Sensor standard operating procedures

February 5-6, 2024

Outline

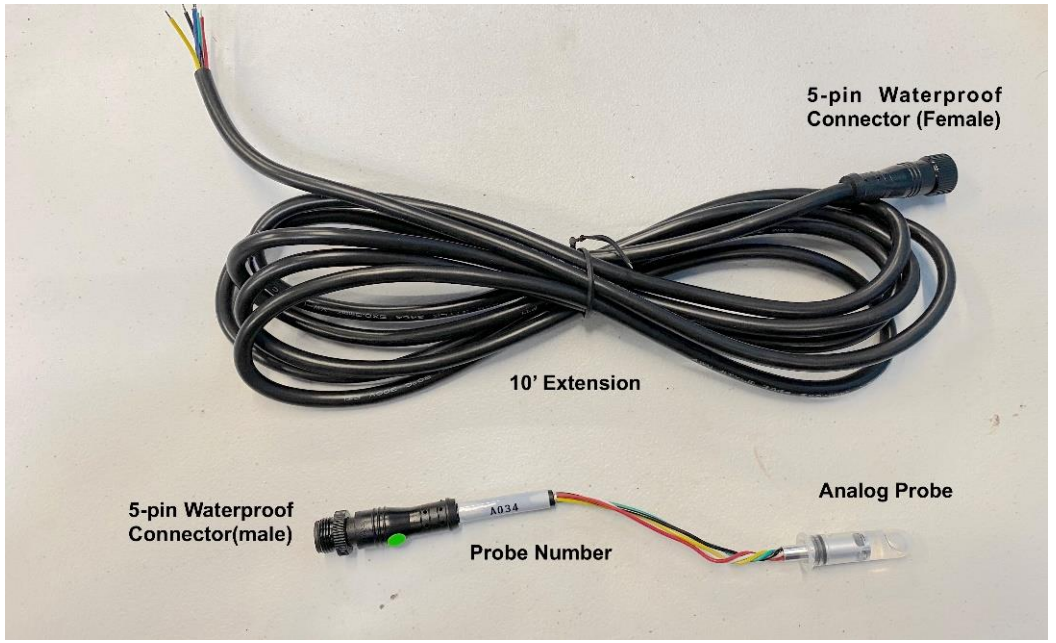
- Sensor limitations
- Reading with a datalogger
- Installation
- De-installation
- Clean-up and storage
- Lab-verification
- Re-installation

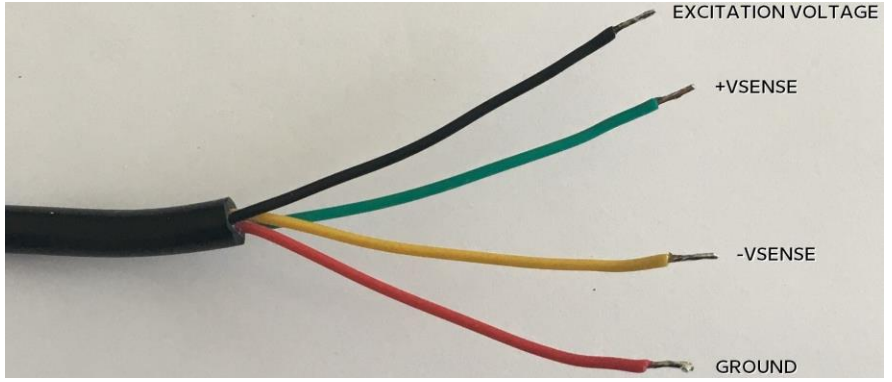
Sensor limitations

- Water potential: 0 to -35 bars. Drier WP may cause cavitation.
- Temperature: 0 to 50°C. Sensor freezes somewhere below 0°C, data nonsensical.
- Crops: works in many crops, but not all due to wounding response and xylem structure. Needs testing in each new crop.
- Size: >5cm diameter for current sensor, ~1.5cm diameter for new small sensor.
- Sensor longevity: sensors have limited longevity due to porous silicon membrane. Seem to last a few years in storage, but recommend use right away. Guaranteed for 1 growing season, but seen them last for 3+ years in the field.
- Reuse: current BIG sensors are somewhat reusable, but may break. Small sensors are less likely to break (more reusable). Move only when needed!
- Install longevity: some crops, such as almond, close up the install site during the winter. Signal shrinks. Recommend re-installation of sensor in spring each year (new wound).

