PRODUCT CONFORMITY CERTIFICATE

This is to certify that the

YSI Professional Plus Portable Multiparameter Water Quality Meter

manufactured by:

YSI Incorporated

1700 / 1725 Brannum Lane
Yellow Springs
Ohio, 45387
USA

has been assessed by Sira Certification Service
and for the conditions stated on this certificate complies with:

MCERTS Performance Standards for Portable Water Monitoring Equipment, Version 2.1, dated August 2010

Certification Ranges :

Dissolved Oxygen (polargraphic)	0 to 200% saturation
pH	2 to 12
Temperature	0 to 45°C
Conductivity	0 to 1 mS/cm
Conductivity	0 to 50 mS/cm

Project No:	16W0397
Certificate No:	Sira MC100179/00
Initial Certification:	09 November 2010
This Certificate Issued	09 November 2010
Renewal Date:	08 November 2015

Technical Director

MCERTS is operated on behalf of the Environment Agency by

Sira Certification Service
12 Acorn Industrial Park, Crayford Road, Crayford
Dartford, Kent, UK, DA1 4AL
Tel: 01322 520500 Fax: 01322 520501

Approved Site Application

Any potential user should ensure, in consultation with the manufacturer, that the monitoring system is suitable for the intended application. For general guidance on monitoring techniques refer to the Environment Agency Monitoring Technical Guidance Notes available at www.mcerts.net

On the basis of the assessment this instrument is considered suitable for use on treated wastewater, untreated wastewater and receiving water applications.

Basis of Certification

This certification is based on the following Test Report(s) and on Sira's assessment and ongoing surveillance of the product and the manufacturing process:

Environment Agency, Warrington Report TR-04 V2, dated September 2010
Environment Agency, Warrington Report TR-05 V1, dated September 2010

Product Certified

The MCERTS measuring system consists of the following parts:

- Professional plus Instrument 6050000 (includes Data Manager software, the ProComm II communications saddle and USB cable)
- Four cable options: single, single with conductivity, dual parameter & Quatro, up to 30m.

  Note: All cables include temperature; cables over 1 metre include cable management kit; cables with conductivity include sensor (no need to order conductivity sensor).
- Additional sensors 605203 Polarographic Dissolved Oxygen and 605101 pH (ISE)
- Optional flowcell, carry case and tripod accessories available.

This certificate applies to all instruments fitted with Pro Plus code Version 3.4 onwards, and Datamanager desktop software 1.1.13 onwards (serial number 07J onwards).

Certified Performance

The instrument was evaluated for use under the following conditions:

Ambient Temperature Range: -2°C to +45°C

Please note, Dissolved Oxygen (DO) stated as % reading, pH stated in pH units, conductivity stated as % span, and temperature stated as °C.

Unless otherwise stated the evaluation was carried out on the certification range Dissolved Oxygen (DO) 0 to 200% saturation, pH 2 to 12, temperature 0 to 45°C, Conductivity 0 to 50 mS/cm.

Test	Results				Other results	MCERTS specification
	<0.5	<1	<2	<5		
Combined performance characteristic						
DO				4.21		6.0
pH	0.13					0.3
Conductivity			1.33			1.5
Temperature	0.22					0.5
Response time						
DO					19s	
pH					<5s	Value to be reported
Conductivity					10s	
Conductivity (0 to 1 mS/cm)					10s	
Temperature					10s	
Mean error						
DO				2.9	Note 1	5.0
pH	0.07					0.2
Conductivity		0.84				1.0
Conductivity (0 to 1 mS/cm)	0.01					1.0
Temperature	0.10					0.3

Test	Results				Other results	MCERTS specification
	<0.5	<1	<2	<5		
Linearity						
DO	0.3				Note 1	2.5
pH	0.03					0.1
Conductivity		0.74				0.2
Conductivity (0 to 1 mS/cm)	0.00					0.2
Temperature	0.11					0.2
Repeatability						
DO	0.2				Note 1	2.5
pH	0.03					0.1
Conductivity	0.14					0.5
Conductivity (0 to 1 mS/cm)	0.01					0.5
Temperature	0.06					0.2
Sample matrix effects						
pH, Conductivity, temperature					Note 2	
Salinity compensation for DO						
DO		0.85				2.5
Warm up drift						
DO, pH, Conductivity, Temperature					<2mins	<2mins
Length of battery operation						
DO, pH, Conductivity, Temperature					Tested over 24 hours	>12 hours / 50 independent measurements
Low voltage					5V to 1.6V	
DO	-0.2					1.0
pH	0.02					0.05
Conductivity	0.00					0.25
Temperature	0.00					0.2

Test	Results				Other results	MCERTS specification
	<0.5	<1	<2	<5		
Ambient temperature					-2°C to +45°C	
DO	0.05					2.5
pH	0.04					0.1
Conductivity	0.04					0.5
Temperature	0.02					0.2
Relative humidity					95% relative humidity	
DO	0.43					2.5
pH	0.04					0.1
Conductivity	0.01					0.5
Temperature	0.01					0.2
Incident light						
DO, pH, Conductivity, Temperature					Note 3	
Sample temperature						
DO			2.0		+5°C to +45°C	2.5
pH	0.01				+5°C to +30°C	0.1
Conductivity	0.13				+5°C to +30°C	0.5
Temperature					-	n/a
Robustness					Not tested	Optional test

Note 1 – The result for DO is based on data obtained from test point 2 (50% DO) to test point 5 (200% DO). Data from test point 1 (10% DO) was not used in these calculations. A mean error of ~300% was recorded at test point 1.

Note 2 –The sample matrix effects test was deemed not applicable for the pH, conductivity, or temperature sensors by the certification committee.

Note 3 – The incident light test is not applicable for the DO, pH, conductivity, or temperature sensors.

Field test results

The field trial was conducted > 3 months on a river monitoring application, where over 120 measurements were taken.

Test	Results				Other results	MCERTS specification
	<0.5	<1	<2	<5		
Error under field conditions						
DO					100%	>90% of errors ≤ Uc value
pH					96.9%	
Conductivity					100%	
Temperature					100%	
Response time (start)					Note 4	
DO					19.8s	
pH					10s	To be reported
Conductivity					5.8s	
Temperature					10s	
Response time (end)					Note 4	
DO					22.2s	
pH					13.2s	To be reported
Conductivity					5.5s	
Temperature					4.8s	
Maintenance	Routine maintenance only					To be reported

Note 4 – The response time was recorded using a stopwatch at the beginning of the field trial, and was recorded using a data logger at the end of the field trial

Description:

The Professional Plus series is a family of rugged multiparameter handheld instruments used to measure water quality in a variety of different applications. The Professional Plus series is available with four different cables options (single parameter, single parameter with conductivity, dual parameter and Quatro) with the ability to measure up to eleven water quality parameters simultaneously.

When used with the Quatro cable option, the Professional Plus meter is a complete sampling and monitoring water quality unit providing continuous data from a compact system measuring Temperature, Conductivity, pH and Dissolved Oxygen (%sat and mg/l). Other parameters include Barometric Pressure, Specific Conductance, Total Dissolved Solids, Resistivity, Salinity plus one of Redox, Ammonium, Nitrate or Chloride.

Working in fresh, polluted, brackish or seawater, the YSI Professional Plus is an IP67 meter with cable lengths up to 30m.

The Professional Plus is designed for either direct in-situ measurement using the field cable, sensors and protective guard or via flowcell for groundwater applications.

General Notes

1. This certificate is based upon the equipment tested. The Manufacturer is responsible for ensuring that on-going production complies with the standard(s) and performance criteria defined in this Certificate. The Manufacturer is required to maintain an approved quality management system controlling the manufacture of the certified product. Both the product and the quality management system shall be subject to regular surveillance according to 'Regulations Applicable to the Holders of Sira Certificates'. The design of the product certified is defined in the Sira Design Schedule for certificate No. Sira MC100179/00

2. If certified product is found not to comply, Sira Certification Service should be notified immediately at the address shown on this certificate.

3. The Certification Marks that can be applied to the product or used in publicity material are defined in 'Regulations Applicable to the Holders of Sira Certificates'.

4. This document remains the property of Sira and shall be returned when requested by the company.

Field Test Report

YSI HYDRODATA LTD Professional Series Instrument Quatro four port cable configuration

Test Report Reference: TR-05

Project Reference: EA-MCERTS-11

Published by The Environment Agency, Date: September 2010
Issue No: 1

Document Reference: N:\UKAS\mcerts\issued\5.10\TR-05 v1.doc

Professional Series
Type Quatro four port cable configuration
Serial no: 09D101346
Manufacturer: YSI HYDRODATA LTD

Instrumentation Facility
Environment Agency, Warrington

Table of Contents

i) Document History

Issue No	Summary of Changes	Author	Issue Date
Draft	Draft for review and approval	PG	August 2010
1	Issued	PG	Sep 2010

ii) Normative References

References

- ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories.

- MCERTS guides and standards, including:
  - Performance Standards and Test Procedures of Portable Water Monitoring Equipment
  - Performance Standards and Test Procedures for Continuous Water Monitoring Equipment

- Instrument specific instruction Manual

- Blue book methods for the measurement of pH, Conductivity, 'Measurement of Electrical Conductivity and Laboratory Determination of pH' 1978 ISBN 0 11751428 4 and DO 'Dissolved Oxygen in natural and waste waters' 1979 ISBN 0 11 751442x.

- Standard Methods for the Examination of Water & Waste Waters 15th Edition 1980

Test programme for YSI HYDRODATA LTD Professional Series Instrument Quatro four port cable configuration Project No: EA-MCERTS-11

Abbreviations

CWM	Continuous Water Monitor
PWM	Portable Water Monitor
MCERTS	Monitoring Certification Scheme

iii) Introduction

Name of Test Organisation:	The Environment Agency
Address:	Richard Fairclough House Knutsford Road Warrington WA4 1HG
Report type:	Field
PWM tested:	Make: YSI Model: Professional Series. Quatro Four Port Cable Configuration Serial No: 09D101346
Type of PWM:	Multi-parameter, (pH, DO, Temperature, Conductivity and Total Ammoniacal Nitrogen (TAN))
Details of any ancillary equipment:	USB connector pack for attachment to PC for charging and use of YSI software.
Condition of Equipment on delivery:	Fully functional
Manufacturer:	YSI Hydrodata
Sponsor:	YSI Hydrodata
Test period :	from: 22/10/09 to: August 2010
Testing carried out according to	MCERTS Test programme TP-07 MCERTS Standard: Portable Water Monitoring Equipment Version 2 2009
Date of report:	August 2010
Report No:	TR-05
Scope of report:	Full Field MCERTS testing to provide performance data both individually and combined for pH, Dissolved Oxygen (Polarographic), Temperature and Conductivity. Total Ammoniacal Nitrogen , (TAN) also partially carried out but not submitted for certification.

Authorised signatories : ☑ P Gibson ☐ D Begg ☐ G Sloane

Certified M.L.

This report only relates to the item(s) tested.

Testing undertaken and original reports prepared by:
Environment Agency Instrumentation (MCERTS) Facility
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1. Test programme

1.1 Field test

The Westy monitoring site employs a flow through system which utilises two duty pumps to send river water through a pipe system. Parameters are measured using a YSI 6 series sonde as part of a HYDROSAM flow cell system. This was used as a Secondary Reference Measurement Device, (SRM), for the sensors under test for DO% and pH. The 6 Series sonde itself has MCERTS certification for these parameters. The pH and DO%, along with Conductivity, Temperature and TAN, would also be checked using other SRM instruments or methods at various points throughout testing, (see TR-04 for details on these instruments and methods).

The Mersey monitoring station test site at Westy in Warrington was chosen for the following reasons:

- Secure site with vehicle access.
- Established fully operational monitoring station.
- Parameters able to be monitored by Agency online telemetry system.
- Adequate space to safely operate instrument for its intended purpose.

The test instrument was taken to the site whenever readings were required. All readings were taken from the site overflow reservoir with the sensor bulkhead fully submerged.

2. Field test

2.1 Nature of test

Westy is an established river monitoring station, (see picture 1). The building has a pipe and pump system which supplies a YSI 6 series V2 sonde as part of a HYDROSAM monitoring unit, (see picture 2). This logs results for parameters including Dissolved Oxygen, pH, Conductivity, Temperature, Turbidity and TAN every 15 minutes. The parameters at Westy can be accessed offsite using a telemetry system, or onsite via a YSI 6500 display device.

Following an initial two week acclimation period, the field test was carried over a span no less than three months in duration from the first readings. Testing was carried out from the 22nd of October 2009 for all parameters, (with the exception of polarographic DO), and completed by the 29th of April 2010. Due to a new Polarographic DO sensor being fitted at the instruction of the manufacturer DO field testing was carried out from the 15th of April 2010 until August 2010.

Data from the instrument was monitored and at least 24 sets of paired readings analysed and compared to the YSI 6600 V2 onsite and various SRM instruments and methods back at the lab, (laboratory readings were always carried out on the same day as the paired reading). Over the course of the study at least 120 measurements for each parameter were taken and these can be found as logged data in Appendix A.

Time for any maintenance was recorded and detailed in this report. Response time tests for the instrument were undertaken at the start and end of the study.

Picture 1 External view of Westy Monitoring Station

Picture 2 Internal view of Westy Monitoring Station

All testing was carried out as outlined in test programme TP-07 and according to the MCERTS performance standard version 2 June 2009. The operating range of the instrument was that as outlined in section 2 of TP-07:

Dissolved Oxygen;	0 to 200% saturation (0-20mg/l)
pH;	2 - 12
Temperature;	0 to 45 ºC
*TAN;	0 – 10.0 mg/l
Conductivity;	0 – 50 mS/cm

*Testing stopped at request of client. Total Ammoniacal Nitrogen Parameter not put forward for certification.

2.2 Details of Instrument — YSI Professional Series Instrument Quatro four port cable configuration. S/N 09D101346.

2.3 Environmental and process conditions

These were subject to the conditions prevalent in the field. The monitoring station itself is climate controlled as best as possible and set to the ambient conditions specified in the standard and in TP-07. Ambient temperature and relative humidity was monitored onsite using a Testo Hydrometer (ref Cal 056). The river water, (test solution), was subject to environmental and seasonal changes for each parameter. This was monitored by the HYDROSAM and sonde system (ref Test 12).

2.4 Maintenance requirements

The test instrument itself did not require any scheduled routine maintenance and was calibrated for each parameter at the start of the study and when deemed necessary by the operator, (as is common with its intended use). Details of calibration and maintenance were logged in the lab record book for the project. The instrument was rinsed in mains tap water after every use in the field and stored when not in use in its calibration cup as recommended by its instructions.

The 6600 V2 sonde at Westy was calibrated for all working sensors on a bi-monthly basis and details can be found in the labs internal calibration records.

The HYDROSAM and pump / pipe system at the monitoring station was maintained when necessary to ensure an adequate flow through of river water with no blockages. This involved an operator switching duty pumps about once a month and flushing the system out. This only took place when sampling and readings were not being taken.

3. Field Test results

3.1 Citation of MCERTS performance specifications

All testing was carried out as outlined in test programme TP-07 and according to the MCERTS performance standard version 2.0 June 2009, (see appendix B). See sections 4.4 and 7.0 along with Annex I of the standard for field test guidance details.

3.2 Equipment

Apart from the YSI 6600 V2 and HYDROSAM system in operation at Westy for SRM readings; the following instruments and methods were also used. In all cases samples from the field were brought back and analysed as quickly as possible in the laboratory. Lag time of analysis was not an issue due to the close location of the Westy site.

3.2.1 HACH Laboratory Spectrophotometer Details.

Although the results for Ammonia testing are not included for MCERTS accreditation, the details of the instrument used as a secondary reference measurement (SRM) are as follows:

A HACH DR 2800 Laboratory Spectrophotometer, (Test 16), was used to compare results of the Pro Series instrument for field sample readings in the lab, (for chemicals and reagent preparation please refer to the reagent preparation SOP 5.4 D3).

The spectrophotometer was checked on each day of use with known standard solutions and a filter set provided by the manufacturer. Results are recorded in the lab record book.

3.2.2 Radiometer Laboratory pH Meter Details

For use in the laboratory a Radiometer PHM 220 pH meter is used, (Cal 067). This is fully integrated into the lab quality system including monthly and daily cross checks, LEAPS external proficiency and calibration routines, (see lab UKAS documentation).

Full uncertainty data is available for this meter, (see record 4.5.2 of the Measurement of Uncertainty Manual in the UKAS records). The maximum uncertainty is at pH 10.00 being 0.066 at k=2. The standard uncertainty being 0.033 pH units.

Instructions for the meter were followed as outlined in the in-house method, (see appendix B).

The YSI 6600 V2 sonde in the field was used as the primary SRM for field test pH samples, (this instrument is already MCERTS certified for pH).

3.2.3 Laboratory Dissolved Oxygen Measurement and Calibration

Laboratory calibration and checks of instruments are carried out in an aerated water bath filled with distilled water which is continuously bubbled via an air stone connected to an aquarium pump.

UKAS uncertainty data and methods for chemically deriving Oxygen values via Winkler titrations are available from in-house methods and can be found in appendix B. Winkler values from samples collected in the field were used to compare results of the Pro series at various points throughout the field test. However these were not carried out for all of the paired readings. The YSI 6600 V2 sonde in the field was used as the primary SRM, (this instrument is already certified under MCERTS for DO).

N.B. There is a 3.12% uncertainty of measurement error associated with the Winkler method, (see SOP 5.4.6 for uncertainty data for DO%). This was applied if necessary and indicated where in the text.

3.2.4 Radiometer Laboratory Conductivity Meter Details

For use in the UKAS laboratory a Radiometer CDM 230 Conductivity meter is used, (Cal 069). This is fully integrated into the lab quality system including monthly and daily cross checks, Leaps external proficiency and calibration routines, (see UKAS documentation).

Full uncertainty data is available for this meter, (see record 4.5.2 of the Measurement of Uncertainty Manual in the UKAS records). The uncertainty value reported by the lab is ± 1.7%

of reading with an error of 0.5% of span. This was applied if necessary and indicated where in the text.

Instructions for the meter were followed as outlined in the in-house method, (see Appendix B).

The YSI 6600 V2 sonde in the field was used as an additional SRM for conductivity.

3.2.5 Laboratory Temperature Device Details

For temperature SRM readings a suitable meter was not available in the lab and it was decided that accurate temperature readings could only be taken like for like in the field at the same time and using the same test solution.

Although not certified under MCERTS the temperature sensor on the YSI 6600 V2 sonde in the field was used for SRM readings. As an additional source of readings a handheld fluke 51 K/J thermometer was also used to compare readings in the field, (ref Cal 038).

3.2.6 Additional Equipment

Additional equipment included basic laboratory glassware and consumables as highlighted in the methodology, (see Appendix B). Other equipment used was the lab stop clocks for the response time tests. Although in some cases the instruments internal data logger was used (this will be indicated in the text).

3.3 Method

Testing for the field study was carried out exactly as outlined in the relevant sections of the standard along with the Test Programme TP-07.

Error under Field conditions was calculated for each parameter under test by taking a minimum of 24 samples and comparing readings to that of a SRM, (details of which can be found in section 3.2 above).

