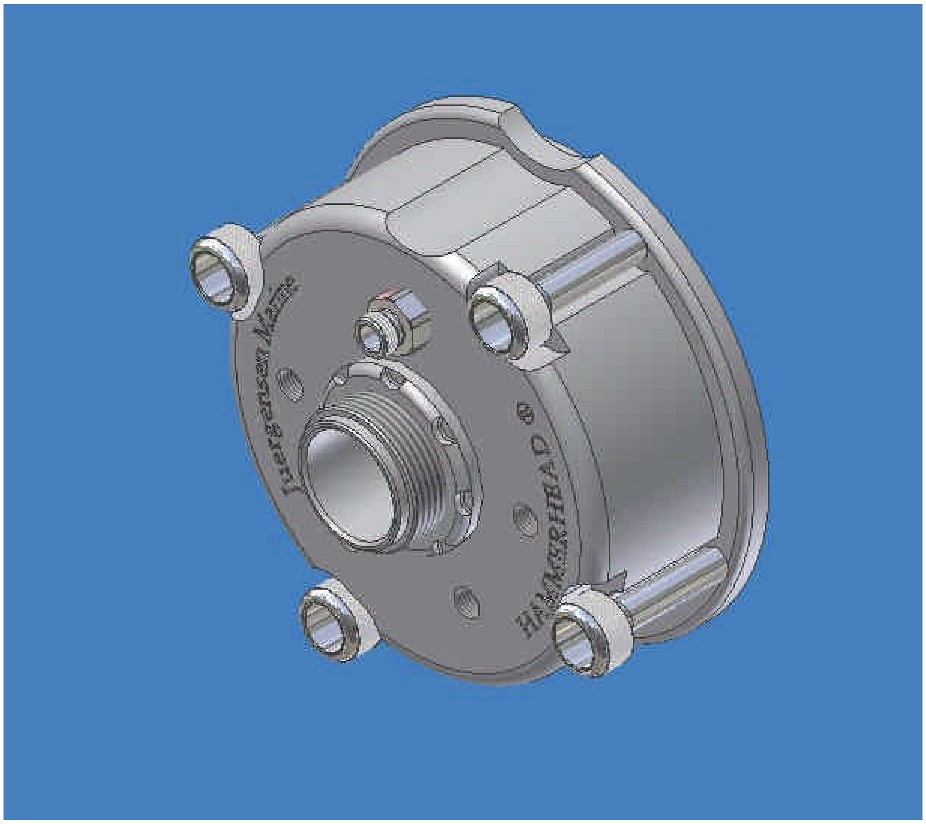
Juergensen Marine



Hammerhead CCR
Instruction Manual
Revision 3.0

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INTRODUCTION

The Hammerhead is a replacement set of electronics and scrubber head for the Inspiration Rebreather. The Wrist Units are available for homebuilders, and retrofitting into commercial rebreathers. The Hammerhead will be available as a complete package utilizing a custom head for the KISS rebreather, or a replacement pod for Biomarine rebreathers. The electronics will be offered as a factory installed option on the Megladon Rebreather. For the purposes of instruction, this manual will assume use with the Inspiration but the programming, calibration, and other functions apply to all versions.

The most important point an Inspiration diver must realize is that once equipped with the Hammerhead electronics the rebreather is no longer an Inspiration. ***The Wrist Units are truly independent; all calibration and set-point changes must be performed on each Wrist Unit.***

The standard Inspiration has two Handsets that are called the ***Master*** and ***Slave***; each handset is capable of operating as the master controller. The Hammerhead has two Wrist Units called the ***Primary*** and ***Secondary.*** Each Wrist Unit serves a particular purpose. The Primary Wrist Unit is responsible for maintaining the chosen set-point, displaying the measured PO_2 for the three main Oxygen sensors, time, depth and decompression information. The Secondary Wrist Unit is a backup display for the main Oxygen sensors, and controller for the DIVA Heads-Up display. The Secondary ***DOES NOT CONTROL the solenoid***; this Wrist Unit enables the diver to manually maintain the breathing loop in the event of a Primary failure. The only common point between the Primary and Secondary are the Oxygen sensors that are wired with additional isolation between the Wrist Units. Each Hammerhead Wrist Units contain an independent and isolated power source.

SETUP and INSTALLATION

The first task is removal of the sensor plate to allow installation of the Oxygen sensors – Teledyne R22d. Other Oxygen sensors designed specifically for rebreather use may be utilized providing the mV reading is above 8.5mV and below 13.5mV in Air and at least 40mv in 100% Oxygen. This plate is held in place by a hand-tightened retaining nut. For convenience the Oxygen sensor plate has the positions numbered on both sides.

The last position is only used when an external PO_2 monitor or integrated dive computer is connected. The proper cable is available for the HS-Explorer and VR3 computers. The sensors should be installed such that the face is visible with the plate numbering on the outer edge. The sensors will work in either orientation but this arrangement permits easy identification while the plate is installed. The sensor o-ring should be removed prior to installation and should be labeled with the installation date and position for future reference. The sensors should be returned to their previous position. Tracking the health of the sensors is easiest by using the cell position as a reference. ***WARNING! The Wrist Units have no way to recognize a sensor has been moved to another location.*** This will result erroneous PO_2 readings until Wrist Units are recalibrated. Prevent potential problems ALWAYS use the same location for each cell.

The Hammerhead electronics aids in sensor health tracking by permitting the user to display actual millivolt readings for each Oxygen sensor. This is done by utilizing the "MV DISPLAY" function available on both the Primary and Secondary Wrist Units. As we have said above, maintaining a log of the millivolt readings for each cell when exposed to air and Oxygen will potentially reveal cells that are beginning to degrade and that are non-linear. The actual Oxygen percentage used in calibration should also be recorded so the correct mV output for the cells can be calculated. A detailed explanation on oxygen sensors is presented later in the manual.

The replacement scrubber lid has five ports. The first port is used for the Oxygen solenoid. This is where the short Oxygen hose used on the Inspiration is connected. This connector was designed for easy removal allowing easy o-ring and solenoid inspection and replacement. The Oxygen hose should only be hand-tightened, ***NEVER USE ANY TOOLS***.

Continuing clockwise the next port is equipped with a 1/4 inch NPT blanking plug. This port is for an external dive computer such as the HS-Explorer and VR3. The proper cable can be purchased from Juergensen Marine or may be obtained from the computer manufacturer. The blanking plug has to be removed and the appropriate cable installed using Teflon tape, ***DO NOT OVERTIGHTEN***. Some of the sensor capable computers have differing polarity requirements depending on the vintage. If no reading is obtained from the sensor, try reversing the polarity of the cable by swapping the two leads within the Molex connector.

The next port is the Secondary cable equipped with a female Fischer connector. The fitting on the lid is a Swagelok connector, ***do not attempt to remove or tighten***. Failure to heed this warning will result in damaging the internal wiring and/or leakage.

The next port is the Lumberg connector for the DIVA Heads-Up display. We recommend that you put a small amount of silicon or other non-conductive gel on the pins the install cable (it only fits one way). This cable must be installed correctly, ***do not attempt to dive without a cable fitted***. It is important to fully tighten the retaining ring on the cable or the connector will not seal.

The last port also has a Swagelok connector; this is the cable for the Primary Wrist Unit. This cable is equipped with a male Fischer connector, and as with the Secondary cable ***do not attempt to remove or tighten the Swagelok fitting***.

If you have purchased the Fischer Cap Kit for the Primary and Secondary Cable Connectors, it is recommended that you keep the connectors covered when not in use. This will help to shield them from salt spray as well as damage to the outermost ring which makes the seal against an internal o-ring in the receptacle on the Wrist Units.

The next step is to install the sensor wiring harness. Turn the head over and locate the Banana Plug Block, as well as the location of the Solenoid. The solenoid is a Snap-Tite 6 volt, 150-PSI Watt Miser and is user changeable with minimal tools. The metal mounting bracket should be dipped in a protective coating, such as "plasti-dip", which is available in many hardware and tools suppliers. Early Hammerheads were shipped with uncoated solenoids and should be protected by the owner to prevent corrosion; all current units are shipped with the solenoid already coated. This solenoid has proven itself in several rebreathers including the MK 15/15.5/16, and the Megladon. The piston within the solenoid operates against the Oxygen source (upstream valve), so a first stage seat failure (rising intermediate pressure), should cause the solenoid to fail closed.

