

InVue® CR288 Concentration Monitor

User guide



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SAFETY

Before assembling, installing or running InVue® CR288 liquid chemical concentration monitor, heed the following:

CAUTION: CR288 is a sensitive electronic device. Rough handling may cause damage. Do not drop.



WARNING:

- Touching live electrical parts can cause fatal shocks and severe burns. Incorrectly installed or improperly grounded equipment is a hazard.
- Do not touch live electrical parts.
- Contact Entegris representative for training before cleaning.
- Keep all panels and covers securely in place.
- Properly ground the system before use. Plug the power supply into a properly wired receptacle.
- Follow local electrical codes and the guidelines in the manual when installing the CR288 concentration monitor. Failure to do so may create an electrical shock hazard. Shock hazards can exist even when equipment is properly installed. The operator should be properly trained and follow established safety practices.



INSTALLATION AND WORKFLOW OVERVIEW

Prepare	Gather user-supplied tools and equipment
Install	Determine best location for mounting equipment Mount sensor, attach fluid lines Connect electrical wiring Install driver and software Connect sensor to software
Setup	Initialize in air Enter initial parameters Re-zero to DI water or other baseline chemical Determine the Temperature Compensation Coefficient (TCC) Implement the calculated TCC Calibrate to the process chemical
Run	Use 288-connect® software to view and log data
Maintain	Clean window, re-zero, re-titrate
Troubleshoot	Software messages, hardware issues

SAFE DISPOSAL

When disposing of any component of the CR288 concentration monitor, observe the local and national requirements for the disposal of electrical and electronic equipment.

Additional technical information is posted on www.entegris.com.

USER-SUPPLIED TOOLS AND EQUIPMENT

These supplies are also required for completing the installation and calibration.

Computer	MS Windows® 98 or higher 128+MB RAM
DI water or other reference index chemical	Used for initial re-zero to DI water
Fluid lines	Fine thread flare, PrimeLock® or Super 300 Type Pillar® standard end connections

Installation tools and fittings to attach lines to CR288 fittings

OPTIONAL USER-SUPPLIED EQUIPMENT

The most common integration is wiring the CR288 concentration monitor with a current measurement device via a Programmable Logic Controller (PLC). See *Installing CR288 Concentration Monitor In-line* to assess the tools and equipment needed.

4-20 mA analog measurement device	Various
Basic wiring tools	
Site-specific installation tools, mounts	

INSTALLING CR288 CONCENTRATION MONITOR IN-LINE

CHOOSING A LOCATION

Environmental Requirements

Process chemical temperature	16°–50°C (60°–122°F)
Ambient Temperature	25°C ±5°C (77°F ±9°F)
Lighting condition changes	Minimal

NOTE: Install a light shield over the concentration monitor and/or translucent fluid lines to minimize changes.

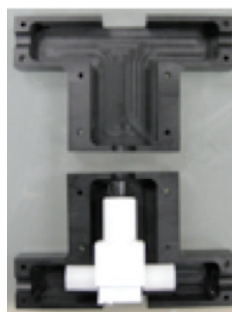


Figure 1. Light shield over concentration monitor.

Fluid Flow Requirements

Fluid flow/direction	Bidirectional
Line pressure	0–5.5 bar (0–80 psig)
Location relative to pump/bellows	Upstream of pump/bellows
Location relative to pressure-regulating device	Downstream of pressure-regulating device

OTHER FLOW CONSIDERATIONS

For accuracy, the in-line location must:

- Provide flow representative of the bulk fluid.
- Maintain adequate flow so that sediment and bubbles do not collect on the sensor.
- Provide minimal flow pulses. Strong pressure pulses in the fluid stream may cause erratic readings.

NOTE: A pressure-regulating device can improve sensor operation and performance.

MOUNTING CR288 CONCENTRATION MONITOR

The sensor is mounted in-line with the process fluid stream using the end connections on either side of the body.

Orientation

Front View

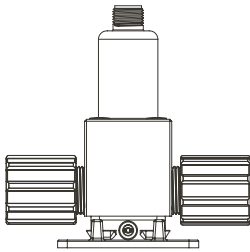


Figure 2. Recommended orientation for normal mounting.

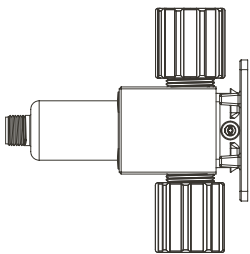


Figure 3. Alternate orientation for minimum bubble rejection.

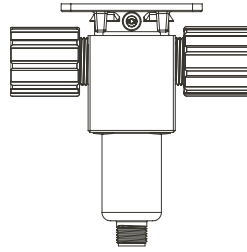


Figure 4. Alternate orientation for maximum bubble rejection.

ATTACHING FLUID LINES

Attach tubes using standard procedure for Teflon® connections.

NOTE: Lines must be dry. Do not use any DI water or process fluids.

INSTALLING THE DIGITAL DISPLAY UNIT (DDU)

CHOOSING A LOCATION

Environmental Requirements

No exposure to moisture and chemicals	Preferred location is in an electrical cabinet
Within 3 m (10') of the sensor	Distance is limited by the length of the supplied interconnecting cable

Other Considerations

Power supply	24 V (dc), ≥1A (included)
On/off switch (optional but recommended)	The DDU does not have a built-in power switch. The system will always be powered on when connected to a power source. Mounting an external power switch to control the DDU's power supply is recommended.

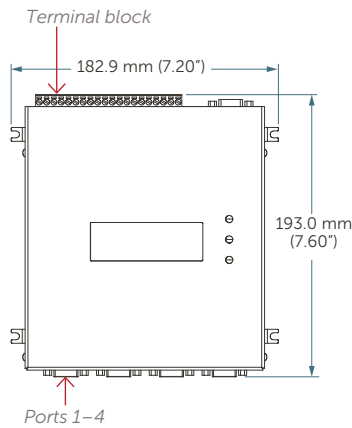


Figure 5. Digital display unit (DDU).

CONNECT CR288 SENSOR(S) TO DDU

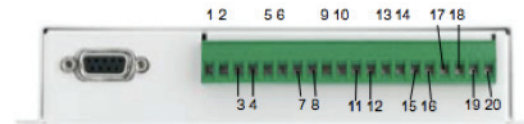
1. To connect the IP67 end of the cable to the top of the sensor, align the keyed connectors and twist the connector hand tight.
2. Connect the HD 15 end of the cable to one of the four sensor input ports on the bottom of the DDU.
3. Use a screwdriver to secure the HD 15 end to the DDU.
4. Connect the USB-to-serial cable to the computer.

CONNECT ELECTRICAL WIRING

CONNECT POWER TO UNIT

1. Wire 24 volts according to the terminal block. See Terminal Block Pinout.
2. Optional: If using 4-20 mA outputs, wire according to the Terminal Block Pinout.
3. Connect terminal block to DDU.

TERMINAL BLOCK PINOUT



	1	24 V+ supply
	2	Power GND
Sensor 1 concentration	3	Source
	4	GND
Sensor 1 temperature	5	Source
	6	GND
Sensor 2 concentration	7	Source
	8	GND
Sensor 2 temperature	9	Source
	10	GND
Sensor 3 concentration	11	Source
	12	GND
Sensor 3 temperature	13	Source
	14	GND
Sensor 4 concentration	15	Source
	16	GND
Sensor 4 temperature	17	Source
	18	GND
Digital alarm 1	19	NC
Digital alarm 2	20	NC

Figure 6. Terminal block pinout.

INSTALL DRIVER AND SET PORT BPS RATE

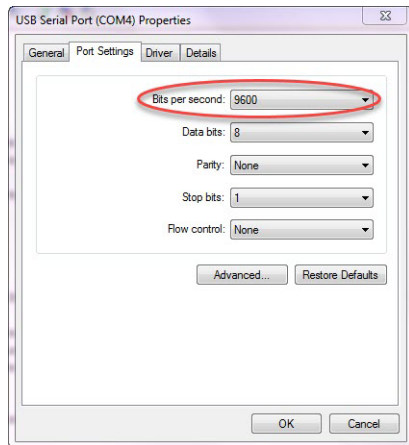


Figure 7. Setting port BPS rate.

1. Plug the RS-232 USB adapter into the selected computer USB port.
2. Wait for Windows to download and install the appropriate driver from the Internet. It may take up to 30 seconds for this process to complete.

NOTE: Internet access is required.

3. Using Windows Menu set the baud rate for the RS-232 cable.
4. Go to Device Manager.
 - a. Right click the COM port for the USB RS-232 cable.
 - b. Select **Properties-> Port Settings**
 - c. Change the Bits Per Second to 9600.

INSTALL AND LAUNCH 288-CONNECT SOFTWARE

1. Download and run the Entegris 288-connect installation program from the entegris.com website.

NOTE: You will need to complete a user profile.
2. Be sure the CR288 sensor is on. Ensure all parts are clean and dry.
3. Launch the program by double clicking on the 288-connect icon on the desktop.



