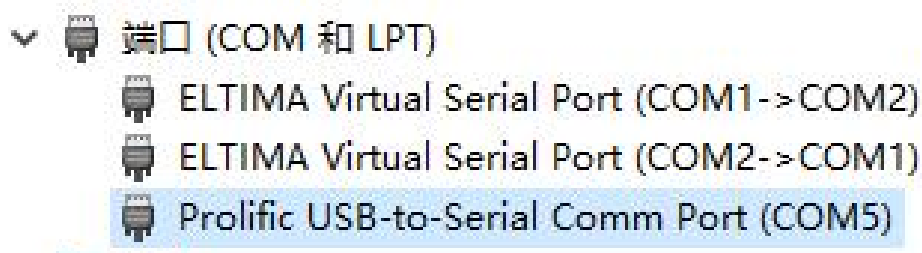
Software: Flash Magic、Foxterm、Program the Hex file

Hardware: Computer with Windows system、RS232 to USB converter

10.2 Upgrade Steps

1. Hardware Connection:

Connect the RS232 to USB converter to the computer via USB and identify the COM port number.

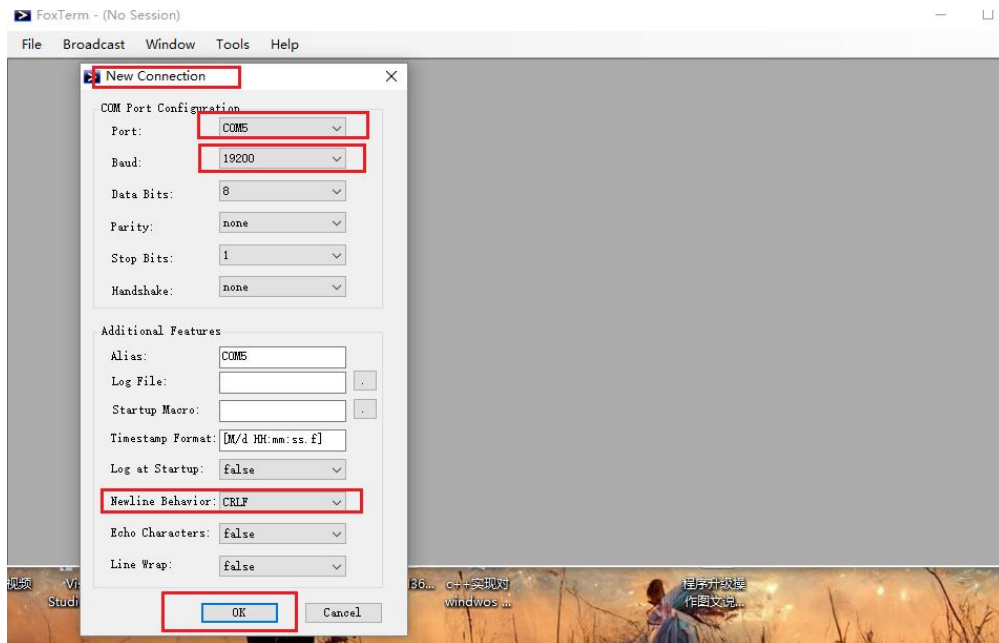


Connect the DB9 connector of RS232 to USB converter to hydrogen sensor, with pin 2 of the DB9 interface connected to TXD, pin3 to RXD, and pin 5 shared with the power ground.



2. Software Operation:

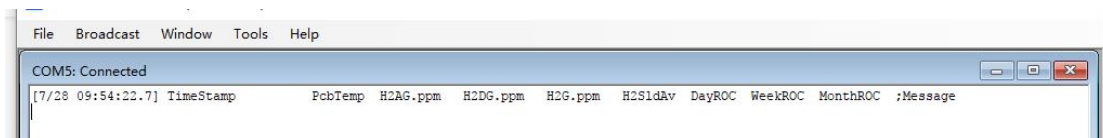
Start the Foxterm software, set the Port, Baud19200, and Newline Behavior CRLF, keep the remaining settings as default and click OK.



