SPN1 -50°C Test Report

Introduction

Whilst preparing for field trials at McMurdo in Antarctica, scientists at Pacific Northwest National Laboratory in the USA asked Delta-T if an SPN1 could survive without power at -50°C.

We had previously successfully cycled SPN1s between -40 and + 40°C in our environmental chambers but did not have access to anything colder.

The British Antarctic Survey kindly offered us access to a freezer capable of -80°C, at their headquarters in Cambridge UK.

During March 2015 an SPN1 was logged over eight days, spending 6 days at -50°C, of which three had no internal heater or sensor warmup power applied.
The unit survived the 3 days without power, showing no sign of damage.

Ten alcohol filled bubble-levels of the sort used in the SPN1 also survived with no apparent damage.

Tested afterwards back at Delta-T the SPN1 showed no significant change in calibration, being with 0.6% of its previous value.

Summary

In summary the logged data and visual inspection showed no indication of malfunction as a result of 3 days at -50°C without power.

Test Protocol and Observations

Day 1: Start at 20°C

On day 1 the SPN1 analogue output was connected to a GP2 data logger logging once every 5 minutes. Two extra wires in the SPN1 sensor's analogue cable were connected to a 12V power supply to power its internal heater.

The functioning of the SPN1 was tested by putting it under a desk lamp for 20 minutes.

The SPN1 was then put in the freezer, connected to the GP2 by 2 five meter lengths of analogue cable, and with the first 4.5 meters fully in the freezer compartment.

A Delta-T type ST4 10K thermistor temperature sensor was also placed alongside the SPN1 also connected to the GP2.

(Note I had programmed this sensor with a lookup table to read down to minus 50C - but had not tested this. In the event the logger rejected all readings below -25°C, logging those readings as faulty, and recording NAN# for "Not A Number". This had no impact on the freezer, which happily achieved -50C in under a day and sat there happily for the whole week as indicated by its independent controller.)

9/3/2015 10:29 GP2 logging started with light on SPN1 on desktop at +20°C (see photo)
10:48 SPN1 moved to freezer along with 10 bubble levels (see photo)

9/3/2015 10:59 Freezer was turned on and set to -50°C
SPN1 Heater on, and being logged every 5 min via analogue cable
14:00 Freezer reached ~ -50°C

Days 2-4: At -50C without power

10/3/2015 10:55 SPN1 isolated from the GP2 logger by breaking the circuit at the in-line connector between the two 5 m sections of analogue cable
The SPN1 now had no heater power and no sensor warmup power.

At this time the analogue cable connected to the GP2 logger was “floating”, not connected to anything, but the logger was left running.
Over days 2, 3 and 4 the SPN1 remained at -50°C without heater power or sensor power.

Days 5-7: At -50°C with power

13/3/2015 10:45 On day 5 the 10m of analogue cable was reconnected at the 5m join, which re-established heater power and sensor warm-up power to the SPN1.

On days 5, 6 and 7 the SPN1 were left in the freezer, still at -50°C.
This has simulated 3 days at McMurdo with power, followed by someone turning up and putting the power back on.

Day 7-8: Light test at -50C, back to 20°C, light test at 20°C

On Monday 16/3/2015 10:00 the top loading freezer was opened and a photo taken of the SPN1 and bubble levels, showing no damage (see photos).

A light was hung above the SPN1 in the freezer and the lid replaced.
The logger Global and Diffuser reading sover the next four logging intervals indicated that the SPN1 was working.

The battery voltage being low, the GP2 battery was replaced.
The replacement battery appeared faulty, so it was replaced by a regulated power supply.
This resulted in a one hour interruption to the logger power supply.

