PHOTOGRAPHIC ENGINEERING ANALYSIS
OF TANZANIAN
WELL MAINTENANCE UNIT

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CONTENTS

1 EXECUTIVE SUMMARY

A Well System for Ongoing Maintenance (AWSOM) unit measures the activity of water wells and send daily texts to head office. The Unit described below has been in Tanzania for almost one year and has now (pre Covid-19) been returned to the UK for detailed analysis. This provides an interesting and informative opportunity to learn and improve the Well Maintenance Unit's build and design. The unit was: built and tested (for over six months) in the UK, it was then shipped out and installed on a water well in Tanzania. The unit worked perfectly for several weeks and, after reaching the limit of the UK SIM card's '*Fair Use Policy'*, was returned for analysis.

This document's main objective is to record the unit's status quo and to ensure that lessons can be learnt from the photographic record. Initial findings are discussed and draft conclusions made.

2 PHOTOGRAPHIC RECORD

Each of the main areas of the well maintenance unit (AWSOM #3888), from its housing to the electronics board, are discussed. Photographic evidence is provided. The unit was exported to Tanzania early 2019 (Figure 1) and returned to the UK early 2020.

The unit has gone through a difficult period and shows signs of stress. The unit worked perfectly for over three weeks in August 2019. This demonstrated that the design, operational concepts and current software work successfully.

Issues of concern are: thermal cycling, well vibration and the SIM card security policy (eg: the policies of the carrier and the security protocols around UK reception of Tanzania SMS texts) (not MMS texts). The above issues must be taken into account in any future installation.

Overall the unit performed well. It survived the harsh physical environment and succeeded in sending texts every day back to the UK proving the hardware and software work well in Tanzania.

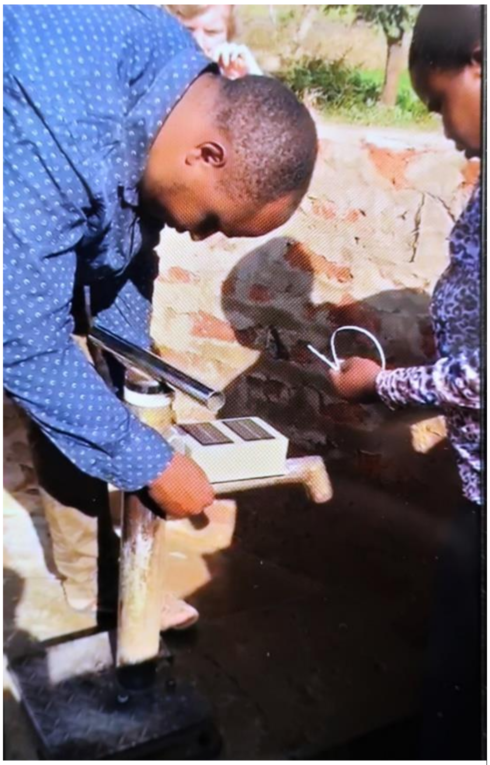

Figure 1:

AWSOM Unit Installation

2.1 SIM Card

The unit was returned to UK after texts were not received from the unit. Investigations have shown that the UK's SIM card's '*fair use policy'* was activated after 90 days and all international texts from the unit were automatically barred. Unfortunately, and simultaneously, the UK's international texting security arrangements were upgraded in line with international regulations at this time. The Tanzanian authorities have not done likewise up to the time of writing.

This mismatch of country security protocols meant that any texts that did manage to penetrate UK airspace were barred. After extensive and numerous phone calls with the UK carriers they stated that they (EE and O2) were complying with international security text regulations. When texts left Tanzania using the old texting security protocols they were not to forwarded to the recipient. The mix of old phone texting module technology combined with the security protocol mismatch was suspected.

It was confirmed that many texts actually left Tanzania and were not received by the author's O2 phone.(However the O2 Technical Team could see the texts were rejected by their systems.) It is expected that the Tanzania authorities would say it was the UK's problem if the texts entering the UK were not relayed on to the recipient.

This impasse, as confirmed by both O2 and EE, will only be resolved when both countries involved resolve the texting security arrangements and implement a working partnership specifically for old type SMS texts from old type of phones. This is not expected to happen quickly. (Note: The modern MMS messaging system is not affected as it is internet based.)

2.2 Housing:

Figure 2 shows the unit after being in Tanzania for almost a year. The rust-like color of the unit demonstrates the high levels of dust (and possibly iron salts) in the soil.

The housing has proved to be mechanically robust and has not cracked or broken. The lifting of the solar cells that was found on the previous versions (where the solar cells were affixed too close to each other which did not allow for thermal expansion) has not occurred.

The upgraded twin solar-cell design with its two-part epoxy adhesive has worked well. Upon arrival in the UK the batteries were charged (5.2v) demonstrating that the twin solar cell approach works satisfactorily.