One of the inherent benefits of the Hammerhead design is the overall integrity of the electrical system. All of the wiring located in the Head is nestled in a channel cut directly into the interior surface of the head itself. The internal wiring in the head is sealed using a waterproof compound to protect the wiring against water intrusion and corrosion. This compound will be visible around the bottom edge of the head. The head can be safely rinsed with fresh water after the sensor plate and harness have been removed. The part of the system that is subjected to the most corrosion, the Sensor Wires, is the part that can be replaced easily, making the Hammerhead a system which should, under reasonable circumstances, give many years of trouble-free service.

The Fischer connectors used on the Hammerhead are as follows:

- Primary Cable: S104 A066-130+
- Primary Receptacle: DEE 104 A066-130
- Secondary Cable: S104 Z066-130+
- Secondary Receptacle DEE 104 Z066-130

The cable clamp set on both the Primary and Secondary is E3 104.2/7.7 +B

The ***Banana Block*** has six connection points; two for each sensor with the sensor grounds identified by the black terminals. The wiring harness is color coded and cut to lengths for clean and optimal placement. Connect the brown stripe wire/plug to the brown terminal, the red stripe wire/plug to the red terminal and the orange stripe wire/plug to the orange terminal. Continue the assembly by connecting the black wires to each associated black terminal. The next task is to connect the sensors, connect the brown cable to sensor 1, the red cable to sensor 2 and the orange cable to sensor 3. Be careful about the polarity of these wires – if any Sensor is reading "zero" on your Primary or Secondary, the black (common) wire and one or more of the colored striped wires are probably reversed at the banana block. The sensors use three pin connectors, **Molex P/N 22-01-3037**, which can only be connected only one way.

The final connection is for sensor 4. This connection is only present when fitted with a cable for an external computer. Attach the Oxygen plate to the head and hand-tighten the retaining nut.

Hardware Revisions

As of October 2003, there are two Hammerhead Wrist Unit hardware revisions: "A" and "B." Revision "A" hardware requires two 3.6v 1/2 AA size lithium cells (Saft LS14250, Tadiran TL2150, TL5101), while Revision "B" units can use any single AA size cell, or two 1/2 AA Cells in each Wrist Unit. The batteries must be installed with the proper orientation; incorrect installation may damage the Wrist Units. The negative terminal must be installed facing the battery cap. Inspect the o-ring for defects, replace with a 2-115 if necessary. Install the battery/batteries and tighten the battery cap with a coin, ***do not over-tighten***. The cap should be snug not cranked down. Several early Wrist Units were damaged by over tightening the battery cap. There have been improvements on the latest Wrist Units making the cap retainer more robust.

Some Notes About Battery Life

The Hammerhead, like many modern dive computers is never really "off". When the Wrist Unit is in low power (sleep) mode there is very little current drain and the batteries can remain inserted under normal conditions, but the unit must, by necessity, "wake up" every second to scan the Wet Sensor and both Push Buttons to see if either has been activated. During an extended period of inactivity (more than a few days), the batteries should be removed to preserve them.

Remember, removing the batteries clears all tissue data, sets the gas to MIX 1, and if in CCR mode sets the PO_2 to 0.7ata. **NO** other settings are altered. User defined settings such as custom gas mixes, conservatism, imperial/metric, CCR/OC, "Sea Level" are unchanged.

WARNING

If the batteries are removed following a dive, the Hammerhead should not be used to calculate decompression obligations for a surface interval of at least 24 hours. Removing the batteries clears all tissue-loading information! This substantially increases the risk of DCI.

The Wrist Units are connected to the head utilizing cables equipped with FISCHER connectors. The Primary and Secondary Wrist Units use opposite connectors making it impossible to connect the wrong Wrist Unit. It is imperative that this connection is checked for residual moisture before joining. ***Failure to heed this warning may result in incorrect sensor readings. This is even more important after being exposed to a salt-water environment***. The proper way to join the two connectors is to align the dots on each of the connectors and push until they snap into place. Proper connection should be confirmed by pulling gently on the cable. The procedure to disconnect the cable from the Wrist Unit is to pull gently on the outer shell of the connector away from the receptacle to operate the integrated lock/release. If the Wrist Units are disconnected between dives, care must be taken to insure no water gets in the connectors. Gently shake excess water off connectors and install supplied plugs for Wrist Units and caps for cables. Water in the Primary connector is usually indicated by sensor readings well above normal on ***BOTH*** the Primary and Secondary Wrist Units while the solenoid is firing.

WARNING

Water in the Primary or Secondary Connector is a DANGEROUS condition that should never be ignored or taken lightly. Set-point maintenance and PO_2 readings may be compromised.

If the Primary Fischer Connector gets flooded, the control system is compromised and the loop should be maintained manually. ABORT THE DIVE.

If the Secondary Fischer Connector gets flooded, Set-Point Maintenance must be evaluated. When necessary, maintain the loop by MANUAL control. ABORT THE DIVE.

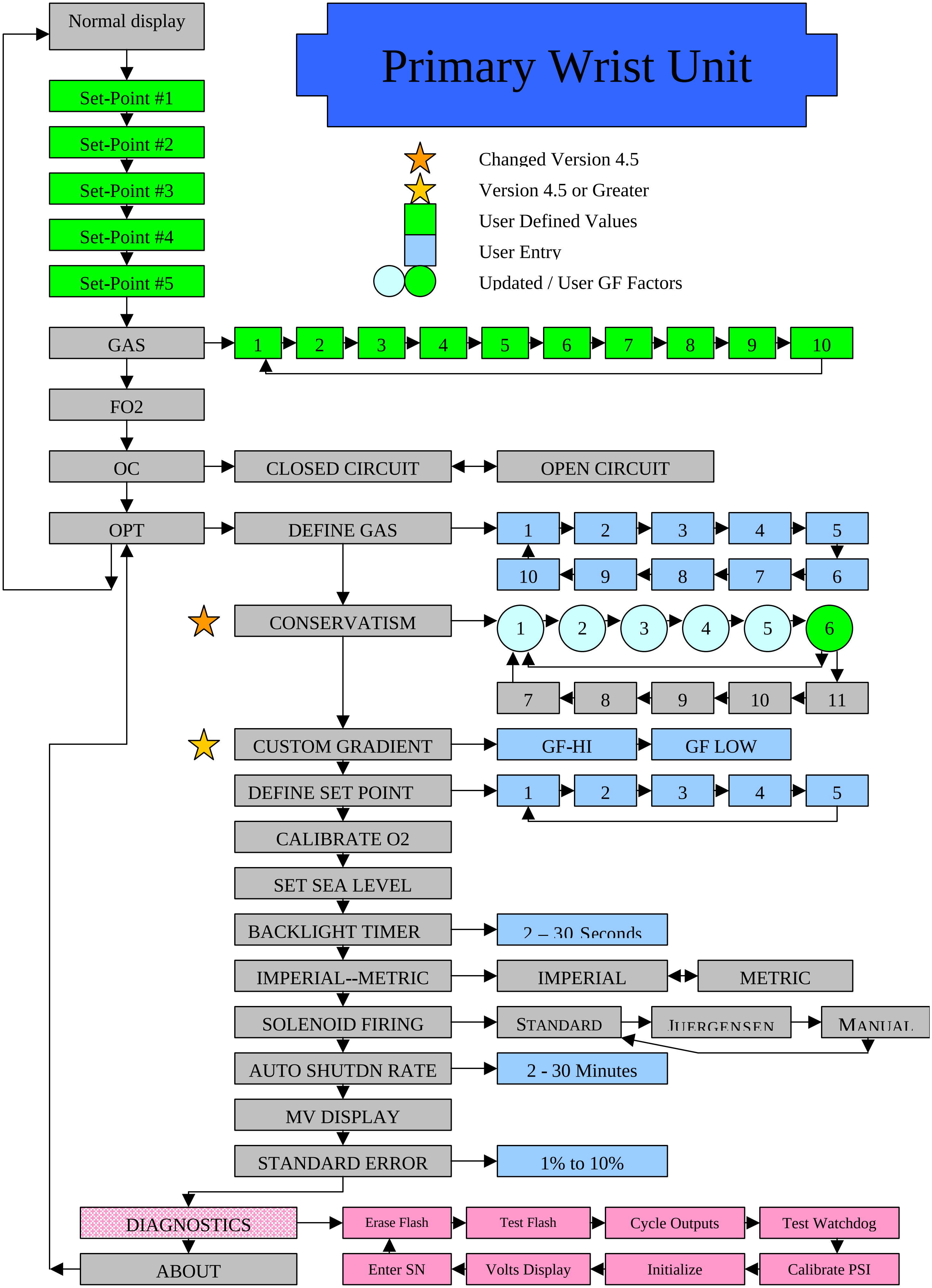
As in any electronic closed circuit rebreather, a flooded connector must be treated as an equipment failure. Under no circumstance should the dive continue normally. The diver has the option of bailing onto open circuit scuba or remaining on the loop and use manual control when necessary. Sensor readings with a flooded Primary connector while the solenoid is idle should only exhibit a marginal error. BOTH displays should be evaluated for accuracy.