Reading with a datalogger – Analog sensor

- Analog sensor is a sensitive Wheatstone bridge, requires precision datalogger.
- Apply 1V power, read millivolt-level signal.
- Programs available for Campbell Sci loggers.
- The included extension cord is 3.3m long, should not be extended because degrades tiny signal. Thus the logger needs to be near the sensor!
- Offset and multiplier given from factory.

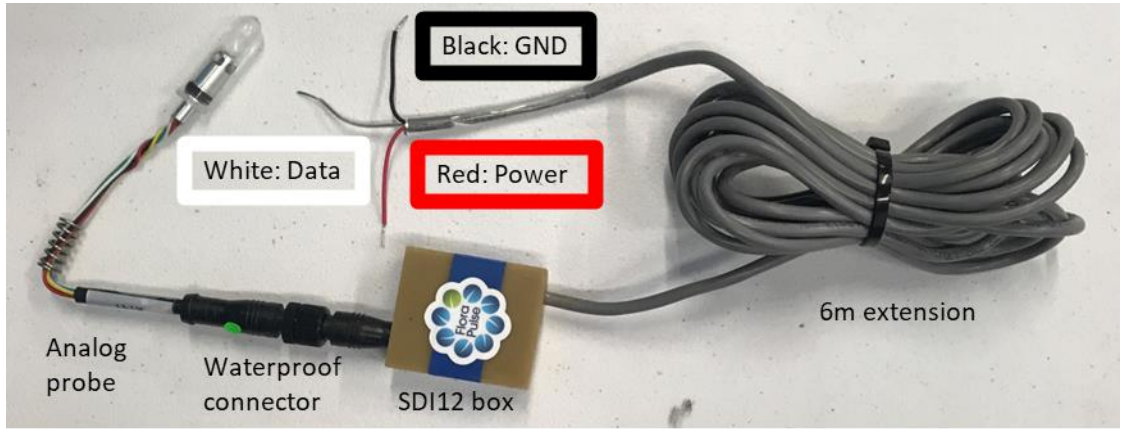


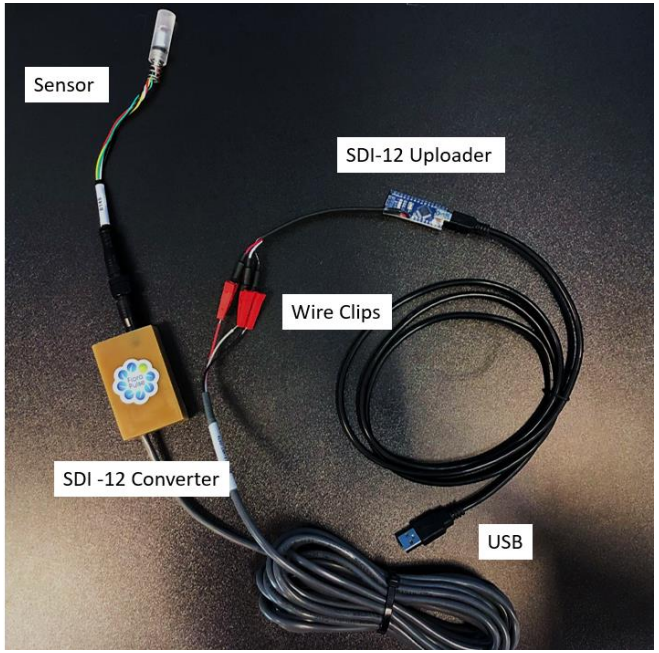


$$Pressure = Offset + Multiplier \times \frac{Voltage\_output}{Voltage\_input}$$

Reading with a datalogger – SDI12

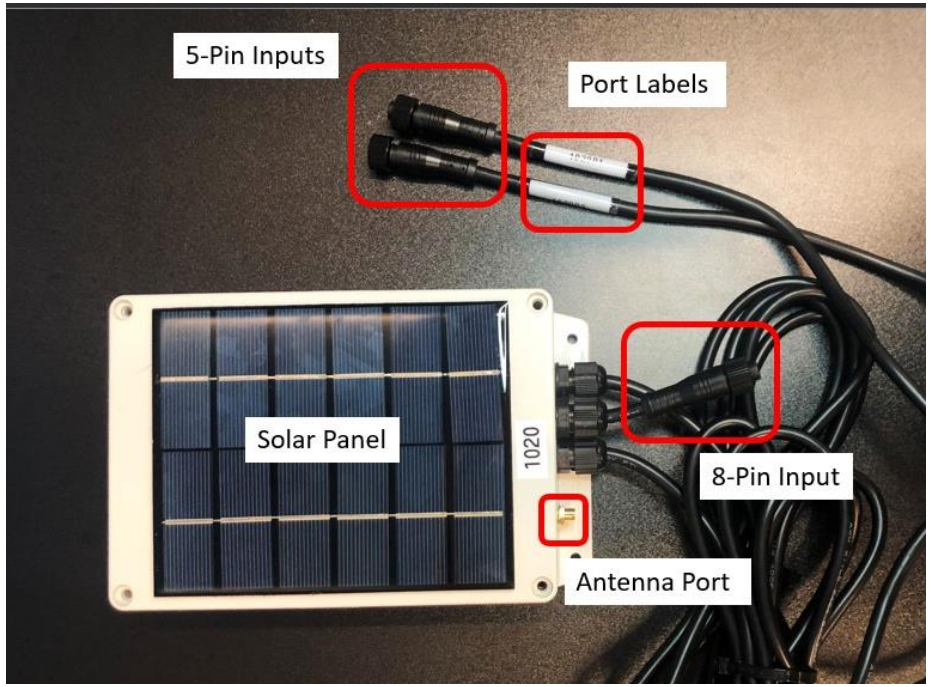
- SDI12 version of the sensor is an analog sensor + a detachable ‘SDI12 box’ that powers/reads the sensor and sends measurements digitally with SDI12 protocol.
- Sensor calibrations are stored in the SDI12 box.