Figure 2: Unit #3888 Returned

Figure 2: The unit at the UK airport.

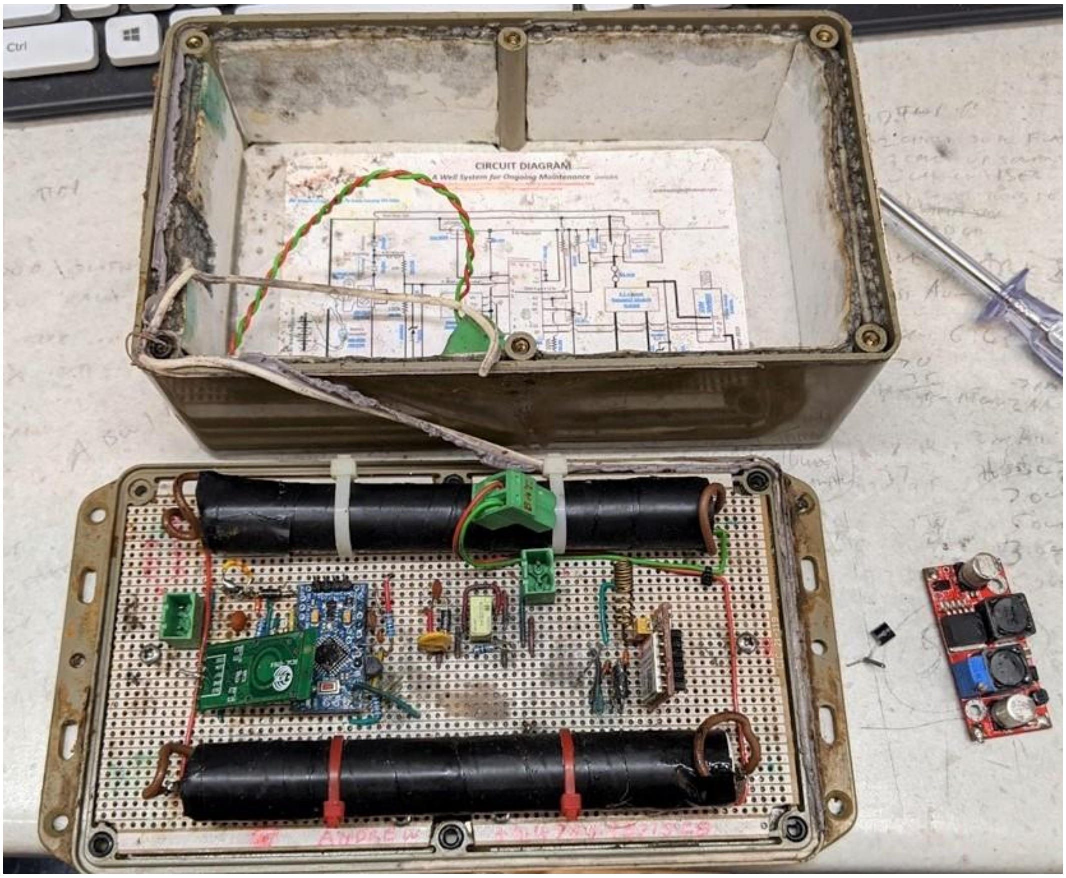

Figure 3: Returned Unit First Opening

Figure 3 shows the unit as first opened. This demonstrates the stressed areas.

The base of the Housing (Figure 4) contained what appeared to be very small chips of 'sparkly' material. This was established to be conformal coating which had come off the electronic parts due to a combination of thermal cycling and vibration of the unit.

Figure 4: Unit #3888 Housing Base

Small variations in the Housing external colour were expected due to the dust/mud and the high levels of Ultra Violet (UV). (The Housing darkened by a couple of shades)

The housing's base gasket appeared crushed and broken in a couple of areas, (Figure 5) but the application of the additional local sealant appeared to have worked well.

Figure 5: Unit #3888 Housing Base's Distressed White Rubber Seal

Figure 6: Flaking Near Well Riser

Figure 7: Top Central Depression

Figure 6 shows the housing's external surface flaking and mold next the water riser. Figure 7 shows the impression of a possible additional local fixing between the solar cells and the well's spout.

2.3 Aluminium Base Plate

The overall impression of the aluminium base plate is that it has rusted. (FeO_2). It is very difficult and highly unlikely for iron oxide to occur this way. When aluminium oxidizes it turns a slightly lighter colour, (AlO_2) not rust brown. Investigations show that it the colour is more likely the result of mixing and baking (by the heat of the sun) high levels of dirt dust and water. (Which could be high in iron salts). The application of a small amount of water and elbow grease shows the bright aluminium underneath. (Figure 8). There are small visible signs of pitting which could have been caused by trapped grit particles combined with spout vibration. There is no other sign of chemical degradation of the metal.