Response time for each parameter under test was calculated over six runs at both the start and end of the study.

All maintenance activities over the course of the study, scheduled or otherwise, were recorded and reported.

In addition 120 samples in total over the course of the study were taken, (usually from batches of logged readings). The results can be seen in Appendix A.

3.4 Maintenance

The test instrument itself required no specific maintenance or remedial actions other than those recommended in its instruction manual. This included storing and cleaning it after use in the correct fashion along with calibrating and checking sensors when necessary.

The SRM instruments described in section 3.2 are all subject to their own maintenance and calibration schedules which can be found in the relevant lab record files. All instruments were maintained to UKAS laboratory standards.

The YSI 6600 V2 sonde and HYDROSAM system was maintained and kept in a functional state as outlined in section 2.4 of this report.

The Pro series itself was always ready for testing in the field apart from the times it was not available for lab testing, (see the dates and reasons in the accompanying lab report TR-04). Testing was not carried out when the monitoring station was being cleaned or the duty pumps switched off or over. It was also not possible to take test readings while the 6600 V2 sonde was offline and back at the lab, (as part of its own calibration and maintenance routine).

Being a PWM the Pro series was only under field test conditions while it was onsite, turned on and exposed to field test solutions.

3.5 Summary of test Results:

For each parameter the field test should provide the information required in table 4 in section 4.4 of the PWM standard. In summary:

Period of Operation; Shall consist of at least 120 measurements taken over a period of at least 3 months.

Error; A minimum of 24 reference measurements shall be taken. In at least 90% of these the error shall be less than or equal to the combined performance characteristic. For Temperature this is 0.3 ºC, pH 0.3 units, DO 6% of reading, Conductivity 1.5% of span, and TAN 12% of reading.

Response Time; Measured at the beginning and end of the trial.

Maintenance; All activities reported. See section 7.5 of the standard for details.

All raw data for the field study results for each parameter under test along with the TAN and Galvanic DO data not put forward for certification can be found in Appendix A.

3.5.1 Temperature Results

Period of Operation

For 120 measurements over the course of the study please refer to the logged data files in Appendix A.

Error

Over the course of the study 31 paired readings were taken, (see table 1 below). Results were compared to the 6600 V2 sonde at Westy and the temperature Fluke (Cal 038) onsite.

It can be seen from the table that over the course of the study 100% of the readings were within MCERTS tolerance limits.

See 3.6.1 for graphical presentation of paired readings

Table 1 Temperature Error Results

Sample	Date	Time	YSI pro series	Fluke (Cal 038)	Difference	Aceptable Tolerance (0.3ºC)	YSI V2 Sonde reading	Difference	Aceptable Tolerance (0.3ºC)
1	22.10.09	14:20	12.2	12.3	0.1	Y	12.25	0.05	Y
2	26.10.09	14:45	13.1	13.1	0	Y	13.09	0.01	Y
3	27.10.09	14:02	12.9	13	0.1	Y	12.95	0.05	Y
4	30.10.09	15:02	13.2	13.3	0.1	Y	13.21	0.09	Y
5	02.11.09	15:32	12.5	12.7	0.2	Y	12.65	0.05	Y
6	03.11.09	10:47	11.8	11.9	0.1	Y	11.9	0	Y
7	27.11.09	11:00	8.8	8.8	0	Y	8.81	0.01	Y
8	30.11.09	14:30	7.9	8.1	0.2	Y	7.91	0.19	Y
9	01.12.09	15:17	7.2	7.3	0.1	Y	7.19	0.11	Y
10	04.12.09	15:02	7.7	7.9	0.2	Y	7.7	0.2	Y
11	08.12.09	15:00	8.4	8.67	0.27	Y	8.4	0.27	Y
12	10.12.09	14:47	8.5	8.6	0.1	Y	8.53	0.07	Y
13	11.12.09	10:00	8.3	8.4	0.1	Y	8.29	0.11	Y
14	16.12.09	11:45	7.5	7.7	0.2	Y	7.61	0.09	Y
15	13.01.10	12:00	3.7	3.8	0.1	Y	4.06	0.26	Y
16	19.01.10	15:00	5.3	5.4	0.1	Y	5.44	0.04	Y
17	22.01.10	15:30	5.9	6.1	0.2	Y	6.01	0.09	Y
18	26.01.10	15:45	5.8	5.8	0	Y	5.82	0.02	Y
19	28.01.10	15:02	5.8	5.8	0	Y	5.81	0.01	Y
20	04.02.10	15:32	4.5	4.3	0.2	Y	4.55	0.25	Y
21	10.02.10	14:30	5.5	5.7	0.2	Y	5.58	0.12	Y
22	11.02.10	14:17	5	5.1	0.1	Y	5.01	0.09	Y
23	22.02.10	14:47	5.1	5.2	0.1	Y	5.09	0.11	Y
24	24.03.10	11:17	9.5	9.6	0.1	Y	9.46	0.14	Y
25	29.03.10	12:10	9.6	9.6	0	Y	9.57	0.03	Y
26	30.03.10	13:02	9.6	9.6	0	Y	9.56	0.04	Y
27	01.04.10	11:02	8	8	0	Y	7.99	0.01	Y
28	07.04.10	14:47	9.3	9.4	0.1	Y	9.3	0.1	Y
29	08.04.10	14:20	9.8	9.9	0.1	Y	9.81	0.09	Y
30	12.04.10	14:30	11.2	11.3	0.1	Y	11.16	0.14	Y
31	15.04.10	14:47	11.5	11.5	0	Y	11.5	0	Y
Percentage acceptable						**100**			**100**

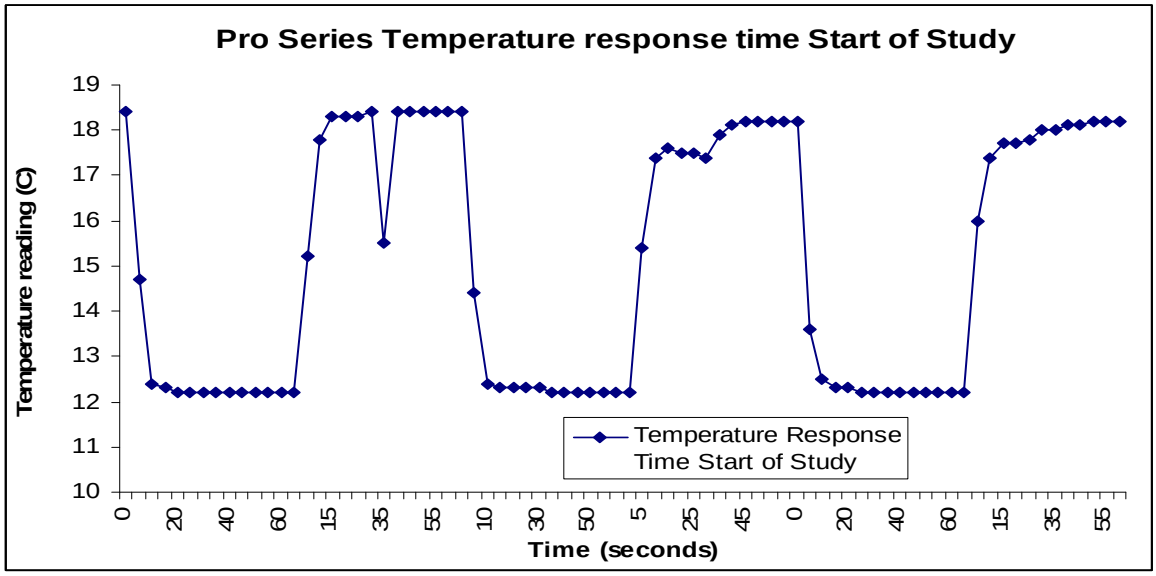
Response Time

At the start of the study the test solutions used were river water onsite for the low range readings, (12.2ºC), and water brought from the lab for high range, (18.4ºC).

The response time at the start of the study was found to be on average 10 seconds over the six runs, (10 seconds for low to high range and vice versa).

N.B This test was carried out using a stop clock and results recorded visually from the instrument display.

Figure 1 Temperature response time at start of study.

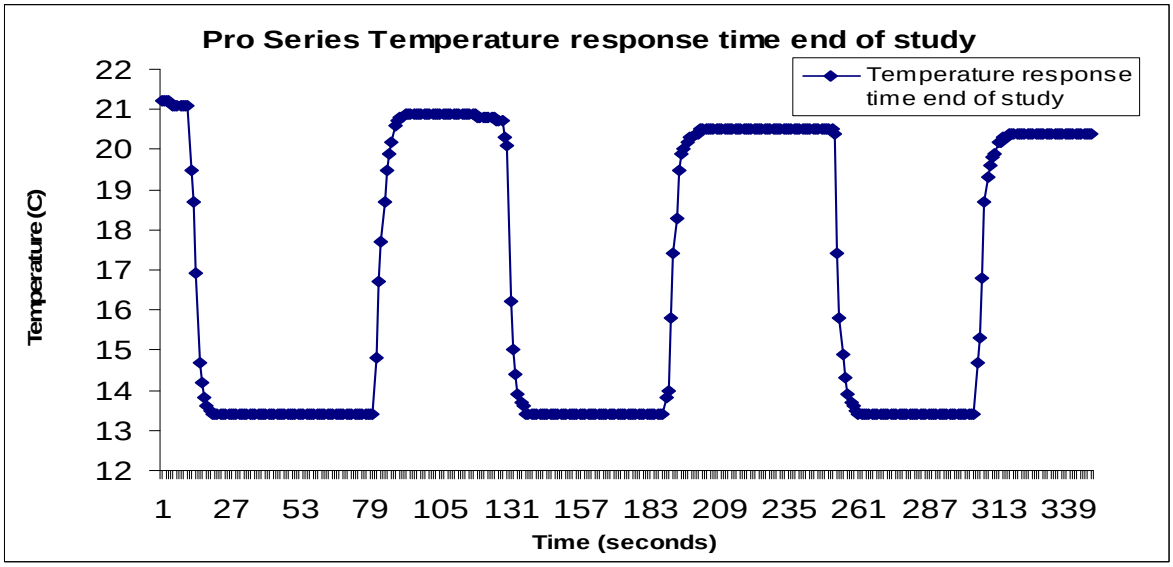


At the end of the study the test solutions used were again river water onsite for the low range readings, (12.4ºC), and water brought from the lab for high range, (21.0ºC).

The response time at the end of the study was found to be on average 4.8 seconds over the six runs, (4.3 seconds for low to high range and 5.3 for high to low).

N.B This test was carried out using the instruments internal data logger.

Figure 2 Temperature response time at end of study.



Maintenance

For the duration of the study the temperature sensor functioned as intended and was stored and used as per the manufacturers instructions. No problems were evident and apart from initial checks as part of the laboratory testing of the instrument, (see report TR-04), no calibrations or further QC checks were made.

3.5.2 Conductivity Results

Period of Operation

For 120 measurements over the course of the study please refer to the logged data files in Appendix A.

Error

Over the course of the study 28 paired readings were taken, (see table 2 below). Results were compared to the 6600 V2 sonde at Westy and the laboratory conductivity meter (Cal 069).

It can be seen from the table that over the course of the study 100% of the readings were within MCERTS tolerance limits.

See 3.6.3 for graphical presentation of paired readings

Table 2 Conductivity Error Results

Sample	Date	Time	YSI pro series	Lab Reading	Difference	% Error of span (0-50000)	Acceptable (Tolerance 1.5% span)	YSI V2 Sonde Reading	% Error of span (0-50000)	Acceptable (Tolerance 1.5% span)
1	22.10.09	14:20	593.2	607	13.8	0.03	Y	594	0.026	Y
2	26.10.09	14:45	626.9	638	11.1	0.02	Y	627	0.022	Y
3	27.10.09	14:02	613.4	645	31.6	0.06	Y	614	0.062	Y
4	30.10.09	14:02	540.3	544	3.7	0.01	Y	541	0.006	Y
5	02.11.09	15:32	361.3	361	0.3	0.00	Y	361	0	Y
6	03.11.09	10:47	293.8	295.5	0.17	0.00	Y	294	0.0004	Y
7	27.11.09	11:00	283.4	285	1.6	0.00	Y	285	0	Y
8	30.11.09	14:30	276.1	282.2	6.1	0.01	Y	278	0.0084	Y
9	01.12.09	15:17	285	287.7	2.7	0.01	Y	287	0.0014	Y
10	04.12.09	15:02	403.3	405.8	2.5	0.01	Y	406	0.0004	Y
11	08.12.09	15:00	314.8	317.5	2.7	0.01	Y	316	0.003	Y
12	10.12.09	14:47	358	361.6	3.6	0.01	Y	361	0.0012	Y
13	11.12.09	10:00	384.9	385.3	0.4	0.00	Y	388	0.0054	Y
14	16.12.09	11:45	467.6	476	8.4	0.02	Y	471	0.01	Y
15	13.01.10	12:00	797.1	806	8.9	0.02	Y	806	0	Y
16	19.01.10	15:00	405.9	403.1	2.8	0.01	Y	413	0.0198	Y
17	22.01.10	15:30	451.6	451.5	0.1	0.00	Y	456	0.009	Y
18	26.01.10	15:45	422.6	426.3	3.7	0.01	Y	426	0.0006	Y
19	28.01.10	15:02	460	462.4	2.4	0.00	Y	465	0.0052	Y
20	04.02.10	15:32	512	507.8	4.2	0.01	Y	516	0.0164	Y
21	11.02.10	14:17	533.8	546	12.2	0.02	Y	539	0.014	Y
22	22.02.10	14:47	644	657	13	0.03	Y	649	0.016	Y
23	24.03.10	11:17	608.4	619	10.6	0.02	Y	586	0.066	Y
24	29.03.10	12:10	462.6	474	11.4	0.02	Y	439	0.07	Y
25	30.03.10	13:02	455.9	448.9	7	0.01	Y	437	0.0238	Y
26	01.04.10	11:02	372.1	368	4.1	0.01	Y	359	0.018	Y
27	07.04.10	14:47	459.9	455.9	4	0.01	Y	443	0.0258	Y
28	08.04.10	14:20	471.4	468	3.4	0.01	Y	455	0.026	Y
Percentage compliance							**100.0**			**100.0**

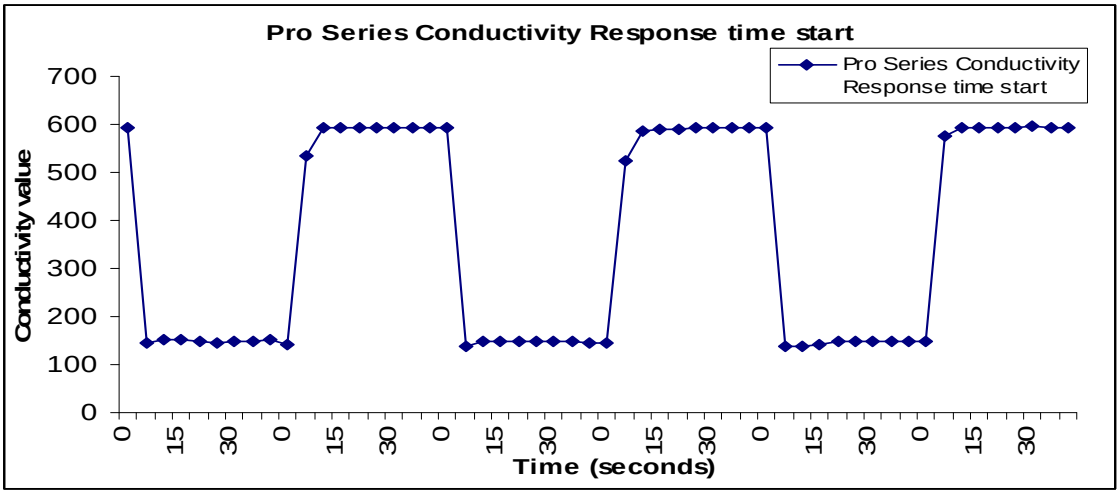
Response Time

At the start of the study the test solutions used were river water onsite for the High range readings, (594 µS/cm), and standard brought from the lab for low range, (145 µS/cm).

The response time at the start of the study was found to be on average 5.83 seconds over the six runs, (6.7 seconds for low to high range and 5.0 for high to low).

N.B This test was carried out using a stop clock and results recorded visually from the display.

Figure 3 Conductivity response time at start of study.

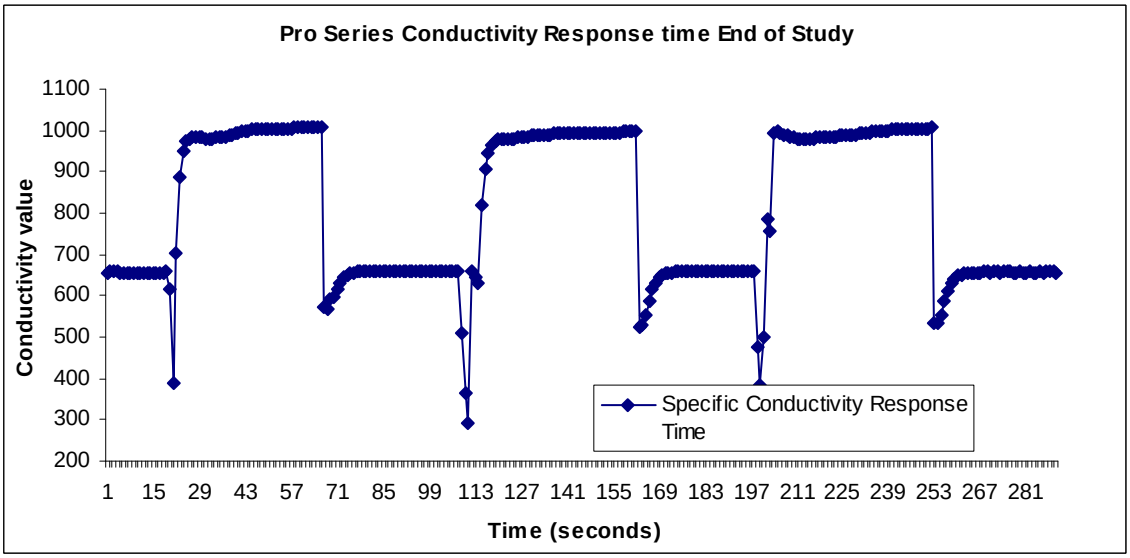


At the end of the study the test solutions used were river water onsite for the high range readings this time, (658 µS/cm), and a 1000 µS/cm standard brought from the lab for low range, (1005 µS/cm ref CS1M9F01).

The response time at the end of the study was found to be on average 5.5 seconds over the six runs, (6.3 seconds for low to high range and 4.7 for high to low).

N.B This test was carried out using the instruments internal data logger.

Figure 4 Conductivity response time at end of study.



Maintenance

For the duration of the study the conductivity sensor functioned as intended and was stored and used as per the manufacturers instructions. No problems were evident and calibration and QC checks were only carried out on the instrument as part of the testing in the laboratory as outlined in the test programme TP-07. Details can be found in the lab record book.

3.5.3 pH Results

Period of Operation

For 120 measurements over the course of the study please refer to the logged data files in Appendix A.