- SDI12 box comes mated with a specific sensor, but can be re-programmed with calibration factors for a different sensor. Can reuse indefinitely.
- SDI12 uploader makes it straightforward to mate with new sensor.
- Includes 6m cable by default, but can be extended up to 60m.
- Multiple SDI12s can be connected to same port.
- More expensive, but easier to work with. Longer cable and no need to worry about calibrations.

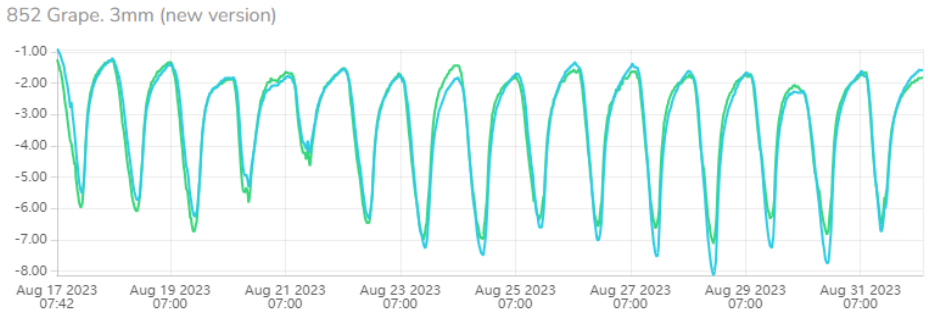




Reading with a datalogger – FloraPulse 4G

- FloraPulse sells a narrow-purpose datalogger for reading our sensors. Include:
  - Solar panel
  - Cellular modem
  - SD card
  - Lithium battery
  - Pressure switch
- Can be used in online mode (uploads to FloraPulse cloud), or offline mode (stores data to SD card).
- Online dataloggers mainly sold in the USA.
- Works fine for reading FloraPulse, but recommend different option if you want flexibility. Can be expensive in Europe due to import taxes.