Figure 8: Aluminium Base Plate

In addition to the compacted mud deposit, the Base Plate has undergone some physical stress. The corner next to the spout is scuffed. Figure 9.

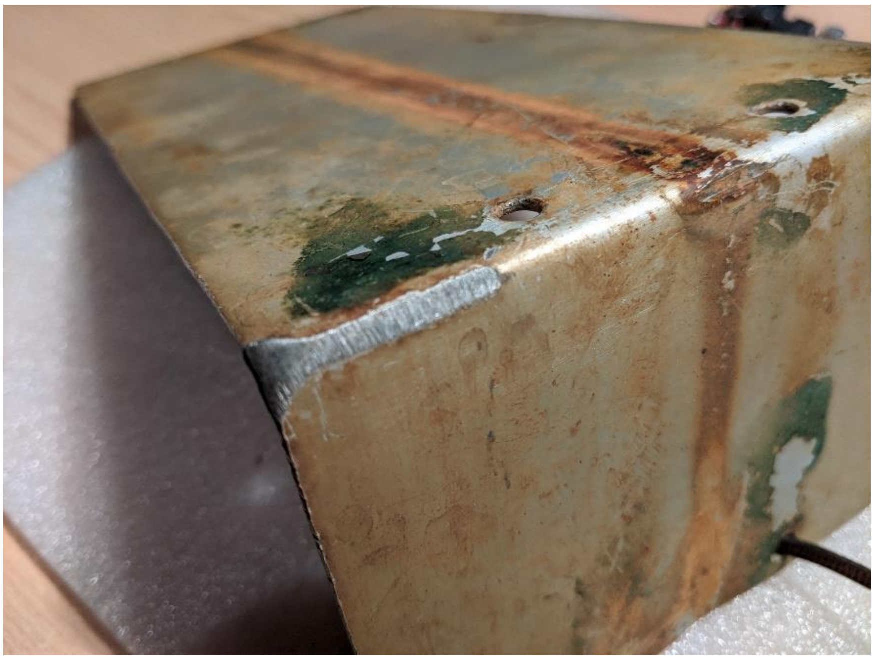

Figure 9: Base Plate Corner Stress

This has not damaged the housing. However if the AWSOM unit was attached to the Base Plate during the time of the occurrence, the amount of force needed to scuff the aluminium would have stressed the internal circuit board.

Figure 10: Vertical Plate Warping

There is a slight bending of the Base Plate's vertical support at the riser-pipe end. This could be the result of strongly attaching the Unit to the well riser pipe. (Figure10). A slightly thicker Base Plate could be used in future versions. (2mm)

2.4 Main Electronics Board

The overall impression of the Main Electronics Board was 'Stress'. The stress could be due to a combination of: physical impact, water ingress, temperature cycling & long-lasting vibrations that the unit experienced.

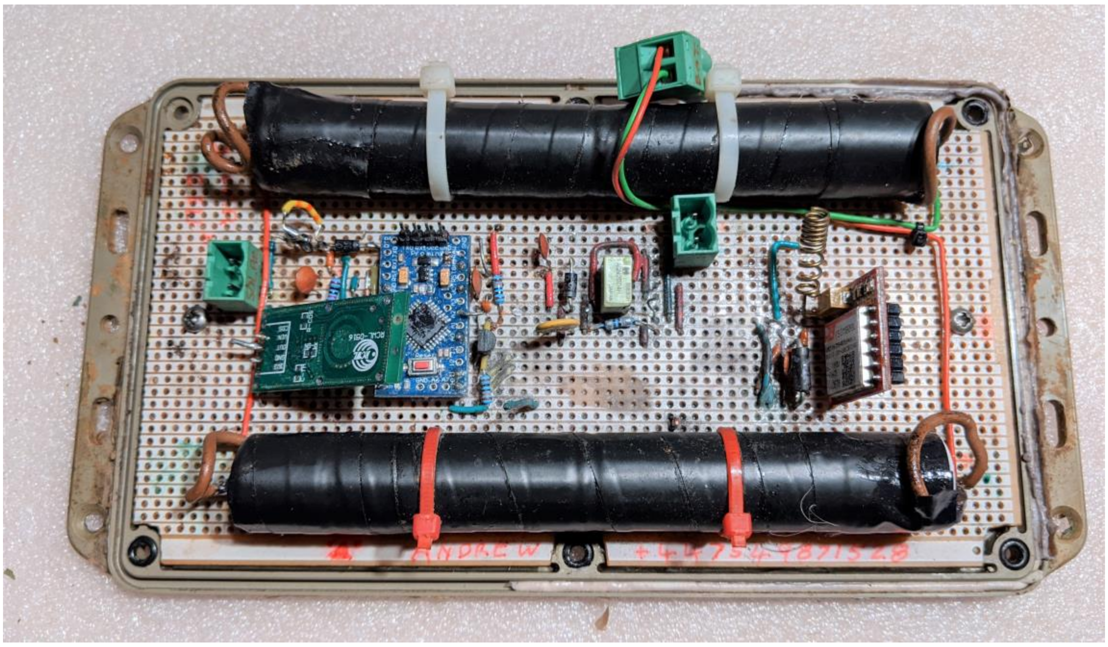

Figure 11: Main Electronics Board Post Installation

Figure 11 above shows the Unit circuit board as returned to the UK.