Install the Flash Magic software. Download URL: www.flashmagic.com

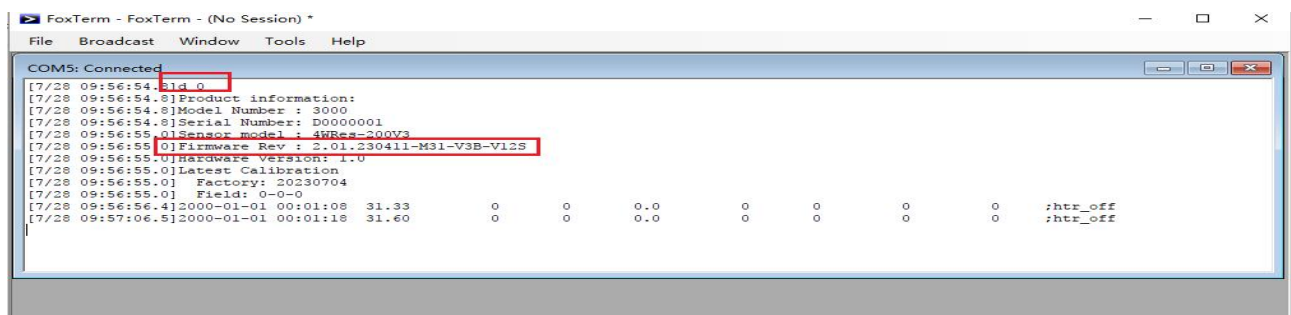
3.Check the Connection:

After all connections are correct, the Foxterm software will actively upload and print the sensor data



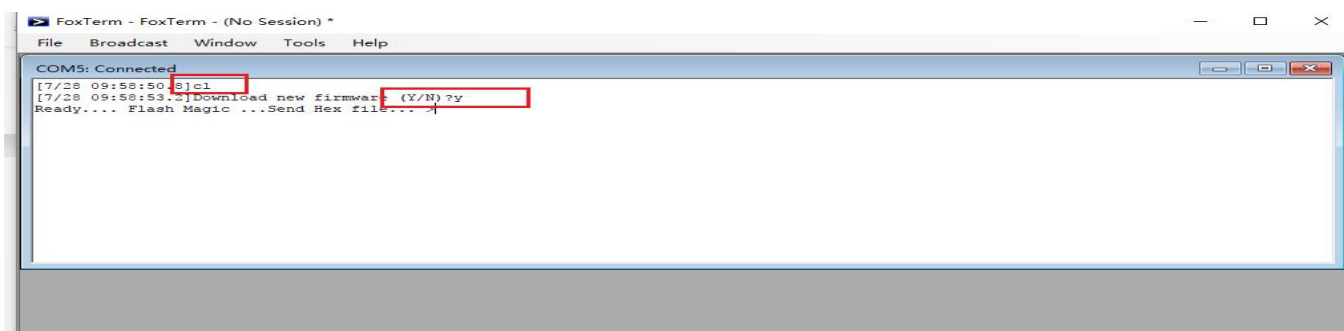
4.Software Burning:

Open the Foxterm software, send the Command d 0 followed by pressing Enter (type the letter'd', add a space, then press Enter), and query the program version number. After confirming the version number, perform the upgrade operation.