Figure 8. 288-connect icon.

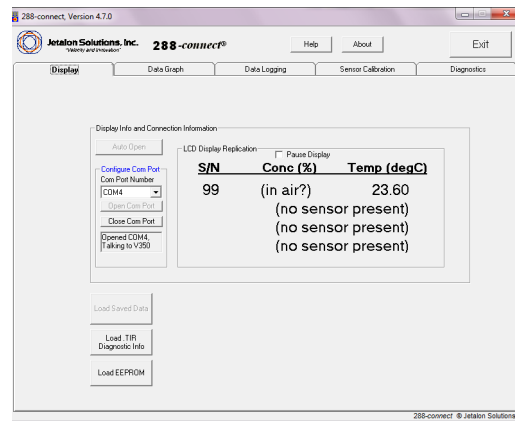


Figure 9. 288-connect opening screen.

4. Select the **Display** tab.
5. Select the COM port from the pull-down menu.

NOTE: If you have trouble establishing communication, power cycle the CR288 to reestablish communication. If you still have trouble establishing communication, contact Customer Service.

6. Access **Expert mode** by clicking the **About** box and entering the password **Advanced288**.

SAVE FACTORY INITIALIZATION SETTINGS TO A FILE

The sensor was initialized in air at the factory. Initializing the sensor in air configures the optical components and removes background and electrical noise. This step records the initialization settings to a file. This file is used to restore the sensor to factory settings.

1. On the Sensor Calibration tab, press Load Memory to import factory settings.
 2. Press Save Complete Sensor Info to File to write the factory settings to a file. The file size is approximately 2 K and has a *.cr288 extension.
- NOTE: Keep this file and back it up to a secure location. The file enables you to restore factory settings.**

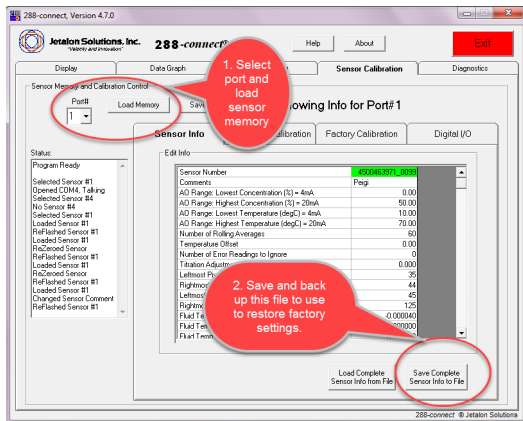


Figure 10. Saving factory settings to a file.

CHECK FACTORY INITIALIZATION

This step confirms that the sensor is functioning in air as expected.

1. On the Diagnostics tab, ensure the TIR curve is flat and the "Line Quality in Air" is below 3.0e-3. See Figure 11. Flat TIR curve.
2. Set initial parameters.

NOTE: If the TIR curve is not flat:

- a. Reconfirm that the CR288 window is clean and dry.
- b. Perform a re-zero. See *Re-zero* for instructions.

If the problem persists, contact Technical Support.

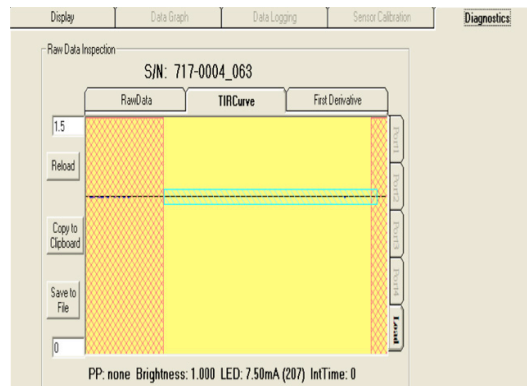


Figure 11. Flat TIR curve.

SET INITIAL PARAMETERS

1. Select the Sensor Calibration tab. Within that tab, select the Sensor Info tab.
2. Set desired number of rolling averages. See *Change Rolling Averages* for information.
3. Optional: On the Sensor Info tab, set 4–20 mA zero to full span to match user PLC settings for concentration.
4. Optional: Set 4–20 mA zero to full span to match user PLC settings for temperature.
5. Leave other settings unchanged.
6. Press **Save Memory** to activate the new settings.

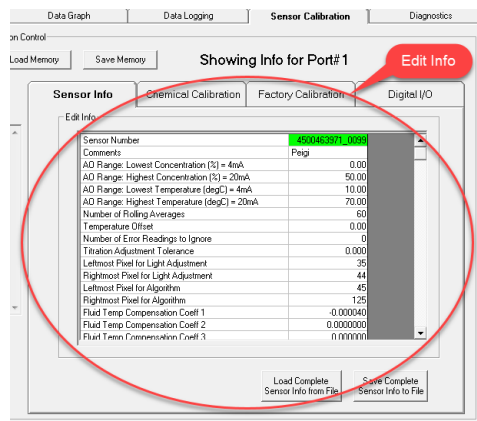


Figure 12. Setting initial parameters.

RE-ZERO

The Re-zero function calibrates the refractive index measurement to a known baseline.

The Re-zero function compensates for differences between sensors and operating environments (ambient temperatures, ambient light, etc.) and for slow drift in the signal.

The typical baseline is DI water (IoR =1.333000). Process lines that cannot be run with water may use another reference chemical of a known concentration or Index of Refraction.

Important Notes

- Only Re-zero when at system operating pressure and flow.
- Follow the Chemical Concentration Offset procedure if it is not possible to run DIW through the sensor. See *Chemical Concentration Offset*.
- If the Chemical Concentration Offset function was used before using the Re-zero function, reset the chemical concentration offset value to zero. See *Chemical Concentration Offset*.
- The quality of the Re-zero procedure depends on having the correct temperature compensation value for the reference chemical. The value of FTCC1 for distilled water at 20°C is -0.00004.

Steps

1. Select port.
2. Run DI water through loop and ensure thermal steady-state stability (<0.1°C) on the Data Graph tab.
3. Go to **Sensor Calibration/Factory Calibration** tab. Click **Load memory**.
4. Click **Re-zero Sensor**.
5. Click **Save Memory**.
6. Go to the **Data Graph** tab.
7. Select the **IoR@20** tab.
8. Observe the IoR@20 data.
9. Ensure that sensor is reading 1.333000 ($\pm 2^{-6}$). If it does not, repeat the Re-zero steps. If problem persists, contact Technical Support.



Figure 13. Performing a re-zero.

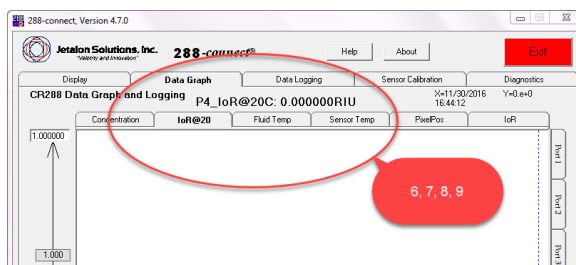


Figure 14. Checking the re-zero.

DETERMINE TEMPERATURE COMPENSATION COEFFICIENT (TCC)

TEMPERATURE COMPENSATION

CR288 actively monitors and compensates for changes in the IoR caused by fluid temperature changes. The compensation is determined by a calculation (TCC).

NOTE: Entegris Technical Support assists customers with setting the TCC. Contact Technical Support.

CR288 applies a linear temperature compensation model as determined by the TCC.

The default is set for H₂O at -4×10 . New TCCs must be calculated for other chemistries or processes.

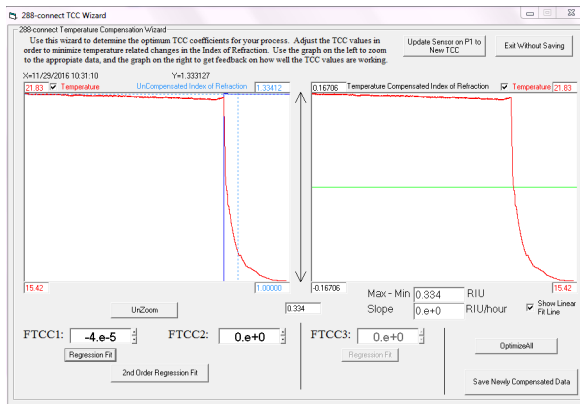


Figure 15. Adjusting the TCC (requires Technical Support).

CALCULATE THE TCC USING EXCEL®

COLLECT DATA

Using the software collect fluid temperature and IoR data that are representative of the process being measured. Examples include:

- 3 batches of chemical exchange
- 3 days for a continuous process
- 3 wafer pods

NOTE: The concentration should not change during the collection time.