Error

Over the course of the study 32 paired readings were taken and compared to the 6600 V2 sonde at Westy and 31 to the laboratory pH meter (Cal 067). See table 3 below for the summary of results.

It can be seen from the table that over the course of the study that 96.9% of the readings were within MCERTS tolerance limits using the lab pH meter with 87.5% when compared to the 6600 V2.

See 3.6.2 for graphical presentation of paired readings

Table 3 pH Error Results

Sample	Date	Time	pH YSI pro series	YSI V2 sonde reading	Error	Aceptable Tolerance (0.3 units)	Lab reading	Error	Aceptable Tolerance (0.3 units)
1	22.10.09	14:20	7.29	7.24	0.05	Y	7.35	0.06	Y
2	26.10.09	14:45	7.24	7.25	0.01	Y	7.22	0.02	Y
3	27.10.09	14:02	7.25	7.23	0.02	Y	7.28	0.03	Y
4	30.10.09	14:02	7.27	7.28	0.01	Y	7.3	0.03	Y
5	02.11.09	15:32	7.29	7.35	0.05	Y	7.3	0	Y
6	03.11.09	10:47	7.33	7.28	0.05	Y	7.26	0.07	Y
7	27.11.09	11:00	7.45	7.43	0.02	Y	7.55	0.1	Y
8	30.11.09	14:30	7.73	7.38	0.35	N	7.67	0.06	Y
9	01.12.09	15:17	7.52	7.42	0.1	Y	7.65	0.13	Y
10	04.12.09	15:02	7.39	7.36	0.03	Y	7.59	0.2	Y
11	08.12.09	15:00	7.53	7.4	0.13	Y	7.55	0.02	Y
12	10.12.09	14:47	7.51	7.41	0.1	Y	7.53	0.02	Y
13	11.12.09	10:00	7.49	7.38	0.11	Y	7.48	0.01	Y
14	16.12.09	11:45	7.53	7.21	0.32	N	7.55	0.02	Y
15	13.01.10	12:00	7.93	7.51	0.42	N	7.46	0.47	N
16	19.01.10	15:00	7.29	7.11	0.18	Y	7.39	0.1	Y
17	22.01.10	15:30	7.29	7.27	0.02	Y	7.35	0.06	Y
18	26.01.10	15:45	7.38	7.3	0.08	Y	7.34	0.04	Y
19	28.01.10	15:02	7.36	7.35	0.01	Y	7.38	0.02	Y
20	04.02.10	15:32	7.48	7.36	0.12	Y	7.45	0.03	Y
21	09.02.10	14:30	7.37	7.4	0.03	Y	n/a	n/a	Y
22	11.02.10	14:17	7.48	7.38	0.1	Y	7.43	0.05	Y
23	22.02.10	14:47	7.6	7.42	0.18	Y	7.41	0.19	Y
24	24.03.10	11:17	7.19	7.13	0.06	Y	7.37	0.18	Y
25	29.03.10	12:10	7.52	7.15	0.37	N	7.47	0.05	Y
26	30.03.10	13:02	7.27	7.21	0.06	Y	7.47	0.2	Y
27	01.04.10	11:02	7.35	7.23	0.12	Y	7.5	0.15	Y
28	07.04.10	14:47	7.35	7.14	0.21	Y	7.57	0.22	Y
29	08.04.10	14:20	7.32	7.26	0.06	Y	7.33	0.01	Y
30	12.04.10	14:30	7.26	7.15	0.11	Y	7.47	0.21	Y
31	15.04.10	14:45	7.36	7.17	0.19	Y	7.41	0.05	Y
32	28.04.10	13:15	7.3	7.15	0.15	Y	7.46	0.16	Y
32	29.04.10	14:17	7.31	7.08	0.23	Y	7.39	0.08	Y
Percentage compliance					**87.5**			**96.9**	

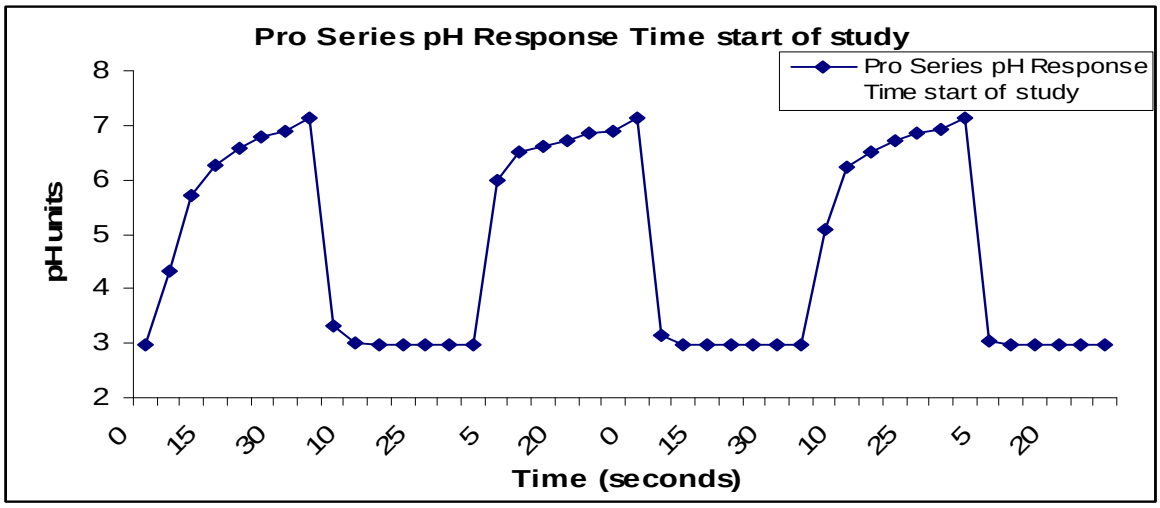
Response Time

At the start of the study the test solutions used were both standards brought from the lab. High range being 7.15 and low range 3.00 pH units.

The response time at the start of the study was found to be on average 10 seconds over the six runs, (15 seconds for low to high range and 5 seconds for high to low).

N.B This test was carried out using a stop clock and results recorded visually from the display.

Figure 5 pH Response time at start of study.

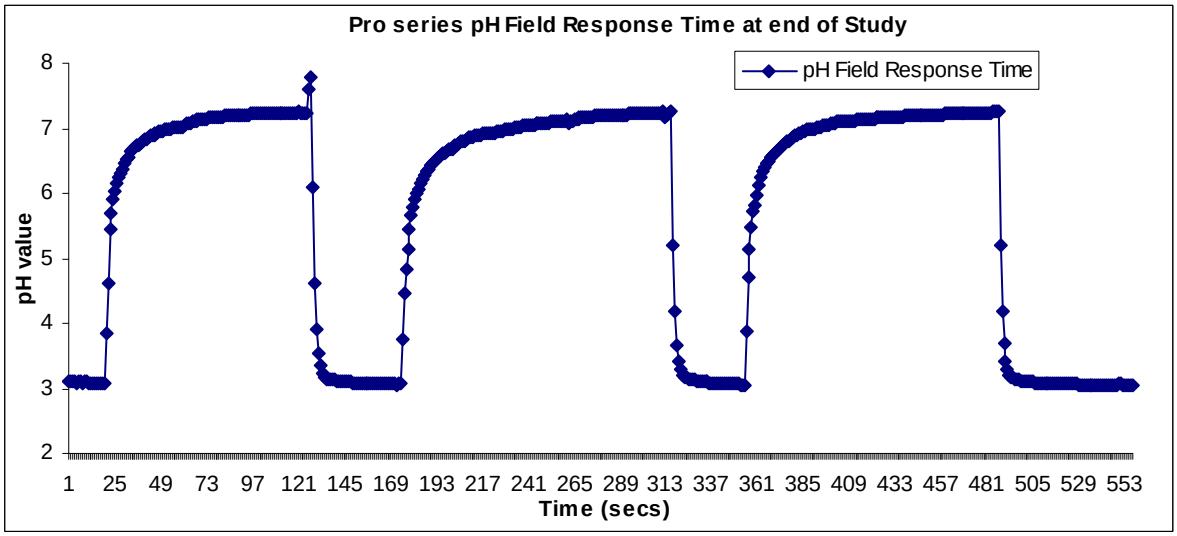


At the start of the study the test solutions used were again both standards brought from the lab. High range being 7.30 and low range 3.00 pH units.

The response time at the end of the study was found to be on average 13.2 seconds over the six runs, (18.3 seconds for low to high range and 8.0 for high to low).

N.B This test was carried out using the instruments internal data logger.

Figure 6 pH Response time at end of study.



Maintenance

For the duration of the study the pH sensor functioned as intended and was stored and used as per the manufacturers instructions. No problems were evident and calibration and QC checks were only carried out on the instrument as part of the testing in the laboratory as outlined in the test programme TP-07. Details can be found in the lab record book.

3.5.4 Dissolved Oxygen Results

N.B. At the start of the study the sensor under test was a galvanic DO one. However after 18 samples in the field the client decided to discontinue both field and lab testing on this sensor, (see project file and lab record book for the details). A polarographic DO sensor was used to replace the galvanic one and field testing on this carried out from the 15th of April 2010. All data in this report is from the polarographic sensor. Galvanic results can be seen for reference purposes in Appendix A.

Period of Operation

For 120 measurements over the course of the study please refer to the logged data files in Appendix A.

Error

Over the course of the study 24 paired readings were taken and compared to the 6600 V2 sonde at Westy and 6 to the laboratory winkler method. See table 4 below for the summary of results.

It can be seen from the table that over the course of the study that 100% of the readings were within MCERTS tolerance limits using the lab winkler method with 100% also within tolerance when compared to the 6600 V2.

See 3.6.5 for graphical presentation of paired readings

Table 4 Polarographic DO Error Results

Sample	Date	Time	Pro Series DO Reading	YSI V2 Sonde Reading	Difference	% Error Reading between sensors	Acceptable Tolerance (<6% reading)	Winkler result	% Error Reading (Winkler)	Acceptable Tolerance (<6% reading
1	15.04.10	14:47	82.1	80.9	1.2	1.46	Y			
2	21.04.10	10:45	73.8	71.1	2.7	3.66	Y			
3	28.04.10	13:15	74	71	3	4.05	Y			
4	29.04.10	14:17	69	66.7	2.3	3.33	Y			
5	06.05.10	14:48	71.3	68.7	2.6	3.65	Y			
6	21.05.10	14:15	81.3	79.5	1.8	2.21	Y			
7	28.05.10	14:38	73.5	73	0.5	0.68	Y			
8	07.06.10	13:15	79.8	80.7	-0.9	-1.13	Y	78.5	1.63	Y
9	11.06.10	13:45	66.7	66.6	0.1	0.15	Y			
10	18.06.10	11:20	66.7	67.5	-0.8	-1.20	Y	65.4	1.95	Y
11	24.06.10	14:30	74.7	75.5	-0.8	-1.07	Y			
12	25.06.10	14:45	79.1	79.4	-0.3	-0.38	Y			
13	29.06.10	14:45	75.7	74.7	1	1.32	Y			
14	09.07.10	14:15	71.8	69.6	2.2	3.06	Y			
15	12.07.10	13:15	62.6	61.2	1.4	2.24	Y	61.3	2.08	Y
16	13.07.10	13:30	67.4	68.5	-1.1	-1.63	Y			
17	26.07.10	15:02	65.9	67.8	-1.9	-2.88	Y	64.2	2.58	Y
18	28.07.10	15:32	71.5	72.3	-0.8	-1.12	Y			
19	30.07.10	15:00	71.8	73.1	-1.3	-18.1	Y			
20	02.08.10	13:32	69.2	70.6	-1.4	-2.02	Y			
21	05.08.10	15:17	78.1	79	-0.9	-1.15	Y			
22	12.08.10	14:47	74.5	76.9	-2.4	-3.22	Y			
23	16.08.10	14:15	79.6	82.2	-2.6	-3.27	Y			
24	24.08.10	15:00	73.5	75	-1.5	-2.04	Y			
25	25.08.10	15:02	81.9	82.3	-0.4	-0.49	Y			
Percentage compliance							**100**			**100**

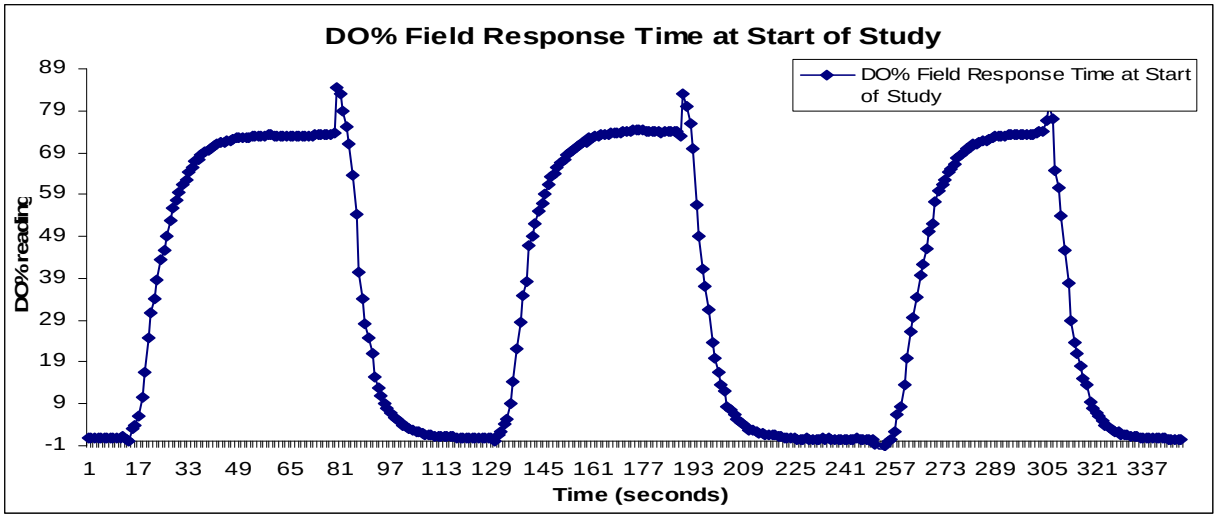
Response Time

At the start of the study the test solutions used were Westy river water for the high range solution at 74%, and laboratory prepared low DO solution (ref 4113) at <10% for the low range.

The response time at the start of the study was found to be on average 19.8 seconds over the six runs, (24 seconds for low to high range and 15.7 seconds for high to low).

N.B This test was carried out using the instruments internal data logger.

Figure 7 DO% Response time at start of study.

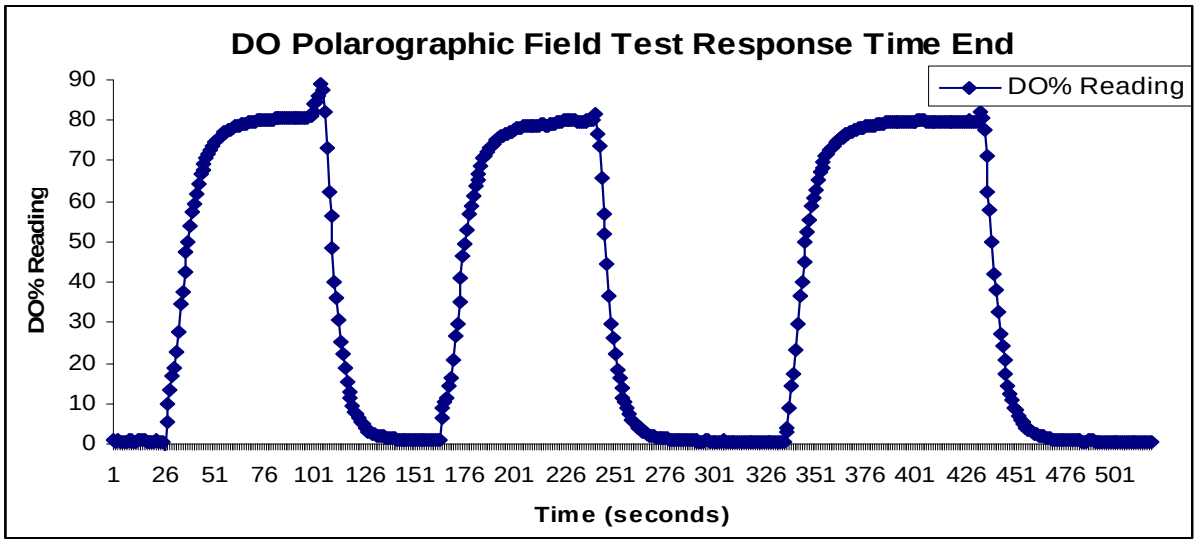


At the end of the study the test solutions used were Westy river water for the high range solution at 81.9%, and laboratory prepared low DO solution (ref 4147) at <10% for the low range.

The response time at the start of the study was found to be on average 22.2 seconds over the six runs, (25.7 seconds for low to high range and 18.7 seconds for high to low).

N.B This test was carried out using the instruments internal data logger.

Figure 8 DO Response time at end of study.



Maintenance

See the notes earlier about the galvanic DO sensor being replaced with a polarographic one.

For the duration of the study the polarographic sensor functioned as intended and was stored and used as per the manufacturers instructions. No problems were evident and calibration and QC checks were only carried out on the instrument as part of the testing in the laboratory as outlined in the test programme TP-07. Details can be found in the lab record book.

Before readings were taken in the field the sensor was exposed to oxygen saturated air in its calibration cup and allowed to stabilise, (usually around 100%), for several minutes. This was carried out according to its instructions and helps provide more accurate readings.

3.5.5 Total Ammoniacal Nitrogen (TAN) Results

Period of Operation

For measurements over the course of the study please refer to the logged data files in Appendix A.

Error

Until testing was stopped, (at the request of the client), 9 paired readings were taken and compared to the 6600 V2 sonde at Westy and to the laboratory spectrophotometer (Test 16). See table 5 below for the summary of results.

It can be seen from the table that over the course of the study that 22.2% of the readings were within MCERTS tolerance limits using the lab spectrophotometer with 0% when compared to the 6600 V2.