Between 11 am and 12:54 am it became unclear whether the SPN1s response to the light was behaving intermittently. (One factor was that I had become confused by the apparent non operation of the red LED light on the SPN1. Subsequently the designer John Wood clarified its operation for me. It only flashes when being logged, even if the heater power is on)

16/3/2015 12:54. Light removed.
Lid replaced on freezer.
Freezer turned off
SPN1 Heater off

17/3/2015 12:00 Freezer back at 20°C
SPN1 on bench under lamp, GP2 still logging analogue output
SPN1 serial output connected to PC running SunRead and logging
The SPN1 serial and analogue readings agree under the desk lamp

17/3/2015 12:35 serial logging stopped
17/3/2015 12:40 analogue logging stopped .

23/3/2015 SPN1 calibration was checked back at Delta-T, showing no significant change in its calibration, being with 0.6% of its previous value.

Photos

Figure 1 British Antarctic Survey test facility used for the -50C trial

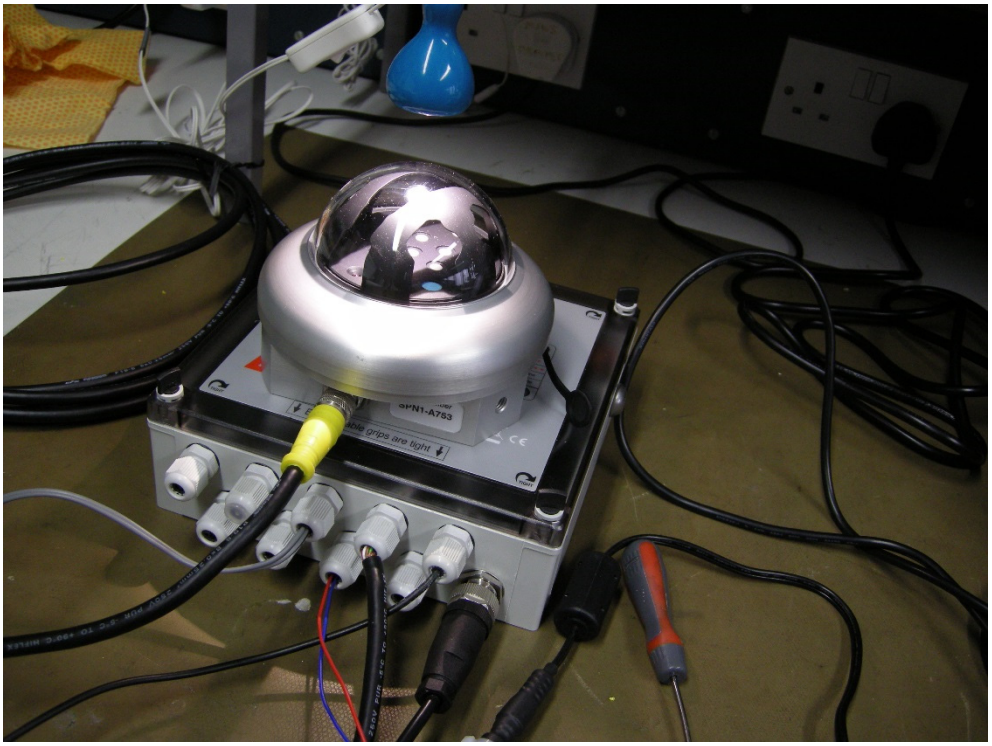

Figure 2 SPN1 running under lamp on GP2 logger on bench before test

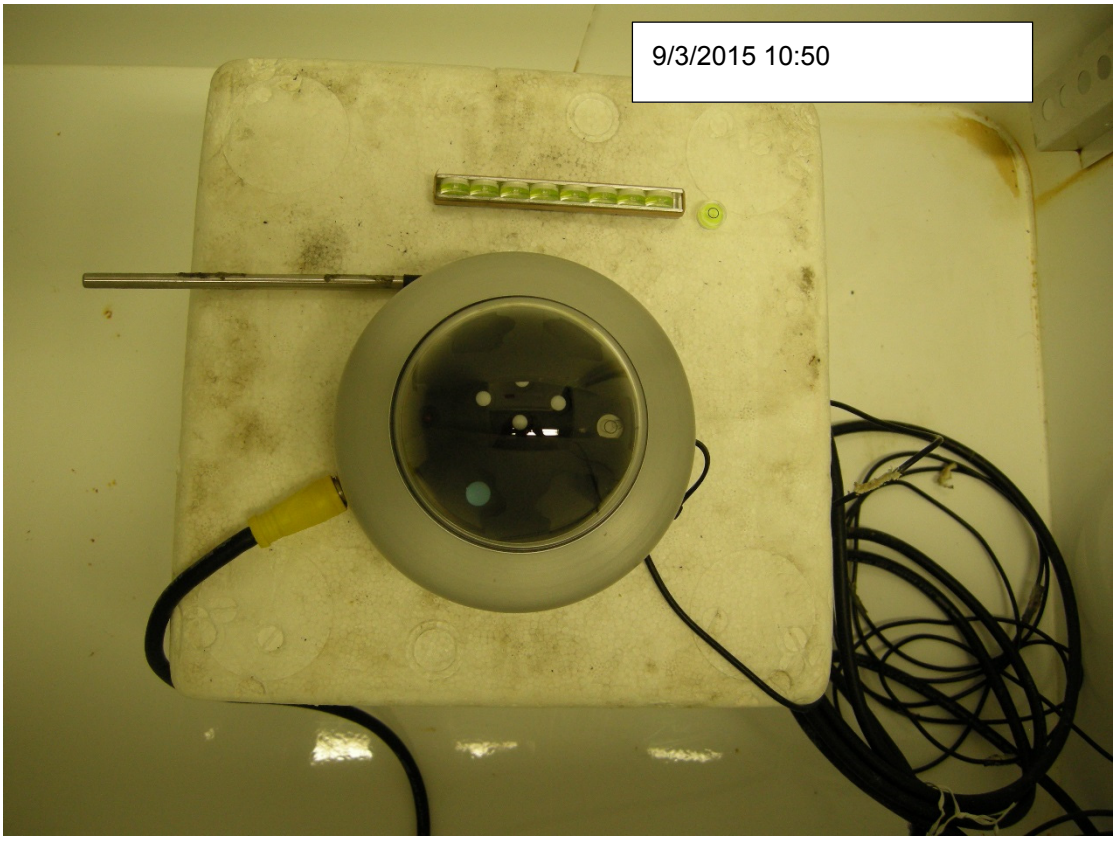

Figure 3 In freezer with bubble levels at 10:50 on 9/3/2015 before freezer is turned on.

