5 Points to Sensor Integrity Preface on history of sensor use and how we got to where we are today

Today, sensors no longer come with a “born on date” but often a “do not install after date” or “do not use after” such-such date. The old days of sensor recommendations were that you should expect that with reasonable diving a diver would get 12 – 24 months of use before replacement. That was based on a "Fresh" sensor, meaning recently manufactured by Teledyne. The date was in a code of letters and numerals to represent month/year of manufacture. Our understanding was based on the "Recommendation" that sensors will last 12-24 months when removed from sealed bag, and one to two years sealed in the bag. Essentially no credit was given if the sensor remained in the sealed bag.

Diver logic proved that when a Teledyne sensor was found in spare parts bin that was already two years aged, it was put into service and lasted a minimum of 24 months! It was a double edge sword as on one side you had an extremely well built sensor that reliably performed for two years, and "maybe" longer??? But the reliability led to divers questioning the time used out of the bag, verse longevity while sealed in bag. And when divers took old sealed sensors and still were able to use them for 2-3 years, this led to divers who figured that with less dives or exposure to high oxygen, the sensor should last longer. This coupled with the concept that divers logic proved that scrubber durations where twice of what manufactures listed times, that divers figured that everything was conservatively listed. It was either this flawed logic, or divers just being cheap bastards, but the dive industry had a serious problem of divers pushing oxygen sensors past the recommended use.

A series of tragic deaths occurred, followed by lawsuits and a couple pariah in the dive industry who had a grudge on AP Diving. The losses that Teledyne faced in lawsuits convinced the company to drop the rebreather dive community and stop selling oxygen sensors for use in rebreathers. This was a huge loss as Teledyne was and still remains the most reliably built oxygen sensor in the world. And it was perhaps a nobel cause or a fools errand that led Martin of APD to develop a proprietary sensor for the Inspiration ccr. What followed was 3 years of disastrous results for AP divers as sensors would last from days to weeks to minutes with no reliability?

No oxygen sensor company is built on the foundation of rebreathers being the profit margin, and with the risks of liability with general dive public verse a hospital or manufacture industry that has safety rules in practice, it was not worth the lawsuits. Dump the dive industry! The lawsuits were responsible for removing the "coded" date and now printing a bold date of either "sell by date", "install by date" or "do not use after".

Good or bad it is bold and specific that a sensor regardless of how it was stored, used or sealed in bag has no more use than printed on package and sensor. If a diver were to install a factory sealed sensor today that was printed "Do Not Use After Jan 2013" and this diver were to suffer a fatality, then it is hard to fight the fact that the diver violated the safe use of the product.

Yes it sucks to have a un-used or factory sealed sensor go out of date, but we are not diving CCR to be cheap bastards.

Five Points to Sensor Integrity

1. Age of your sensor by date of installation. Today the recommendation is 12 months or one year whichever comes sooner, unless you follow the 6 month rotation schedule as outlined by Paul at rEvo. The cell manufacture gives no credit for being sealed in the bag, it is the date that is printed on the package! I will take a sharpie pen and write month/year that I install a sensor in clear or visually identifiable location. The “use by” date that is given by the manufacture as well as the date that I install a sensor is relative as I will always carry a spare sensor or two in my kit that stays factory sealed. The date that I open and start to use the sensor as compared with the factory “use/install by date” is important to me as when the bag is open and I start using it in air to high oxygen content that the sensor starts working.
2. Always wake up your rebreather with the oxygen sensors “naked” or exposed to ambient air – not enclosed in the ccr as nobody can accurately state what gas is inside? Often divers make the mistake of starting a "Build Checklist" and when midway through the build process they check the Po2 and Mv. At this point, who knows if gas was turned on that would contaminate "ambient air". When woken up exposed in open air you will compare what reading the sensors are giving .19 - .24 -? And this is relative to when did you last calibrate? If the calibration was yesterday, then you hope that the linearity of the sensor would come back to a .20-21 reading. If you have changed locations, environments, or time has elapsed then it is most likely that the reading is errant. Do not confuse the Po2 with Mv as both are important but different numerals. Depending on computer you may have Mv on one screen and Po2 on main display. It is typical on the Cal screen that both may be displayed. The second bit of data is more critical as the sensor Mv reading is converted to display the Po2 upon calibration. The Mv reading is spec from manufacture for a range in air to oxygen, and the rebreather manufacture will specify what Mv range the sensors that are used in the ccr should maintain. A typical Mv may be in range of 9-12 Mv. These two bits of data are best recorded on a rebreather build sheet or in your log.
3. The test when conducting oxygen flush to calibrate the rebreather will be where you record the Mv reading in pure oxygen. You must review the process of what constitutes purity of oxygen at the altitude, temp, humidity that you are at just as well as inputting the correct value of oxygen that you have analyzed. Remember that not all oxygen supplied to divers around the world is “pure”oxygen and in several remote diving locations you may be given oxygen that is less than 98% purity due to it being manufactured on location and not industrial pure oxygen. Again the Mv reading is specified by the sensor manufacturer and confirmed by the rebreather manufacture for the range that these operate in. You need to regularly log this “high end” Mv reading in your log book as the power to display values on Po2 display is directly related to sensors strength at high end. Record this in your build sheet or log book.
4. Know the “personality” of each sensor and how they react as sensors tend to be consistent when you monitor them closely, and you may see one being slower/faster than another, etc. By comparing the previous bits of information on age, air Mv, then oxygen Mv, you may track that as the low end and high end reading start to fade that the sensor should be consistent in its life. Inconsistency breeds lack of confidence in sensors. Along these habits of the sensor you can get some confidence in operation but not complete without the 5th step.