See 3.6.4 for graphical presentation of paired readings

Table 5 Total Ammoniacal Nitrogen (TAN) Error Results

Sample	Date	Time	YSI Pro Series (mg/l)	Lab Reading Test 16 (mg/l)	Difference (mg/l)	% Error of reading	Acceptable Tolerance (12%)	YSI V2 Sonde Reading (mg/l)	Difference (mg/l)	% Error of reading V2
1	22.10.09	14:20	0.98	1.01	0.03	3.06	Y	3.619	2.64	269.29
2	26.10.09	14:45	1.14	0.993	0.147	12.89	N	3.629	2.49	218.33
3	27.10.09	14:02	1.08	0.919	0.161	14.91	N	3.643	2.56	237.31
4	30.10.09	14:02	0.85	0.656	0.194	22.82	N	3.453	2.60	306.24
5	02.11.09	15:32	0.58	0.616	0.036	6.21	Y	3.111	2.53	436.38
6	03.11.09	10:47	0.53	0.744	0.214	40.38	N	3.357	2.83	533.40
7	27.11.09	11:00	0.39	0.545	0.155	39.74	N	n/a	n/a	n/a
8	30.11.09	14:30	0.43	0.399	0.031	7.21	N	3.716	3.29	764.19
9	01.12.09	15:17	0.68	0.32	0.36	52.94	N	3.781	3.10	456.03

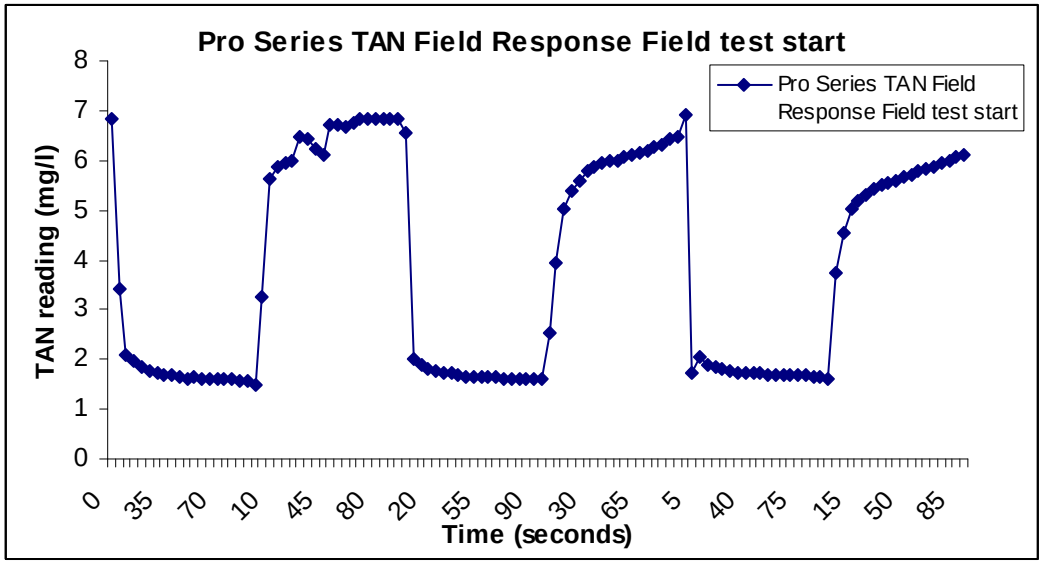
Response Time

At the start of the study the test solutions used were Westy river water for the low range solution at 1.6mg/l, and laboratory prepared standard at 6.85mg/l for the high range.

The response time at the start of the study was found to be on average 46.7 seconds over the six runs, (65 seconds for low to high range and 28.3 seconds for high to low).

N.B This test was carried out using a stop clock and results recorded visually from the display.

Figure 9 TAN Response time at start of study.



The testing had stopped so there is no response time data for the end of the study.

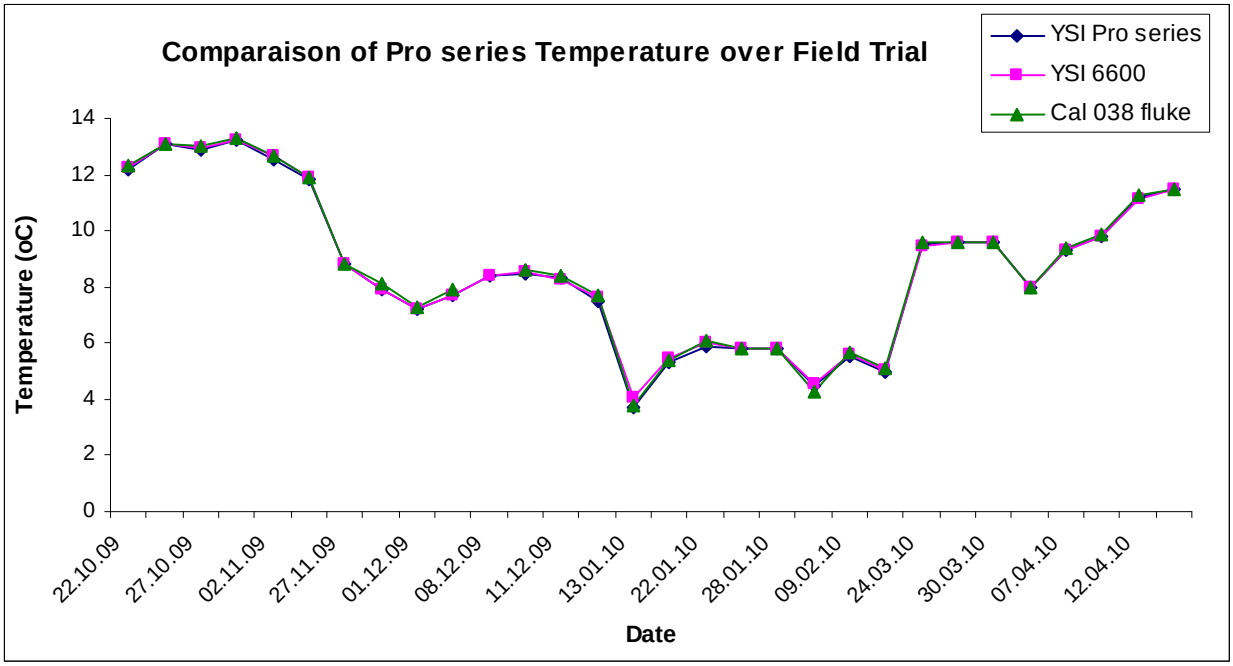
Maintenance

For the duration of this shortened study the TAN sensor functioned as intended and was stored and used as per the manufacturers instructions. No problems were evident and calibration and QC checks were only carried out on the instrument as part of the testing in the laboratory as outlined in the test programme TP-07. Details can be found in the lab record book.

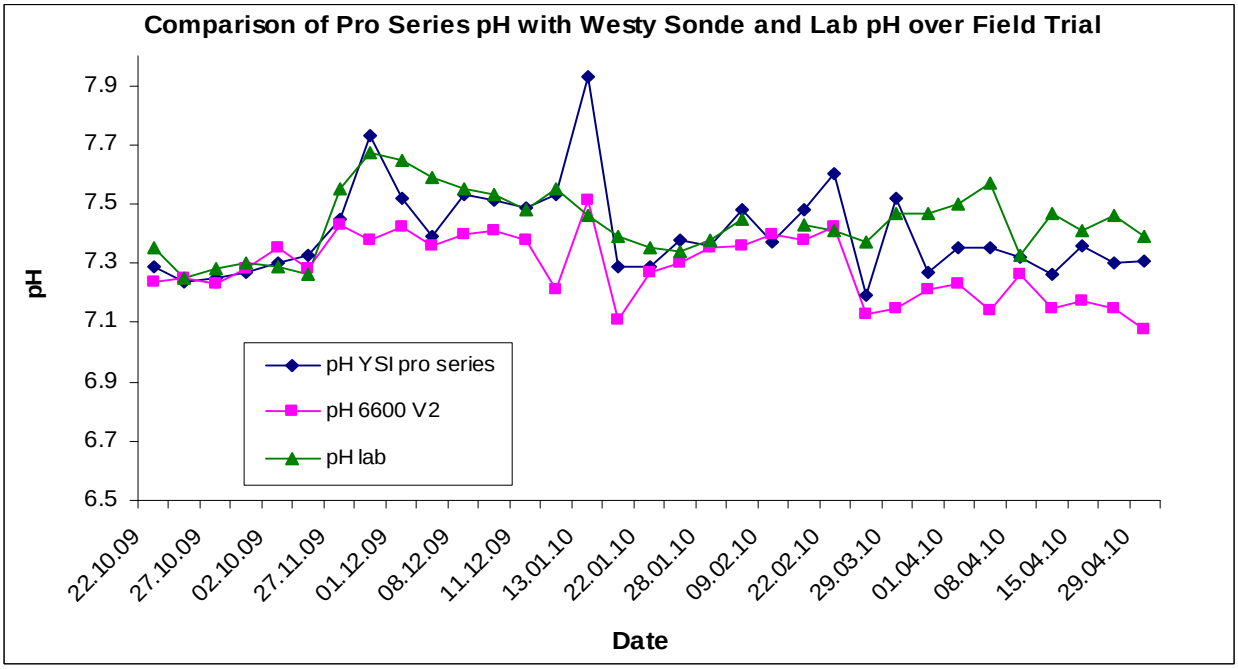
TAN data is presented in this report, but has not been put forward for MCERTS certification. Raw data can be found in Appendix A.

3.6 Graphical presentation of results

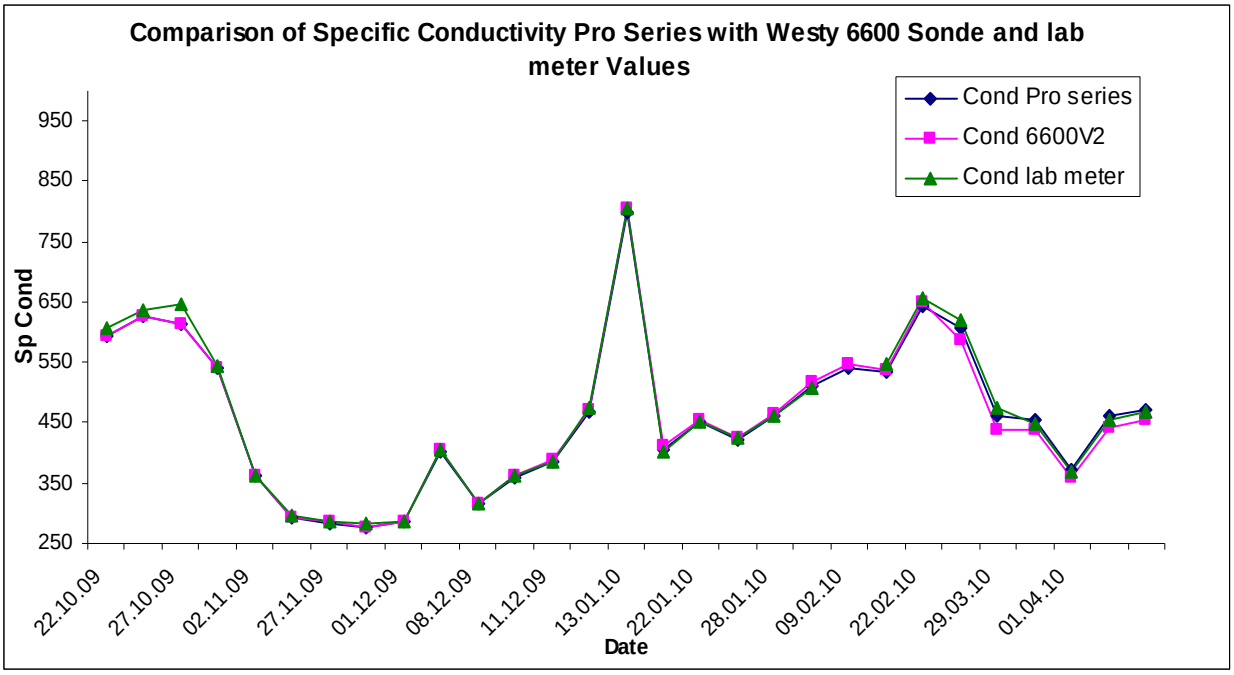
3.6.1 Paired Readings for Temperature



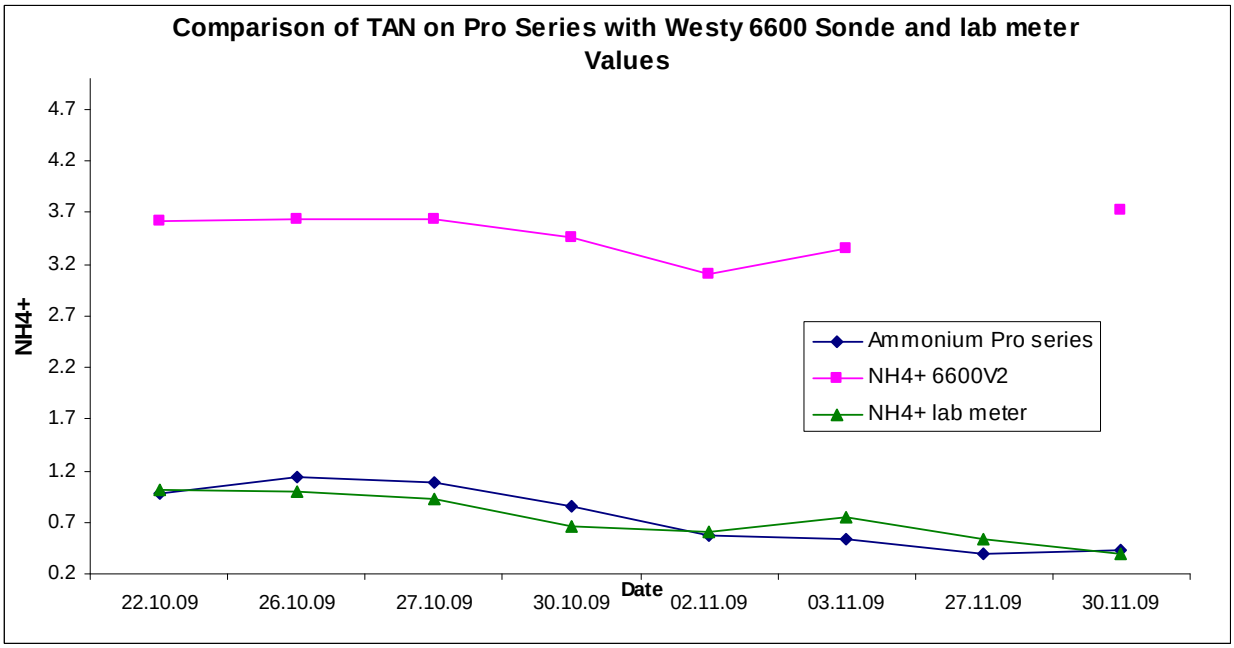
3.6.2 Paired Readings for pH



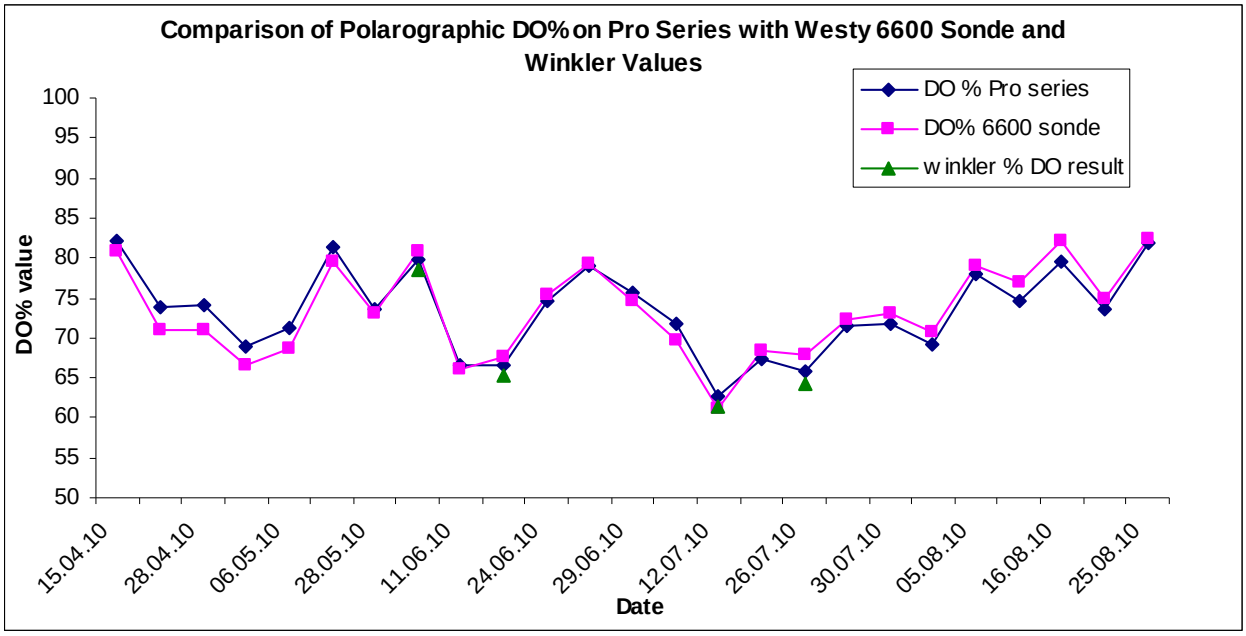
3.6.3 Paired Readings for Specific Conductivity.



3.6.4 Paired Readings for TAN



3.6.5 Paired Readings for Polarographic Dissolved Oxygen



Appendices

Appendix A: Raw data from the tests see accompanying disk

Appendix B: Operating instructions

1.	Professional Series Manual	See Disk
2.	Radiometer PHM220 pH Meter Lab SOP 7.3/C1	See Disk
3.	DO by Titrimetry 7.3/D5 Laboratory Method	See Disk
4.	Hach Laboratory Spectrophotometer Manual SOP 5.4 B9	See Disk
5.	Radiometer Conductivity Meter Manual SOP 5.4 B10	See Disk
6.	Calibration of YSI 6 Series Sonde Lab SOP 7.3/A3	See Disk

Laboratory Test Report

YSI HYDRODATA LTD Professional Series Instrument

Quatro four port cable configuration

Test Report Reference: TR-04

Project Reference: EA-MCERTS-11

Published by The Environment Agency, Date: September 2010
Issue No: V1

Document Reference: N:\UKAS\mcerts\issued\5.10\TR-04 V1 .doc

Professional Series
Type Quatro four port cable configuration
Serial no: 09D101346

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TABLES

GRAPHS

FIGURES / PICTURES

Appendices .....

i) Document History

Issue No	Summary of Changes	Author	Issue Date
Draft	Draft for review and approval	PG	May 2010
V2 Draft	Draft for review and approval to ver 2.1 of MCERTS standard	MW	Aug 2010
V1	Issued	PG	Sept 2010

ii) Normative References

2.1 References

- ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories.

- MCERTS guides and standards, including:
  - Performance Standards and Test Procedures of Portable Water Monitoring Equipment

- Instrument specific instruction Manual

- Blue book methods for the measurement of pH, Conductivity, 'Measurement of Electrical Conductivity and Laboratory Determination of pH' 1978 ISBN 0 11751428 4 and DO 'Dissolved Oxygen in natural and waste waters' 1979 ISBN 0 11 751442x.

- Standard Methods for the Examination of Water & Waste Waters 15th Edition 1980

- Test programme TP-07 Project No: EA-MCERTS-11

2.2 Abbreviations

PWM	Portable Water Monitor
MCERTS	Monitoring Certification Scheme
SRM	Secondary Reference Measurement
TAN	Total Ammoniacal Nitrogen
DO	Dissolved oxygen

iii) Introduction

Name of Test Organisation:	The Environment Agency
Address:	Richard Fairclough House Knutsford Road Warrington WA4 1HG
Report type:	Laboratory
PWM tested:	Make: YSI Model: Professional Series. Quatro Four Port Cable Configuration Serial No: 09D101346
Type of PWM:	Multi-parameter, (pH, DO, Temperature and Conductivity)
Details of any ancillary equipment:	USB connector pack for attachment to PC for charging and use of YSI software.
Condition of Equipment on delivery:	Fully functional
Manufacturer:	YSI Hydrodata
Sponsor:	YSI Hydrodata
Test period (DD/MM/YYYY):	from: 16/06/09 to: July 10
Testing carried out according to	MCERTS Test programme TP-07 MCERTS Standard: Portable Water Monitoring Equipment Version 2.1 2010
Date of report:	September 2010
Report No:	TR-04
Scope of report:	Full Laboratory MCERTS testing to provide performance data both individually and combined for pH, Dissolved oxygen (Polarographic), Temperature and Conductivity. TAN also carried out but not submitted for certification.