Figure 12 below shows the Unit pre-export.

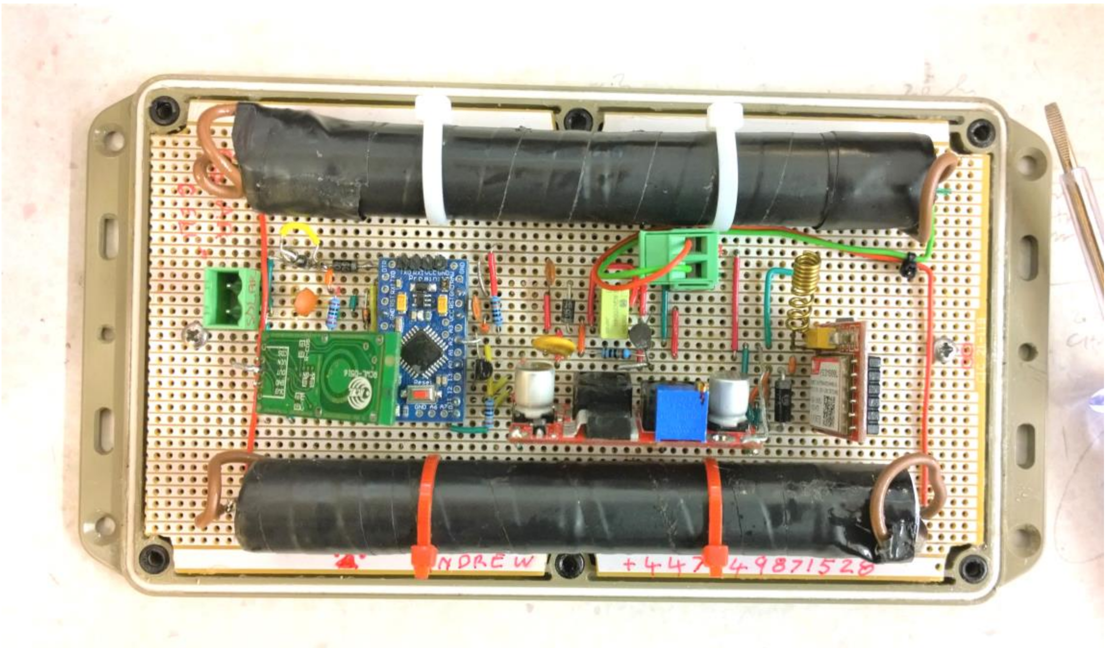

Figure 12: Main Electronics Board Export

Apart from the aluminium base plate, there are four principal areas where the unit has undergone change whilst in Tanzania:

1. The voltage regulators.
2. The power switching Relay.
3. The conformal coating.
4. The (white) Rubber Seal.

Each is discussed below.

2.5 SIM Voltage Regulator

The large Central 4.1V SIM voltage regulator should be attached to the Vero-board through four soldered joints. This unit was loose in the box upon arrival in the UK. Without the voltage regulator the SIM texting module would not have been able to power-up.

The regulator could have become loose due to some unknown physical action or through the continual vibration of the unit on the well spout. The continual vibration could have caused metal fatigue in each of the four wires connecting it to the Main Electronics board. As the board is mounted vertically the vibrational stress could have been instrumental in freeing the regulator.

The SIM voltage regulator coming loose poses a question. Why did the radar module and the SIM module itself not also become loose? They too are mounted vertically but are orthogonal to the SIM voltage regulator. This discussion is beyond the scope of this paper at this time.

Additional stress was noted on the voltage regulator. The two I/O capacitors have undergone surface abrasion. The abrasion to the plastic coating can be seen in figure 13.

