Brian Bugge Incident – 20 May 2018

City and County of Honolulu, Hawaii

Dept. of the Medical Examiner

Case No. 18-1242

Timeline of events relevant to the dive that took place on
20.5.2018 07:49:58

Table of Contents

Terminology

CU: Control unit of the rebreather, two interconnected computers placed inside of the rebreather head (left-hand side and right-hand side) each with its own battery, sensors, and solenoid.

Handset: Control terminal of the rebreather, two handsets are connected to the head through a cable (left-hand and right-hand, each to its CU).

HUD: Head-up display, contains 3 LEDs, each is separately controllable.

Critical Alarm: all LEDs are glowing red, text on both handsets, vibrating alarm on both handsets.

ppO2: Partial pressure of oxygen, or the fraction of oxygen in the breathing mix. Air contains 21% oxygen, or 0.21 bar, at the surface (if no oxygen is added or depleted, the ppO2 will double with every 10m of increasing depth due to increasing water pressure). The physiological safety band of oxygen pressure for human beings is 0.16 to 1.6 bar. If the ppO2 drops below 0.16 bar, the diver will lose consciousness from hypoxia. Loss of consciousness is almost instantaneous.

Used data

SYSLOG.DSF Non-dive data log (also available in text format SYSLOG.CSV)

CONFIG.DCF Configuration record (also available in text format CONFIG.CSV)

00000033.DLF Dive log (also available in text format 00000033.CSV)

The events from 00000033.DLF are timestamped and are counted from the start of the dive.

In the timestamp they are listed with an added time 20.5.2018 07:49:58.

Data from SYSLOG.DSF are marked with the letter S.

Data from 00000033.DLF are marked with the letter L.

All files are from right CU.

List of configurations

Imperial units

Sea water

Last stop 3m/10ft (default)

Stop rounding for plan 60s (default)

Pyle Deep stops on, 2 minutes

Gas switch stop minimal length 2 minutes (default)

GF 30/80 (default)

Bailout GF 80/85 (default)

ppO2 low limit 0.3 bar (default)

ppO2 high limit 1.6 bar (default)

Stack time on surface "Running"

Active switchable alarms: CNS, Ascent rate (default)

Other values and settings

Setpoint 0.7 bar

Recorded water temperature 25.5 to 25.7 deg Celsius

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Timeline from 2018-05-19 20:56:15 to 2018-05-21 03:12:37

2018-05-19

S   20:56:15   Switch on by the Left CU

S   20:56:22   Connection with Left Handset and Left CU established

S   20:58:26   Calibration of O2 sensors started, using 98% Oxygen

S   20:59:42   Calibration finished, timestamp from configuration 2018.05.19 20:59:42

S   21:01:24   Calibration of He sensors started

S   21:01:36   Calibration finished

S   21:07:36   Predive check started

S   21:11:34   Predive check finished

S   21:12:59   Shutdown

2018-05-20

S   07:08:54   Switch on by the Right Handset (Surface mode initiated)

S   07:09:03   Connection between Right Handset and Right CU established

S   07:09:06   Connection with Left CU established

S   07:09:38   Predive check started

S   07:12:03   Predive check finished -> all tests confirmed as OK

S   07:12:09   Manual switch to CCR mode

S   07:14:32   Manual switch to Surface mode

S   07:25:47   Shutdown (probably by 10min timeout)

S   07:35:56   Switch on by the Left CU (Surface mode initiated)

S   07:36:03   Connection with Left Handset and Left CU established

S 07:49:57   Switch to CCR mode (emergency initiation of dive mode by submersion to depth greater than 1.5m)

            (The time spent in depth lower than 1.5 meters cannot be acquired from the logs, as the unit was not in dive mode)

L 07:49:58   Dive started (dive log timestamp 00:00:00)

            Last known ppO2 according to individual sensors:

            0.05bar (2.34mV), 0.04bar (1.76mV), 0.04bar (1.94mV), 0.04bar (1.82mV)

            All O2 sensors in Error state ("voltage too low" – meaning O2 readings are too low)

            Critical Alarm "ppO2 measuring lost"

L 07:49:59   Attempted O2 backup measuring (false due to air in the loop, instead of the configured diluent)

L 07:50:32   Total loss of O2 measuring, both main and backup (probably due to sea water on the sensors a flooded loop)

L 07:50:33   O2 injection, for 3 seconds
            (repeated every 3 to 6 seconds)

L 07:50:39   Critical Alarm "Hypoxia"
            (repeated every 30 seconds)

L 07:51:06   Maximum depth of 37.86m reached

L 07:52:15   Ascent to 37.09m (probably caused by the start of recovery of the diver)

L 07:54:09   Surface reached

S 22:12:22   Connection with the Left CU lost

S 22:12:27   Connection with the Left CU established
            (repeat 5x)