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Certified M.L.

This report only relates to the item(s) tested.

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1. Synopsis with proposed scope of certification

1.1 Summary of test results for a summary of all test results see the tables in section 6.5 and 1.3.

1.2 PWM details

This report describes the evaluation of a YSI Hydrodata handheld Professional Series Quatro instrument with four port cable configuration. The instrument was supplied with 2 C cell type batteries for testing along with a USB connector pack and cable for the back of the instrument. This would enable the instrument to be powered by a PC when acceptable for testing and to use the YSI data manager software.

Test Instrument:
YSI Hydrodata Ltd Professional Series with Quatro Four Port cable configuration.

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The tests were applied to the pH, dissolved oxygen, temperature and conductivity sensors. Tests for Total Ammoniacal Nitrogen (TAN) were also carried out and are included in this report, but have not been submitted for MCERTS certification. These were supplied mounted onto a four port Quatro bulkhead which itself was attached via a cable to the main body of the Professional Series handheld unit.

Test data was taken directly from the instrument display, or from real time data via a connected PC running YSI data capture software. For certain tests the instruments internal data logger would be used and data downloaded from the instrument upon completion. The method of data capture for each test will be highlighted in the appropriate section of this report.

The instrument was supplied in working order by YSI and was calibrated by trained laboratory staff to the satisfaction of the manufacturer. All sensors were calibrated before the start of testing and at various stages throughout when necessary. All calibration details were recorded in the laboratory record book. See appendix B.

The instrument was submitted to Sira Environmental for certification under the UK Environment Agency's Monitoring Certification Scheme (MCERTS). This is an accredited product certification scheme that complies with the requirements of ISO/IEC Guide 65. The MCERTS

certification scheme requires both laboratory and field test data. In addition the MCERTS Scheme requires an instrument manufacturer to demonstrate to Sira Environmetal on an ongoing basis that the manufacturing process for that product is controlled under a quality management system to produce instruments that deliver consistent performance.

The YSI Professional Series of handheld portable instruments are intended for short term independent field deployment in a variety of environments according to specification. The instruments main function is to obtain rapid spot test results. The instrument also has an internal logging facility from which data can be downloaded following a deployment period when batch samples have been logged. See Appendix B for the full instruction manual.

Picture 1 YSI Professional Series handheld instrument with Quatro Four Port Configuration

1.3 Test Summary

Table 1

Parameter / Test	Mean Error	Linearity	Repeatability	Supply Voltage (Battery)	Ambient Temperature	Relative Humidity	Response Time	Warm up Drift	Sample Temperature	Length Battery Operation	Interferents
Dissolved Oxygen (Polarographic sensor)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	*
pH	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-
Conductivity Low Range	✓	✓	✓	-	-	-	-	-	-	-	-
Conductivity High Range	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-
Temperature	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	-
Total Ammoniacal Nitrogen **	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-

Tests marked with a '✓' were completed and are covered by our ISO 17025 accreditation.
Tests marked with a '*' were completed, but are not covered by our ISO 17025 accreditation. They have had the same rigours of the ISO 17025 management system applied.
Tests marked with '–'were not carried out.
*** TAN data not put forward for certification under MCERTS.*

Summary tables in this report give results of the tests and have been compared to the MCERTS standard. The compliance figure is calculated in accordance with the principles laid down in M3003. Compliance or non compliance has only been calculated at the measured points.

2. Task definition

2.1 Nature of the tests

All testing, unless specified, is preliminary testing undertaken for the first time for the purpose of MCERTS certification. Where existing data is available and used in results, or when the testing has been repeated this will be highlighted in the text of the relevant section. Further details can be found in the Test Programme TP-07. It should be noted that the instrument originally came in for additional testing on an ISE Ammonia sensor, which was detailed in TP-07. However, after some of the results reported were analysed the manufacturer wished to not continue with the testing of this sensor. The data for Ammonia will be included in this report, but is not submitted for MCERTS accreditation.

Similarly the instrument was submitted originally for Dissolved Oxygen testing on a Galvanic sensor. This was later changed to a polarographic one on request of the manufacturer (see the project file for further details). This change was updated into the test programme TP-07. However, the tests and their ranges did not change between sensors. All data in this report is for the polarographic sensor.

2.2 Objectives

1) Response Time – DO, pH, Temperature, Conductivity and TAN

2) Accuracy, repeatability and linearity - DO, pH, Temperature, Conductivity (high and low range), and TAN

3) Warm up Drift (2 Hours) - DO, pH, Temperature, Conductivity, and TAN

4) Interference due to Chloride - **DO only**

5) Power Supply – DO, pH, Temperature, Conductivity, and TAN

6) Length of Battery Operation – DO, pH, Temperature, Conductivity, and TAN.

7) Sample Temperature - DO, pH, Conductivity, and TAN

8) Ambient Temperature and Relative Humidity - DO, pH, Temperature, Conductivity**,** and TAN

See test programme TP-07 and the relevant performance standard for more detail.

3. Description of PWM tested

3.1 Measuring principle

See the manufacturer's literature and instruction manual in Appendix B for details on the types of sensors and the measuring principles used for each.

3.2 Measuring system scope and set-up

Refer to page 4 of the manufacturer's manual for the set-up of the Quatro bulkhead. The information on pages 8-10 show how to connect the cable to the main instrument body and the details of operation via the key pad buttons on the front of the instrument below the LED display.. See appendix B of this report for the instruction manual..

4. Test programme

4.1 Laboratory test / laboratory inspection

The test program is based on specifications for the DO, pH, Temperature, Conductivity and Ammonia (TAN) sensors in version 2.0, (but has been amended to reflect the newer version 2.1 (Aug 2010)), of the Environment Agency 'Performance Standards and Test Procedures for Portable Water Monitoring Equipment'.

Testing was carried out according to the outline in the standard and as detailed in the Test programme TP-07, with the exception of the Ammonia sensor as mentioned in section 2.1 of this report. TP-07 also covers testing in a Field Study. See report TR-05 for the findings of this.

5. Methods of reference measurements

This report has been prepared with reference to the test methods, test results and conclusions presented in the following documents:

Test Programme Issue 5 September 2009 ref; TP-07

MCERTS Portable Water Monitoring Equipment Procedures for Conformity testing of On-Line analysers. Version 2.1 Aug 2010

YSI Hydrodata Professional Plus User Manual (lab ref Cal 037)

Radiometer PHM 220 Laboratory pH meter. (refs: Man 032 ID: Cal 067)

Radiometer CDM230 Laboratory Conductivity meter. (refs: Man 023 ID: Cal 069)

Reagecon pH solution certificates of analysis and MSDS.

Reagecon Conductivity solution certificates of analysis and MSDS.

TTI 2 Accurate Temperature Measuring instrument (refs: Cal 032 and Cal 071 for Platinum Resistance Thermometer used. Man 032 and SOP 7.3/B9 for instructions).

ASL F100 PRT Temperature measuring devices (ref Cal 074 and Cal 075)
SOP 5.4 B13 and MAN 029.

DO by Titrimetry 7.3/D5 Laboratory Method.

Operation of Environmental Chamber lab SOP 5.4 B1 and Man 030.

CPX200 TTI Variable Power Supply lab SOP 5.4 B2 and Test 08 / Man 033.

pH Measurement checks 7.3/C1 Laboratory method

Conductivity Measurement checks 7.3/C2 Laboratory method

Laboratory MCERTS Uncertainty of Measurement Manual 5.4.6

Laboratory Reagent Preparation Method 7.3/D6

Laboratory SOP 5.4 B7 Water Baths

Laboratory SOP 5.4 B8 Gas system

Laboratory SOP 5.4 C1 Temperature and Humidity Check

The following SOP methods were used when testing for Ammonia, although as stated previously results from this are not submitted for MCERTS accreditation.

Laboratory SOP 5.4 B9 HACH DR2800 Spectrophotometer

Laboratory SOP 5.4 D3 Reagent Preparation for the Testing of Ammonia Analysers

6. Test results

6.1 Citation of MCERTS

MCERTS Portable Water Monitoring Equipment : Procedures for Conformity testing of On-Line analysers. Version 2.1 Aug 2010.

6.2 Equipment

6.2.1 HACH Laboratory Spectrophotometer Details.

Although the results for Ammonia testing are not included for MCERTS accreditation, the details of the instrument used as a secondary reference measurement (SRM) are as follows:

A HACH DR 2800 Laboratory Spectrophotometer, (Test 16), was used to compare results of the Pro Series instrument and for checking MCERTS standards and solutions made up for testing, (for chemicals and reagent preparation please refer to the reagent preparation SOP 5.4 D3).

The spectrophotometer was checked on each day of use with known standard solutions and a filter set provided by the manufacturer. Results are recorded in the lab record book.

6.2.2 Radiometer Laboratory pH Meter Details

For use in the laboratory a Radiometer PHM 220 pH meter is used. This is fully integrated into the lab quality system including monthly and daily cross checks, Leaps external proficiency and calibration routines, (see UKAS documentation).

Full uncertainty data is available for this meter, (see record 4.5.2 of the Measurement of Uncertainty Manual in the UKAS records). The maximum uncertainty is at pH 10.00 being 0.066 at k=2, the standard uncertainty being 0.033 pH units.

The lab meter was used to test reagents used in MCERTS in such tests as repeatability and accuracy. It was also used for checking calibrations of the YSI instrument. Instructions for the meter were followed as outlined in the in-house method, (see appendix B).

Uncertainty values were also supplied for the certified pH solutions. These can be found on the individual data sheets and certificates of analysis in appendix B.

6.2.3 Laboratory Dissolved Oxygen Measurement and Calibration

Laboratory calibration and checks of instruments are carried out in an aerated water bath filled with distilled water and aerated continuously via an air stone connected to an aquarium pump.

Theoretically the dissolved oxygen value in this water bath should be 100%. UKAS uncertainty data and methods for chemically deriving Oxygen values via Winkler titrations are available from in-house methods and can be found in appendix B. Winkler values from the water bath were used throughout MCERTS testing to check calibration of the YSI instrument and the values of some test solutions. There is a 3.12% uncertainty of measurement error associated with the Winkler method, (see file 5.4.6 in the uncertainty file). This will be applied if necessary and indicated where in the text.

6.2.4 Radiometer Laboratory Conductivity Meter Details

For use in the UKAS laboratory a Radiometer CDM 230 Conductivity meter is used. This is fully integrated into the lab quality system including monthly and daily cross checks, Leaps external proficiency and calibration routines, (see UKAS documentation).

Full uncertainty data is available for this meter, (see record 4.5.2 of the Measurement of Uncertainty Manual in the UKAS records). The uncertainty value reported by the lab is ± 1.7% of reading with an error of 0.5% of span.

The lab meter was used to test reagents for use in MCERTS in such tests as repeatability and accuracy. It was also used for checking calibrations of the YSI instrument. Instructions for the meter were followed as outlined in the in-house method, (see appendix B).

Uncertainty values were also supplied for the certified conductivity solutions. These can be found on the individual data sheets and certificates of analysis in appendix B.

6.2.5 Laboratory Temperature Device Details

For use in the UKAS laboratory a TTI 2 and PRT, (refs Cal 032 and Cal 071), system is used for accurate temperature measurements in solutions. This was used when necessary for the testing of the Pro series instrument and as a SRM for such tests as Accuracy and Repeatability. The operation of this can be found in SOP 7.3/B9.

Handheld ASL F100 PRT Temperature measuring devices, (ref Cal 074 and Cal 075), were also used in some tests as SRM. Instructions in operation were followed as outlined in SOP 5.4 B13 and instruction manual ref MAN 029. Details of when they were used can be round in the lab record book.

6.3 Method

All methods were followed out in accordance to instructions in the test programme, MCERTS standard and YSI instruction manual. These can be found in the relevant appendices. Deviations, or problems and adaptations will be indicated in the individual section for each test in the report.

6.3.1 Response Time pH

This was carried out as outlined in the response time section of the Test Programme and section 6.3.2 of the MCERTS standard. A low range pH solution of 5.00 was used, (read as 5.06 on the lab pH meter), and a high range solution of 10.00, (read as 10.02 on the lab pH meter).

The sensor bulk head was moved from low to high and high to low on 3 continuous occasions making a total of 6 runs. The time taken to reach a stable reading within 90-110% of the actual reading was recorded for each run. These equate to within 4.50-5.50 pH units for low range and 9.00-11.00 pH units for high range.

All raw data and results from this test can be found in appendix A. For each run the response time was found to be less than 5 seconds. This was found at both the low and high ranges.

6.3.2 Response Time Temperature

This was carried out as outlined in the response time section of the Test Programme and section 6.3.2 of the MCERTS standard.

Two Temperature controlled water baths set to Low and High Temperature ranges were set up and the temperatures checked using the lab TTI-2 and PRT system. A low range Temperature water bath of 7.5ºC was set up which read 7.4ºC on the PRT. A high range water bath was set up at 22.5ºC which read 22.5ºC on the PRT.. The instrument was moved from low to high and high to low on 3 continuous occasions making a total of 6 runs. The time taken to reach a stable reading within 90-110% of the actual reading was recorded for each run. These equate to within 6.75 – 8.28ºC for low range and 20.25 – 24.75ºC for high range.

All raw data and results from this test can be found in Appendix A. For each run at both ranges the response time was found to be 10 seconds..

6.3.3 Response Time Dissolved Oxygen

This was carried out as outlined in the response time section of the Test Programme and section 6.3.2 of the MCERTS standard.

Two gas controlled water baths set to test points two and four, (50 and 150% Oxygen), using mixtures of oxygen were set up and diffusers used to pump the gas into the water. The instrument was moved from low to high and high to low on 3 continuous occasions making a total of 6 runs. The time taken to reach a stable reading within 90-110% of the initial readings was recorded for each run. These equate to within 44.2 – 54% for low range (with an initial value of 49.1), and 130.6 – 159.6% for high range (with an initial value of 145.1).

All raw data and results from this test can be found in Appendix A. For the low runs the average time was calculated as 23.7 seconds with the high being 15 and the average over all runs 19.3 seconds.

6.3.4 Response Time Conductivity

This was carried out as outlined in the response time section of the Test Programme and section 6.3.2 of the MCERTS standard. A low range conductivity solution of 1000 µs/cm was used, (read as 10824 on the lab conductivity meter). A high range solution of 50000 µs/cm, (read as 49467 on the lab Conductivity meter), was used.

The sensor bulk head was moved from low to high and high to low on 3 continuous occasions making a total of 6 runs. The time taken to reach a stable reading within 90-110% of the actual reading was recorded for each run. These equate to within 900-1100 µs/cm for low range and 45000-55000 µs/cm for high range.

All raw data and results from this test can be found in appendix A. For each run the response time was found to be 10 seconds. This was found at both the low and high ranges..

6.3.5 Response Time Ammonia

This was carried out as outlined in the response time section of the Test Programme and section 6.3.2 of the MCERTS standard. All test solutions were prepared from a 1000mg/l Ammonia stock solution. A low range Ammonia solution 2.5mg/l was used, (read as 2.5m/l on the lab spectrophotometer). A high range solution of 7.5mg/l, (read as 7.5mg/l on the lab spectrophotometer), was used.

The sensor bulk head was moved from low to high and high to low on 3 continuous occasions making a total of 6 runs. The time taken to reach a stable reading within 90-110% of the actual reading was recorded for each run. These equate to within 2.25-2.75mg/l for low range and 6.75-8.25mg/l for high range.

All raw data and results from this test can be found in appendix A. For the low runs the average time was calculated as 55 seconds with the high being 61.7 and the average over all runs 58.3 seconds.

6.3.6 Mean Error, Linearity and Repeatability pH

This was carried out as outlined in the relevant section of the Test Programme and section 6.3.3 of the MCERTS standard..

Five certified pH solutions of 3.0, 5.0, 7.0, 9.20, and 11.0 at 20.0ºC, were used. On the lab pH meter these read 3.00, 4.99, 7.01, 9.20 and 10.93 over 20.6-21.3ºC respectively. The instrument was put in the lowest solution first and readings taken when stable. It was then moved up at the concentration range and the readings taken when stable. After readings at the highest pH solution were taken the instrument was moved back down the range to the lowest solution. This was repeated in its entirety, (a further two times), giving a total of six runs. Three from the lowest to highest solution and three from highest to lowest.

All raw data and calculations can be found in appendix A. The maximum mean error from the data over the six runs was found to be 0.07 at pH solution 7.00. MCERTS gives a maximum mean error tolerance value of 0.2 pH units.

Linearity was calculated to be 0.03 with an MCERTS tolerance of 0.1 pH units. Like wise Repeatability was calculated as 0.03 with a tolerance of 0.1 pH units. See appendix A for all raw data.

6.3.7 Mean Error, Linearity and Repeatability Temperature

This was carried out as outlined in the relevant section of the Test Programme and section 6.3.3 of the MCERTS standard. Five temperature controlled water baths over the range specified in the test programme, (1.5, 7.5, 15.0, 22.5, and 28.5 ºC), were set up. These were checked on the lab TTI 2 and PRT as 2.09, 8.50, 15.5, 21.1, and 28.5ºC respectively. All of these were acceptable values for test purposes.

The instrument was put in the lowest temperature water bath first and a reading taken when stable.. It was then moved up at the concentration range and the same readings taken at each when stable. After readings at the highest temperature were taken the instrument was moved back down the range to the lowest. This was repeated in its entirety, (a further two times), giving a total of six runs, three runs from the lowest to highest and three from highest to lowest.

All raw data and calculations can be found in appendix A. The maximum mean error from the data retrieved over the six runs was found to be 0.1 ºC. MCERTS states a maximum mean error tolerance value of 0.3 ºC..

Linearity was calculated to be 0.11 ºC with an MCERTS tolerance of 0.2ºC.. Like wise Repeatability was calculated as 0.06 with a tolerance of 0.2ºC. See appendix A for all raw data.

6.3.8 Mean Error, Linearity and Repeatability Dissolved Oxygen Sensor

This was carried out as outlined in the relevant section of the Test Programme and section 6.3.3 of the MCERTS standard. Five water baths containing distilled water were set up in the laboratory and flat diffuser blocks attached to the relevant gas supply placed in each.

Accurate gas mixtures were pumped from cylinders containing certified concentrations into each to give different Dissolved oxygen values (see the gas system method in Appendix B20). Water baths were set up at <10.0, 50, 100, 150 and 200% dissolved oxygen. The actual values from each were found to be ,7.55, 50.1, 97.4, 140.8, and 182.2%, from average calculated Winkler values, (see appendix 12), from each bath at the start and end of the study. The instrument was put in the lowest water bath first and a stable reading taken.. It was then moved up the concentration range and readings taken. After readings at the highest DO% water bath, the instrument was moved back down the range to the lowest water bath. This was repeated in its entirety a further two times giving a total of six runs. Three runs from the lowest to highest water baths and three from highest to lowest. All raw data and calculations can be found in appendix A.