CALCULATE THE TCC

1. Highlight the Fluid temp column data and the Raw Refractive Index data columns.
2. Go to the insert tab in Excel®.
3. Click on scatter graph option.
4. Select the scatter with only markers option.
5. Right click data and select add trend line.
6. Click display equation on chart and R² value on chart.

The slope value from $y = mx + b$ is the new TCC.

NOTE: TCC is always negative and generally ranges between -4×10^{-5} and 1.5×10^{-4} .

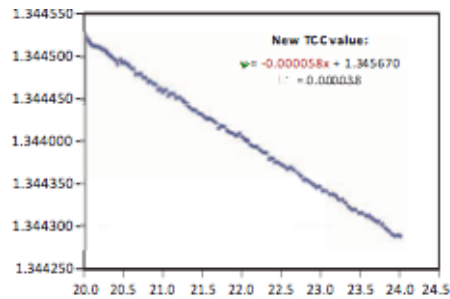


Figure 16. Scatter graph from Excel.

IMPLEMENT THE CALCULATED TCC

1. Input the Fluid Temperature Compensation Coefficient (FTCC) values into the Sensor Info tab. See Figure 7. Setting Initial Parameters. CR288 now automatically correct data for fluid temperature changes.
2. Click Save Memory.
3. Perform a Re-zero. See Re-zero.

OPTION: RUN OR CONTINUE CALIBRATION

After Temperature Compensation, the sensor is ready to read and collect the IoR and temperature of any liquid. The next steps depend upon how the user wants the data reported:

OPTION	RESULT	ACTION
Run without further calibration	Customer can immediately use CR288 to report IoR (Index of Refraction) and Temperature (T) of any liquid. The IoR changes as the process chemical changes. The user evaluates the state of the process chemical using the IoR data. Concentration measurements, such as wt% and percent concentration, cannot be read.	No action needed
Calibrate CR288 to a specific liquid chemical	This enables the sensor to report percent concentration values for the specific chemical	See <i>Calibrate Sensor to a Chemical</i>

CALIBRATE SENSOR TO A CHEMICAL

Each sensor head can be set to read a chemical signature using a user-created chemical calibration table.

NOTE: The detailed procedure is discussed during a call with Entegris Technical Support.

BASIC PROCEDURE

1. Prepare chemical at target calibration point.
2. Verify the chemical's concentration with offline analysis (if possible).
3. From the **Sensor Calibration/Chemical Calibration tab**, input the concentration value into the **Concentration %** field.
4. Click **Add calibration Point**.
5. Repeat for remaining calibration points.

NOTE: It is typical to add 2-10 points.

6. Press **Save Present Chemical** to save the Chemical Calibration Table to the user specified file location.
7. Click **Save Memory** to activate the calibration file on the selected sensor.

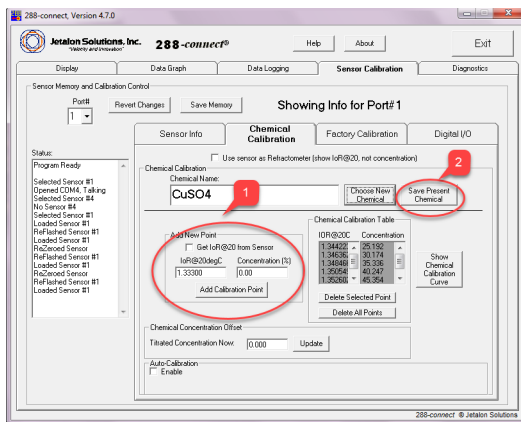


Figure 17. Chemical calibration tab.

UNIT OPERATION

LAUNCH THE PROGRAM

Double-click on the CR288 icon to launch the program.

Launch more than one session

Each open session of 288-connect software supports one DDU. To access more DDUs simultaneously, open additional sessions.

FUNCTIONS

The user interface is divided into tabs. This section describes the functions available under each tab.

DISPLAY TAB

Connect to a COM port

The quickest way to access data from a specific sensor is to select its COM port from the drop down list.

Open a COM port:

1. Choose a COM Port Number from the dropdown box.
2. Press **Open COM Port**. The message box displays "Opened, Talking" if a DDU is attached to the COM port.

The screen displays the current sensor information, duplicating the display from the DDU.

The message box displays "Auto: No ebox found" if no DDU is found attached. See *Troubleshooting* for more information.

Close a COM port:

1. Choose a COM port number from the dropdown box.
2. Press **Close COM Port**. A warning box appears.
3. Click ok. The message box displays "Status: closed."

Find a COM port:

1. Press **Auto Open** to have the DDU automatically check all COM ports for an attached sensor. The message box shows “Trying Com” until the software detects all the COM ports attached to the DDU.
2. The box then displays “Opened, Talking.”

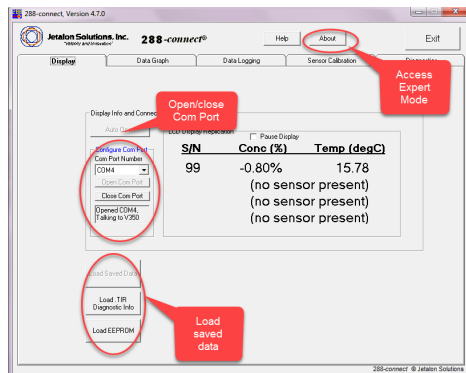


Figure 18. Display tab.

Access Saved Data

Load Saved Data Log (.csv):

1. Press **Load Saved Data**.
2. Select a .csv file from browser window.

Load Diagnostic Graph (.TIR):

1. Press **Load .TIR Diagnostic Info**.
2. Select a .TIR file from the browser window.
The display shows the stored graph.

See *Diagnostics Tab* for more information.

Help/Software Version

Press **Help** to display the software version. Further help is available from the user guide and your authorized representative.

About/Access Expert Mode

Press **About** for information about Jetalon Solutions, Inc. or to access **Expert Mode** functions.

NOTE: The Expert Mode password is **Advanced288.**

DATA GRAPH TAB

Select the **Data Graph** tab to display real-time graphical representations of the sensor output.

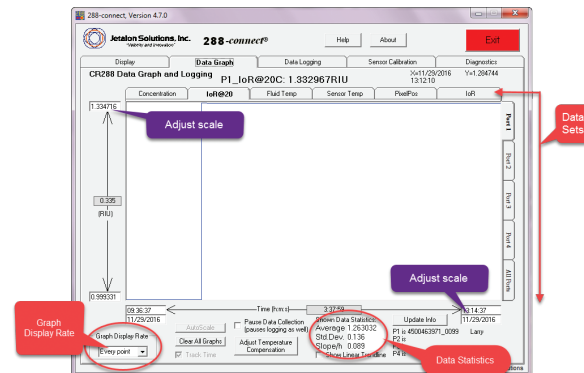


Figure 19: Data graph tab

Choose the data to display

Select a tab on the top of the graph or on the right side of the graph window to change the data set being displayed.

Concentration

Select the **Concentration** tab to display the percent-age change in concentration over time.

The concentration percentage is the ratio of a fluid component A (a solute) to a fluid component B (a solvent).

IoR@20

Select the **IoR@20** tab to display the changes in IoR@20 over time.

The IoR@20 is the fluid's index of refraction over time, as if it were compensated to a standard temperature of 20°C.

Fluid Temperature

Press the **Fluid Temp** tab to display the changes in temperature over time. The temperature is measured by a thermistor in the sensor.

Sensor Temp

For information, contact Technical Support.

Pixel Pos

For information, contact Technical Support.

IoR

This display presents the IoR without temperature compensation.

Graph Display Rate

Use the dropdown box to select the data point display rate:

- Every point
- Every 5 points
- Every 10 points

The display automatically resizes the graph to show the maximum data at that rate.

NOTE: The display rate is separate from the data logging rate. Data will continue to be logged at the rate set on the Data Logging Tab.

Scale Adjustment

Change the scale: Edit the values in the scale labels to adjust the scale shown by each axis.

NOTE: Changing the values only affects the active tab, but disables automatic resizing.

Restore the scale to show maximum data: Press **AutoScale** to restore automatic resizing.

View new data points: Press **Track Time** to show new data points in real time.

Show trendline: Check **Show Linear Trendline** to superimpose a line on the data showing the trend of the entire data set.

NOTE: This line always shows the trend for the entire data set. That is, if you zoom in on an area of data, the line does not change to show the trend of the displayed section. It still represents the trend of the entire set.

Zoom

Press the right mouse button and draw a box around the data. Press **AutoScale** to reset.

Shown Data Statistics

1. Set the display to show a subset of the data. (For example, use **Zoom** to select a subset of data.)
2. Press **AutoScale** to restore automatic resizing to the maximum set of data.

Average: Average of the measured values.

To move the data to a database:

1. Right click the **Average** box.
2. Copy the value.
3. Switch to the database.
4. Paste.

Standard Deviation: Square root of the variance in data.