WARNING

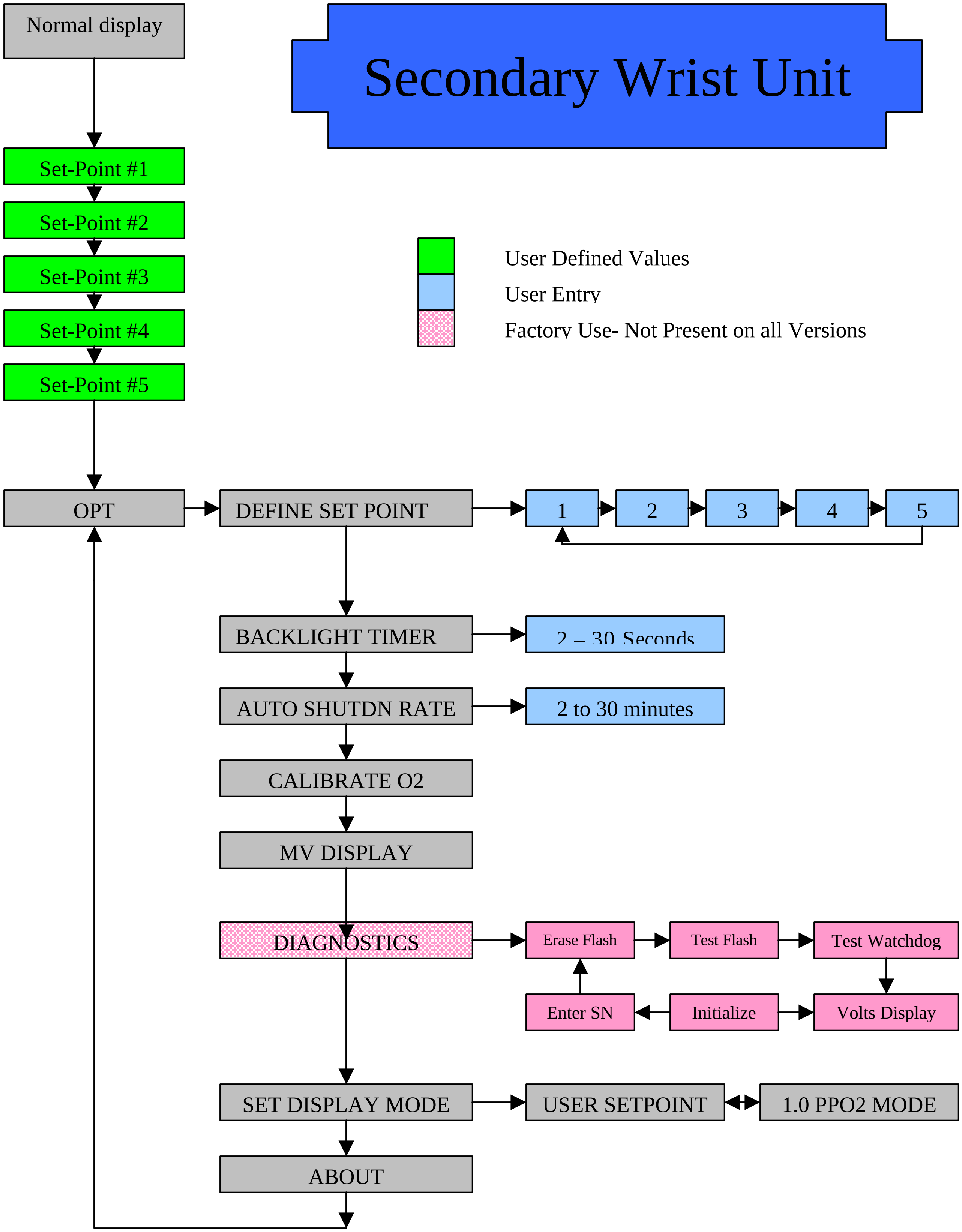
Water in the Secondary connector is a CRITICAL Condition.
There is no method to disable the DIVA.
Diving any ECCR without a reliable Secondary is Dangerous!

PO_2 errors ***may*** be observed when the secondary fires the LED or vibrator in the DIVA. The diver must carefully evaluate BOTH the Primary and Secondary displays and decide if any errors are present. When present, the diver must determine which display is affected, how serious these errors are, and if the diver can safely remain on the loop. The replacement head has been equipped with isolation resistors, this *should* allow the Primary to maintain the PO_2 with a flooded Secondary connector. DO NOT TAKE THIS CONDITION LIGHTLY! A flooded connector must be treated as an equipment failure. Under no circumstance should the dive continue normally.

The following pages are graphical representations of the Menu Screen Selections present in the Primary and Secondary Displays.



Primary Wrist Unit
Changed Version 4.5
Version 4.5 or Greater
User Defined Values
User Entry
Updated / User GF Factors
Normal display
Set-Point #1
Set-Point #2
Set-Point #3
Set-Point #4
Set-Point #5
GAS
1 2 3 4 5 6 7 8 9 10
FO2
OC
CLOSED CIRCUIT
OPEN CIRCUIT
OPT
DEFINE GAS
1 2 3 4 5
10 9 8 7 6
CONSERVATISM
1 2 3 4 5 6
7 8 9 10 11
CUSTOM GRADIENT
GF-HI
GF LOW
DEFINE SET POINT
1 2 3 4 5
CALIBRATE O2
SET SEA LEVEL
BACKLIGHT TIMER
2 – 30 Seconds
IMPERIAL--METRIC
IMPERIAL
METRIC
SOLENOID FIRING
STANDARD
JUERGENSEN
MANUAL
AUTO SHUTDN RATE
2 - 30 Minutes
MV DISPLAY
STANDARD ERROR
1% to 10%
DIAGNOSTICS
Erase Flash
Test Flash
Cycle Outputs
Test Watchdog
Enter SN
Volts Display
Initialize
Calibrate PSI
ABOUT



Secondary Wrist Unit
User Defined Values
User Entry
Factory Use- Not Present on all Versions
Normal display
Set-Point #1
Set-Point #2
Set-Point #3
Set-Point #4
Set-Point #5
OPT
DEFINE SET POINT
1
2
3
4
5
BACKLIGHT TIMER
2 – 30 Seconds
AUTO SHUTDN RATE
2 to 30 minutes
CALIBRATE O2
MV DISPLAY
DIAGNOSTICS
Erase Flash
Test Flash
Test Watchdog
Enter SN
Initialize
Volts Display
SET DISPLAY MODE
USER SETPOINT
1.0 PPO2 MODE
ABOUT

System Overview

Before using the Hammerhead, it is necessary to understand a few basic conventions used by the controllers, calibrate the Oxygen sensors and set diver preferences. Initially out of the assembly plant, FIVE common set-points are defined, all gas mixes are programmed to AIR, and "sea level" is set at approximately 300ft of altitude. If the Wrist Unit has been recalibrated at the Juergensen Marine facility, "sea level" is set to approximately 1840ft of altitude. "Sea Level" should be set upon reaching the diving destination. Removing the power source **does not** clear this value, it is recorded into non-volatile memory. The Primary Wrist Unit can operate using Imperial or Metric units of depth, with the factory default being imperial units. The PO_2 on both Wrist Units is in units of ATA not Bar, unlike the Inspiration and several dive computers. The variation is minimal, and conforms to NOAA exposure definitions. The European tradition of using NOAA exposure tables but treating the values, in units of Bar is slightly more conservative for Oxygen exposures. Planning the dive with the set-point in Bar while set-point is actually in ATA will result in a slightly more conservative profile.