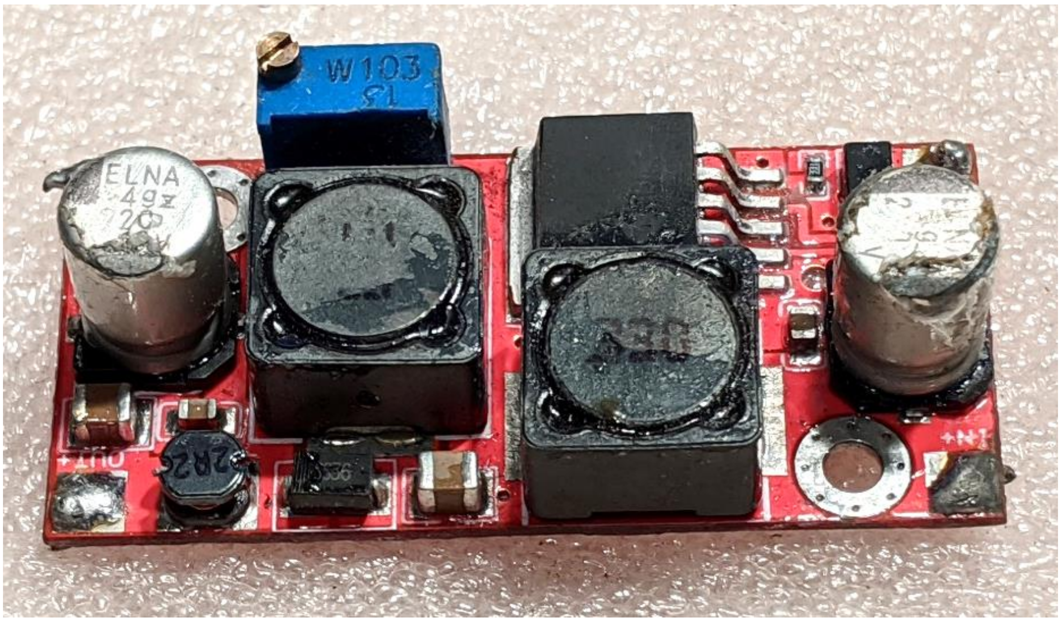

Figure 13: SIM Voltage Regulator

The scuffing of the two silver colored capacitors is from an unknown source. The scuffs are in line with each other and in the same direction an angle (up/down & at 45 degrees).

2.6 Computer Voltage Regulator.

The main computer on the circuit board is an Arduino mini pro. It provides all the logic functions, codes and sends and records the texts and all the data. The Arduino computer is driven by a 5 V regulator. This Voltage regulator also came detached from the Electronics board. Two of its three wires were broken at its base. This small 5V low volt-drop regulator is about the size of a garden pea and is of low mass. It is unlikely therefore that vibration alone could have caused the breakage of these two wires.

Figure 14: Computer Voltage Regulator

The Arduino voltage regulator (Figure 14) was situated very close to the power relay. (See figure 12) In addition to the voltage regulators the control relay's mechanical integrity has been compromised in one corner. The damage to the control relay is close to where the computer regulator would have been. The close proximity of these two units could have meant that one adversely affected the other.

2.7 Control Relay.

The control relay switches the power to the SIM texting module and diverts power away from the battery when an overcharge is detected. The integrity of the relay's housing has been compromised (Figure 15). It must be remembered that this corner is closest to where the 5V regulator would have been.

Figure 15: Control Relay

Chipping off the corner of the relay needed a high level of force. The resistor below is still operational but has also suffered damage. Whether this damage was the result of a mini-explosion inside the relay or is the result of accidental impact is unknown at this time.

Discussions with RS-Components said that they could not help directly as I had last purchased a relay of this type over a year ago (July 2018). RS Components (the relay suppliers) pointed me in the direction of the manufacturer, Panasonic. Discussions with Panasonic in the USA continue as to the failure modes of these type of relays. Photographs are being sent to the USA for analysis. The response of Panasonic is awaited. (The resistor below the relay could be indicative of what happened)

The level of dust and debris on the circuit board is apparent from figure 15. Although the wires look black and burnt they had not got that hot as the black coating was easily removed revealing the PVC underneath, it was clear and undamaged.

2.8 Conformal Coating:

The conformal coating used was an acrylic clear paint-like material. It is used to cover all the electronic components. This coating protects the board from water damage. The coating is tough but can be melted or cracked off the components when required. The cracked coating on the black Zener diode in Figure 16 should be noted. There is also a significant level of debris on the board. The blue wire has been coated with an unknown black substance. (mud/dust?) The black residue can be removed (Figure 16) by low levels of abrasion.