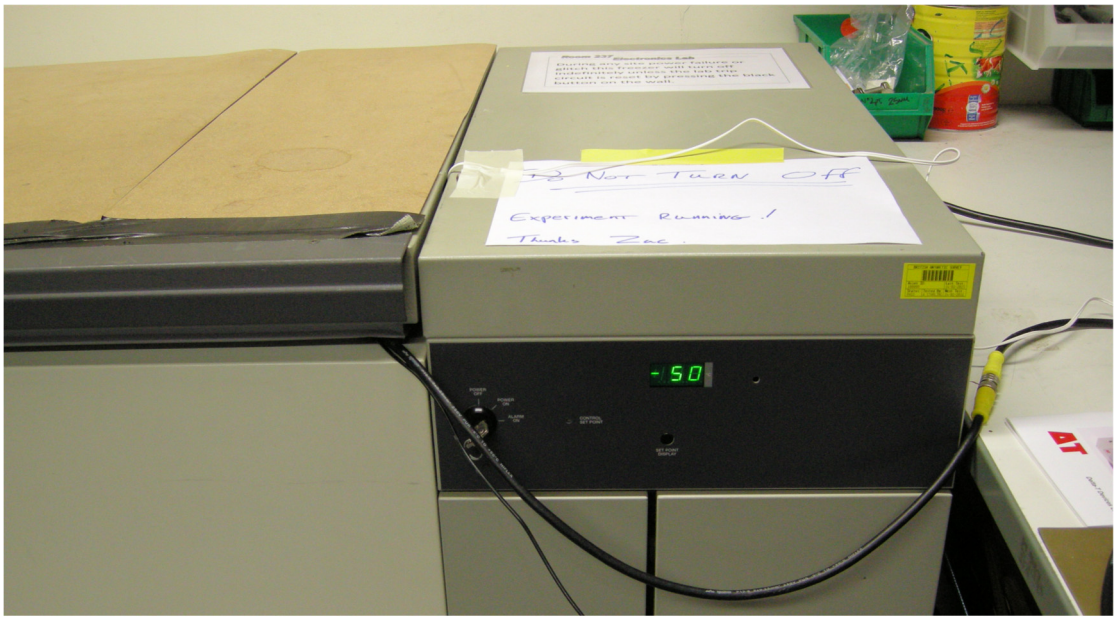

Figure 4 BAS Freezer at -50C showing the inline M12 connector in the SPN1 analogue cable. This connection was disconnected for 3 days to simulate 3 days without power at McMurdo