The Hammerhead electronics are unique in several ways, the key areas being set-point switching and set-point maintenance. There are electronics that are fully automatic, mixed, and manual only, the Hammerhead offers all of these options to the diver. Closed circuit rebreather divers typically use more than a one set-point during a dive. Manufacturers have combated this in various ways, some have taken the standpoint that the user is not capable of switching set-points and the electronics must do it. This typically involves setting up two predetermined points and when a manufacturer chosen dive depth is reached the controller automatically adopts the appropriate set-point. Other manufacturers have taken the stance that the diver should have full control of the set-point switching such as the Inspiration. This puts full responsibility for all set-point switches squarely on the diver. Lastly, there are manual rebreathers that do no set-point maintenance at all, the loop composition is the responsibility of the diver. The first case is probably best for the new CCR diver, while manual set-point switches are probably the mode of choice for the experienced diver. Manual rebreathers are not recommended for general use. The Hammerhead supports all modes. ***The manual mode is designed for emergency use only.*** The two set-point switching modes are supported based on the starting set-point. If the diver selects a set-point greater than 1.0 ATA, the electronics will start the dive with a set-point of 0.4 ATA, transition to 1.0 ATA at 1m, and finally the chosen set-point at 3m.

The other unique feature pertaining to set-point maintenance is the control algorithm used to hold the desired set-point. Each manufacturer invents a unique formula to determine when Oxygen is injected; on most systems, the user has no control over this function. The Hammerhead has two user selectable algorithms, standard, which allows a user defined deviation below set-point before solenoid firing, or Juergensen, which adapts to depth and set-point deviation to determine firing duration and frequency.

Each wrist unit has two buttons, which are used for programming and control. Pressing either button will activate the backlight for the user chosen time, and will wake up a Wrist Unit that is in sleep mode. The left button scrolls through menu selections and values while the right button selects the current value. The Wrist Units will timeout after a 10 second period of inactivity, and return to the normal operation mode. Certain user options will require confirmation before changes are accepted. Confirmation is accomplished using the LEFT button to prevent accidental confirmation caused by an double button press. Failure to confirm desired action cancels any changes. The Wrist Unit Backlight and LEDs also serve as a **CRITICAL ALARM.** This alarm is disabled on the Primary while operating in open circuit mode.

Battery low measurement had been added starting with hardware revision B. Prior to this revision, the only indication of a low battery on the Primary is the dimming of the display when the solenoid fires or when the backlight is engaged. The lower the battery voltage the greater the dimming. This will continue until characters are no longer visible. The voltage required by the display is usually greater than the solenoid so the addition of Oxygen should continue. Eventually the battery will drain to a point that the firing of the solenoid will drop the voltage lower than the requirements of the microprocessor and the Wrist Unit will reset on each firing. It is highly unlikely that the solenoid is activating and injecting Oxygen. The PO_2 must be monitored and manually controlled by utilizing the Secondary display. The higher the IP setting, the greater the voltage required to operate the solenoid will be. The Secondary Wrist Unit will exhibit the same low battery conditions when engaging the backlight or vibrating the DIVA. Any dimming of the Primary or Secondary displays should be treated as an equipment failure. The dive should be aborted and the PO_2 carefully monitored.

The design goal of the Hammerhead electronics was to make the safest CCR controller in the industry. All reasonable attempts have been made to prevent a single failure from becoming a life-threatening occurrence. When the electronics were being designed, Kevin Juergensen sketched out what he called a “Threat Matrix”, listing possible conditions along with generated warnings and solutions.

Juergensen's Threat Matrix

- Diver forgets to turn on unit:
  - Answer: Wet Switches

- Wet Switches Fail:
  - Answer: Pressure Transducer will activate unit at 1m pressure

- Diver sets unit to Open Circuit, but is still breathing the loop.
  - Answer: Solenoid Override at 0.19 PO_2

- Diver sets unit to Manual Control, but forgets to add O2:
  - Answer: Solenoid Override at 0.19 PO_2

- Diver ignores Primary and Secondary Display:
  - Answer: Add HUD/DIVA

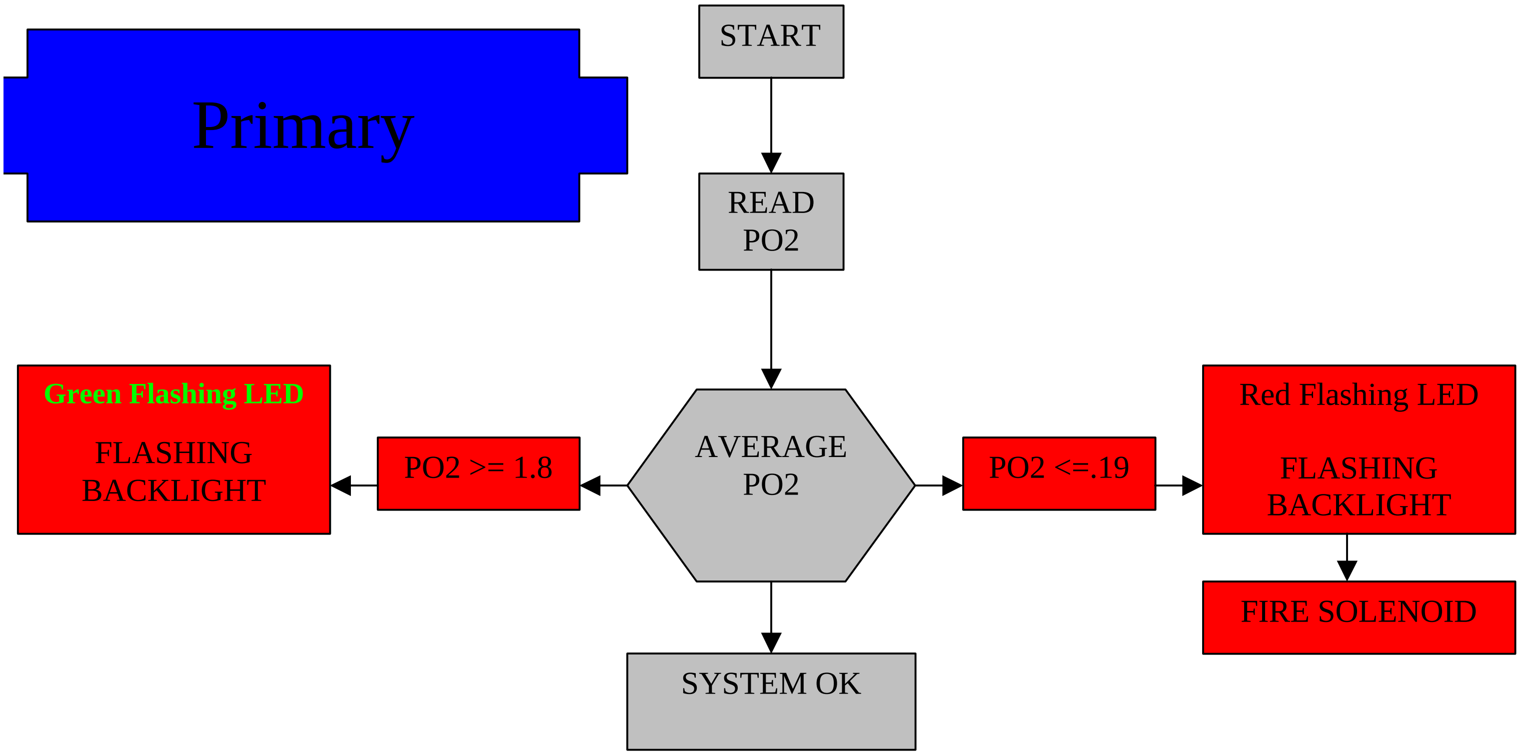
- Diver ignores or is unaware of DIVA LED Red Warning of PO_2 Danger:
  - Answer: Trigger Vibrator at 1.8 and above, or 0.19 and below.