Data in FloraPulse dashboard, 2 sensors.

Installation

- Let’s go through the install manual and I’ll discuss the steps in person as well.

Pick a clean site

After leaf-out

Install in scaffolds (better)
Or main trunk.

Install parts

Install early in the season after leaf-out. Do installation without long pauses to avoid drying out the wound, sensor, or mating compound.

Install at the top of the main trunk, or at the base of a 2+” scaffold branch. Pick a site that is healthy and flat without knots.

Older trees often have thick bark (thicker than 4 mm) that will interfere with installation. Remove this outer bark at the installation site to create a flat site to hammer into.

Install

Hammer sleeve, nails up

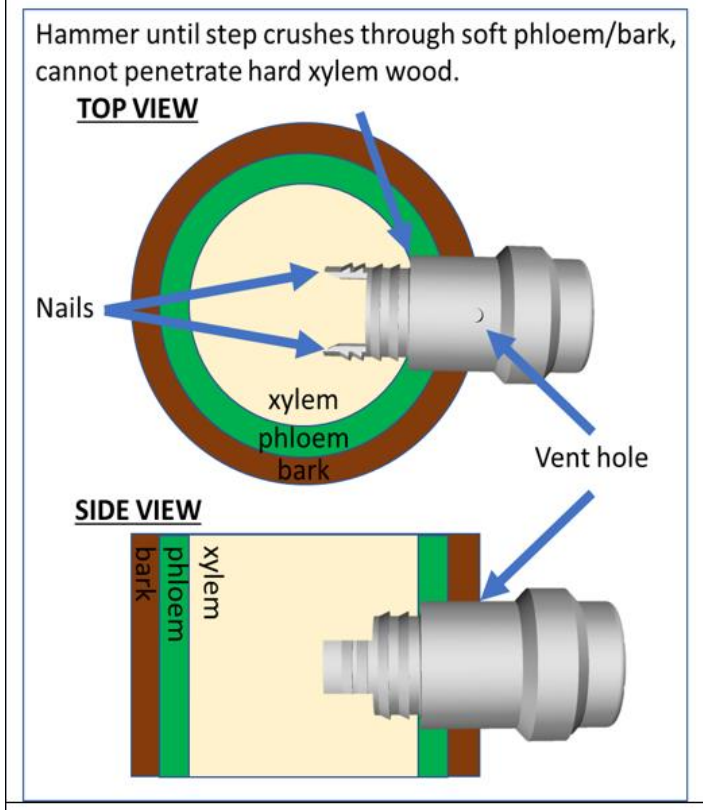
1. Remove the cap from the sleeve. Gently push the sleeve into the install site, with the vent hole facing up trunk/branch and the nails on the sides (parallel with the xylem direction).

Hammer sleeve into the wood. The sleeve step will crush through the soft bark and phloem tissue, but will stop at the harder xylem tissue.

In other words, use a hammer to **pound the sleeve into the tree until the sleeve will not penetrate into the wood any deeper**. The step will easily crush through the soft bark/phloem tissues, but it will not penetrate into the harder xylem tissue.

Insufficient hammering of the sleeve will allow wounding gels to infiltrate the install site and block the sensor!

Hammer until sleeve stops going in



Drill inside sleeve until drill stop

2. Drill into sleeve with the provided end-mill until the drill stop. Pull out the bit periodically to remove the wood shavings.