The maximum mean error from the data retrieved over the six runs was found to be 2.9% of reading at the water bath at 182.2%. The maximum mean error tolerance value for MCERTS is 5% error of reading.

Linearity was calculated to be 0.3% with an MCERTS tolerance of 2.5% of reading. For Linearity the plot was not taken through zero and the lowest test point at <10% was removed from the calculation due to inaccuracies with accuracy at this low test point. Repeatability was calculated as 0.2% with an MCERTS tolerance of 2.5% of reading. See appendix A for all raw data and calculations and section 6.6 for graphical presentation of results.

N.B. There is an error associated with the uncertainty of this method of 2.7% of reading, (see section 6.3.2).

6.3.9 Mean Error, Linearity and Repeatability Conductivity

This part of the conductivity testing was carried out at two ranges. One deemed high Range and the other Low Range. Refer to section 5.3 of the Test Programme for further details.

Both tests were carried out as outlined in the relevant section of the Test Programme and section 6.3.3 of the MCERTS standard.

6.3.9.1 Low Range Conductivity

The Low range study was carried out over a range of Five conductivity solutions; four of which were certified at 25.0 ºC at 50, 200, 500 and 1000µs/cm and a one made up in house at 720 µs /cm. All were checked at the start and end of the study on the lab conductivity meter cal 069. Average readings on Cal 069 were 64.3, 209.05, 507.5, 725.5 and 1002.0 µs/cm.

The instrument was put in the lowest solution first and readings taken when stable. It was then moved up the concentration range and the same set of readings taken. After readings at the highest solution were taken the instrument was moved back down the range to the lowest solution. This was repeated in its entirety, (a further two times), giving a total of six runs, three from the lowest to highest solution and three from highest to lowest.

All raw data and calculations can be found in appendix A. The maximum mean error from the data over the six runs was found to be 0.01% of span at conductivity solution 200.0 µs/cm. The MCERTS standard gives a maximum mean error tolerance value of 1.0% of span.

Linearity was calculated to be 0.003% with an MCERTS tolerance of 0.2% of span. Likewise Repeatability was calculated as 0.01% with a tolerance of 0.5% of span. See appendix A for all raw data.

6.3.9.2 High Range Conductivity

The Low range study was carried out over a range of Five conductivity solutions; four of which were certified at 25.0 ºC at 1.0, 10.0, 20.0 and 50.0ms/cm and one made up in house at 32.5 ms/cm. All were checked at the start and end of the study on the lab conductivity meter cal 069. Average readings on Cal 069 were 1.341, 9.896, 19.680, 34.350 and 48.850 ms/cm.

The instrument was put in the lowest solution first and readings taken when stable. It was then moved up at the concentration range and readings taken. After readings at the highest solution were taken the instrument was moved back down the range to the lowest solution. This was repeated in its entirety, (a further two times), giving a total of six runs, three runs from the lowest to highest solution and three from highest to lowest.

All raw data and calculations can be found in appendix A. The maximum mean error from the data retrieved over the six runs was found to be 0.84% of span at the conductivity solution at 50.0 ms/cm. The MCERTS standard gives a maximum mean error tolerance value of 1.0% of span.

Linearity was calculated to be 0.74 with an MCERTS tolerance of 0.2% of span. Likewise Repeatability was calculated as 0.14 with a tolerance of 0.5% of span. See appendix A for all raw data.

N.B. It should be noted that the test point that caused the largest error in the linearity plot was that at test point 4. This was the only point that was from a solution made up in house from a stock solution, and not from a certified standard. If the linearity is only calculated from the certified standards then the result changes to 0.14% of span, (see appendix A for raw data).

6.3.10 Mean Error, Linearity and Repeatability Ammonia

This was carried out as outlined in the relevant section of the Test Programme and section 6.3.3 of the MCERTS standard. Five test solutions were made up from a 1000mg/l Ammonia stock solution, the details of which can be found in the lab record and reagent book.

Test solutions were made up at 0.5, 2.5, 5.0, 7.5 and 9.5mg/l and the actual values checked on the spectrophotometer Test 14. These were found to be 0.503, 2.70, 5.05, 7.25, and 9.17mg/l (see appendix 12). The instrument was put in the lowest solution first and a stable reading taken.. It was then moved up the concentration range and readings taken. After readings at the highest test solution, the instrument was moved back down the range to the lowest. This was repeated in its entirety, (a further two times), giving a total of six runs, three runs from the lowest to highest and three from highest to lowest. All raw data and calculations can be found in appendix A.

The maximum mean error from the data retrieved over the six runs was found to be 6.1% of reading at the test solution at 2.7mg/l.

Linearity was calculated to be 5.4% of reading. It should be noted that the result for linearity was taken from test point 2. The % error of reading of test point 1 was in fact greater than that of 2, but is not reported as the greater error due to higher % errors of reading being associated

with lower concentrations. Repeatability was calculated as 2.2% of reading. See appendix A for all raw data and calculations and section 6.6 for graphical presentation of results.

6.3.11 Warm up Drift Test (2 hours)

This was carried out as outlined in the test programme and section 6.3.4 of the MCERTS standard. The instrument was tested with all the sensors on for the duration of this test and values for each were logged every 5 seconds using the internal software. Data was downloaded from the instrument via the USB connection port and can be seen for all parameters in appendix A. The test solution used was an ammonia one at 7.5mg/l. Although Ammonia is no longer being put forward for MCERTS accreditation the results for this test are still valid for the other sensors and the Ammonia results are included for reference.

When reporting Warm Up Drift the Repeatability value of the instrument is also taken into account. This is reported as UR and can be seen in the relevant section for each parameter for Repeatability in this report.

Values reported for Warm Up Drift will include data for V_1 (which is the reading after one minute of exposure), V_S (the value when the reading is stable), and $V_S \pm U_R$ (the value of final stability plus and minus the value calculated for Repeatability). The time taken for the instrument to reach the values between $V_S \pm U_R$ is reported as the Warm up Drift stability time.

See appendices for all raw data along with warm up drift test plots for each parameter with tolerance limits.

6.3.11.1 Warm up Drift pH

V_1 and V_S readings for pH were both 6.03 pH units. The repeatability tolerance value for pH from the standard is 0.1 pH units (see raw data and the relevant section in this report for further details).

The range for V_S was 6.00 to 6.06. V_S plus U_R gave a value of 6.13, with V_S minus 5.93. The stability time between these two values was calculated to be less than 2 minutes.

6.3.11.2 Warm up Drift Temperature

V_1 and V_S readings for temperature were seen from the logged data to be both 21.91ºC. The repeatability tolerance value for temperature is 0.2ºC from the standard, (see raw data and the relevant section in this report for further details).

V_S plus U_R gave a value of 22.1ºC, with V_S minus 21.7ºC. The stability time between these two values was calculated to be less than 2 minutes.

6.3.11.3 Warm up Drift Dissolved Oxygen

V_1 and V_S readings for Dissolved Oxygen were seen from the logged data were 101.4 and 100.8% respectively. The repeatability tolerance value for Dissolved Oxygen is 2.5% of reading, (see raw data and the relevant section in this report for further details).

V_S plus U_R gave a value of 103.3%, with VS minus 98.3%. The stability time between these two values was calculated to be less than 2 minutes.

6.3.11.4 Warm up Drift Conductivity

V_1 and V_S readings for Conductivity were seen from the logged data to be both 82.6 µs/cm. The repeatability tolerance value for conductivity is 0.5% of span according to the standard, (see raw data and the relevant section in this report for further details).

V_S plus U_R gave a value of 322.6,µs/cm with VS minus a reading of 0.0 µs/cm. The stability time between these two values was calculated to be less than 2 minutes.

6.3.11.5 Warm up Drift Ammonia

Drift testing for ammonia was also carried out although as stated previously the results are not being submitted for MCERTS certification. However the logged data from this study can be found in appendix 1 along with a plot of results. The stability time was also calculated to be under 2 minutes for this sensor.

6.3.12 Interference Tests

6.3.12.1 Interference due to Chloride - DO only

This was carried out as outlined in the relevant section of the test programme and according to section 6.3.4.2 of the MCERTS standard for Dissolved Oxygen instruments.

In this study an aerated water bath at 100% DO was used as the reference and a 2 litre beaker of distilled water containing 25g/l of Chloride which was constantly aerated used as the test solution. The instrument was moved between the two a total of three times and the average error as % reading calculated.

Over the 3 runs the average % error of reading on the instrument was calculated to be 0.85%. The error in units of mg/l was calculated to be -21.8% of reading, with the expected error calculated from ISO 5814, (as required in the standard), calculated to be -22.7%. The difference between the two being -0.9%. MCERTS has a tolerance of 2.5% error of reading for interferents for Dissolved Oxygen. All raw data and calculations can be found in appendix A.

N.B. The results from this study are not used in the calculation for combined performance.

6.3.12.2 Interference by Inorganic salts on Ammonia Sensor.

This was highlighted as a test to carry out in section 6.3.3 of the Test Programme TP-07. However, testing on the Ammonia sensor was stopped before this could be done.

6.3.13 Low Voltage Test

This was carried out as part of the Electrical Conformity Tests as detailed in sections 6.3.6 of TP-07 and the MCERTS standard.

The test solution used for all sensors was Ammonia standard made in-house at 7.5mg/l. All initial values for each parameter were taken at the start of the test with the voltage of the variable power supply unit, (Test 08), set at 5 volts. The voltage was then turned down by 0.5 volt increments and the readings for each parameter recorded.

A separate test was carried out on the Polarographic DO sensor.

The aim of this test was to report the voltage at which either; a low battery alarm occurs, a reading changes by more than 10% of an initial value, or the voltage at which the instrument switches off or fails to switch on again.

6.3.13.1 Low Voltage Test pH

The pH at the start of the study was 5.86 units. The instrument display turned off when the voltage supplied by Test 08 reached 1.6 volts. From the start at 5 volts until the instrument turned off at 1.6 volts the pH reading changed by a maximum of 0.02 pH. The maximum change acceptable under MCERTS is 0.05 pH.

6.3.13.2 Low Voltage Test Temperature

The Temperature at the start of the study was 20.5ºC. The instrument display turned off when the voltage supplied by Test 08 reached 1.6 volts. From the start at 5 volts until the instrument turned off at 1.6 volts the Temperature reading did not change. The maximum change acceptable under MCERTS is 0.2ºC.

6.3.13.3 Low Voltage Test Dissolved Oxygen

The DO% at the start of the study was 98.1%. The instrument display turned off when the voltage supplied by Test 08 reached 1.55 volts. From the start at 5 volts until the instrument turned off at 1.55 volts the DO% reading changed by a maximum of -0.2% of reading. The maximum change acceptable under MCERTS is 1.0%.

6.3.13.4 Low Voltage Test Conductivity

The Specific Conductivity at the start of the study was 120.5 µS/cm. The instrument display turned off when the voltage supplied by Test 08 reached 1.6 volts. From the start at 5 volts until the instrument turned off at 1.6 volts the Specific Conductivity reading changed by a maximum of 0.5µS/cm which equals 0.0005% of test span. The maximum change acceptable under MCERTS is 0.25% of span.

6.3.13.5 Low Voltage Test Ammonia

Although carried out, this test is not part of MCERTS accreditation.

The Ammonia value at the start of the study was 7.62mg/l. The instrument display turned off when the voltage supplied by Test 08 reached 1.6 volts. From the start at 5 volts until the instrument turned off at 1.6 volts the Ammonia reading changed by a maximum of 0.39mg/l which equals 2.56% of reading.

All raw data and results for the Low Voltage testing of all sensors can be found in appendix A.

6.3.14 Length of Battery Operation

This was carried out on all sensors and as detailed in the test programme TP-07 and in section 6.3.7 of the MCERTS standard.

The instrument sensor bulkhead was placed in a beaker of certified pH buffer 10.00. The Ammonia sensor was covered as instructed by the manufacturer, (extremes of pH can be damaging to the sensor). The instrument, (with fresh batteries supplied and the power indicator showing ‘full’), was switched on and initial values for all parameters recorded in the lab record book.

The instrument was left switched on for 24 hours and the parameters taken at the end. Battery power lasted the duration of the test with all sensors taking readings. The power level indicator at the conclusion of the test was still three quarters full.

For all raw data and settings see the details in appendix A.

6.3.15 Sample Temperature - pH

This was carried out as outlined in the relevant section of the test programme and in section 6.3.9 of the MCERTS standard.

Certified pH 10.00 was used as the test solution, and this was read on the lab pH meter at the start of the study as 10.03 at 18.1 ºC.

Three 250ml volumes of pH 10.00 solution in glass beakers were prepared. One was kept at ambient laboratory temperature on a work bench (20 ± 2°C). Another was placed in a water bath controlled with a chiller unit at temperatures at the lower specification of the instrument, (5 ±2ºC). Similarly, the final beaker was placed in a water bath controlled at temperatures at the higher specification of the instrument, (30 ± 2ºC).

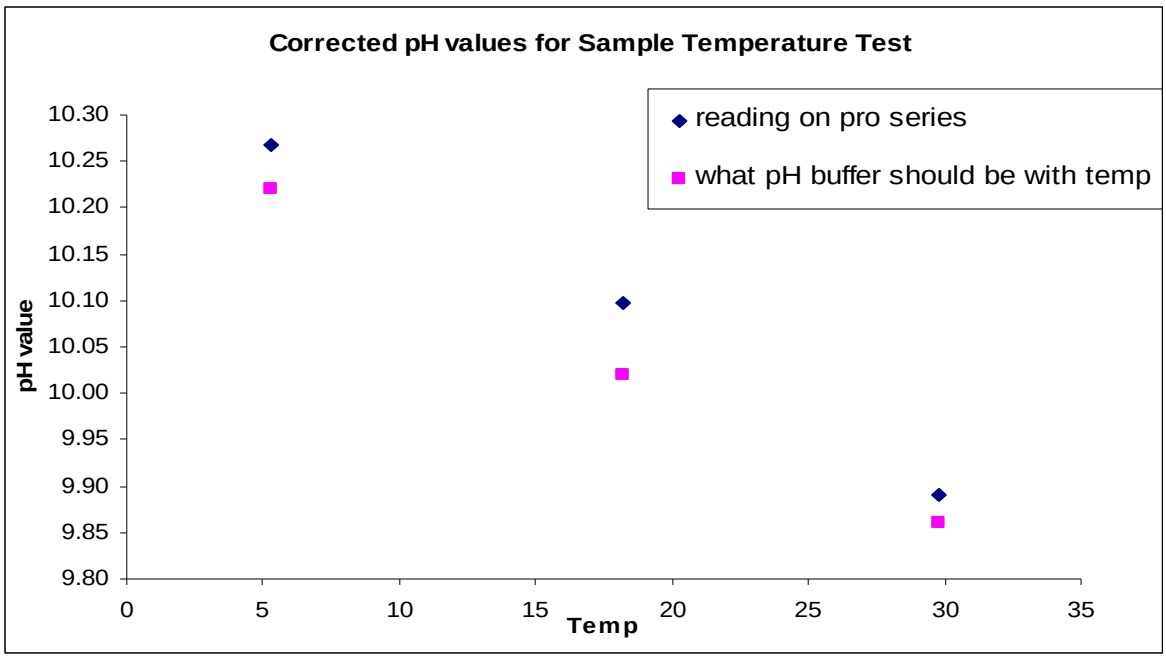
Three discrete measurements were taken at each sample temperature when readings were stable moving from lower to higher temperatures over each run. The change in error in pH units was calculated from the data.

Each buffer has its own temperature characteristics and these therefore need to be taken into account before calculating any errors associated with the temperature changes. Temperature compensation values were worked out from the data supplied with the certified buffer and applied to the calculations.

The error in pH units of the three temperature ranges was determined to be 0.008 pH units. The acceptable tolerance value under MCERTS is 0.1 pH units

See appendix A for all raw data and calculations.

The plot below shows the average results of the instrument at the three sample temperature test points plotted against the theoretical values at the temperature test points of the certified pH 10.00 buffer solution.



6.3.16 Sample Temperature - Dissolved Oxygen

This was carried out as outlined in the relevant section of the test programme and in section 6.3.9 of the MCERTS standard.

Three laboratory water baths with aquarium air pumps and diffuser stones were used to create test solutions in distilled water with a theoretical oxygen value of approx 100%. One water bath was kept at ambient laboratory temperature (20 ± 2°C). Another was placed in a water bath controlled with a chiller unit at temperatures at the lower specification of the instrument, (5 ±2ºC). Similarly, the final water bath was controlled at temperatures at the higher specification of the instrument, (45.0 ± 2ºC).

Three discrete measurements were taken at each sample temperature when readings were stable moving from lower to higher temperatures over each run. The change in error in % of Dissolved Oxygen reading was calculated from the data.

The error in % reading of DO of the three temperature ranges was determined to be 2.00%. The acceptable tolerance value under MCERTS is 2.50% of DO reading.

See appendix A for all raw data and calculations.

6.3.17 Sample Temperature - Conductivity

This was carried out as outlined in the relevant section of the test programme and in section 6.3.9 of the MCERTS standard.

Conductivity at approximately 32.5 mS/cm was made up according to laboratory methods using potassium chloride salt dissolved in distilled water (see laboratory MCERTS reagent book). N.B no certified solutions were available at this test point, (which was the required concentration as highlighted in the test programme). This reagent was checked on the laboratory conductivity meter Cal 069 and found to be 35.3 mS/cm at 22.3°C.

Three separate beakers were filled with 250ml volumes of this test solution. One was kept at ambient laboratory temperature on a work bench (20 ± 2°C). Another was placed in a water bath controlled with a chiller unit at temperatures at the lower specification of the instrument, (5

±2ºC). Similarly, the final beaker was placed in a water bath controlled at temperatures at the higher specification of the instrument, (30 ± 2ºC).

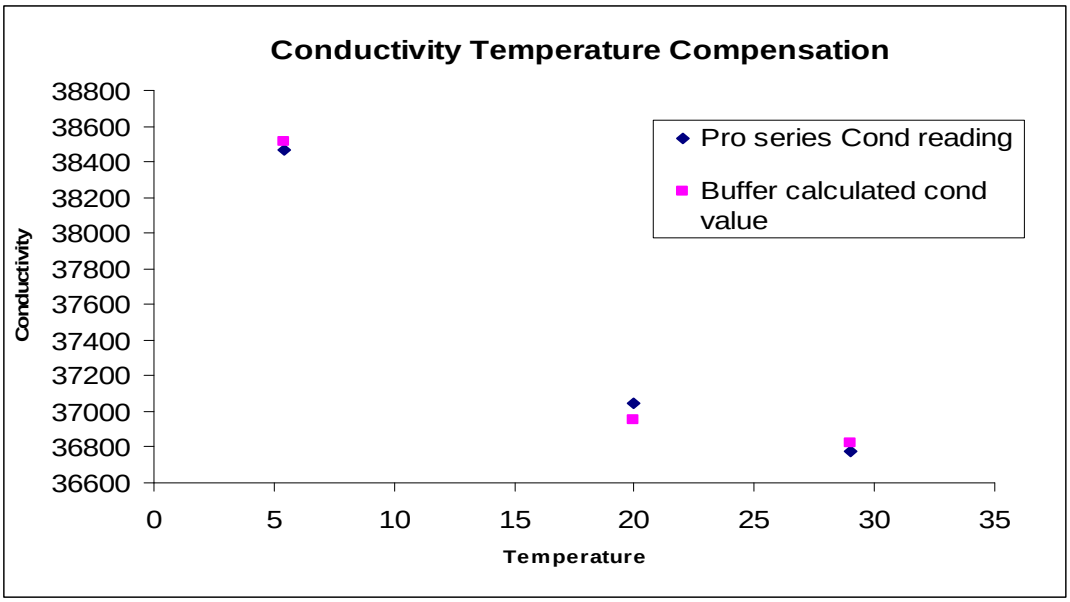
Three discrete measurements were taken at each sample temperature when readings were stable moving from lower to higher temperatures over each run. The change in % error of span of conductivity was calculated from the data.