Slope/h: Indicates if the data is trending upward (positive) or downward (negative).

Pause Data Collection

1. Check the box to stop the data log from storing further data from the sensor.
2. Click to restore data collection.

NOTE: The sensor will continue to gather data and output the data to the analog outputs, digital outputs and DDU, but the software will stop storing data.

Clear All Graphs

Clears the data graph(s) on the display.

NOTES:

Clear all graphs only affects the graphic buffer.

Clear all graphs does not affect the data log.

New displayed data continues from the time of the last data point.

Update Info

Enables you to:

- Change the sensor serial number
- Show edits in the sensor comments. To edit comments, see the *Sensor Info Tab Fields*.

NOTE: Update Info changes the information at that point in the data file. Sensor numbers and comments made before the update do not change.

Adjust Temperature Compensation

See *Temperature Compensation*.

DATA LOGGING TAB

Select the **Data Logging** tab to change the parameters for logging the data.

By default, the software collects one data point every 1.3 seconds and stores the last 5000 data points in memory for display. The display can show up to 108 minutes of data for each sensor.

Where

- Put the file location and name into the **Where** box either manually or by using the **Browse...** button.

File name: The date and the file name extension *.csv are automatically added to the file name.

- Set the number of data points to be stored in each log file.

NOTE: The default is 10,000 points. The maximum is 64,000 points.

When the data point limit entered is reached, the data log automatically rolls over to a new file with the same name originally specified and a new time stamp.

What (Data Set)

- Select the ports from which to log data.
- Select the data types to log:
 - Basic data:
 - Concentration
 - IoR@20
 - Fluid temperature
 - All data:
 - Concentration
 - IoR@20
 - Fluid temperature
 - Sensor temperature*
 - Pixel position
 - Index of refraction (IoR)

*Expert mode only.

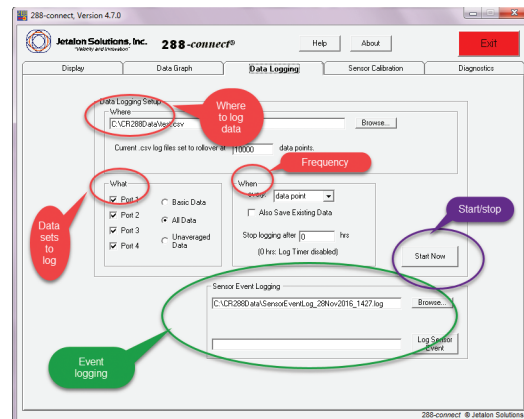


Figure 20. Data logging tab.

When

- Select how often data is stored in the data log file:
 - Every data point
 - 5 seconds
 - 10 seconds
 - 30 seconds
 - Minute
 - 5 minutes
- Check the **Also Save Existing Data** box to continue storing raw data when averaged data is being displayed.
- Enter a time to stop logging data, in hours or fraction of an hour as a decimal value.
 - For continuous data logging, leave the value at "0."
- Press **Start Now** to begin logging.

The program maintains a count of the logged points on the left side of the screen. This confirms that the data is being logged.

SENSOR CALIBRATION TAB

Sensor calibration functions are available only when Expert Mode is activated. See About/Access Expert Mode.

Select Port and Load Memory

1. Select a port from the drop-down list.
2. Press Load Memory.

Status Window

Provides a visual record of the recent operator actions.

Load or Restore Memory

This button toggles to load or restore the selected sensor's information.

Load Memory displays when 288-connect is initially opened and after Save Memory is used.

Revert Changes displays after Load Memory is pressed and restores the previously saved sensor information.

Save Memory

Press to write the sensor data to user-specified location.

Load or Restore Complete Sensor Info From File

Press and use the dialog box to load information from a previously saved sensor file.

Save Complete Sensor Info To File

Press to save data from the sensor to a file.

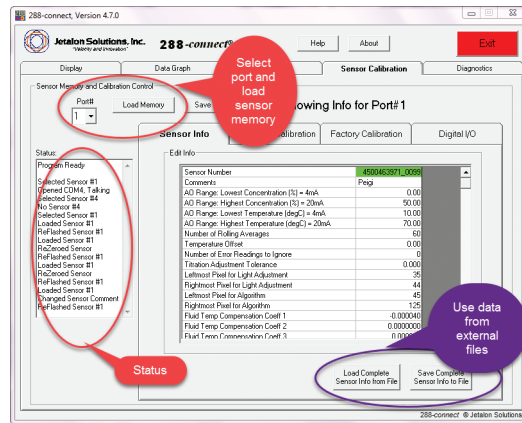


Figure 21. Sensor calibration tab.

SENSOR INFO TAB FIELDS

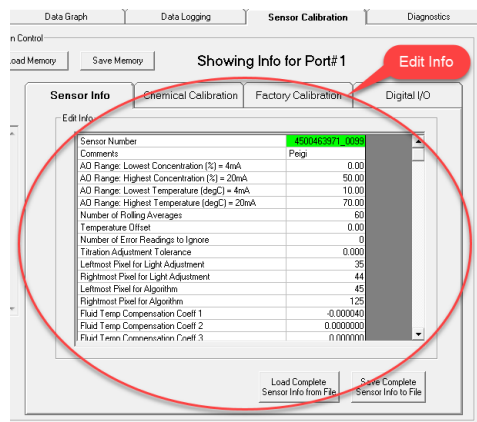


Figure 22. Sensor calibration/sensor info tab.

Sensor Number

This is the number laser etched on the sensor. This value cannot be edited.

Comments

This may be edited to any 20-character string.

NOTE: If comments are edited, a red text box appears in the lower left corner of the displayed screen indicating a change.

AO Range

Adjust the concentration and temperature ranges of the analog outputs.

Number of Rolling Averages

Use Rolling averages to increase the amount of averaging that the sensor performs on the data. This reduces measurement noise but increases DDU response time.

NOTE: Collecting a point requires approximately 1.3 seconds; therefore 10 points add approximately thirteen seconds to the response time.

Rolling averages can be applied to the following data to be observed on the Data Graph Tab:

- Concentration ?
- Temperature
- IoR@20
- PixelPos

Rolling averages cannot be applied to the IoR.

Change Rolling Averages

1. Click on the **Rolling Averages** field.
2. Enter a number where the number is greater than zero and less than 100 ($0 < n <= 100$) to specify the number of points to maintain in the rolling average.
3. Press **Save Memory**.

Temperature Offset

Calibrates the fluid temperature sensor to an external reference temperature.

1. Press **Temperature Offset**.
2. Enter a value.

This value is added to all of the fluid temperature readings for the selected sensor.

Number of Error Readings to Ignore

Number of errors or out of bounds signals that the sensor ignores before the set alarms trigger. See *Setting Alarms*.

Pixel for Light Adjustment

Edit to adjust the left and right-most pixel position used for the TIR curve on the Diagnostics Tab. It also adjusts the light intensity for proper sensor operation.

Pixel for Algorithm

Defines the range of pixel positions the software algorithm uses to determine the critical angle and associated IoR.

Fluid Temperature Compensation Coefficient

Enter a value or see *Temperature Compensation Wizard*.

NOTE: You can also set this value using the Adjust Temperature Compensation button on the Data Graph tab. See *Data Graph Tab*.

Save Factory-Loaded Sensor Information

See *Save Factory Initialization Settings to a File*.

Restoring Factory-Loaded Information

1. Press **Load Complete Sensor Info from File**.
2. Select a file.

NOTE: Do not use a file from one sensor to restore a different sensor. The data over-writes the sensor serial number.

CHEMICAL CALIBRATION TAB

Chemical calibration tells the sensor the characteristics of the chemical to be monitored. The relationship between concentration and index of refraction is near linear for most chemicals at a constant temperature and can be defined with only two points.

However, some chemicals do have a non-linear relationship making it necessary to enter additional data points. Higher system accuracy requirements can also require more data points. The 288-connect software accepts up to ten data points to compensate for non-linear relationships, allowing for polynomial fits.

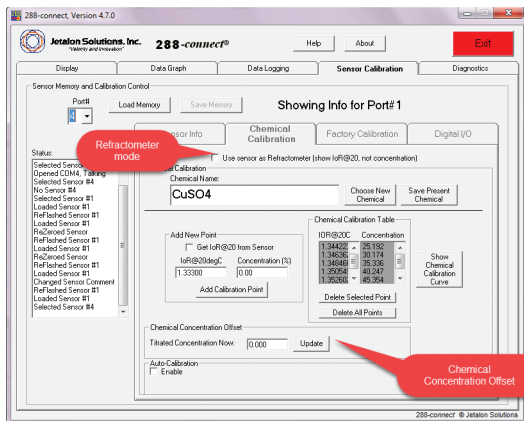


Figure 23. Chemical calibration tab.

Refractometer Mode

Check Use Sensor as Refractometer to display IoR values instead of concentration.