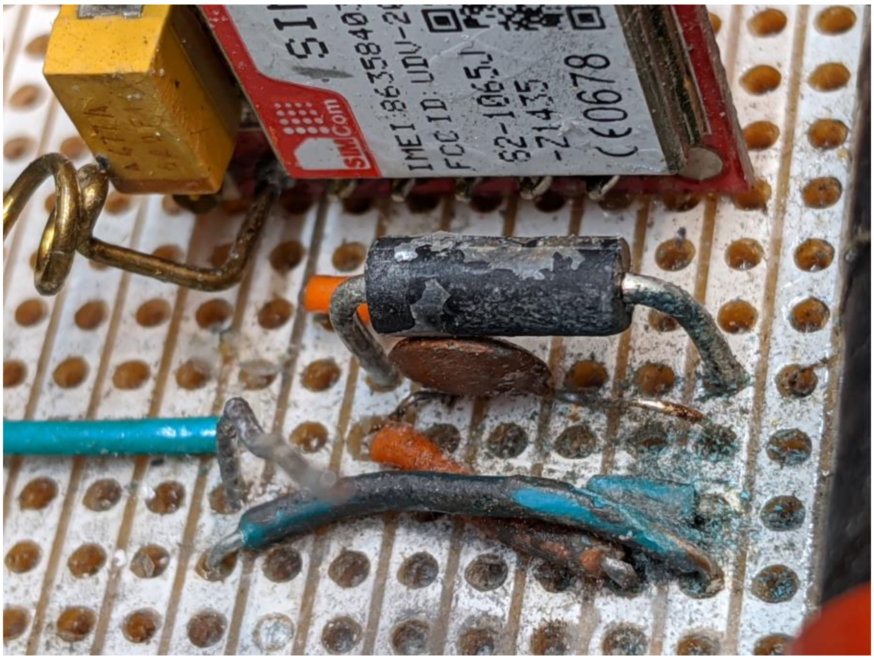

Figure 16: Chipped Conformal Coating on Zener

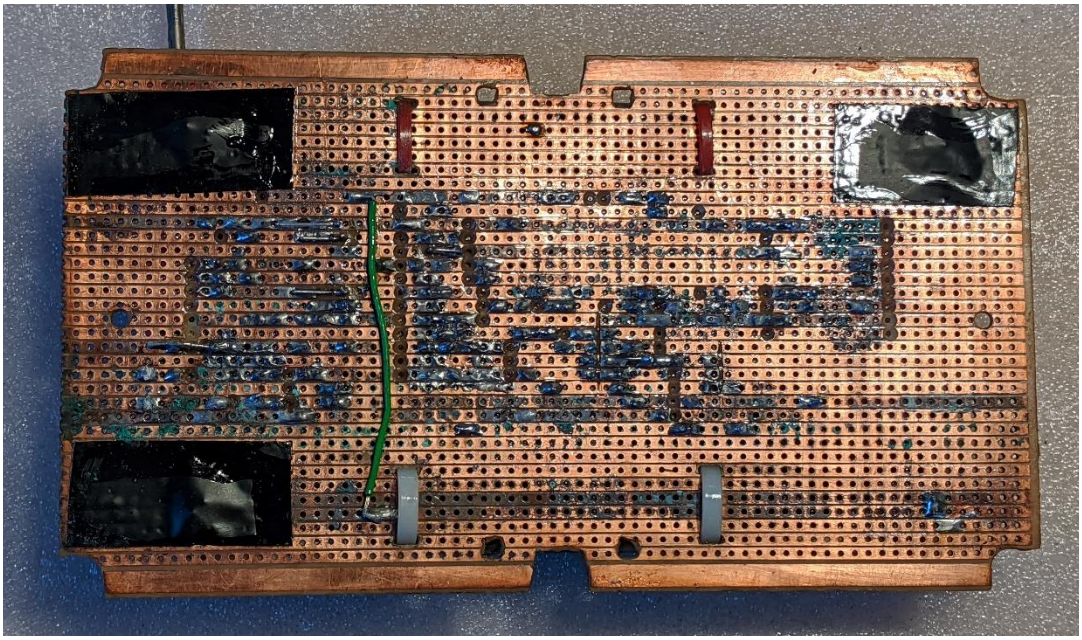

Figure 17: Conformal Coating - Track Side

The wet-look to Figure 17 and Figure 18 is the conformal coating on the copper tracks. Track degradation appears to follow the high voltage (5v) power lines (bottom of figure 17). Figure 18 shows some of the detail of copper degradation on the upper-right of the board.