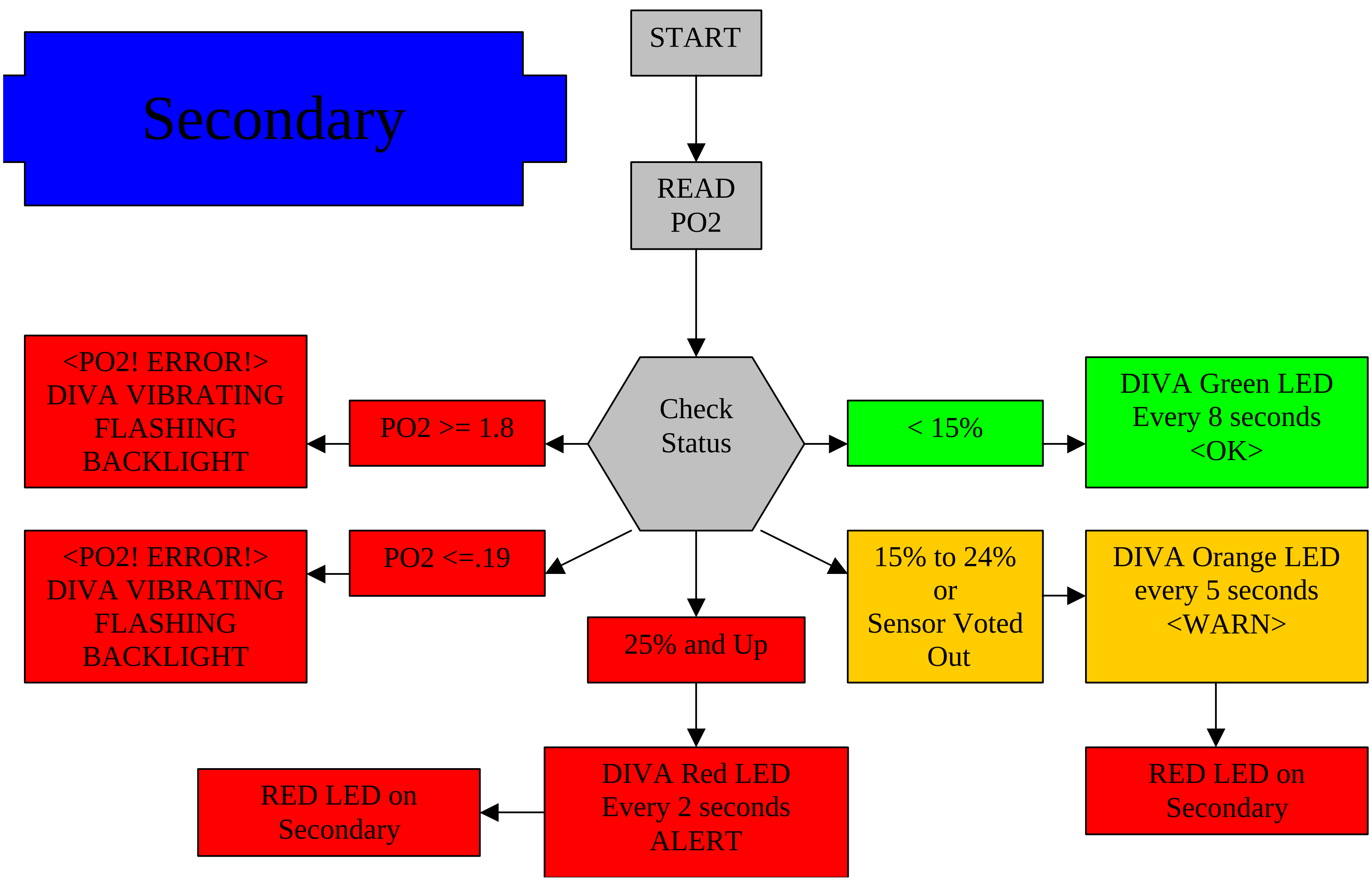
- Diver ignores Vibrator and LED:
  - Answer:
    - Primary Red or Green LED firing
      - Red for Low PO_2
      - Green for High PO_2
    - Secondary Red LED firing

- Diver ignores LED's in Primary and Secondary:

Answer: Backlights on **BOTH** Wrist Units begin to flash. This is type of alarm is highly visible to the diver, and anyone else in the area.

ALARMS


Primary
START
READ PO2
AVERAGE PO2
PO2 >= 1.8
Green Flashing LED
FLASHING BACKLIGHT
PO2 <=.19
Red Flashing LED
FLASHING BACKLIGHT
FIRE SOLENOID
SYSTEM OK


Secondary
START
READ PO2
Check Status
PO2 >= 1.8
<PO2! ERROR!> DIVA VIBRATING FLASHING BACKLIGHT
PO2 <=.19
<PO2! ERROR!> DIVA VIBRATING FLASHING BACKLIGHT
< 15%
DIVA Green LED Every 8 seconds <OK>
15% to 24% or Sensor Voted Out
DIVA Orange LED every 5 seconds <WARN>
RED LED on Secondary
25% and Up
DIVA Red LED Every 2 seconds ALERT
RED LED on Secondary

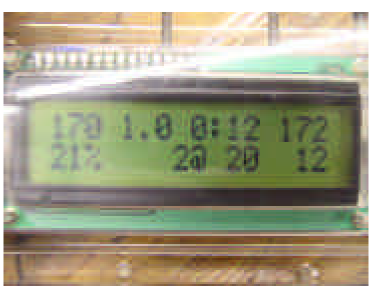
Primary Wrist Unit Display Details

The Primary Wrist Unit has several informational screens that vary depending on whether the unit is in surface mode, no deco obligation, or deco required conditions.

The first screen of interest is the surface mode display. The top line consists of the surface interval, selected set-point or open circuit indicator, maximum depth of previous dive, and finally dive time. The bottom line is the current PO_2 reading for the three Oxygen sensors. These sensors respond in real time and are not buffered or averaged over some arbitrary sample time. This allows the diver to accurately judge the response time of the sensors and see how the gas is mixing within the head. The diver should not be concerned over a short spikes or transient variations in readings between the sensors. The two outer sensors, one and four, are positioned closest to the solenoid and will exhibit the greatest transient spiking.

The next screen is the first of three displays presented while in dive mode. The top line displays current depth, chosen set-point, dive time and maximum depth. The bottom line displays the PO_2 readings of the three sensors as in the previous display. If any sensor reading is followed by a "*" that sensor has been voted out and is not used in the average PO_2 calculation.

The next display depends on the status of the diver's decompression obligation. The top line is the same as on the previous screen with the change being on the second line. Instead of the PO_2 being displayed, the Oxygen percentage of the selected diluent and "No Stop" is displayed until the diver enters a required decompression stop.



Once a decompression ceiling is present, the next display becomes active. The top line remains unchanged, while the bottom line displays the Oxygen percentage of the diluent, deepest stop depth and time, followed by the total ascent time. The sample screen shows the deepest stop at 20fsw for two minutes and a TTS of 12 minutes.

The final display may seem like an annoyance, but it serves as a reminder to the diver. The name of the diluent the diver has selected and the programmed Oxygen percentage of the diluent.are displayed on the bottom line. This should help insure the diver doesn't try and use a nitrogen mix with same Oxygen percentage as a helium based gas.

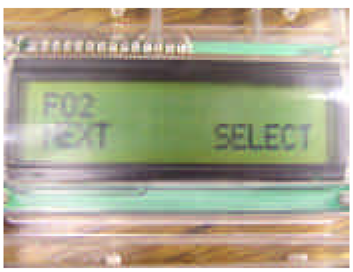
Set-Point Operation

One of the main features of the Hammerhead is the ability for the diver to select a new set-point based on a user programmed set of five choices. The Hammerhead comes pre-programmed with set-points of 0.4, 0.7, 1.0, 1.2, and 1.4. Regardless of the current operating set-point pressing the left button will cycle through the set-point choices in sequence. Once the desired set-point is displayed it is selected by pressing the right button.

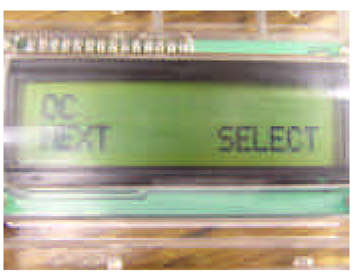
The diver must not forget, **ALL** set-point changes performed on the Primary **MUST** be performed on the Secondary. If a set-point is changed on the Primary, failure to change the Secondary will result in either False alarms or lack of alarms on the DIVA and Secondary Wrist Unit. Common situations that would produce these results would be the Primary holding the set-point accurately, but the PO_2 is out of range for the value selected on the Secondary or the Primary is NOT holding set-point but is within the acceptable values for selected set-point on secondary.

Options and Programming

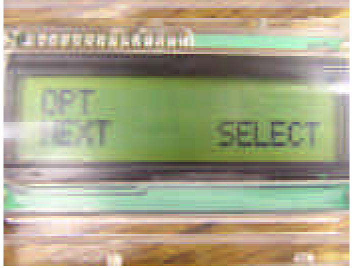
The additional functions in both the Primary and Secondary are accessed by scrolling past the set-point selections using the left button. On the Primary, the first option available is the gas selection prompt. Pressing the right button will select this function. Each press of the left button scrolls to the next programmed gas mix until all 10 are displayed, eventually returning to first mix. Once the desired mix is displayed, pressing the right button will select it. The diver will then be prompted to confirm or cancel the mix change. Pressing the left button confirms the selection, while the right button cancels the switch. Failure to confirm the selection aborts the gas switch.