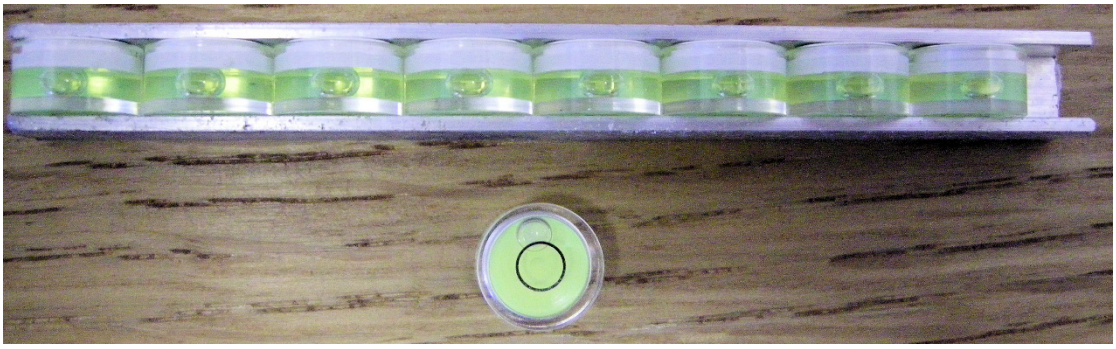

Figure 5 Bubble levels before -50C test

Figure 6 Bubble levels after 6 days at -50C

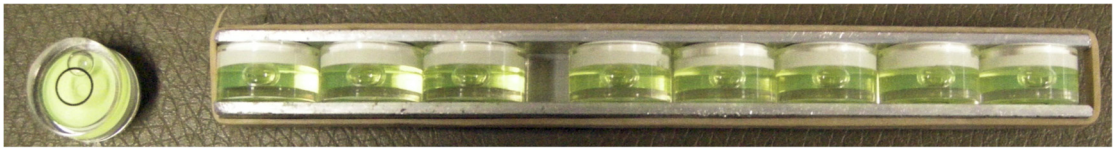

Figure 7 Bubble levels after -50C test

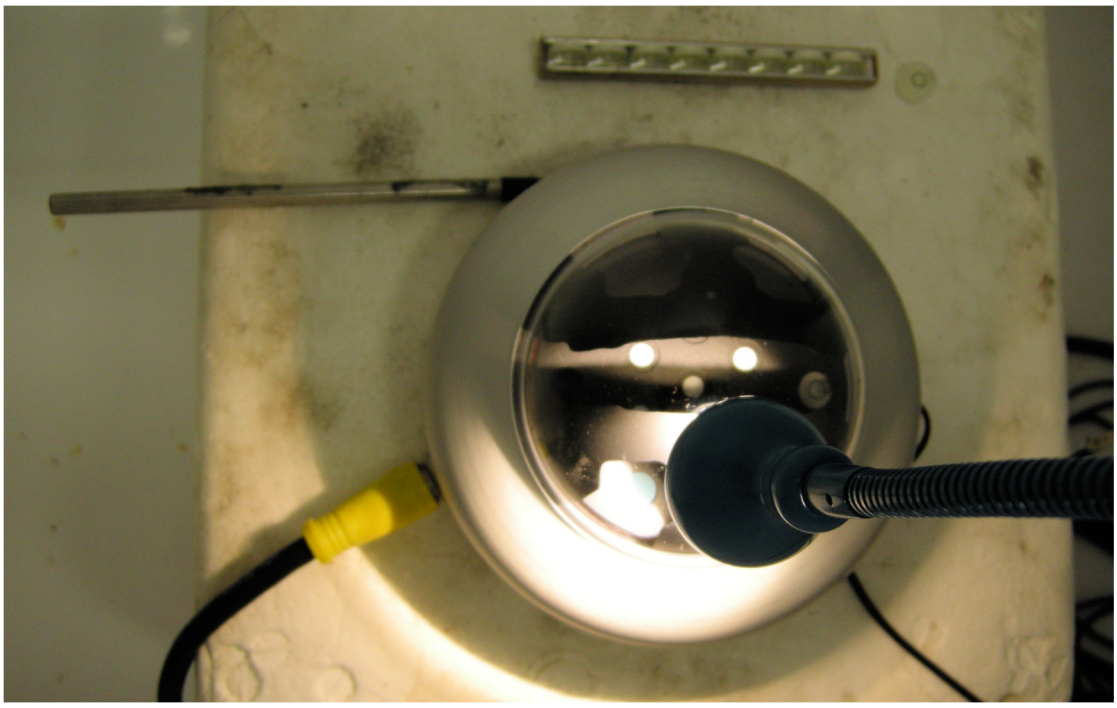

Figure 8: SPN1 in freezer at -50C, still logging after 6 days at -50C, of which 3 were without any power. The picture also shows 10 bubble levels and a Delta-T type ST4 thermistor temperature sensor. The light was applied temporarily to check the SPN1 was still working.