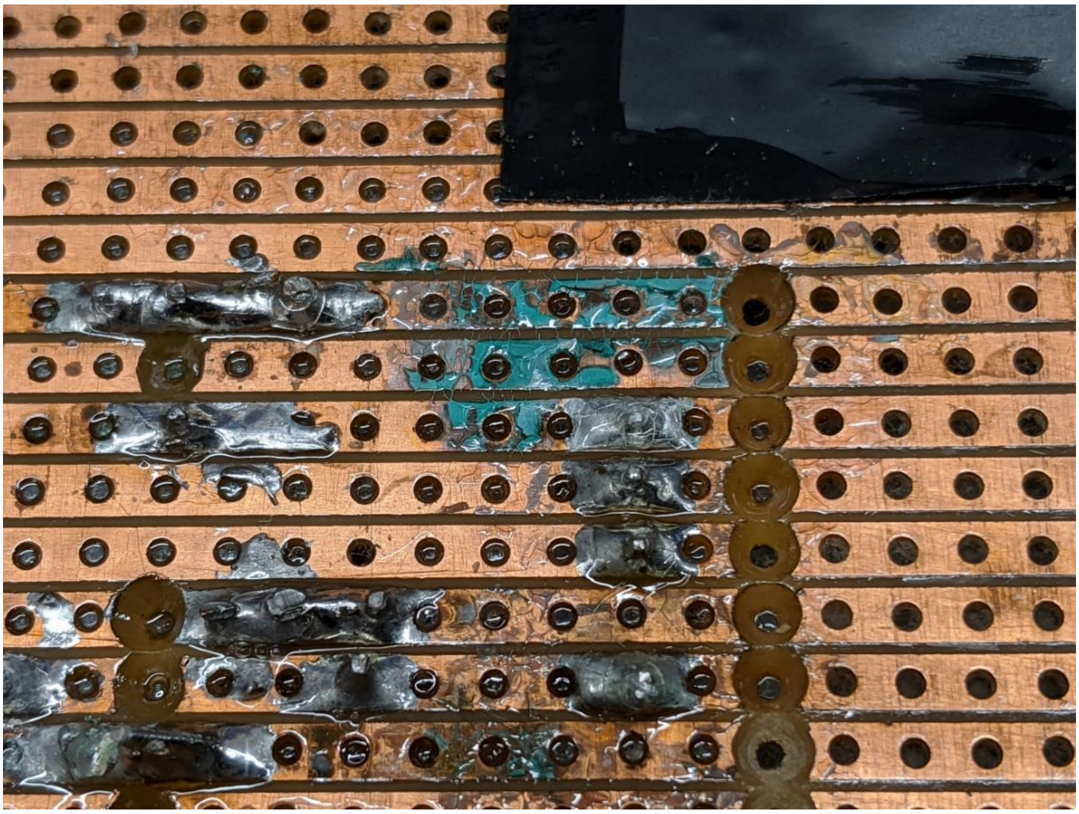

Figure 18: Conformal Coating Degradation

The wet-look on this board (Figure 18) shows the extent and the coverage of the conformal coating. The green areas in the middle of the picture indicate where the copper has been eroded and oxidized and where the conformal coating failed. It is unclear whether water ingress was from the bottom trackside or through the holes in the top of the board. In future units the conformal coating must be more flexible and tolerant of vibrational stress. (NB: The airborne Radar & defense industry have occasionally used a thin layer of two part epoxy resin successfully)

2.9 Vero Board:

The Vero board used on the prototype units has performed well. Even though water has managed to penetrate the conformal coating the thick copper layer and broad width of copper tracks has lasted well. It should be noted that any future PCB tracks should be as wide and thick as possible.

Some unusual markings appeared on top of the Vero board. The white covering on the Vero board was missing. It is unclear how this occurred. Very high levels of abrasion are needed to remove the white coating. A combination of heat, temperature cycling, dust and some form of vibration could have removed the covering but it is unclear precisely how this occurred. Figure 19 shows a patch where the white-coating has been lost and the Vero board base layer exposed.