Install

Clean drill site

Use the spatula from your install kit to clear any remaining debris. The hole should look bright white - abandon install site if it looks brown or discolored.

Add mating compound
No air bubbles!

3. Uncap the mating compound syringe, and fill sleeve with mating compound from bottom up to avoid air bubbles. **Ensure mating compound can exit through vent hole. In trees with thick bark or phloem, the vent hole may be covered. If so, use the spatula to dig into the phloem to open the vent hole.**

Cap syringe to prevent it from drying out. (Reseal with provided parafilm for long term storage).

Remove water capsule and insert sensor

Press in with cap + spring
Spring sets defined force.

4. Remove sensor plastic capsule and gently place sensor in sleeve. **The sensor will dry out if left exposed to dry air without the capsule – so insert it right away.** Follow with spring and cap. The spring goes between the sensor and cap and pushes the sensor towards the xylem.

Note: Handle the sensor with care, and do not force it into the sleeve. Cap and spring will push the sensor against the xylem with a pre-defined force as the cap is screwed in.

Install

Clean area and add grease as backup seal

6. Clean off excess mating compound with spatula/napkin. Excess mating compound will prevent grease from sealing.

7. With the wire cutters, cut the end of the grease syringe and deposit grease over the vent hole and around the perimeter of the sleeve.

Note: if the install is reading dryer than expected and the sensor data seems to consistently drift down, the seal may have failed allowing humidity to escape. Adding more grease can sometimes fix this issue.

Recommend installing 2 sensors

8. Install a second sensor into same tree/vine for verification. Install at least 3" to the side or diagonally away from the first sensor (not directly above or below because the sensors will interfere with each other).

Secure wires to prevent snagging

9. Zip tie probe wire to trunk. This helps protect the probe from being yanked out if the cable is pulled.

Zip tie excess wire against the trunk as well. Loose wire can get caught in machinery.

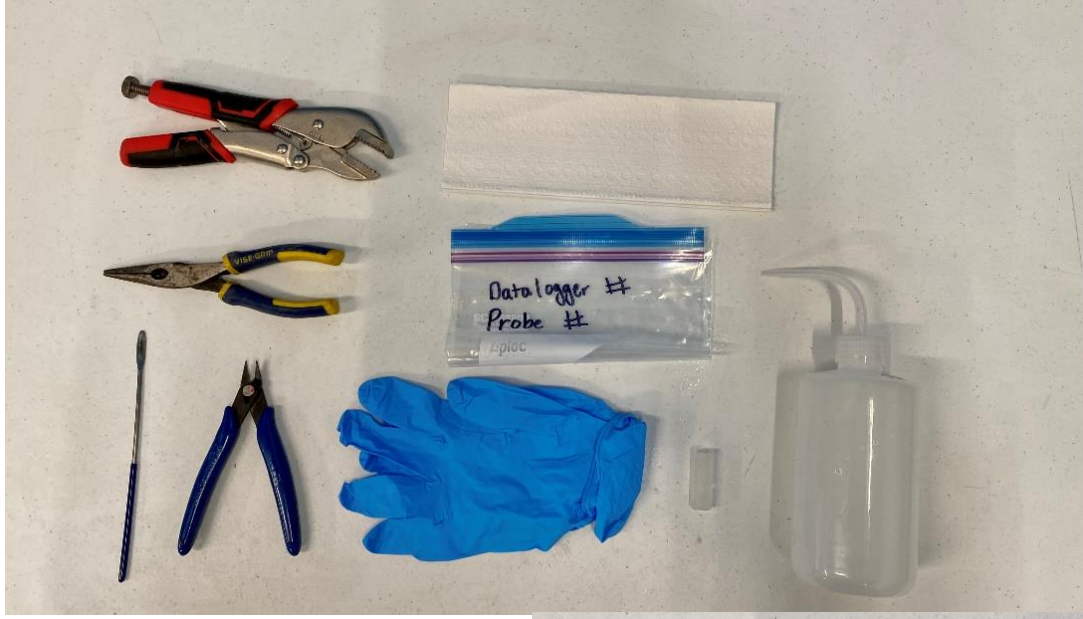
Bubble wrap around sensor. Protect against sunlight, but allow excess water to evaporate.