Graphs and Data

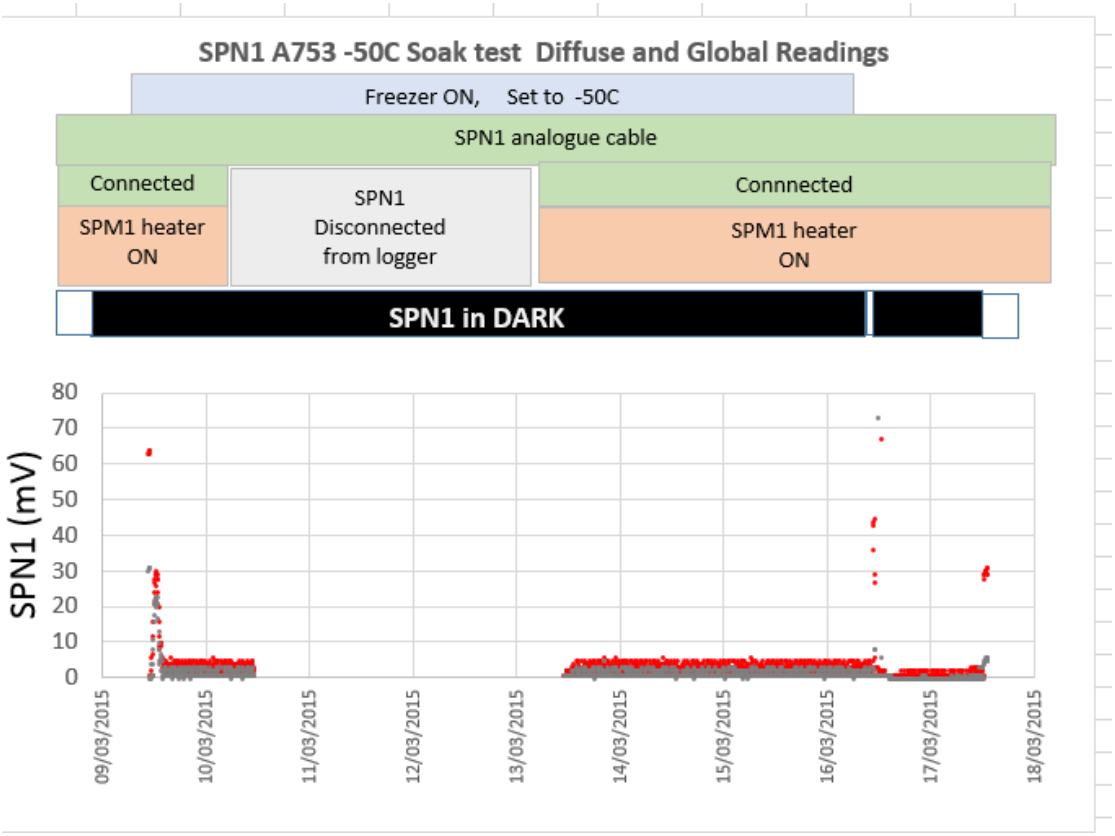

Figure 9 SPN1 Global and Diffuse readings logged as mV over 8 days

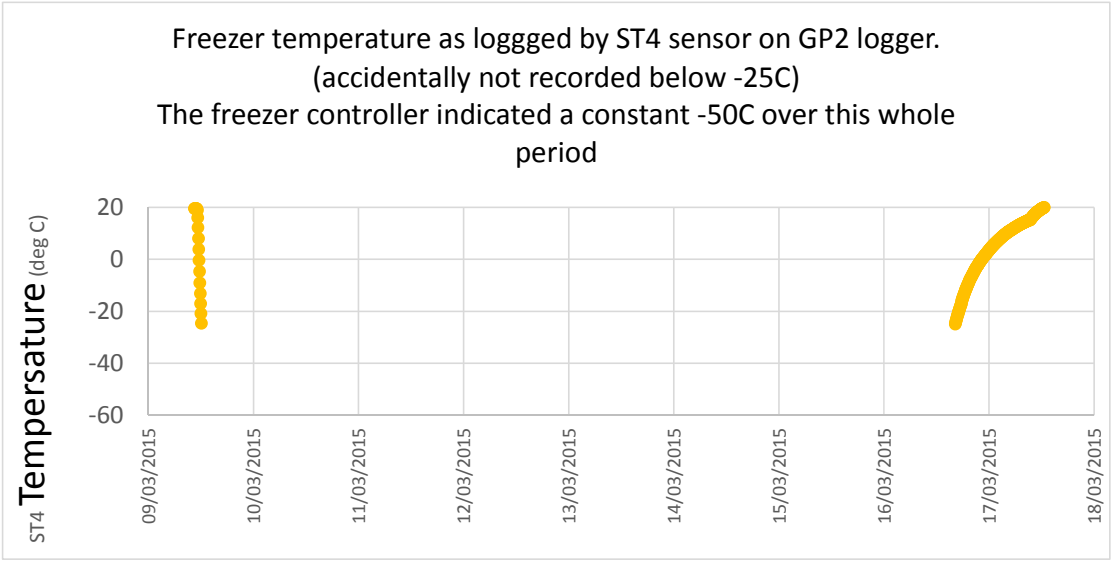

Figure 10 ST4 thermistor sensor readings in freezer. Data accidentally clipped below -25 C