NOTE: No data will display on the concentration display tab while this mode is active.

Choose New Chemical

Press to enter a chemical calibration table for a different chemical. See Create a New Chemical Calibration Table.

Chemical Concentration Offset

Chemical concentration offset modifies the concentration reading from the calculated concentration. Use the Chemical Concentration Offset when the concentration of the liquid under measurement is known.

NOTE: This function does not over-write the chemical calibration table entered and saved to sensor memory. It is typically used to compensate for minor variances due to:

- Chemical process changes
- Chemical lot-to-lot
- Supplier variations

NOTE: If the IoR of the liquid under measurement is known, follow the Re-zero procedure instead. See Re-zero.

1. Select the port number for the desired sensor.
2. Press Load Memory.
3. Enter the actual concentration of the chemical in the present fluid stream in the Titrated Concentration Now box on the bottom left of the screen.

4. Press Update.

A new value appears in the box on the right. This value represents the amount subtracted from the concentration before displaying it or outputting it to the analog outputs or software.

5. Press Save Memory.

The sensor memory makes the chemical concentration offset permanent.

6. Observe the Data Graph to verify that the concentration is now the same as the value entered.

Factory Calibration Tab

Entegris Technical Support uses the Factory Calibration Tab to calibrate and customize the sensor.

Consult Technical Support for detailed information on these features.

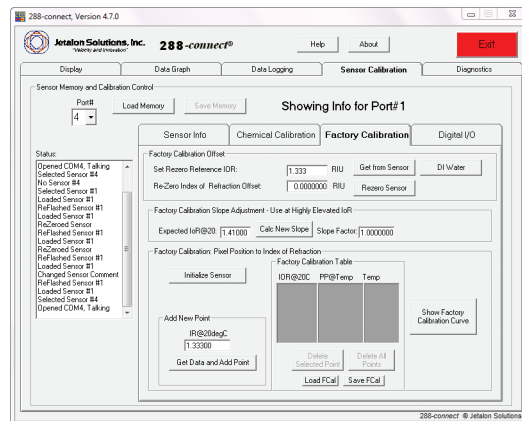


Figure 24. Factory calibration tab.

Re-zero IoR Offset

1. Select the correct port number for the desired sensor.
2. Press Load Memory.
3. Ensure that the sensor is exposed to DIW (deionized water) at a stable temperature ($\pm 2^{\circ}\text{C}$).
4. Select the Data Graph/IoR@20 tab.
5. Ensure that the slope of the IoR@20 value remains $2e^{-5}$ or lower over two minutes.

NOTE: If the slope is greater than $2e^{-5}$, check for any temperature or concentration variations in the system. Stabilize any variations.

6. Select the **Sensor Calibration/Factory Calibration** tab.
7. Press **Get from Sensor** to copy the IoR@20 value from the sensor to the Re-zero Reference IoR field.

NOTE: This is useful when multiple sensors are exposed to the same chemical.

8. Press **DI Water** to reset the Re-zero Reference IoR to 1.333000.
9. Press **Re-zero Sensor** to reset the IoR@20 for the sensor to the Re-zero Reference IoR value.
10. Press **Save Memory**.
11. Return to the **Data Graph** tab.

The IoR@20 should now be 1.33300 ±0.00001.

Initialize Sensor

Initializing performs dark field correction and normalizes pixel brightness. See "Cleaning and Re-initialization."

NOTE: Any sensor that was disassembled should be re-initialized.

Slope Adjustment

The sensor is shipped from the factory with a generic calibration curve. The calibration of the refractive index can be improved when the refractive index standards are known. Use this feature to change the generic calibration curve to a specified calibration curve. The values in the Factory Calibration table used to calculate the IoR are modified by an amount proportional to their difference from the Re-zero reference IoR.

1. Confirm that the Slope Factor field reads 1.000000. Edit if necessary.
2. Re-zero the sensor using a reference fluid, typically DI water.
3. Input the refractive index value of a known fluid, one similar to the typical system fluid, into the **Expected IoR@20** field.
4. Expose the sensor to the second fluid.
5. Press the **Calc New Slope** button.

Pixel position to Index of Refraction

The factory calibration table calculates concentration by translating the sensor output into refractive index values at defined pixel positions at a defined temperature.

DIGITAL I/O TAB

Digital Outputs: Alarm

The DDU provides two 5 V (dc) digital output channels, on pins 19 and 20 of the terminal block. These channels are used to activate alarms on an external device if the concentration moves outside the user-defined range.

Sensor Info	Chemical Calibration	Factory Calibration	Digital I/O
<div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <p>Digital Output Settings for Terminal 19</p> <p><input type="checkbox"/> Alarm outside concentration range</p> <p>Lowest Concentration: <input type="text" value="0.00"/> %</p> <p>Highest Concentration: <input type="text" value="100.00"/> %</p> <p><input type="checkbox"/> Alarm on sensor problem (bubbles, window fouling, etc)</p> <p><input type="text" value="0"/> Number cycles to delay Alarm</p> </div> <div style="width: 48%;"> <p>Digital Output Settings for Terminal 20</p> <p><input type="checkbox"/> Alarm outside concentration range</p> <p>Lowest Concentration: <input type="text" value="0.00"/> %</p> <p>Highest Concentration: <input type="text" value="100.00"/> %</p> <p><input type="checkbox"/> Alarm on sensor problem (bubbles, window fouling, etc)</p> <p><input type="text" value="0"/> Number cycles to delay Alarm</p> </div> </div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div style="width: 48%;"> <p>Digital Input Settings for Terminal 19</p> <p><input type="checkbox"/> Enable Remote-Reset for T19</p> <p><input type="checkbox"/> Enable Remote-Reset for T19</p> </div> <div style="width: 48%;"> <p>Digital Input Settings for Terminal 20</p> <p><input type="checkbox"/> Enable Remote-Reset for T20</p> <p><input type="checkbox"/> Enable Remote-Reset for T20</p> </div> </div>			

Figure 25. Digital I/O tab.

NOTES:

- There will be no software indication of an alarm.
- The digital outputs can be set for each sensor, and each sensor can control both channels.
- If alarms are set for multiple sensors, there is no indication of which alarm is being activated.
- If two sensors have an alarm set for the same output channel, both alarms are active on that channel.

Example:

The sensor on Port 1 activates the alarm on pin 19 when the concentration percentage drops below 5%.

The sensor on Port 2 activates the alarm on pin 19 when the concentration percentage goes above 10%.

If the alarm on pin 19 is activated, either the sensor on Port 1 is below 5% or the sensor on Port 2 is above 10%.

Setting Alarms

1. Select the correct port number for the desired sensor.
2. Press **Load Memory**.
3. Select alarm type.
 - **Alarm outside concentration range:** Activates an alarm when the reported concentration goes outside of the range.
 - **Alarm on sensor problem:** Activates an alarm when the sensor has a problem. A common cause of this is the sensor being exposed to air. This error also causes the DDU to display "Sensor In Air?" on the screen.
 - **Number cycles to delay alarm:** Delays the alarm for the number of consecutive cycles entered. It can be useful in compensating for expected process transients.
4. Press **Save Memory**.

Digital Input Settings

Digital inputs for alarms require a combination of hardware and software inputs. Contact Technical Support to implement these functions.

Enable Remote Re-zero

Enables a sensor Re-zero when a 5V signal is applied to a specified pin on the DDU.

NOTE: Requires appropriate DDU jumper pin modification. Contact Technical Support.

Enable Remote Retitrate

Enables a titration offset when a 5 V signal is applied to a specified pin on the DDU.

NOTE: Requires appropriate DDU jumper pin modification. Contact Technical Support.

DIAGNOSTICS TAB

This tab provides information to analyze the quality of the sensor signals and to troubleshoot measurement inaccuracies.



Figure 26. Diagnostics tab.

Update, Copy to Clipboard, Save to File**Update**

Press to display the most recently acquired pixel data.

Copy to Clipboard

Press to copy the TIR curve to a .tir file.

Save to File

Press this button to save the RawData, TIRCurve, and the First Derivative to a .tir file stored on the computer. This file can then be loaded from the **Display** tab. The file does not include the background temperature data.

Set Bounds of Interest

The hashed boundaries on the left and right side of the display tabs define the upper and lower pixel limits used to calculate pixel position. The operating range defined by these boundaries allows measuring the IoR between 1.29 and 1.45 RIU.

NOTE: The user can modify these boundaries but noisy outer pixels will affect the accuracy of the data.

RAW DATA TAB

Displays a profile of the 128 pixel values with no averaging. This is periodically transmitted as analog light levels from the sensor and is digitized by the DDU into discrete 12-bit values.