10. Zip tie the bubble wrap insulation around the trunk. Add zip ties above and below the installed sensors. You can chain zip ties together to make a longer tie as needed.

The main purpose of the insulation is to protect the sensors from UV light and dramatic changes in temperature from sun exposure. In wet climates, the insulation should be attached loosely to allow condensation to dry out and prevent accumulation of water. Excess moisture in the install will hinder measurement accuracy and may lead to mold problems.

Removal

Materials for sensor removal.



Save these from the install kit for re-installation!

Removal

Remove insulation and clean area.
Eliminate contaminants that may foul sensor.

Remove cap, use vice grip if necessary.

Prepare capsule with water.

	1. Carefully cut down the surrounding insulation/wiring.
	2. Using a napkin, clean off the excess grease and wounding gels from the install site. A clean area will help prevent contamination of the probe upon removal. You may apply water to help clean the area.
 	3. Using your hands twist off the cap. Squirting water on the threads can help loosen the cap. If necessary, use a vise grip to remove the cap. Keep the cap for the sensor reinstallation. Fill an extra capsule with water and set aside. Capsule should be filled to below halfway, leaving space for the sensor and an air gap.

Removal

Squirt water inside the sleeve to soften kaolin.

4. Once the cap is off, rinse the sleeve interior with water to loosen the dried mating compound.

Use needle-nose pliers to pull on sensor METAL tail.
Rotate as you pull to soften clay.
Try not to pull on wires.

5. To remove the probe, try pulling on the wires by hand (GENTLY! OR THE WIRES WILL BREAK) to see if the sensor is loose and will come out easily.

If the sensor is stuck, use needle-nose pliers to gently pull on the metal 'tail' base of the probe and remove the sensor.

DO NOT PULL ON THE WIRES WITH PLIERS!

When sensor out, rinse with water and place in plastic capsule.

There will be clay stuck on the sensor and that is OK!

6.Pull the sensor straight out, and quickly place the sensor inside the plastic capsule with water. You may want to rinse the sensor with a stream of water before capping.

*KEEP SENSOR FRONT WET IN WATER AS MUCH AS POSSIBLE.

Removal

After rinsing, place sensor in capsule.
Now it's ready to use!

9.After sensor is removed and cleaned, cap your sensor and put aside.

You may choose to label the sensor with the datalogger #, port # or anything else to help keep track of where the probe should be reconnected if needed.

SENSORS MUST BE KEPT IN WATER AT ALL TIMES.

If sensor is really stuck, use the vice grip to pull whole sleeve out. Place whole sensor in ziploc bag with water for temporary storage.

Leave in water overnight to soften clay, then try removing from sleeve again.

7. Some installs, especially older ones, can get very dry and stuck. If the sensor still won't come out, fill a container (in this case a Ziploc bag) with water.

Using your vise clamp, grip the sleeve and pull the sensor and sleeve straight out together. Try to avoid moving/wiggling the sleeve because this places stress on the probe microchip.

Place the sleeve and sensor inside the water-filled container, and keep it in water overnight until the sensor can be separated. Water will hydrate the dried mating compound over time and the sensor will come loose.

Storage post removal

- After sensor removal, place in capsule. There will be clay stuck to the sensor. That’s ok. It’ll still work fine.
- Leave in water overnight to soften clay if you want to remove it better.
- Avoid trying to remove clay around the chip. The chip is very fragile and pressing on it could break the solder joints.

Sensor reuse/re-installation

- If sensor was working properly when removed, then it likely still works fine! We recommend placing it in a capsule, then moving it to a new install right away. No need for lab testing. (WE DO THIS ALL THE TIME).
- If questions on sensor performance, recommend lab testing, then reuse.
- Recommend remove/re-install sensors once per year after leaf out for best measurement quality. Some trees close up wound over winter.