S 22:13:51   Connection with the Left CU lost
            (unit probably switched off by jumpers removal)
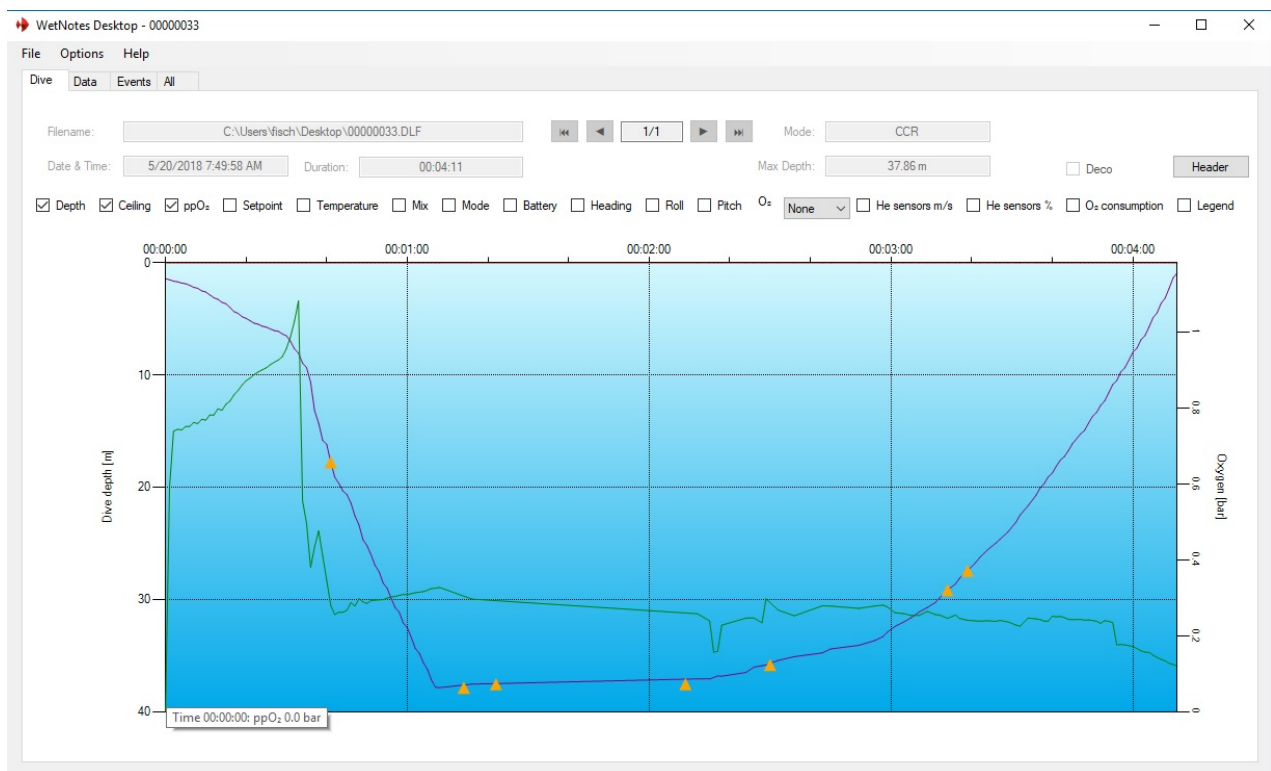
2018-05-21

S 03:01:05   Reset (power up) and an attempt at connecting with the left CU
                (unsuccessful, probably due to the left battery running out)
                (repeat until 03:12:37, probably due to the right battery running out)

Dive Profile

Conclusions

All of the data obtained from the rebreather's controls leads to the conclusion that the unit had been switched ON in "surface mode" at the time the diver entered water, not in "CCR mode" for diving. As the diver passed below a depth of 1.5m, the rebreather's electronics were triggered by increasing water pressure to switch into CCR mode, or dive mode.

We do not see any shut OFF between the last switch ON and emergency switch into the CCR mode triggered by surrounding pressure. Activity in surface mode is not logged.

While in surface mode, the unit is designed to maintain a pre-set oxygen volume of 23% by adding oxygen if the O2 sensors detect a drop below this amount. This addition of oxygen functions automatically and is intended as a safety feature to prevent depletion of oxygen from the loop while the unit is running unintentionally in surface mode. However, for this feature to work, the diver must first open the valve on the rebreather's oxygen tank so gas can flow to the rebreather's solenoids, which will be triggered to fire and add oxygen to the breathing loop if the sensors detect a drop below 23%.

This diver's unit was unable to sustain the pre-set volume of oxygen on 23% in surface mode, to maintain the low limit default setpoint of 0.30 bar in CCR mode, or to achieve the user setpoint of 0.70 bar in CCR mode. The most probable reason for this is a closed or blocked oxygen supply. We tested for this at the equipment exam on 8 June 2018. Both solenoids, as well as the low and hi-pressure regulators and hoses, were proven to be functional at the exam. Therefore, we are convinced that the oxygen valve must have been closed prior to and during the submergence of the unit.

The first and last known and verifiable ppO2 reading from the O2 cells is: 0.05bar (2.34mV), 0.04bar (1.76mV), 0.04bar (1.94mV), 0.04bar (1.82mV). This occurred at the switch on to CCR mode at 1.5m depth. After this, we cannot verify that the readings are correct because the unit became flooded with sea water and the sensors' ability to accurately read oxygen became corrupted. Nevertheless, the oxygen solenoids fired repeatedly throughout the dive but the ppO2 continued to fall after an initial spike, likely caused by an increase of water pressure during the descent and possibly an initial short burst of residual oxygen in the oxygen hose.

The verified oxygen levels are well below the ppO2 required to sustain consciousness (0.16 bar). This supports the conclusion that the diver lost consciousness at or near the surface. Furthermore, as the diver descended to the bottom, multiple alarms were given by the rebreather but none were acknowledged by the diver.