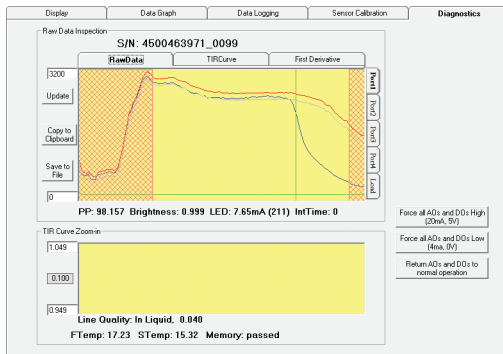


Figure 27. Raw data tab.

Four curves are superimposed on this graph:

- **Green:** displays the background reference, a measure of the baseline intensity levels when the LED is turned off. The background curve is unique to that sensor.
- **Grey:** displays the air reference, a measure of the baseline intensity levels when the sensor is exposed to air. The air reference curve is unique to that sensor.
- **Red:** displays the sum of the background and air reference values.
- **Blue:** displays the real time raw data curve.

TIR Curve Tab

Displays the sensor’s reflected light of the measured liquid from the 128 pixels derived from the raw data and normalized by the background and air reference curves.

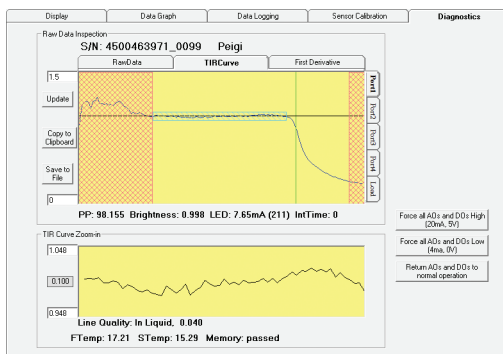


Figure 28. TIR curve tab.

A sensor that is functioning properly displays:

- A flat line within the pixel position range with a smooth cutoff following
- An LED brightness value between 0.97 and 1.01.

The bottom display provides a zoomed-in view of the “head” or leaning line before the drop off.

- During sensor initialization, a line quality of 1×10^{-3} is typical.
- During regular operation, a line quality of 0.03 to 0.04 is typical.

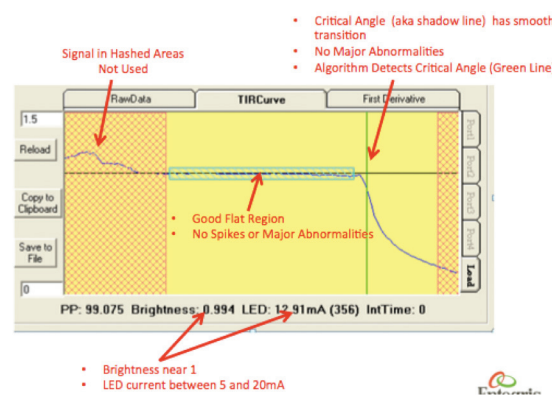


Figure 29. Features of healthy TIR curves.

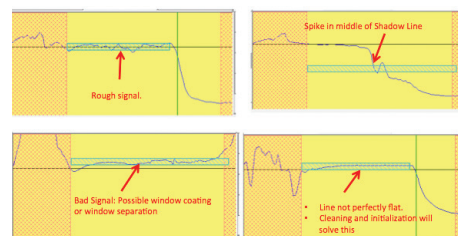


Figure 30. Features of bad TIR curves.

Potential solutions would be to clean, visually inspect and reinitialize the sensor. See *Troubleshooting a TIR Curve*.

FIRST DERIVATIVE TAB

Displays the rate of change in the TIR curve across a selected region of interest. It is used to calculate the loR and concentration.

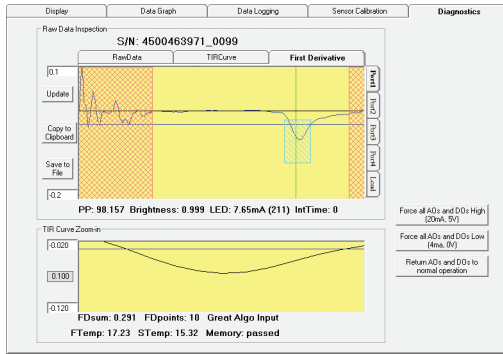


Figure 31. First derivative tab.

A good derivative curve has a depth exceeding the blue threshold line as shown.

MAINTENANCE

RE-ZERO AND RE-TITRATION

Re-zero is performed for setup, maintenance, and to correct sensor drift.

Re-titration is an adjustment of the concentration value and is performed as necessary.

Re-zero for Maintenance

To re-zero, See *Re-zero* for instructions. Re-zero the sensor:

- On an as needed basis
- When changing sensors

Re-zero Due to Sensor Drift

If H₂O is available, Re-zero the Refractive index value to 1.33300.

NOTE: If performing a Re-zero does not correct the problem, see *Cleaning the Sensor Window*.

Re-Titration Offset

1. Take an offline lab measurement.
2. Go to the Sensor Calibration/Chemical Calibration tab.
3. Enter a value to offset chemical calibration.

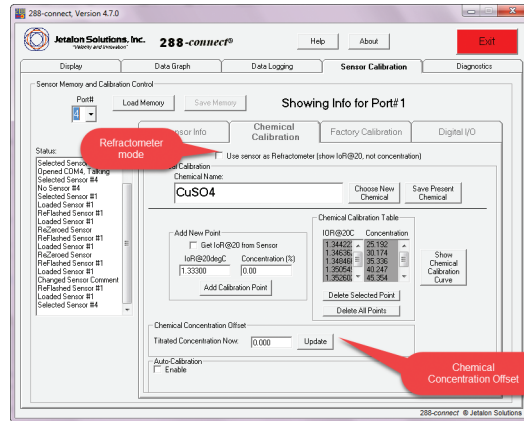


Figure 32. Resetting chemical concentration offset.

CLEANING AND RE-INITIALIZATION

PRECAUTIONS

- ⚠ **WARNING:** Before servicing any installed sensor, you must depressurize and flush the system.
- ⚠ **WARNING:** Residual chemicals may be left in the sensor and the system. Refer to the MDDS for exposure precautions.

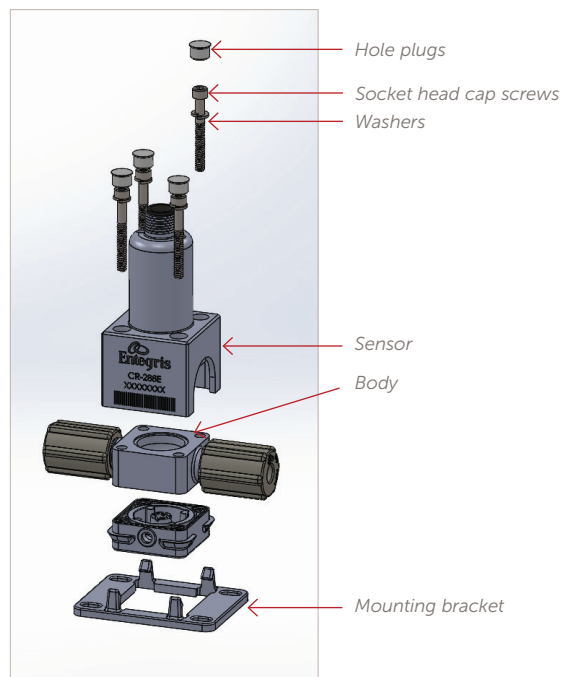


Figure 33. Disassembled sensor.

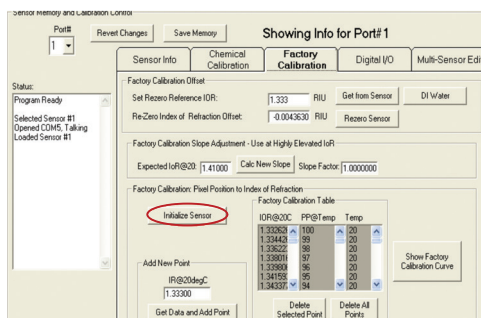
CLEANING THE SENSOR WINDOW

Over time, some fluids may develop a film that coats the sensor's optical window. This may cause poor sensor performance. If the Re-zero procedure does not correct the issue, the sensor may be disassembled to clean the optical window.

1. Disconnect the sensor cable and remove the sensor from the system.

NOTE: Do not twist the cable to remove.