If good: remove > reuse

If not sure: remove > test > reuse

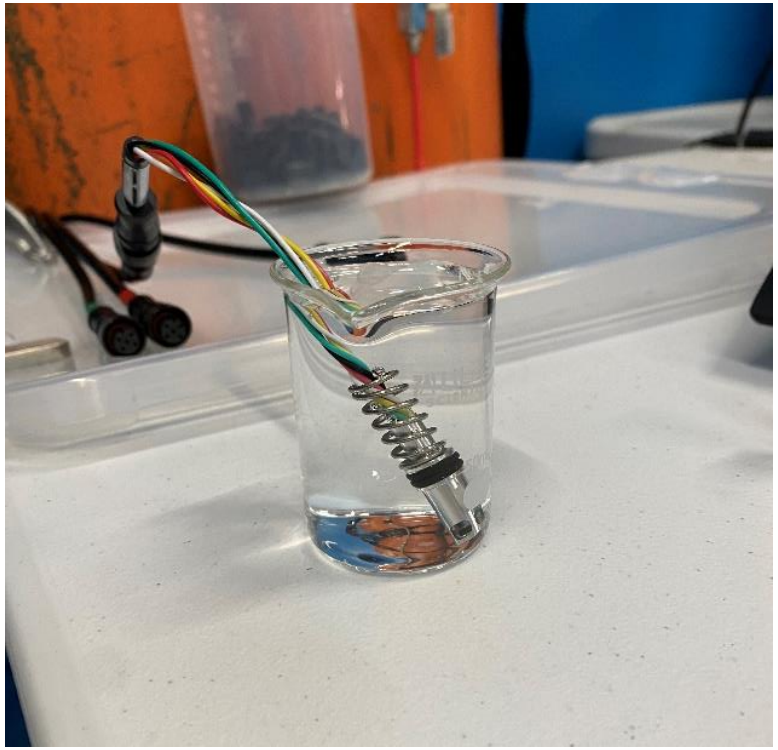
Laboratory testing

- 2 tests to see if sensor works properly:
  1. Is the offset (reading in water) stable?
  2. Does the sensor respond to dry air quickly?
- If the sensor is slow:
  - Sand pores and re-test
- If the sensor is unresponsive:
  - Sand pores
  - Refill
  - Re-test

Sensors should always be kept in water
Long-term dry-storage will foul/block the membrane.