5. Regular oxygen flushes under pressure will allow you to raise the Po2 above 1.0 or 100% oxygen that we flush at the surface. This is commonly done at depths of 20 ft, with a strategic slow flush of rebreather in same manner that you suck, vent the loop to ensure that you are filling it completely with 100% oxygen. Here technique is valuable. By subjecting the oxygen sensors to 1.6 ata you will be able to test the sensor for “current limiting” in hopes of seeing the sensor raise the Po2 to equal or very close to 1.6. This is critical since we operate the ccr at lower regular operating Po2 of 1.0 -1.3 and we cant ensure that the sensor has enough “umph” or power to display higher. If your rebreather has an accessible display to read the Mv at this location make note of this as well. Now it is time again to remind divers of the value of the lesson of “conventional wisdom” and how divers borrow logic from one venue such as Bill Stones concept of “spiking Mv reading on descent” and applying this to the practice of “current limiting at the beginning of a dive” where this logic cannot be used in same manner due to the process that Bill has employed and the validation process he uses verse “voting logic” used in every other ccr. (if this discourse does not sound familiar you need a refresher on subject – please ask – another reminder of internet forum logic being wrong) . And recently Paul at rEvo was able to debunk the myth that you could do current limiting test at beginning of dive (again on conventional ccrs only) where the sensors may prove to be ok, yet after 40 minutes the cells fail under temperature and humidity and become current limited

I was taught at beginning of my ccr diving to routinely do an oxygen flush at end of a dive. It was the internet pundits who said I was foolish to do this at the end "how do you know you start the dive with a safe sensor"? And these same pundits claim the discovery of Stones spiking on descent logic of sensor testing. Unfortunately this is false logic as Stone does not use three sensors for voting logic, but he uses "Constant Validation". It was the constant testing to validate the sensor that allowed Bills concept of spike at descent to be valid as he does it throughout the entire dive. And Paul at rEvo showed the dive industry that it cannot be done at beginning as even expired sensors will often spike to 1.6 (or Mv equivalent) to show strength at beginning, yet after 20-30 minutes of diving will crash and fail. Somehow the early instructors had the intuition to know when to test a sensor.

Air your sensors out after diving, or allow the sensor tray / head to dry in ambient air. In some cases a sensor try or head may be removed to be dried inside an air conditioned room or cabin on live aboard. Dive boats typically do not allow dive gear to be taken into rooms as liveaboard boats constantly fight humidity and mold in cabins. But consider the environment that you expose the ccr electronics to drying. In tropic or seaside locations you will have salt spray in the blowing wind. Myself being typically a Great Lakes freshwater diver became complacent with location as salt was not a factor. This was until I had rotten wiring and bad molex connections that led to irregular and erroneous readings. It was a combination of leaving a ccr closed for long periods of time after diving, or travel to salt water destinations where I was not considerate of the environment that I was drying. Moisture on sensor face causes slow and errant readings, as well as corrosion on wiring.

Keep your molex (radial or other) connections clean of corrosion. Another dilemma occurred when I started using Y splitters, which increases the amount of connections to be affected as well as possibility of resistance in connections. I will regularly clean molex connections with Solid Gold contact cleaner. You do not want to spray this on your sensor connections as you do not want to spray foreign stuff into a sensor. The sensor connections are typically gold plated pins, and may be wiped of carefully with a swab only but no aggressive action. After cleaning a molex connection I would use a spray of Triolube, but do not put other grease or etc on connections.

You must use more than one of these points regularly and I advocate using all of them to gain confidence in your rebreather sensor output. Its your life after all, take these points seriously and learn how to use them so they will not be a task load, but second nature or routine. Routine or consistent proper behavior is the key

Please do not be cheap with sensors and never hesitate to change out a sensor if you are concerned with their integrity. And if you need sensors, please ask now for new and fresh sensor delivery.

Please also read the following

Paul's article on understanding oxygen sensors

http://www.revo-rebreathers.com/wp-content/uploads/2016/02/Understanding_oxygen_sensors.pdf

Shearwater article from engineers on calibration with oxygen verse air

https://www.shearwater.com/monthly-blog-posts/why-do-you-calibrate-a-ccr-with-pure-oxygen/

ISC Megalodon Apex 4 Operational Manual has a great review on how Mv converts to Po2 and how to do the math on the fly.

http://www.megccr.com/wp-content/uploads/2015/07/AP4-63-pages.pdf

The more you know about sensors, the less you get sucked into the black hole where only Black Matter Matters. All Matter Matters!

Safe Diving

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