2. Remove the hole plugs, socket head cap screws, and washers. Separate the sensor from the body. Remove the gasket from the body.
3. Carefully clean the optical window with an appropriate solvent and a clean cloth.
4. Rinse off with DI water and dry with a lint-free wipe.
5. Place the mounting plate against the bottom of the body.
6. Install the gasket back into the top of the body. Carefully center the window into the gasket.
7. Assemble the sensor to the body and insert the washers and socket head cap screws.
8. Torque the socket head cap screws to 0.14 to 0.17 N•m (20 to 25 in•ozf) using a cross pattern.
9. Torque the cap screws again, to 0.31 to 0.34 N•m (45 to 48 in•ozf), using a cross pattern. Insert the hole plugs.
10. Re-initialize the sensor
 - a. Make sure the sensor is clean, dry and placed in lighting similar to system conditions
 - b. Go to the Chemical Calibration tab and select Factory Calibration tab



- c. Press the Initialize Sensor button (the software will take about 10 seconds to complete)

- d. **IMPORTANT** – If the initialization is successful, go back to the Sensor Calibration Tab and “Save Memory”

11. Reinstall the sensor into the system and reconnect the sensor cable.
12. Pressurize the system and inspect for leaks.
13. Follow the Re-zero procedure.

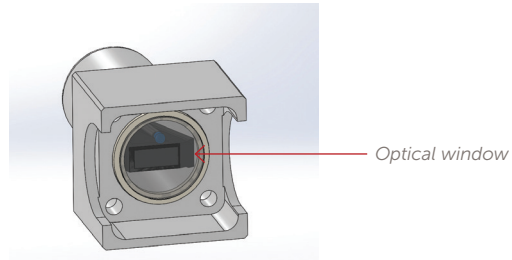


Figure 34. Underview of sensor.

TROUBLESHOOTING

Possible reasons for measurement inaccuracies include, but are not limited to:

- Window fouling
- Restricted flow across the sensing surface
- Bubbles or air pockets
- Inadequate light shielding
- Environmental noise
- Delamination of the sensing surface (rare)

Examining the TIR curve on the Diagnostics Tab is a useful step in identifying the source of measurement inaccuracies. See *Diagnostics Tab*.

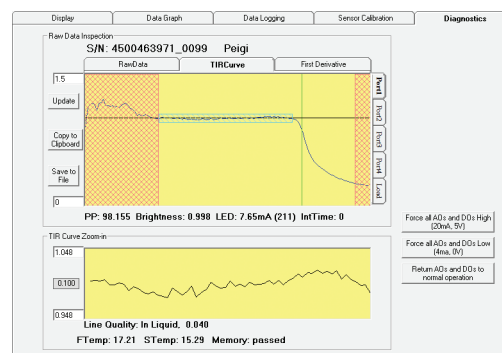


Figure 35. Healthy TIR curve.

Troubleshooting a TIR curve

Table 1. Troubleshooting a TIR curve

Characteristic of a healthy TIR curve:	If this is not the case:
A smooth active section (highlighted by a box on the curve) as indicated by a line quality <0.04 and a brightness level near 1.0. The line quality can also be observed in the zoom display with the brightness value indicated beneath the TIR curve.	<ol style="list-style-type: none"> 1. Clean the sensor surface 2. Re-zero 3. Initialize the sensor 4. Verify that the sensor is properly shielded from ambient light
A line quality stating "In Liquid."	<ol style="list-style-type: none"> 1. Press Update several times to verify the problem is repeatable 2. Ensure there are no air pockets in system flow
<p>A smooth, sharp "shadow curve" or dropoff point.</p> <p>A typical healthy curve will drop from a brightness of 1.0 at the head to 0.3 at the tail on the y-scale, within a span of 5 to 10 pixels. A steeper curve indicates improved measurement resolution.</p>	<ol style="list-style-type: none"> 1. Clean the sensor 2. Re-zero 3. Initialize 4. Optional: Adjust the lower pixel bound used by the measurement algorithm. The sensor is typically limited to readings below 1.42.
A curved tail section flattening out at a brightness of 0.3 on the y-scale.	<ol style="list-style-type: none"> 1. Clean the sensor 2. Re-zero 3. Initialize <p>If the display shows too few tail pixels:</p> <ol style="list-style-type: none"> 4. Adjust the upper pixel bound used by the measurement algorithm. The sensor is typically limited to readings above 1.32.

General Troubleshooting

SYMPTOM	PROBABLE CAUSE	REMEDY
Display says "no sensor present"	Loose cable/bad cable/sensor not connected	Detach and reattach both ends Replace or swap cable
	Bubble trapped in flow cell	Turn the sensor upside down (cable points downward) to release the bubbles. Mounting in this position may prevent future occurrences.
Display says "Sensor in Air" when chemical is flowing	Dirt or other optical window fouling	Inspect the TIR on the Diagnostics tab for a non-linear curve in a "mountain" pattern. Clean window with a DIW flush and Re-zero.
	Cable issue/sensor malfunction	Inspect the TIR curve on the Diagnostics tab. If it's non-linear or not appearing, swap cables. If there is still a problem, replace sensor.

General Troubleshooting (continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Excessive noise (signal drifts more than 0.04% in stable chemical)	Optical window fouling	Clean window with a DIW flush and Re-zero.
	LED brightness issues	Check the Diagnostics Raw Data tab for the brightness. It should be ~1.000. If not, clean the window with a DIW flush and Re-zero.
	Sensor temperature noise appears correlated across multiple sensors.	This is a function of incoming power fluctuation and represents baseline performance for the CR288 monitor(s).
	Bad calibration	Verify chemical calibration represents the current chemical. If necessary, recalibrate the sensor. See <i>Create a New Chemical Calibration Table</i> .
Large, rapid concentration or IoR changes	Ambient light changes	Protect sensors from significant external changes in light. Clean and Re-zero the sensor for any permanent changes in light conditions.
Small, rapid concentration or IoR changes	Sensor was moved to a different port	Re-zero or maintain original port location(s).
	Pressure pulses from the system pump	Move the sensor to a position that is upstream from the pump
Can't get "Opened, Talking" status	Serial cable disconnected	Ensure that the serial cable is properly connected to the computer and to the DDU
	Power not connected	Unplug the DDU for five seconds, then reconnect power
	Software	Restart 288-connect
	USB to serial converter error	Reload converter driver. Restart 288-connect and DDU.
	Bad USB port on computer	Move cable to a different USB port
	Bad port on the DDU	Move cable to a different port on the DDU
	Bad cable	Replace cable
"Auto: No E-box found"	Loose cable	Check cable connections
	Insufficient admin rights on the computer	Restart 288-connect Use a different serial port on the computer or use serial-to-USB converter

General Troubleshooting (continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Red error box on screen	Software error	Unplug the DDU for 5 seconds then reconnect. Restart 288-connect.
Concentration reading changes incorrectly when temperature changes	Improper temperature compensation	Change the temperature compensation coefficient. See <i>Temperature Compensation Wizard</i> .
	Variable heating and cooling temperature rates.	Expose sensor to similar heating and cooling rates. Adjust the temperature compensation coefficient as needed.
	Rapid temperature change	Dampen any heating and cooling rates above 5°C/min.
Concentrations are incorrect by a small constant offset	Sensor needs to be Re-zeroed	See <i>Re-zero</i> .
Concentrations scale incorrectly (Fine at low concentrations but increasingly incorrect at higher ones)	Chemical calibration is incorrect	Select the correct chemical on the Sensor Calibration Chemical Calibration tab. See <i>Chemical Calibration Tab</i> . For custom chemicals, recreate the chemical calibration table. See <i>Create a New Chemical Calibration Table</i> .
Power LED does not illuminate when device appears to be properly powered	Voltage across the power terminals is not 24V (DC)	Check the voltage.
Red LED comes on	Error signal from sensor	Contact Technical support.
Old sensor information displayed on Data Graph tab	Sensor and DDU not synchronized.	Press Update Info on the Data Graph tab. See <i>Data Graph Tab</i> .

APPENDIX A: ADVANCED FEATURES

CREATE A NEW CHEMICAL CALIBRATION TABLE

Create a different Chemical Calibration Table for each chemical the sensor monitors.

Select the **Sensor Calibration/Chemical Calibration** tab.

1. Change the chemical name and press **Delete All Points**. This clears all data from the chemical concentration table.
2. The next steps depend on the available information, such as data from an offline analysis. See *Calibrate Sensor to a Chemical*.
3. When the desired number of points are recorded, press **Save Present Chemical**.
The software writes a file with a *.chem extension on the hard drive. This file can then be used to import the chemical calibration table to other sensors.
4. Press **Save Memory** to update the sensor memory.

TEMPERATURE COMPENSATION WIZARD

The Temperature Compensation Wizard (TCC Wizard) allows users to employ an automatic temperature compensation feature to desensitize the product's refractive index response to temperature change.

This feature provides an adequate baseline for most processes. For finer control of temperature compensation, you may use a manual temperature compensation procedure. Manually removing stray points from the data log in Microsoft Excel® can also improve the performance of the TCC Wizard.

The need for temperature compensation depends on the consistency of the process. If the process is known to vary, you may need to perform temperature compensation several times during setup.

1. Select the **Data Graph** tab.
2. Let the sensor run for the period of time and the range of temperatures representative of a typical process cycle. Keep the chemical concentration constant.