Test #1 - sensor offset stability

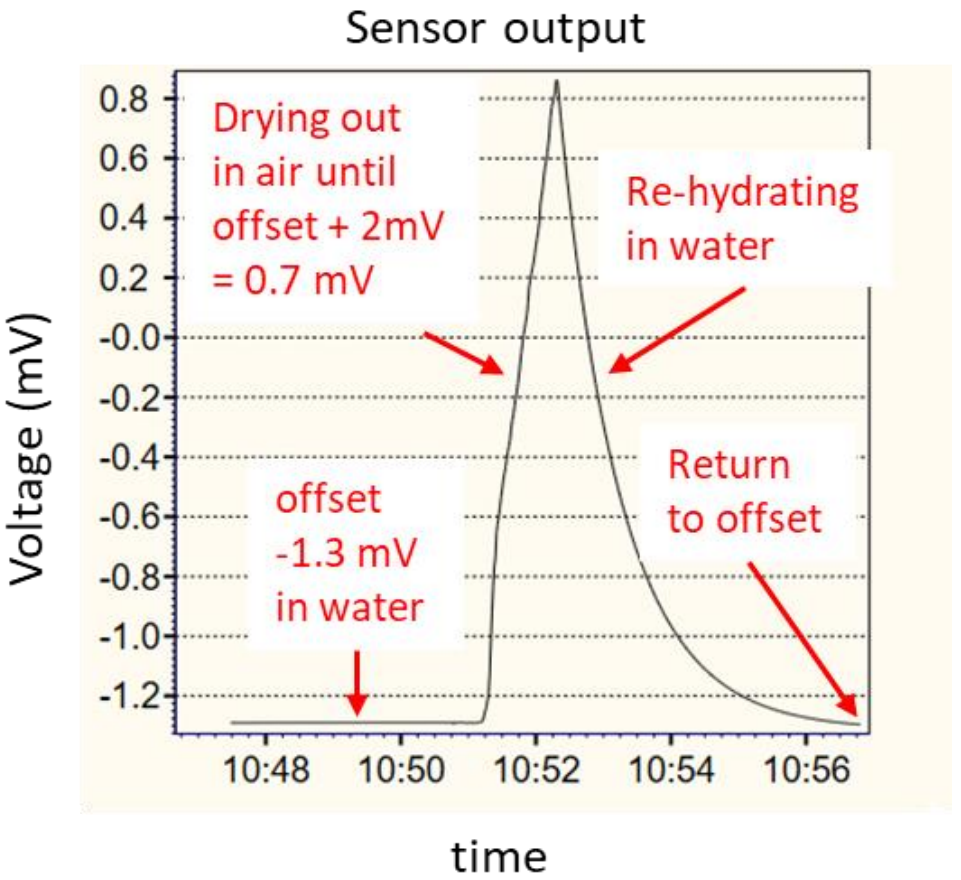
- Place sensor in water and read its output for at least an hour.
- Output should be:
  - Close to zero bars.
  - Offset sometimes changes (but it’s rare).
  - Electrical noise within ±0.2 bars or ±0.04 mV
- If the offset changed, but is stable, just use the new offset (i.e. voltage output in water).



Test #2 – Sensor dry/wet response time

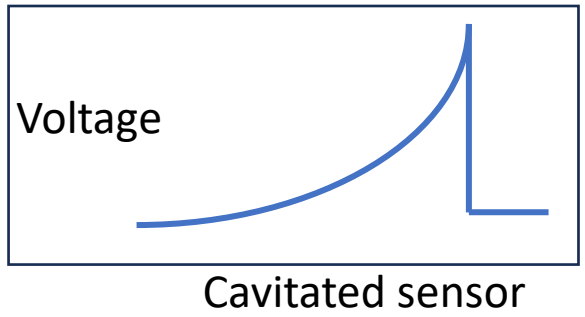
- Test sensor response to dry air and water to verify it is full of water and responding quickly enough. With datalogger.

1. Leave sensor in water until reading stabilizes. Note reading.
2. Remove from water. Dry-off chip front with clean napkin. DO NOT TOUCH CHIP WITH BARE HANDS.
3. Leave probe in dry air, facing up, and watch response. Until offset + 2mV.
4. Replace in water. See sensor return to offset.



Issues seen

• Large noise or random jumps.	sensor broken.
• Offset slowly decreasing.	wait longer for offset to stabilize.
• Sensor output does not change during dryout.	sensor cavitated or pores broken. Try refilling.
• Sensor response is very slow.	sensor partially blocked. Try sanding pores.
• Sensor output increases, then drops suddenly.	Sensor cavitated because it dried too much. Try refilling.



Cavitated sensor

Sensor sanding of pores

- If sensors are slow, sanding the chip pores may help.

1. Pull out of water, leave pores wet.
2. Use clean sanding stick, apply light pressure and abrade pores (top slit of chip) for 60 seconds. Hear scratching noise.
3. Replace in water. Wait for reading to stabilize. Re-test response.

Sensor refilling

- Sensors that don’t respond to drying out might be reusable if sanded and re-filled.
- Always keep in water to keep pores hydrated.
- Refilling requires placing the probe in 600 psi pressure water overnight (8+ hours). Only Lab-Ferrer has this capability at the moment.
- Generally, probes should never cavitate if used properly.