The instrument compensates for natural waters and not Potassium Chloride solution. Therefore a correction has to be made to account for this difference. Temperature compensation values were worked out from the data supplied with certified solutions either side of the concentration of the one made up in-house test solution.

The % error in span of conductivity of the three temperature ranges was determined to be 0.13 %. The acceptable tolerance value under MCERTS is 0.5% of span.

See appendix A for all raw data and calculations.

The plot below shows the average results of the instrument at the three sample temperature test points plotted against the theoretical conductivity values at the temperature test points worked out for the test conductivity solution.



6.3.18 Sample Temperature - Ammonia

This was carried out as outlined in the relevant section of the test programme and in section 6.3.9 of the MCERTS standard.

Testing was carried out in a similar way as the other parameters highlighted above using a known solution of Ammonia.

The results can be seen in table 1 and raw data in appendix A of this report.

The error for sample temperature at an Ammonia concentration of 7.5mg/l was calculated to be 28.7% of reading.

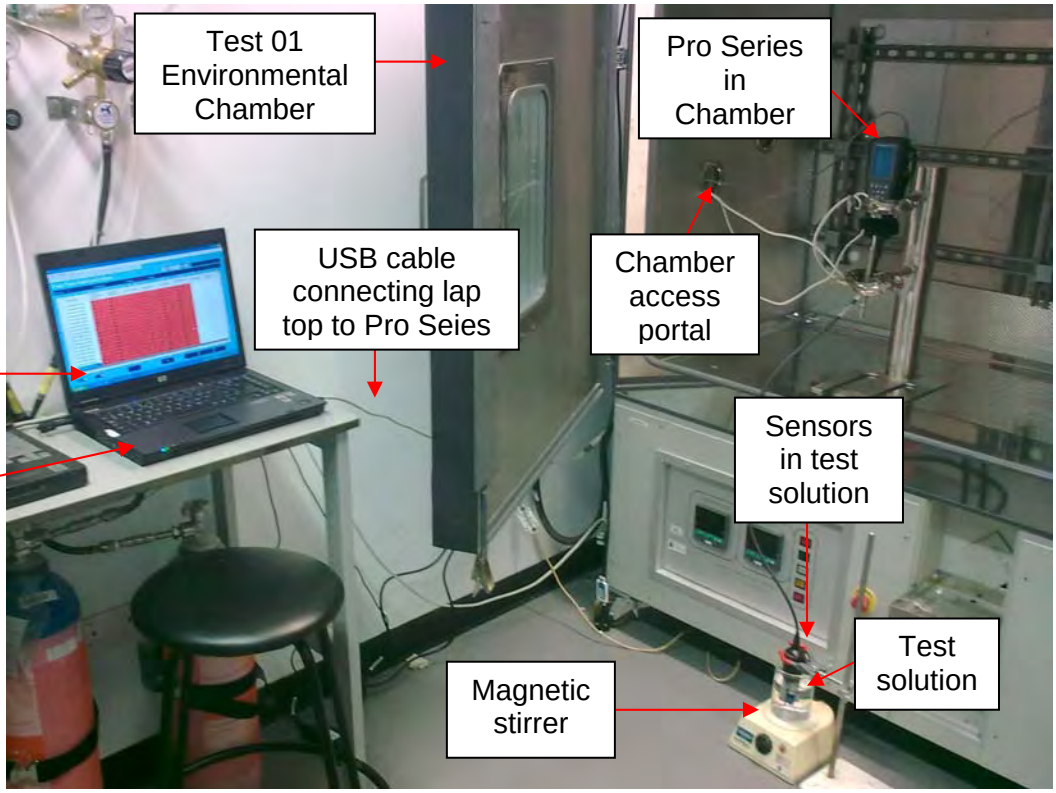
6.3.19 Ambient Temperature and Relative Humidity

This was carried out as outlined in the relevant section of the test programme and in section 6.3.8 of the MCERTS standard.

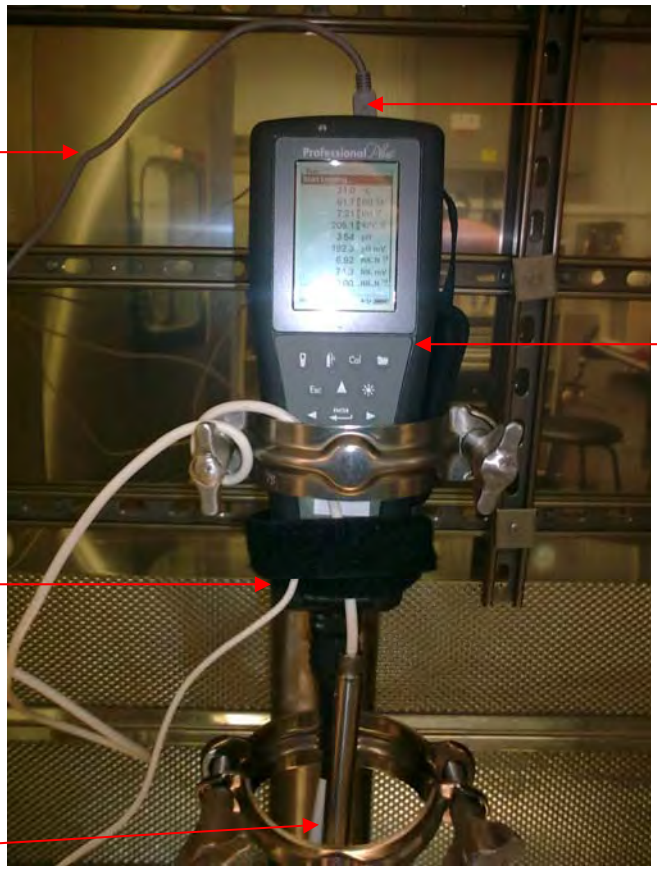
In this study all sensors were on and the instrument logging (using either internal memory or plugged directly into a laptop). A test solution used for all sensors was pH buffer 9.20 (reagent ref M205). The lab was maintained at the ambient temperature for testing using the in-house air conditioning.

The instrument was positioned in the Environmental chamber as shown below in the diagrams.

Picture 2 Test set-up prior to starting Environmental chamber



Picture 3 Diagram of Pro-series in Chamber



The instrument was set up as shown in pictures 2 and 3 in the environmental chamber. The test solution of pH 9.20 buffer, (reagent number M205), was kept outside the chamber and the Pro-Series sensor bulkhead submerged in this with the cable running to the main body of the instrument in the chamber.

Conditions inside the chamber for temperature and humidity were checked throughout the study using the internal sensors of the chamber itself and external sensing devices, (Test 21 and Test 15). The sensors for these have the main body of each instrument outside the chamber with cables running to the sensors inside the chamber through side and top access ports. One of the sensors, (from Test 15), can be seen in picture 3 above wrapped around the test instrument itself via a Velcro strap which gives an accurate reading of temperature for the surface of the instrument. A second sensor, (primarily measuring Humidity Test 21), was attached to the back of the chamber and was checked whenever test readings were taken.

Throughout the duration, the test solution was kept as close to ambient conditions as possible outside the chamber in an air conditioned laboratory at 20 ± 2.0°C. The test solution was positioned on a magnetic stirrer containing a flea spinning at a constant velocity to ensure mixing. This would also help stabilise the Dissolved Oxygen concentration for the test duration.

The chamber was kept closed for the duration where the temperature settings were other than ambient. All readings were taken from the instruments display which could be seen through the glass window of the chamber when test points were required. Additionally the instrument was set to log all readings every 5 seconds for the duration of the study. The Pro-Series was connected to a lap top outside the chamber through the side access port via the

USB connection. This would provide power to the instrument for part of the test duration and also real time displayed data using the YSI data manager software.

The following conditions in the chamber were set in this order and readings taken at each step:

1) Ambient 20°C
2) Hot / Dry 45°C
3) Ambient 20°C
4) Cold / Dry -2°C
5) Ambient 20°C
6) Hot / Humid 45°C and 95% humidity
7) Ambient 20°C

The change in error for ambient temperature in this test was found by comparing steps 2, 3, and 4.

The change in error due to high humidity and temperature was found by comparing the difference in steps 5 and 6. It should be noted that for conductivity the difference in steps 6 and 7 were used to calculate this error. This was because of a change in reading of the pH buffer over the duration of the test, due to condensation. This was confirmed by the laboratory conductivity meter CAL069 and an error factored into the calculation. The conductivity read at the start on CAL069 was 6580µS/cm for ambient conditions but following exposure to temperature and humidity extremes in the chamber this was later read as 5600µS/cm at the same ambient conditions. It can be seen that this is a change in actual test solution concentration and not a change in instrument reading.

Humidity results are not included in the calculation of the overall performance characteristic (see annex D of the standard).

Raw data for all test parameters in this study along with all raw data and logged chamber parameters can be found in appendix A.

6.3.19.1 pH, Ambient Temperature and Humidity

The error for Ambient Temperature over the three sample temperature points was calculated to be 0.04 pH units. The acceptable tolerance limit for Mcerts is 0.1 pH units.

The error for Humidity in this study was calculated to be 0.04 pH units. The acceptable tolerance value for MCERTS is 0.1 pH units.

6.3.19.2 Temperature, Ambient Temperature and Humidity

During the course of this study measures to keep the sample solution temperature as constant as possible were taken. However, it was noted that the temperature of the test solution fluctuated slightly. It was concluded that this was probably due to the heating effect of the magnetic stirrer on the test solution. Temperature variations in the laboratory atmosphere with the chamber in operation could also be responsible for test solution temperature changes. Temperature fluctuations were kept to a minimum by using in-house air conditioning and putting a mat on the magnetic stirrer to reduce any heat transfer. However, a handheld Lab PRT device, (ref Cal 074), was used to monitor the test solution and any correction factor noted and factored into calculations.

The error for Ambient Temperature over the three sample temperature points was calculated to be 0.02°C. The acceptable tolerance limit for MCERTS is 0.2°C.

The error for Humidity in this study was calculated to be 0.01°C. The acceptable tolerance value for MCERTS is 0.2°C.

6.3.19.3 Dissolved Oxygen, Ambient Temperature and Humidity

The error for Ambient Temperature over the three sample temperature points was calculated as % error reading of Dissolved Oxygen as 0.05%. The acceptable tolerance limit for MCERTS is 2.5 % error of reading.

The error for Humidity in this study was calculated to be 0.43% of reading of Dissolved Oxygen. The acceptable tolerance value for MCERTS is 2.5% error of reading.

6.3.19.4 Conductivity, Ambient Temperature and Humidity

The error for Ambient Temperature over the three sample temperature points was calculated as % error of span for Conductivity as 0.038%. The acceptable tolerance limit for MCERTS is 0.5% of span.

The error for Humidity in this study was calculated to be 0.01% of span for Conductivity. The acceptable tolerance value for MCERTS is 0.5% of span.

6.3.19.5 Ammonia (TAN), Ambient Temperature and Humidity

This test was carried out as part of the study and the results can be seen in the table at the start of this report and along with all raw data in Appendix 1. Results for Ammonia are not considered for MCERTS certification.

The error for Ambient Temperature over the three sample temperature points was calculated as % error of reading for Ammonia as 1.41%.

The error for Humidity in this study was calculated to be 8.4% of reading for Ammonia.

6.3.20 Initial Instrument Warm up

Initial Warm up observations on each sensor were carried out where the instrument was switched on and the time taken for a stable reading for each parameter recorded. The Polarographic DO sensor was placed in an aerated water bath at approx 100% DO. It took the instrument 1 minute and 20 seconds to give a stable reading of 97.3%.

The pH sensor was placed in a known buffer standard and this took 32 seconds seconds to stabilise while the Temp sensor took 23 seconds in a controlled water bath to give a stable reading of 23.7ºC.

The conductivity sensor was placed in a known conductivity standard and this took 25 seconds seconds to stabilise.

The Ammonia sensor test was not carried out, although data can be seen from the Warm up Drift test which can in essence be used for initial warm up readings, (see section 6.3.11)

6.4 Maintenance and problems

The instrument was maintained and calibrated in line with the manufacturers instruction manual and recommendations. All details were entered into the projects lab record book.

6.4.1 pH Sensor Replacement

On the 14th of August 2009 the pH bulb was smashed by a member of staff while cleaning the bulkhead. A new sensor was ordered as a replacement from YSI.

This was received and fitted to the instrument on the 25th of August 2009. The instrument was re-calibrated for pH following fitting of the new sensor.

Smashed Sensor; Model number 1001 serial number; 09C
Replacement Sensor; Model number 1001 serial number; 09G

6.4.2 Instrument returned to Manufacturer

After a number of problems with the Galvanic DO sensor, (specifically with high readings in the field test), the manufacturer was contacted on the 22nd of February 2010 to discuss the issues, (refer to the note to file dated 22.02.10 in the project file). It was decided between the Test-House and the client to send the instrument back to manufacturer for further investigation. This was done on the 23rd of February 2010, (see project file for further details).

The email dated the 19th of March 2010 from the manufacturer shows what changes the manufacturer carried out on the instrument before sending it back to the test house to complete the project. The main change was replacement of the Galvanic sensor as the client suspected that it was out of date and needed replacing. Dissolved Oxygen testing would need to be repeated and the client requested that the Galvanic sensor was replaced by a Polarographic sensor. The client was concerned the Galvanic sensor would take longer to certify The Galvanic sensor is not included for MCERTS certification in this report.

The instrument was returned to the test house on the 22nd of March 2010.

6.5 Summary tables of tests

Table 2 Summary for pH

Standard	Term	Acceptable standard for pH in error pH units	Result calculated from pro series display	Confidence level of meeting specification
Mean Error	X	0.2	0.07	99.9
Repeatability	u_R	0.1	0.03	99.9
Warm up Drift	X_D	N/A	< 2minutes	N/A
Linearity	X_L	0.1	0.03	99.9
Ambient Temp	X_T	0.1	0.04	89
Supply Voltage (battery)	X_V	0.05	0.02	99.9
Sample temp	X_{ST}	0.1	0.008	93
Relative Humidity	X_{RH}	0.1	0.04	91
Response Time	N/A	N/A	< 5 seconds	N/A
Battery Power	N/A	N/A	> 24 hours	P
Combined performance	**U_c**	**0.3**	**0.13**	**99.9**

Note Where it is not possible to calculate the confidence level of meeting specification, the following key applies

- P The result is below the specification limit by a margin les than the measurement uncertainty; it is therefore not possible to state compliance based on the stated coverage probability. However the result indicates compliance is more probable than non-compliance with the specification limit.
- NP. The result is above the specification limit by a margin less than the measurement uncertainty; it is therefore not possible to state non Compliance based on the stated coverage probability. However the result indicates non Compliance is more probable than compliance with the specification limit.
- F The result is above the specification limit by more than the uncertainty of measurement.
- N/A The result has not been compared to the MCERTS specification, See table 1 for accreditation status of result.

Tests marked with a '–' were not carried out

Table 3 Summary for Polarographic DO%

Standard	Term	Acceptable standard for DO% in error % of Reading	Result calculated from pro series display	Confidence level of meeting specification
Mean Error	X	5	2.88	99
Repeatability	u_R	2.5	0.20	99.9
Warm up Drift	X_D	N/A	< 2minutes	N/A
Linearity	X_L	2.5	0.3	99.9
Ambient Temp	X_T	2.5	0.05	99.9
Supply Voltage (battery)	X_V	1	-0.2	99.9
Sample temp	X_{ST}	2.5	2.0	99.9
Relative Humidity	X_{RH}	2.5	0.43	99.9
Interference	X_{IN}	2.5	0.85 / -0.9 for mg/l	P
Response Time	N/A	N/A	19.3 seconds	N/A
Battery Power	N/A	N/A	> 24 hours	P
Combined performance	**U_c**	**6**	**4.21**	**P**

Note Where it is not possible to calculate the confidence level of meeting specification, the following key applies

- P The result is below the specification limit by a margin les than the measurement uncertainty; it is therefore not possible to state compliance based on the stated coverage probability. However the result indicates compliance is more probable than non-compliance with the specification limit.
- NP. The result is above the specification limit by a margin less than the measurement uncertainty; it is therefore not possible to state non Compliance based on the stated coverage probability. However the result indicates non Compliance is more probable than compliance with the specification limit.
- F The result is above the specification limit by more than the uncertainty of measurement.
- N/A The result has not been compared to the MCERTS specification, See table 1 for accreditation status of result.

Tests marked with a '–' were not carried out

Table 4 Summary for Temperature ºC

Standard	Term	Acceptable standard for Temperature in error ºC	Result calculated from pro series display ºC	Confidence level of meeting specification
Mean Error	X	0.2	0.10	99.9
Repeatability	u_R	0.2	0.06	99
Warm up Drift	X_D	N/A	< 2minutes	N/A
Linearity	X_L	0.2	0.11	99
Ambient Temp	X_T	0.2	0.02	99.9
Supply Voltage (battery)	X_V	0.2	0	99.9
Relative Humidity	X_{RH}	0.2	0.01	99.9
Response Time	N/A	N/A	10 seconds	N/A
Battery Power	N/A	N/A	> 24 hours	P
Combined performance	**U_c**	**0.5**	**0.22**	**89**

Note Where it is not possible to calculate the confidence level of meeting specification, the following key applies

- P The result is below the specification limit by a margin les than the measurement uncertainty; it is therefore not possible to state compliance based on the stated coverage probability. However the result indicates compliance is more probable than non-compliance with the specification limit.
- NP. The result is above the specification limit by a margin less than the measurement uncertainty; it is therefore not possible to state non Compliance based on the stated coverage probability. However the result indicates non Compliance is more probable than compliance with the specification limit.
- F The result is above the specification limit by more than the uncertainty of measurement.
- N/A The result has not been compared to the MCERTS specification, See table 1 for accreditation status of result.