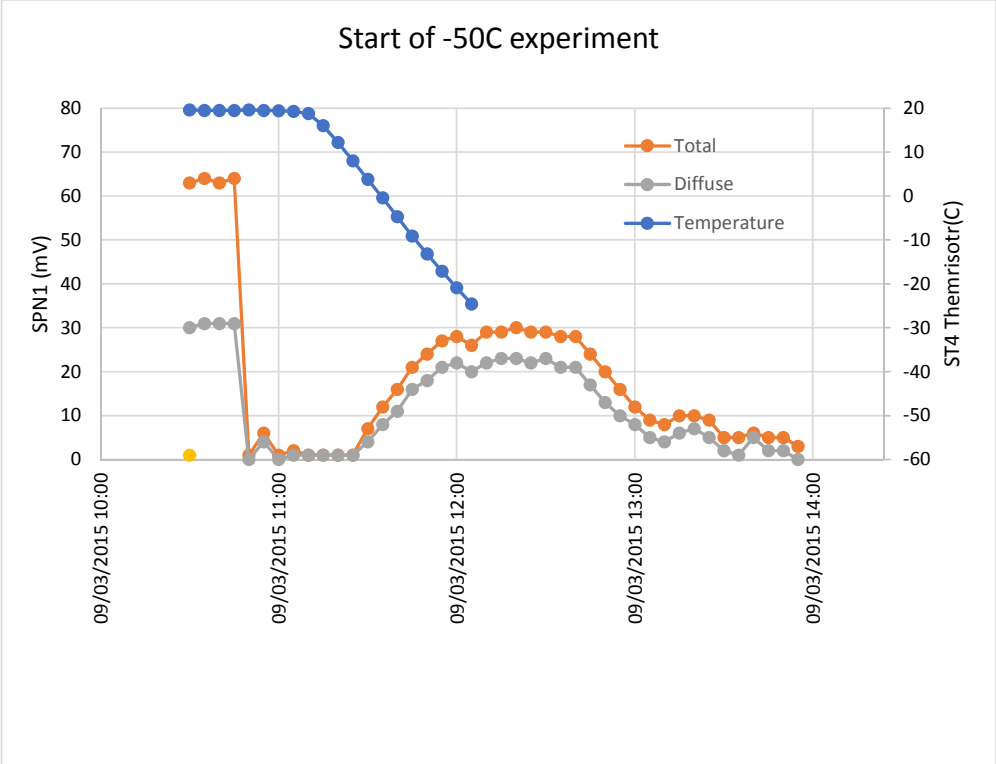

Figure 11 Logged data at the start. Steady Global and Diffuse readings under the desk light on the bench. SPN1 then into the freezer in the dark. During the rapid cool- down the SPN1 sensors show a tempco offset error. The oven was observed to reach -50C by about 2pm. After this the Global and Diffuse readings stabilised at 3 (±1) and 1.4 (±0.7) mV.