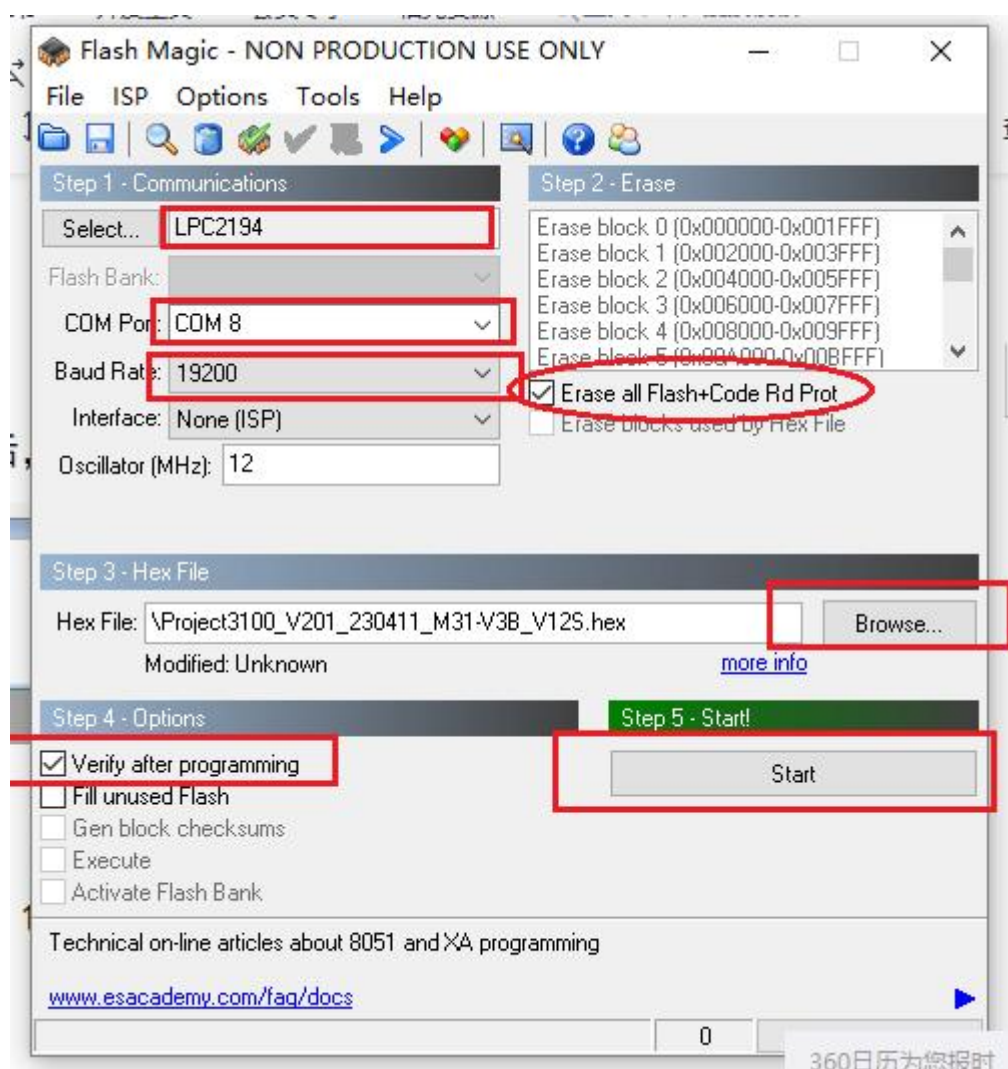


After confirming the version number and the upgrade file to be updated, send the

command `cl` and press Enter; the sensor will enter the program upgrade state.



5. Open the Flash Magic software



**Step1**

Select device LPC2194, Port, Baud 19200, ISP mode, 12MHz.

Step2

Check the box for 'Erase all Flash+Code Rd

Step3

Select the the Hex file to burn.

Step4

Check the box for 'Verify after programming'.

Step5

After burning succeeded, power off and restart the sensor manually.

Key reminder: During the program upgrade process, do not perform any operations. Ensure the power supply is normal and wait patiently for the upgrade progress bar to complete; otherwise, the sensor will disappear!

11. Operation and Usage

11.1 User Mode

The device is set to user mode by default. It needs to preheat for approximately 30 minutes when powered on for the first time before starting to output hydrogen concentration. After that, the device remains in the real-time hydrogen concentration measurement state. The sensor's temperature control adjusts adaptively with changes in oil temperature, and the appropriate chip operating temperature is automatically selected based on the current oil temperature. The specific temperature control logic is as follows:

When the oil temperature is below 45 °C , the sensor's temperature control setpoint is 50°C;

When the oil temperature is above 45 °C but below 65 °C , the sensor's temperature control setpoint is 70°C;

When the oil temperature is above 65 °C but below 85 °C , the sensor's temperature control setpoint is 90°C;

When the oil temperature is above 85 °C but below 105 °C , the sensor's temperature control setpoint is 110°C.

11.2 Lab Mode

The user needs to use the MS command in Section 6.14 of Chapter 6 to manually switch the monitor's working mode from user mode to laboratory mode. When operating in laboratory mode, the monitor will run at a fixed temperature of 70°C and output the current value of dissolved hydrogen in oil approximately 30 minutes after being powered on.

Warnig:  The user needs to confirm that the measured oil temperature is not higher than 65°C. Otherwise, the device will not work properly in laboratory mode.