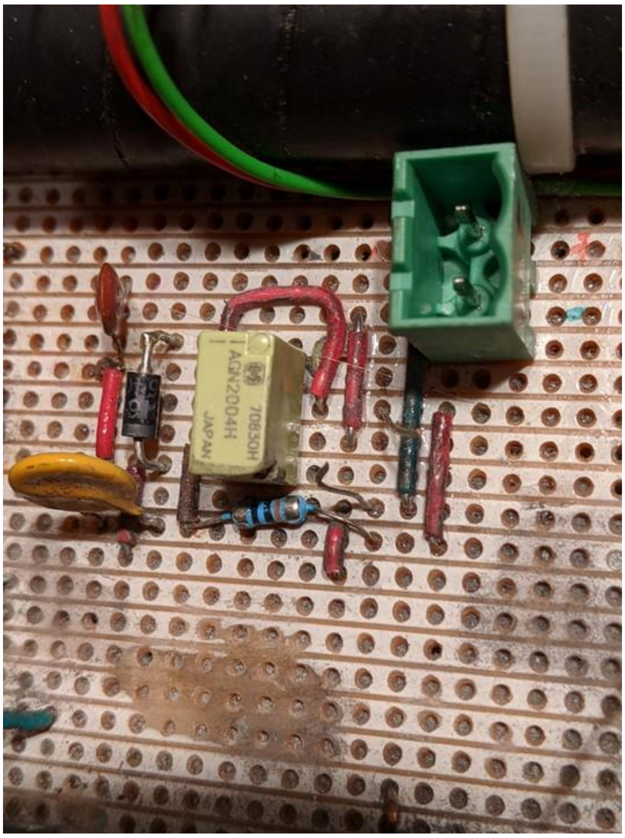

Figure 19: Vero Board Base Layer Exposed

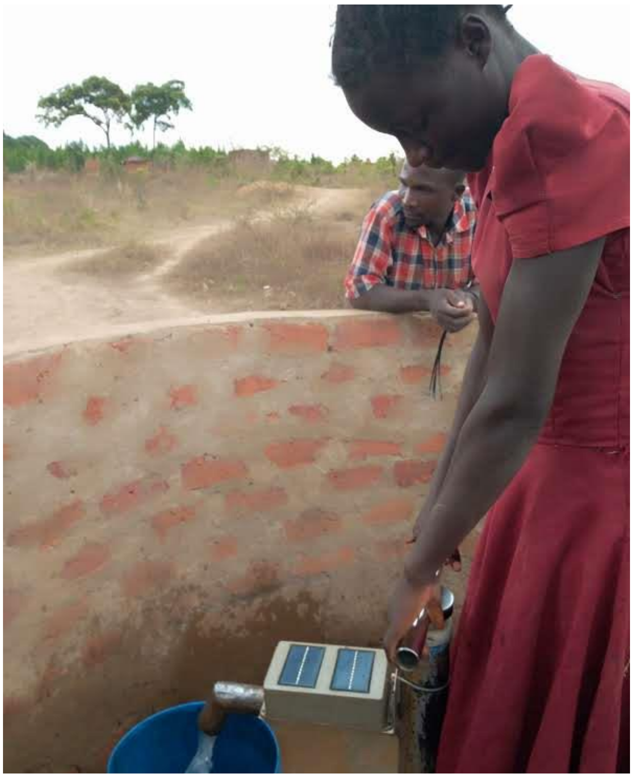

Figure 10: AWSOM Unit Installed

3 CONCLUSIONS & RECOMENDATIONS

There are a number conclusions and recommendations that can be drawn from this photographic record. Investigations continue and it is expected that some of the questions asked above will be answered over the forthcoming months.

Overall the system worked for several weeks in August 2019. Water did make it through to the underside of the circuit board however, the unit survived for a several months. The mechanical structural integrity of the unit was maintained but the rubber seal was compromised. The hardware and software functioned as expected.

The recommendations are:

1. Use a thin layer of clear two-part epoxy as conformal coating on both sides of the Electronics board. (This will avoid the conformal coating cracking off under vibration) Also, ensure the all housing's top surface is abraded to assist solar cell adhesion.

2. Ensure the copper tracks of the positive and ground lines are not adjacent to eachother and are as substantial as possible. (To avoid 'high' voltage differences between closely spaced tracks and possible track corrosion).

3. Make the aluminium base plate 2 mm thick rather than the current 1.5 mm thick. (To prevent bending)

4. Construct the unit so that there is no need to open the housing after UK testing. (To prevent dust ingress etc.)

5. Have pre-registered and working local Tanzanian SIM cards posted to UK for installation and testing in the unit prior to shipment. (To avoid SIM issues).

6. Consider whether the relay specification must be improved (Discussion with the USA supplier continue on relay failure modes).

The author would like to thank all those involved in the project. It has taken four years and high levels of tenacity to arrive at the working prototypes. A valiant effort has been made by all concerned - Many thanks, Andrew 2020

4 TERMS OF REFERENCE

Mike De Haaff (Guernsey) initiated this *African Water Well Maintenance Unit Challenge* (19th June 2016). Several e-mail exchanges later data was collected and the specification document produced. The prototypes took about two years to evolve and produce, testing and installation took about the same.

This document records issues over the past 12 months of one unit in particular, #3888, after almost one year testing in Tanzania. This document is for the discussion purposes only.

5 AMENDMENT SUMMARY

Author	Summary	Revision	Date
Andrew WS Ainger	First issue - Technical discussions	Draft 1	2020-02-20
Andrew WS Ainger	Draft issue - Released for internal use only	Draft 2	2020-03-26
Andrew WS Ainger	Aluminium Base Plate photo improved	Draft 3	2020-03-28
Andrew WS Ainger	Updated conclusions – issue status	Issue 4	2020-04-17

6 APPENDIX: REFERENCED ORGANISATIONS

1. Panasonic USA 0800 587 0991
2. RS Components UK 0845 720 1201
3. The Tanzanian Team (Godfrey and Ray et. al.)
4. The Guernsey Team (Mike and Allister)
5. The UK Team (Maurice, Rob, Bob, Peter and Graham)

The author would like to thank all those involved in this project. It has taken four years and high levels of tenacity to arrive at the working prototypes. A valiant effort has been made by all concerned - Many thanks, Andrew 2020

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