3. Press **Adjust Temperature Compensation**.
The TCC wizard window opens.
4. Determine if the response of the sensor is under- or over-compensating for temperature. See *Figure 36. TCC wizard screen 1*.
5. Using the graph on the left, zoom in on the data set to use to calculate the temperature compensation value. Take data near the target temperature and concentration of the application.

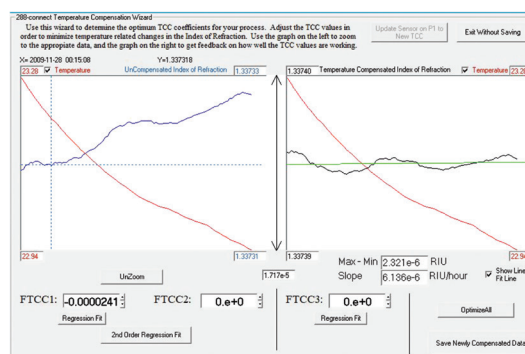


Figure 36. TCC wizard screen 1.

6. Press **Regression Fit** under FTCC1. The software calculates the fluid temperature compensation value (FTCC1) and the Temperature Compensated IoR. The right-hand graph shows the effect of the temperature compensation on the data graph FTCC1.

Note: Used in every case, this linear model for temperature compensation is appropriate as the sole temperature compensation for most systems.

- Press **2nd Order Regression Fit** to calculate a second order coefficient, FTCC2.

This is useful in processes characterized by large temperature variations FTCC2. If the temperature varies over a significant range (process dependent), invoking the second order term allows the software to incorporate a non-linear temperature behavior.

This coefficient is very dependent on the data set used to develop it. The data used to develop the coefficient should have a temperature range equal to or greater than the range the sensor sees in use. The user must determine if using FTCC2 is appropriate for their system.

- Press **Regression Fit** under FTCC3 to calculate a third coefficient, FTCC3. This is a derivative term that is useful in processes with rapid temperature variations FTCC3. Rapid changes in temperature may not register immediately due to the response of the onboard temperature sensor. FTCC3 compensates for these time delays by factoring the time rate of change of the temperature into the compensation algorithm.

NOTE: Use FTCC3 only when FTCC1 and FTCC2 do not compensate adequately. Including this term dramatically increases the noise values.

- Press **Optimize All** to have the graph perform the best mathematical least-squares fit using all three coefficients. Manually adjust coefficients using the up and down arrows on the screen or by entering new values.
- Press **Save Newly Compensated Data**. The data log files contain the calculated temperature compensation coefficient and also reflect the new IoR@20 values.
- Press **Update Sensor on Px to New TCC** (where x = the port number in use) to apply the temperature compensation to the data graph tab display. The software returns to the Sensor Calibration tab with the calculated Fluid Temp Compensation Coeff added to the Sensor Info table.
- Press **Exit Without Saving** to exit the wizard and not apply the temperature compensated index of refraction to the data graph display.

- Save the temperature compensation value either by pressing **Update Sensor to New TCC** or by entering it manually into the Sensor Info tab.

- Re-zero the sensor with DIW.

INFORMATION FOR 4-20 MA APPLICATIONS

Table 2. Equation to translate signal output to concentration and temperature

$$\text{Concentration (\%)} = (\text{mA} - 4) / 16 * (C_{20\text{ma}} - C_{4\text{ma}}) + C_{4\text{ma}}$$

$$\text{Temperature (}^\circ\text{C)} = (\text{mA} - 4) / 16 * (T_{20\text{ma}} - T_{4\text{ma}}) + T_{4\text{ma}} \text{ where:}$$

$$C_{4\text{ma}} = \text{AO Range: Lowest concentration (\%)} = 4 \text{ mA}$$

$$C_{20\text{ma}} = \text{AO Range: Highest concentration (\%)} = 20 \text{ mA}$$

$$T_{4\text{ma}} = \text{AO Range: Lowest concentration (}^\circ\text{C)} = 4 \text{ mA}$$

$$T_{20\text{ma}} = \text{AO Range: Highest concentration (}^\circ\text{C)} = 20 \text{ mA}$$

If the sensor has never been used or changed, the values are at the factory defaults. See Table 3. Factory Default mA Settings for Concentration and Temperature.

Table 3. Factory default mA settings for concentration and temperature

Concentration corresponding to 4 mA	-1.00%
Concentration corresponding to 20 mA	30.00%
Temperature corresponding to 4 mA	10°C (50°F)
Temperature corresponding to 20 mA	65°C (149°F)

APPENDIX B: THEORY OF OPERATIONS

This information provides a basic background introduction into the operation of the SRSensor™, which is the optical backbone to the CR288 Liquid Chemical Analysis System.

SRSensor

The Liquid Chemical Analysis system is built upon a miniaturized optical bench that is composed of an LED, Optical Prism, Optical Window, and a 128 Pixel Photodiode array. Figure 37. Optical Sensor shows a picture of SRSensor.



Figure 37. Optical sensor.

Inside the SRSensor, a monochromatic light (fixed wavelength) is emitted from a light source, travels through a prism, through sapphire and to the liquid at a steep angle. Depending on the refractive index of the media, part of the light will be refracted into the media, while another portion is reflected back to the sensor and to the PDA.

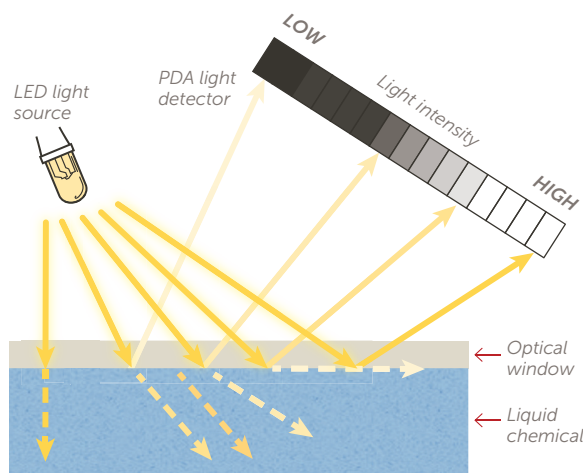


Figure 38. SRSensor operation.

The PDA contains many small pixels that are sensitive to changes in light. As the media backscatters the light and reflects it back into the photodiode array, the “critical angle” shifts left and right depending on the electron density difference between the liquid and the sapphire optical window. After processing through the CR288’s digital device unit (DDU) the “pixel position” of the critical angle is location is recorded for calculation to refractive index.

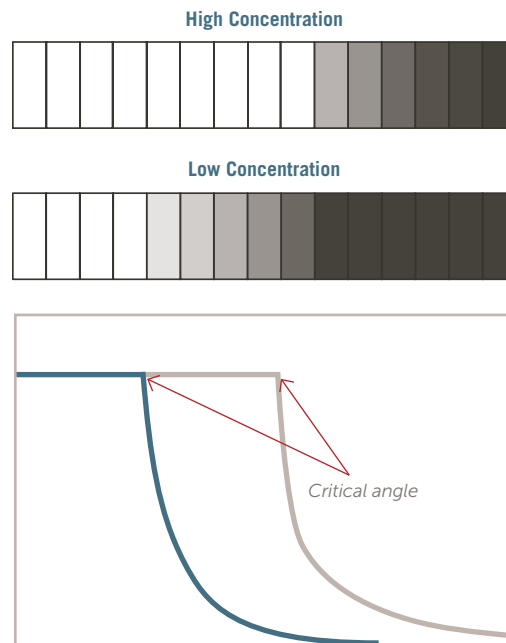


Figure 39. PDA and TIR curves as media concentration moves from low to high.

When the firmware identifies the pixel position, the associated refractive index is found via a factory calibration which is a procedure performed on the sensor prior to measurements so that the sensor properly associates the pixels on the array.

APPENDIX C: PERFORMANCE DATA

Performance data is based on operation within the calibrated range, $\pm 0.3\%$ of the refractive index calibration point or $\pm 0.3\%$ of concentration.

NOTE: The fluid temperature compensation coefficient (TCC) is shipped with a factory setting using room temperature DI water.

CRITERIA	VALUE
Refractive index accuracy (Refractive Index Units, RIU)	$\pm 2 \times 10^{-4}$
Refractive index repeatability	2.5×10^{-5}
Refractive index resolution	1.0×10^{-5}
Concentration accuracy	± 0.2 wt% Based on measuring ethylene glycol at 0.345 bar (5 psig) with a maximum variation of 0.017 bar (± 0.25 psig) and a temperature of $20^{\circ}\text{C} \pm 0.1^{\circ}\text{C}$ ($68^{\circ}\text{F} \pm 0.18^{\circ}\text{F}$)
Concentration repeatability	± 0.025 wt%
Concentration resolution	Chemical-dependent, 0.01 wt% or better
Response time	1.2 sec standard, no rolling average enabled, rolling averaging is user-configurable

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