The next selection is the FO2 display screen. Pressing the right button will immediately display the calculated PO_2 for the current diluent and current depth. A proper loop flush with diluent should result in this value.



The next option allows the diver to select open circuit or close circuit mode. In open circuit mode, the flashing backlight alarm is disabled as well as solenoid control. The solenoid will fire in the event the measured PO_2 falls to 0.19Ata. This open circuit / closed circuit function serves two purposes. The first allows the diver to use open circuit bail out and still have decompression obligations calculated. The second allows the Primary Wrist Unit to function as a stand-alone dive computer. The left button toggles between modes while the right button selects displayed mode. If the diver chooses a set-point while operating in open circuit mode, the Wrist Unit immediately switches to closed circuit mode with the chosen set-point.



The next set of options is entered through the “OPT” menu. Selecting this screen enters a sub-menu containing programming, calibration, and testing options. Some options will be locked out once the Wrist Unit enters dive mode.

The first function available under the "OPT" menu is the "DEFINE GAS" option; this allows the diver to program up to ten custom mixes. These gases can be any nitrogen-Oxygen, helium-Oxygen, Oxygen, or trimix. Each gas can have a user-selected name consisting of 6 characters and should be named to allow easy identification.

Once the "Define Gas" screen is displayed, the diver must press the right button to select. The next prompt is "Gas Mix 1"; continue pressing the left button until the mix to be programmed is displayed. The right button will select this mix for programming and enter the gas-naming screen. Choose any name up to six characters; the current position and character will be designated by underlining the character. The left button will cycle through all available characters while the right button proceeds to the next character. After all six characters have been entered; entry of the gas composition will be prompted, starting with the Oxygen percentage followed by the helium percentage. The remainder will be assumed nitrogen. For Oxygen, enter an Oxygen percentage of 99%.

The next option is setting the level of conservatism for the decompression model. The original software has eleven levels of conservatism, setting "1" being the least conservative and setting "11" being the most conservative. The GF-low and GF-high limits are decreased equally with increasing level of conservatism forcing deeper stop depths and lower allowed limits of inert gas loading. Starting with version 4.5, true gradient factors are employed with separate limits determining where the stops begin and when to proceed to the next level. There are now five preprogrammed gradient factor sets and one user programmable setting. The preprogrammed levels are in increasing level of conservatism. The selected gradient factor can be changed during the dive allowing full control over the dive profile. The user programmable selection can even be reprogrammed while in dive mode.

Changing the conservatism requires scrolling the past the set-point selections until the “OPT” screen is displayed then selecting, scroll past the “Define Gas” until “Concervatism” is displayed. Press the right button to select, The original software will scroll through 11 levels without any additional information. Starting with version 4.5 there are now 6 selections each will display the associted GF-Low and GF-High settings associated with the selection. The conservatism level is selected with the right button then must be confirmed.

All confirmations are made utilizing the left button. This was chosen to prevent accidental confirmations due to double key presses.

For a detailed explanation of Gradient Factors see Erik Bakers paper on Deep Stops available at ftp.decompression.org and many other decompression software sites. Gradient factors is a method used to control the shape of the decompression profile. in a consistent manner. There are two parameters GF-Low and GF-High. The first parameter determines where the initial stop begins and the second parameter determines the maximal allowing tissue loading upon surfacing. These two points determine the slope used to modify the “M-values” during the ascent. For each given depth the “M-value” is lowered based on the computed GF for that depth. For example if the GF settings are 10/95, the diver is allowed to ascend until the tissue loading is 10% of the controlling compartment, at each sucessive stop depth, the maximal tissue loading is increased based on the calculated slope until the GF-High is reached on the last stop. GF-High is the ultimate level of conservatism determing the final surfacing compartment tension. The lower the value is for GF-Low the deeper the first stop will be. The lower the value is for GF-High the longer the overal decompresssion will be.

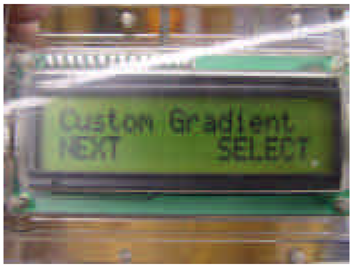
A unique ability of the Hammerhead decompression software is allowing the diver to change conservatism levels while underwater. This has some potential benefits as well as potential downsides. If the diver plans on using the ability to change conservatism while underwater , the diver should start with the most conservative setting expected, and lower the level of conservatism, conditions permitting. Higher levels of conservatism and/or lower GF-Low will generall result in deeper initial stops. It is not recommended going from a higher GF-Low value to a lower value while underwater unless you are still below the expected stop depth of the new setting. Changing to a new conservatism level with a lower GF-Low might require the diver to descend to the new required stop depth or stay at current level until offgassing catches up. The alternative is to program a custom conservatism setting with the same GF-Low setting and a new less conservative GF-High setting.

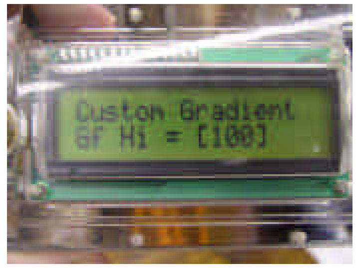
The first predefined conservatism setting 10/100 is very aggressive with deep initial stops with a surfacing compartment gradient equal to Buhlman's limits. This setting is primarily designed for fit individuals in good physical fitness. The second setting 20/95 stages the initial stop shallower but backs off allowable surfacing limits The third setting is applicable to most divers with light workloads and warm water. The fourth setting covers most divers with moderate work loads for a wide variety of water temperatures. The last predefined value is ultra conservative with the lowest allowable tissue tensions. This setting has the shallowest of the initial stops and longest stop times. The final setting defaults to 36/71 which is almost identical to setting 5, and just serves to initialize the variables and should.be redefined to some suitable values. The Hammerhead enforces that the GF-Low setting must be 5% less than the GF-High value. In practice, this limitation should force a stop depth one level deeper than the maximal allowable tissue loading.

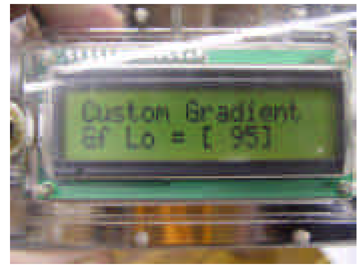
Creating and using custom gradient factors should only be undertaken by those that understand the consequences of these settings. The limits imposed by the "Custom GF" entry insure that settings should not be less conservative ***in theory*** than an unmodified Buhlman profile. Aggressive settings should not be undertaken lightly, the risk of decompression sickness is real. It is not recommended diving any computer to the maximal limits. Conservatism settings 3 and 4 are a good balance of potential risk and decompression obligation.

NO conservatism setting or decompression plan can guarantee ZERO risk of decompression sickness!

The next option allows the entry of the custom gradient discussed in the previous section. The first value entered is the GF-High, followed by the GF-Low setting. This is necessary to allow setting the upper limit for the GF-Low setting 5% below the GF-High value.







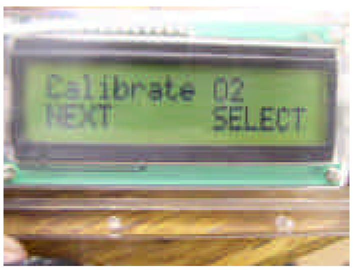
This function is available while in dive mode. Special care must be taken when choosing the value for GF-Low while at depth. Remember a ***LOWER*** value is more conservative and forces deeper stops. As mentioned earlier, using a GF-Low greater than the current setting *may* require stops deeper than the current depth. If this happens, raising the GF-low is preferred over descending to complete “required” stops. The GF-high setting can also cause stops deeper than current depth. If there is an increase in conservatism after the decompression phase has begun, current tissue loading may be greater than allowed by current depth. The preferable method for increasing the conservatism setting would be to extend the current stop depth for several minutes before trying to increase the conservative setting of the computer.

Important Decompression Information

The decompression algorithm employed within the Hammerhead tracks closely with profiles generated by many gradient factor dive-planning packages. The time-to-surface (TTS) calculation and displayed stop times for **ALL** stops are rounded up to whole minutes. The Wrist Unit will clear each stop based on actual required stop time. The initial deep stops may be less than one minute, and it is not uncommon for the initial stops to clear before they are actually reached.