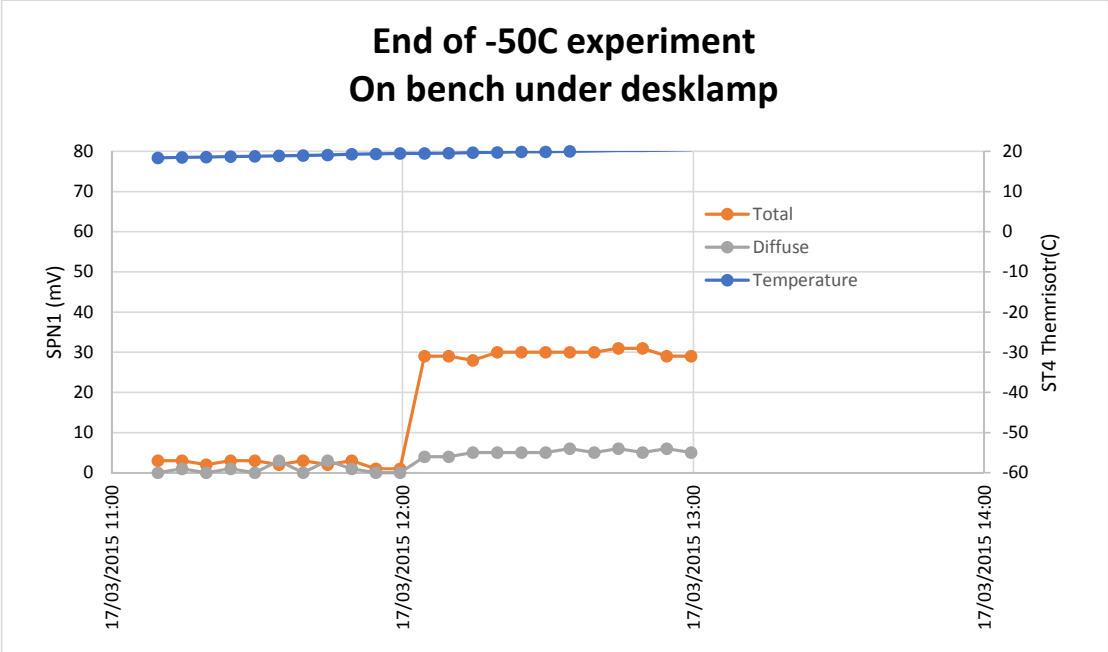

Figure 12 SPN1 data at end of experiment on bench under lamp. The measured Global and Diffuse readings have returned to the pre-test values.

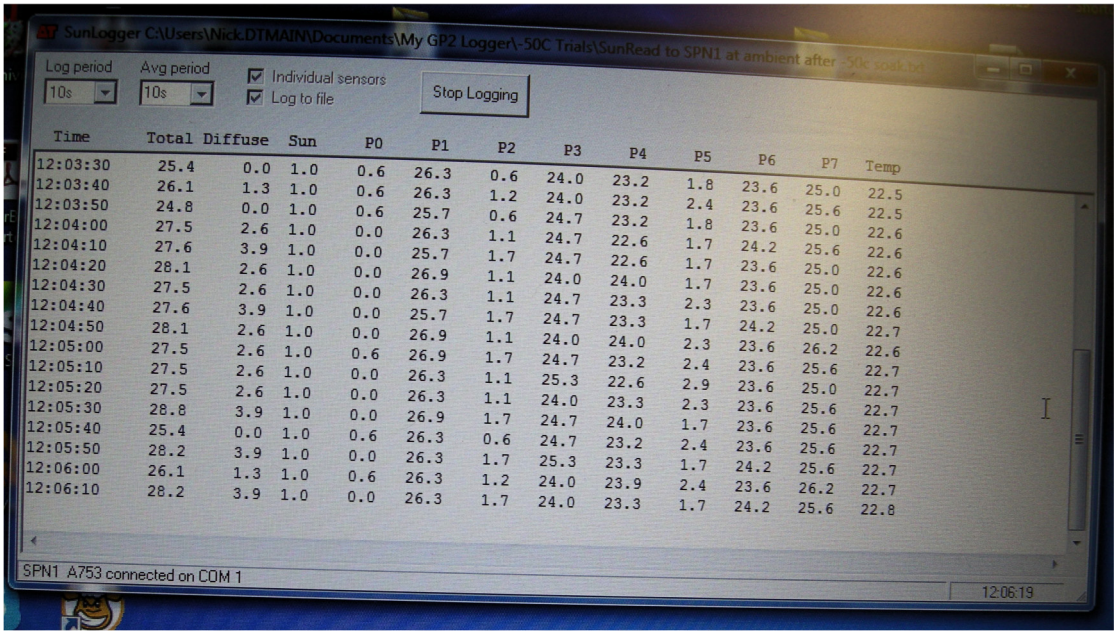

Figure 13 SPN1 serial data being logged on PC via SunRead after -50C test.
So both the analogue and serial outputs are still working.

Analysis of Logged Data

Once stable at -50°C the average logged SPN1 Global and Diffuse readings were 3.0 (±1) and 1.4(±0.7) mV. These positive offsets are normal for SPN1s in the dark.

During the rapid cool down to -50°C both Global and Diffuse showed positive offset errors up to 30mV.
On warmup from -50 to 20°C (without the SPN1 heater on) the offset moved in the other direction, reducing to 1.3 and 0.09 mV respectively. This behaviour is what one would expect from a normally functioning SPN1.

Finally, back at ambient 20°C under a lamp both analogue and serial reading tracked each other.

There was also no indication from the serial readings, which included individual readings from each of the 7 thermopiles, of any individual thermopile going adrift.

In summary the logged data and visual inspection showed no indication of malfunction as a result of 3 days at -50°C without power.