Consider a dive to 60m for 30 minutes using a set-point of 1.3 ATA with a 21% Oxygen 35% Helium diluent and a GF of 25/85. The assumed ascent and descent rate is 10m per minute, resulting in the ascent beginning at 36 minute into the dive. The displayed TTS will be approximately 69 minutes, while Gap predicts that the TTS would be 61 minutes. This may seem like a large discrepancy but all stop predictions are rounded up for safety. Any diver that proceeds as each of the displayed stops clear will end up with a profile nearly mirroring those predicted by many desktop planning applications.

This option allows the defining of five set-points. After choosing the "Define Set Point" option, the Wrist Unit will begin prompting with "Set Point 1" the left button scrolls to the next set-point while the right button enters the programming for the displayed set-point. The Wrist Unit will display the current value. The left button is used to change the value of the chosen set-point. This starts with the current setting, incrementing to a maximum of 1.6 and rolling over back to the low value of 0.4. Once the desired value is displayed, the right button is used to select the setting. Values that are programmed on the Primary should also be programmed on the Secondary. The diver needs to select the same set-point on both Wrist Units, since alarm generation on the Secondary is based on variation from the selected set-point.



Once the calibrate option is selected the next screen will show "Fill Loop w/o2", with prompts for "Ready " and "Cancel". This action is confirmed with the ***RIGHT*** button. The calibration technique used with the Hammerhead electronics is the same as most other CCRs and requires a different approach from the original Inspiration electronics. The Hammerhead holds a very stable calibration; it is not necessary to constantly recalibrate the Wrist Units. The recommended method is to evacuate all the gas from the loop, flush with Oxygen and repeat at least ***FOUR*** times. On the final flush, totally fill the loop until the OPV releases. Go to the "MV display" screen and take note of the values, exit this screen to prevent the unit from remaining on. Let the unit sit for at least FIVE minutes (longer is better). This allows time for any inert gas remaining in the loop to mix. Top with Oxygen and go to the "MV display" screen again. If the sensor values have decreased, the flush was incomplete. The flush and test procedure must be repeated until MV readings are stable. Now, vent excess gas until the loop is at ambient pressure (the easiest way is to vent through the OPV, opening the DSV risks contamination), enter the "Calibrate O2" screen and select ready. Immediately go to the "Calibrate O2" screen on the Secondary, select and calibrate. The Primary and Secondary each require calibration. The two Wrist Units are independent! This option is disabled while in dive mode for safety.

The Wrist Units will reject any cell that reads less than 40mV in Oxygen; this corresponds to approximately 8.35 mV measured in air. The mV display option rounds values to nearest mV, the calibrate function uses the ***ACTUAL*** value so a cell registering 39.5 mV will be displayed as 40 mV. If any single cell is rejected, the calibration information for that cell will be erased and the remaining cells will be calibrated. The failed cell will be locked out until the next calibration. In the event more than one cell fails, the message ***FAILED*** will be displayed and ***NO CALIBRATION DATA WILL BE ALTERED, ALL ORIGINAL CALIBRATION INFORMATION WILL REMAIN.***

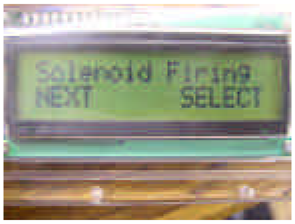
TIP

The calibration procedure can be integrated into pre-dive loop integrity checks. Start with the negative pressure test, refill loop with Oxygen, close the OPV, and proceed with remaining Oxygen loop flushes. On the final flush, overfill until OPV releases and complete positive pressure test with Oxygen.

This setting is used to "zero" the pressure transducer. The electronics are calibrated at the factory or Juergensen Marine facility, which is located 1840 feet above sea level. This pressure difference is slightly less than 1m of seawater pressure. This may cause the Wrist Unit to display a depth while on the surface. The expected readings would be 2-3fsw or 1m. This option should be used if there are drastic changes in atmospheric pressure or diving at different altitudes. The next screen will show "New Sea Level", with prompts for "Cancel " and "Ready". This action is confirmed with the ***RIGHT*** button. This option is disabled while in dive mode for safety.

This option sets the length of time the backlight remains illuminated after pressing either button. The shortest is 2 seconds with a maximum time on period of 30 seconds. The use of the backlight should be kept to a minimum to increase battery life.

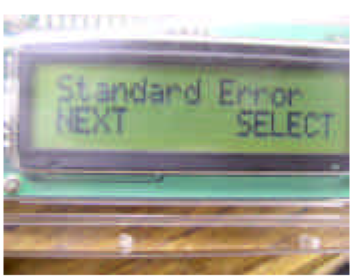
The Imperial – Metric setting selects system of units that will be used for displaying depth. Future upgrades will add temperature measurement. Entering this function displays the currently selected units of measurement. Pressing the LEFT button toggles imperial/metric units, while the RIGHT button selects the displayed setting.



The solenoid firing function sets the set-point control algorithm. The Hammerhead supports two automatic control methods: “Standard Mode” and “Juergensen Mode”, plus “Manual Mode”. Standard mode uses the setting from “Standard Error”, while “Juergensen” is an adaptive mode that changes firing duration and rate based on depth and ascent/descent rates. “Manual Mode” requires the diver to manually maintain the loop’s PO_2; automatic PO_2 control of the loop is disabled. The Wrist Unit will override the manual setting and fire the solenoid if the measured loop PO_2 drops to a 0.19 or less.

This option selects the required period of time that must elapse before the Wrist Unit enters shutdown/low power mode. The valid settings are two through thirty minutes. Care must be taken when choosing this timeout period. A long timeout drains batteries faster, while a shorter timeout saves power but increases the risk of the Wrist Unit shutting down while breathing the loop out of water. Choose a timeout period that is longer than the expected time required to enter the water. ANY TIME the loop is used out of the water, care must be exercised. Once the Wrist Unit enters shutdown mode PO_2 monitoring and control is inactive. Failure to monitor the Wrist Units may lead to a hypoxic loop and eventual unconsciousness.

This option displays the calculated milivolt output on each of the three Oxygen sensors. All measurements are rounded to the nearest mV. ***The backlight will remain illuminated and will not timeout. Failure to exit this test will drain the battery.*** Pressing either button will exit this test. The output of each of the three main sensors should be recorded while in both AIR and Oxygen.

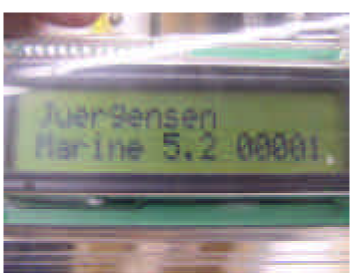


This option sets the allowable error before the solenoid fires in “Standard Mode”. The valid range is from 1% to 10%. A lower value is not necessarily a better setting. In shallow water, a low value will hold a stable set-point with little or no overshoot, but as depth increases, overshooting the set-point is probable. An error setting of 5% works well over a wide range of depths with acceptable results for most divers. The general rule of thumb is as depth increases; the allowed error should be increased to prevent overshooting the target PO_2. Dive mode does not lock out this option; this allows the value to be changed at any time. Once this option is selected, the currently programmed value will be displayed. Each press of the LEFT button will increase this setting by 1% until a maximum of 10% error is reached. This value will then roll over to the low setting of 1% error. The RIGHT button chooses the programmed setting.

The diagnostics menu is mainly for factory use. However, there are currently two safe options for use by the diver. The first is “Test Watchdog” and the second is “Volts display”. No other options from the diagnostics menu should be used without direction from the factory.

The “Test Watchdog” option performs a hard reset on the Wrist Unit. This action has the same effect as removing and replacing the battery/batteries.

The “Volts Display” option displays various voltages within the Wrist Unit. This option will not time-out and failure to exit this screen will quickly drain the battery/batteries. This information is being presented for completeness. This option serves no real value for the diver. Its sole purpose is to aid the factory in isolating troubles. The top line is the raw amplified voltage output from the sensors. The bottom line is the voltage from the pressure transducer, voltage to the processor and wet switch voltage.



The “About” screen displays the current software revision and the copyright information.

Secondary Wrist Unit

The Secondary Wrist Unit has many of the same options as the Primary Wrist Unit. The first options are selecting and programming the operating set-points, which on the Secondary determines the alarm values instead of solenoid firing values. The Secondary has the same options to program the backlight timer, auto shutdown rate, and Oxygen calibration along with MV display, diagnostics and the “about” display.

The Secondary has one additional option, “Set Display Mode”. This option controls the function of the DIVA/HUD. The two selections are “User Set Point” and “1.0 PPo2 Mode”. Currently only the user set-point mode is implemented, The 1.0 set-point mode will display the PO_2 based on blinks.

The diver must not forget, **ALL** set-point changes performed on the Primary **MUST** be performed on the Secondary. If a set-point is changed on the Primary, failure to change the Secondary will result in either False alarms or lack of alarms on the DIVA and Secondary Wrist Unit. Common situations that would produce these results would be the Primary holding the set-point accurately, but the PO_2 is out of range for the value selected on the Secondary or the Primary is NOT holding set-point but is within the acceptable values for selected set-point on secondary.

The Secondary Wrist Unit displays system status, warnings and PO_2 on a single screen. ***All PO_2 changes on the Primary should also be performed on the Secondary.*** All warnings and alarms are based on the deviation from the selected set-point. The operating set-point is chose in the same manor as the Primary, pressing the left button to cylce through the choices and the right button to select the displayed set-point.

The top line of the display shows the system status (<OK>, <WARN>, ALERT, or PO2! ERROR!). This is followed by the calculated average PO_2 , and the selected set-point. The bottom line displays the calculated PO_2 measurements for each sensor. Any individual sensor out of range will be voted out. The voting logic used in both the Primary and Secondary Wrist Units is identical. Any sensor that is 15% out of range from the average of the remaining two sensors will be voted out. The second, third and fourth screenshots show sensor one voted out. The second screenshot shows system status of <WARN>, this is indicated if any sensor is voted out or average PO_2 is at least 15% from selected set-point. The next screen shot shows an error of at least 25%, so ALERT is indicated. The last screen shows a status that no diver wishes to see, PO2 ERROR, this will be indicated if the average PO_2 reaches 1.8 or is 0.19 and below, the RED LED and the backlight are illuminated.

Oxygen Sensors

Oxygen sensors are micro-fuel cells, where part of the fuel is stored within the cell and a necessary component comes from an outside source. The outside source in this case is oxygen. The cell consists of several major components an Anode (+), a Cathode (-) and electrolyte. The cathode is a noble metal, such as gold, silver or platinum directly behind a diffusion barrier usually made up of Teflon. The working electrode is the Anode and is made up of lead.

The cell produces free electrons (e-) through a chemical reaction where the lead is consumed by joining with oxygen forming lead-oxide (PbO). The two electrodes are bathed in a common electrolyte usually Potassium Hydroxide (KOH). The purpose of the membrane is to provide a diffusion rate that allows the oxygen to be consumed without allowing a reaction that causes a rapid build up of lead-oxide along the sensing surface. The thickness of this diffusion barrier is carefully controlled during the manufacturing process. If the diffusion barrier is too thick, the flow of Oxygen is restricted to a point where the response time of the sensor is too slow for practical use. When Oxygen diffuses through the membrane, it interacts with water molecules and free electrons within the electrolyte forming Hydroxyl ions (OH-). The hydroxyl ions interact with the lead of the anode, releasing water, two free electrons and creating lead-oxide. The fuel-cell portion of the sensor is actually a current source, not a voltage source. The output from the sensor is measured in mV because attached to this current source is a network consisting of resistors and a thermistor connected across the output pins. This creates a fixed reference and performs temperature compensation.

The most common failure mode for Oxygen sensors is failing to achieve the proper output for a given Oxygen concentration and pressure, resulting in a lower than true reading. This generally occurs when there is insufficient lead or water remaining to sustain the chemical reaction. As the sensor ages, lead is consumed in the reaction and water molecules are gradually lost in the electrolyte through diffusion. This loss of water molecules inhibits the creation of Hydroxyl ions. Some sensors fail suddenly, stopping all current production, while others give off a burst of energy before ceasing output. The most serious failure for rebreather divers is a sensor failing to produce the correct output above a given level. This failure taken to the extreme results in a sensor generating a fixed high-level output regardless of the amount of Oxygen the sensor is exposed to. This sudden loss of linearity through hyperbaric levels is particularly dangerous to a CCR diver, and the primary reason many recommend avoid changing all three sensors at the same time. Many sensors at the end of its useful life will calibrate normally at 1.0 atm of O_2, but will not generate enough current to indicate a PO_2 above the 1.0 ATM level. If all three sensors used exhibited the same problem, a Set-Point above 1.0 ATM could prove fatal. The rebreather electronics would have no method to detect elevated PO_2 concentrations, and would continue firing the solenoid, potentially creating a hyperoxic condition. The lack of linearity can be caused by insufficient lead available for the chemical reaction or a condition known as breakthrough. This failure is caused by uneven consumption of the lead, where a “break” is created in the anode, separating it into more than one section. There is still an adequate quantity of lead for the reaction but the measured potential is only determined by the portion of the anode still connected to the outside.

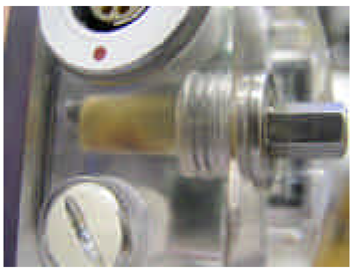
A failure mode that is not commonly recognized is a sensor temporarily reading a value that is greater than normal. If the sensors are calibrated during this period, the output will now indicate a value greater than is actually present. There are two causes for this type of failure, the primary being air bubbles trapped in the electrolyte. A sudden rapid temperature drop causes any bubbles within the electrolyte to shrink causing a greater diffusion through the membrane than normal. This condition should be short lived and normal operation should resume quickly. Avoid attempting calibration immediately following a rapid temperature change. The second cause is less common; it is caused by storing the cells without being connected to a load. If the cells are disconnected and oxygen is available, an excess charge will be created. The cells should be allowed time to “drain” to normal levels. Avoid calibration immediately after connecting the sensors.

Some divers believe sensors should be disconnected and stored in containers flooded with Nitrogen, or Helium. In practice, these divers get about a year of service out of the sensors. Others believe that the sensors should be removed and stored in the refrigerator. In practice, these divers get 12 months of service out of the sensors. It would not be difficult to imagine, flushing the sensors with Nitrogen or Helium, packing them in an airtight container, and storing in the refrigerator, the expected service life would be as much as 365 days.

As you can see, expected sensor life is around a year. We’re of course, being flippant, but only to highlight a very specific point – In a normally functioning ECCR, the only thing between the diver and a serious if not fatal accident is the Oxygen Sensor. This singular fact is often overlooked. Trying to “squeeze” as much time as possible out of a sensor is an invitation to disaster. Sensors are relatively inexpensive; it’s far better to replace the sensors earlier and more often than necessary than wait for eventual failure.

Maintenance

The design goals of the Hammerhead included long-term reliability and minimal user maintenance. The head was designed with easy sensor removal, supplied with caps for Wrist Unit cables, and waterproof wiring within the lid to facilitate cleaning with a fresh water rinse. The Wrist Units should be given a freshwater bath after each day of diving using the supplied sealing plugs. This should help reduce corrosion on the springs and the magnets within the push buttons. The buttons assembly consists of an outer boss that mounts to the Wrist Unit, a stainless steel spring and a push button with an imbedded rare earth magnet. These parts are exposed to the surrounding environment, while a magnetic proximity switch remains in the sealed Wrist Unit compartment. Eventually the buttons will show corrosion due to the use of dissimilar metals. Fortunately, these buttons can be disassembled and cleaned with minimal effort. The springs are a standard size, and are readily available. The replacement specifications are 316 SS 1 inch by 0.25-inch diameter with a wire size of 0.029 inches.



The picture to the left shows typical corrosion of the switch assembly. This is usually the result of salt-water residue in the switch cavity and can usually be prevented by proper rinsing. This switch will be disassembled to inspect, clean and replace components if necessary.

The first step is to loosen the boss assembly using an adjustable or ¼ inch wrench. Do not use excessive force. Once the assembly is free, remove it from the Wrist Unit.

Even though the push button and spring are made out of stainless steel, corrosion can be seen on both parts. This is due to the reaction between the different stainless steel alloys used. The corrosion can be removed by placing the individual components in a diluted bath of common household vinegar for several minutes.

Clean out the compartment with a Q-Tip, lube the components with some silicon, and reassemble. The picture on the right shows the same compartment after cleaning.