Tests marked with a '–' were not carried out

Table 5 Summary for Conductivity µS/cm (High Range)

Standard	Term	Acceptable standard for Conductivity in % error span	Result calculated from pro series display	Confidence level of meeting specification
Mean Error	X	1	0.84	87
Repeatability	u_R	0.5	0.14	99.9
Warm up Drift	X_D	N/A	<2 mins	N/A
Linearity	X_L	0.2	-0.74	F
Ambient Temp	X_T	0.5	0.038	99.9
Supply Voltage (battery)	X_V	0.25	0.001	99.9
Sample temp	X_{ST}	0.5	0.13	99.9
Relative Humidity	X_{RH}	0.5	0.01	99.9
Response Time	N/A	N/A	10 seconds	N/A
Battery Power	N/A	N/A	> 24 hours	P
Combined performance	**U_c**	**1.5**	**1.33**	**P**

Note Where it is not possible to calculate the confidence level of meeting specification, the following key applies

- P The result is below the specification limit by a margin less than the measurement uncertainty; it is therefore not possible to state compliance based on the stated coverage probability. However the result indicates compliance is more probable than non-compliance with the specification limit.
- F The result is above the specification limit by more than the uncertainty of measurement.
- N/A The result has not been compared to the MCERTS specification, See table 1 for accreditation status of result.

Tests marked with a '–' were not carried out.

Table 6 Summary for Conductivity µS/cm (Low Range)

Standard	Term	Acceptable standard for Conductivity in % error span	Result calculated from pro series display	Confidence level of meeting specification
Mean Error	X	1	0.01	99.9
Repeatability	u_R	0.5	0.01	99.9
Linearity	X_L	0.2	0.003	92

Note Where it is not possible to calculate the confidence level of meeting specification, the following key applies

- P The result is below the specification limit by a margin les than the measurement uncertainty; it is therefore not possible to state compliance based on the stated coverage probability. However the result indicates compliance is more probable than non-compliance with the specification limit.
- NP. The result is above the specification limit by a margin less than the measurement uncertainty; it is therefore not possible to state non Compliance based on the stated coverage probability. However the result indicates non Compliance is more probable than compliance with the specification limit.
- F The result is above the specification limit by more than the uncertainty of measurement.
- N/A The result has not been compared to the MCERTS specification, See table 1 for accreditation status of result.
- Tests marked with a '–' were not carried out.

Table 7 Summary for Ammonia (TAN)

Standard	Term	Acceptable standard for Ammonia (TAN) in % error reading	Result calculated from pro series display
Mean Error	x	10	6.1
Repeatability	u_R	5	2.2
Warm up Drift	X_D	N/A	< 2mins
Linearity	X_L	2	5.4
Ambient Temp	X_T	2.5	1.41
Supply Voltage (battery)	X_V	2.5	5.1
Sample temp	X_{ST}	5	28.7
Relative Humidity	X_{RH}	5	8.38
Combined performance	**U_c**	**12**	**35.22**

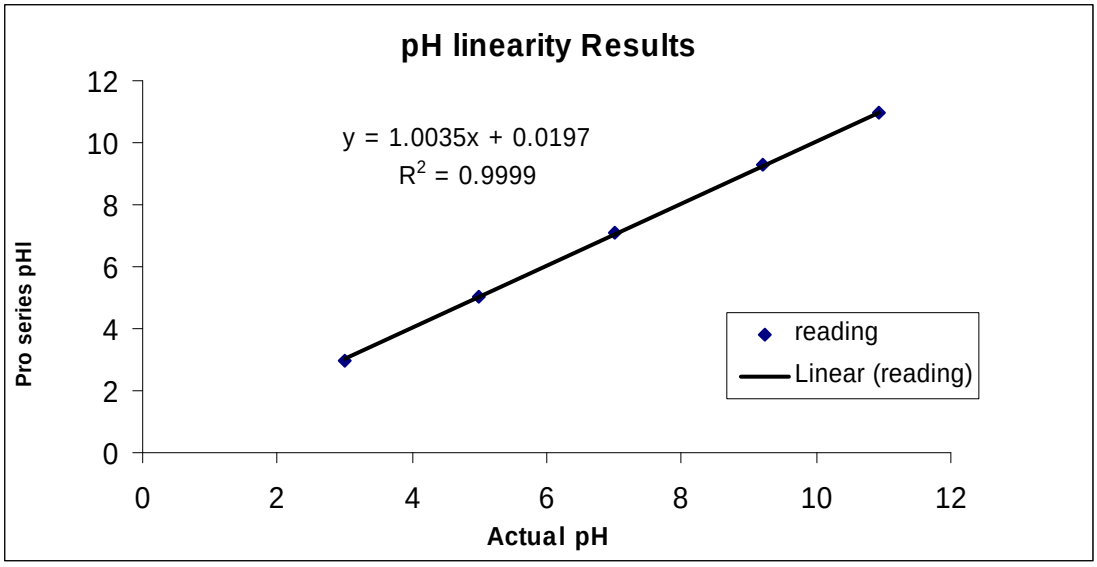
Note: Confidence limits not calculated as parameter not being certified

- N/A The result has not been compared to the MCERTS specification, See table 1 for accreditation status of result.

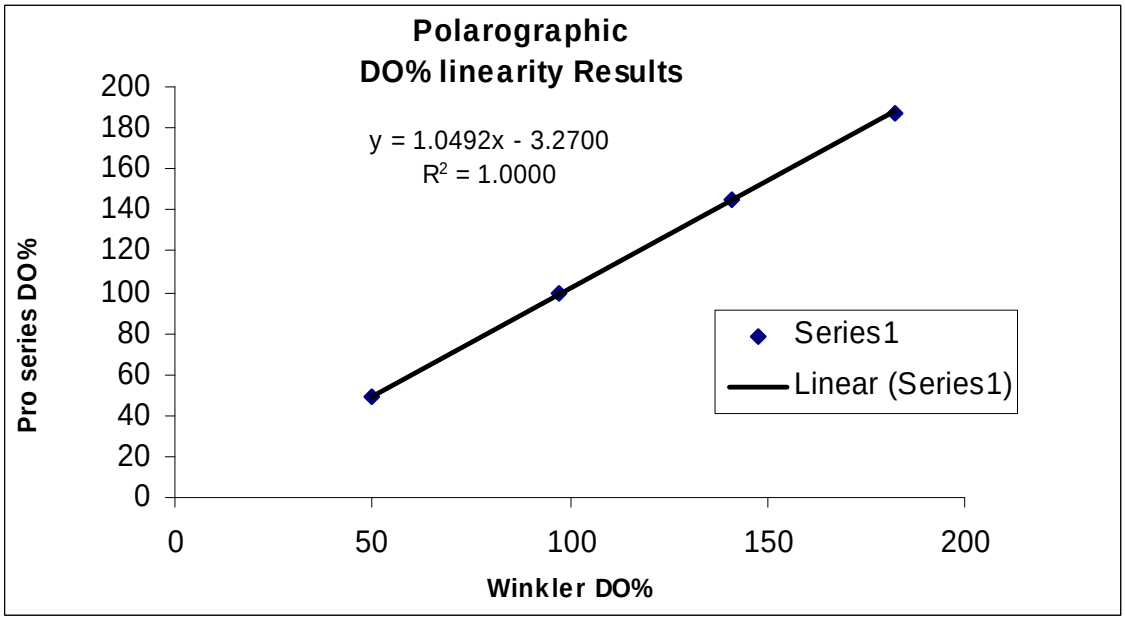
The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor (*k* = 2), providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

6.6 Graphical presentation of results

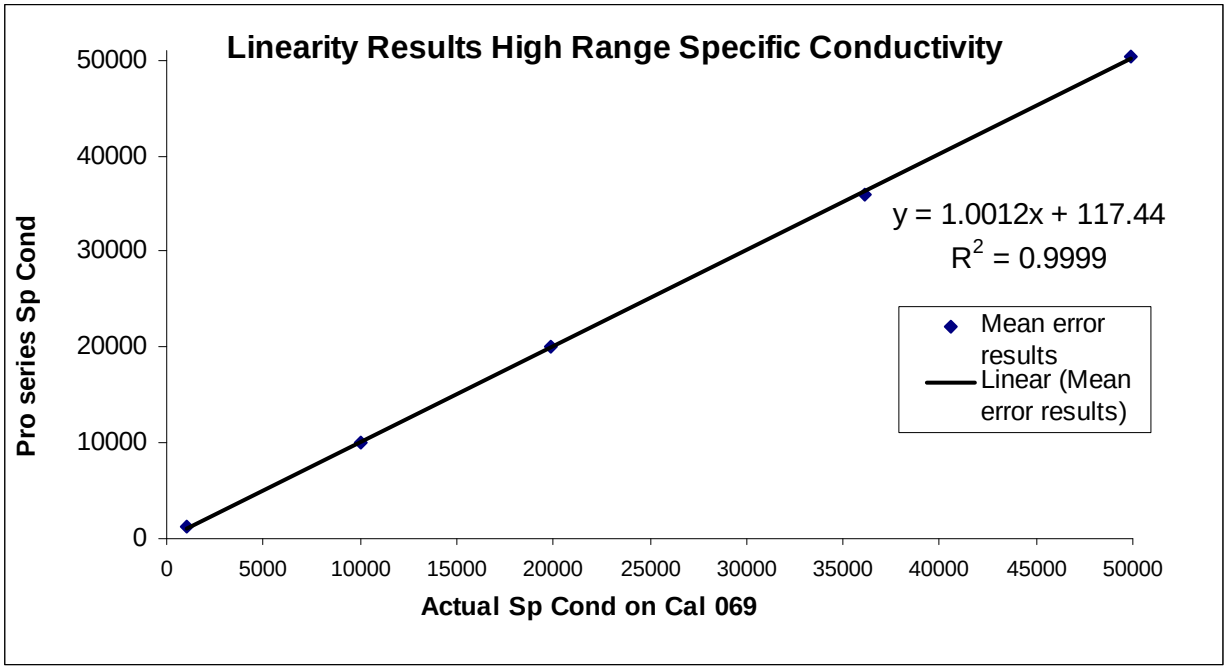
6.6.1 Linearity regression graph pH

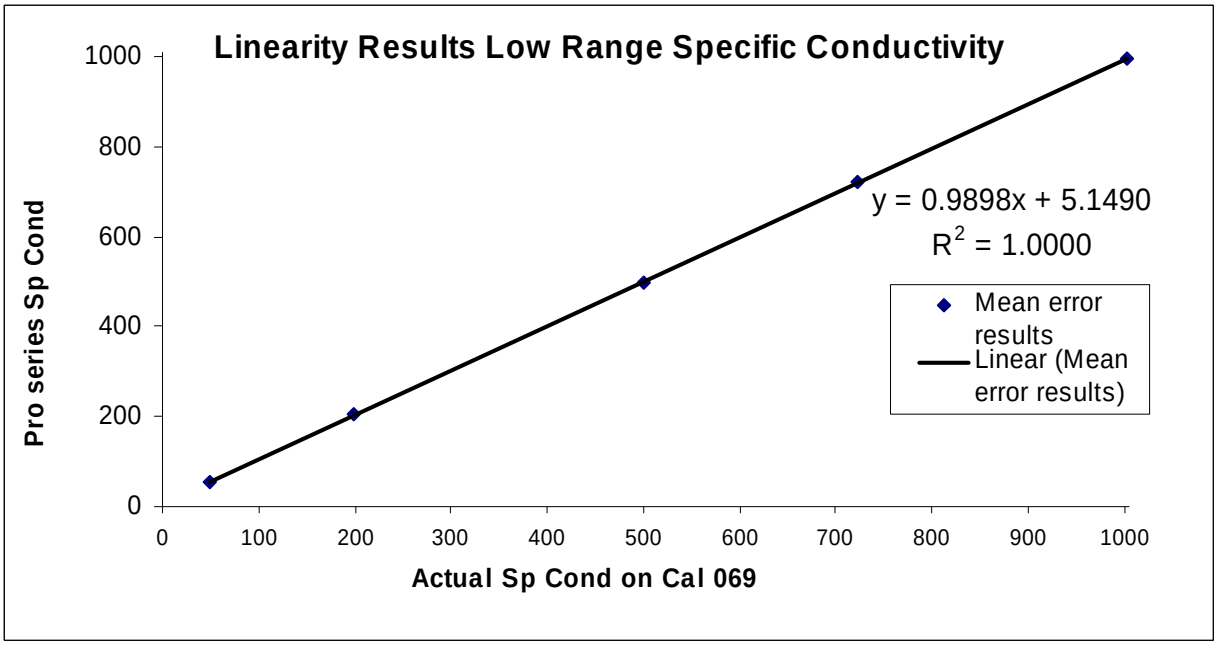


6.6.2 Linearity regression graph DO%

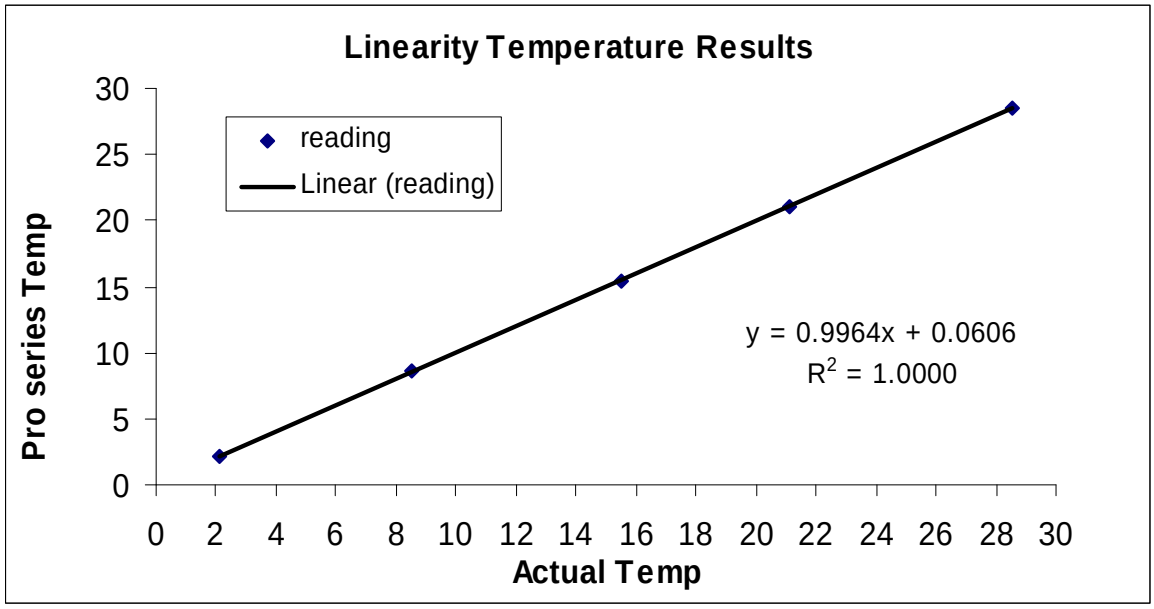


6.6.3 Linearity regression graphs Conductivity

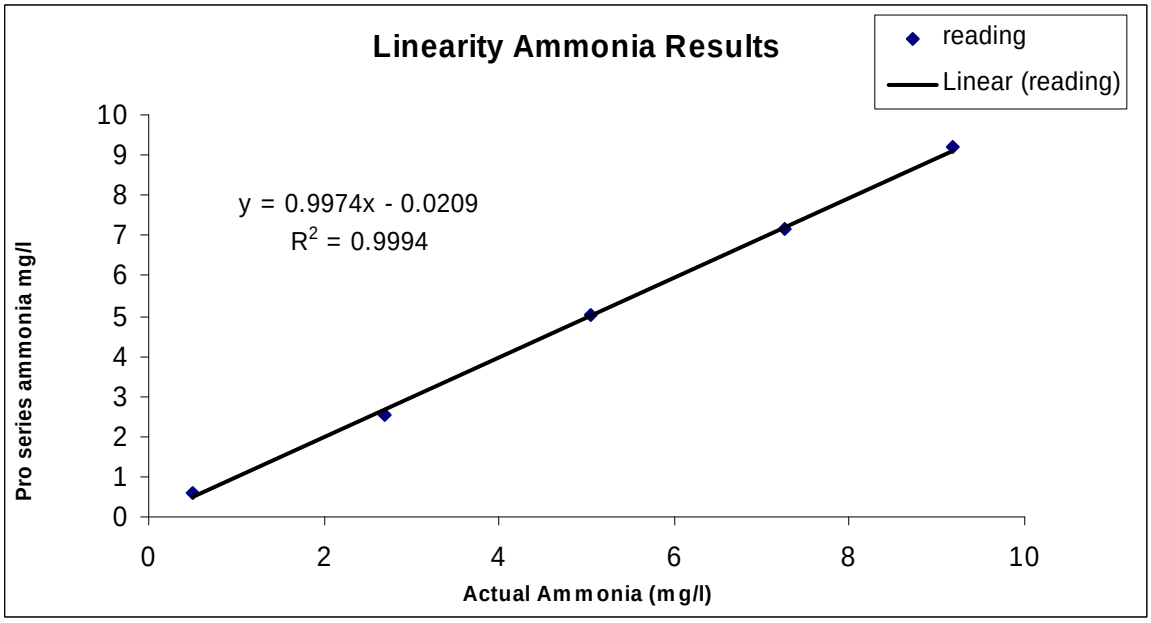




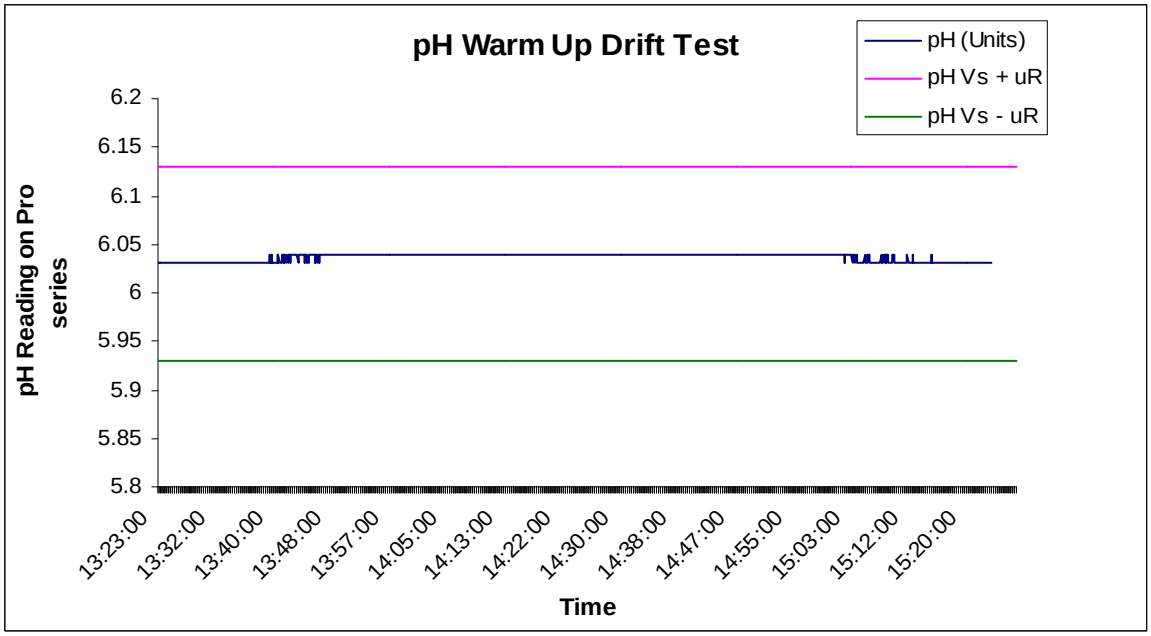
6.6.4 Linearity regression graph Temperature

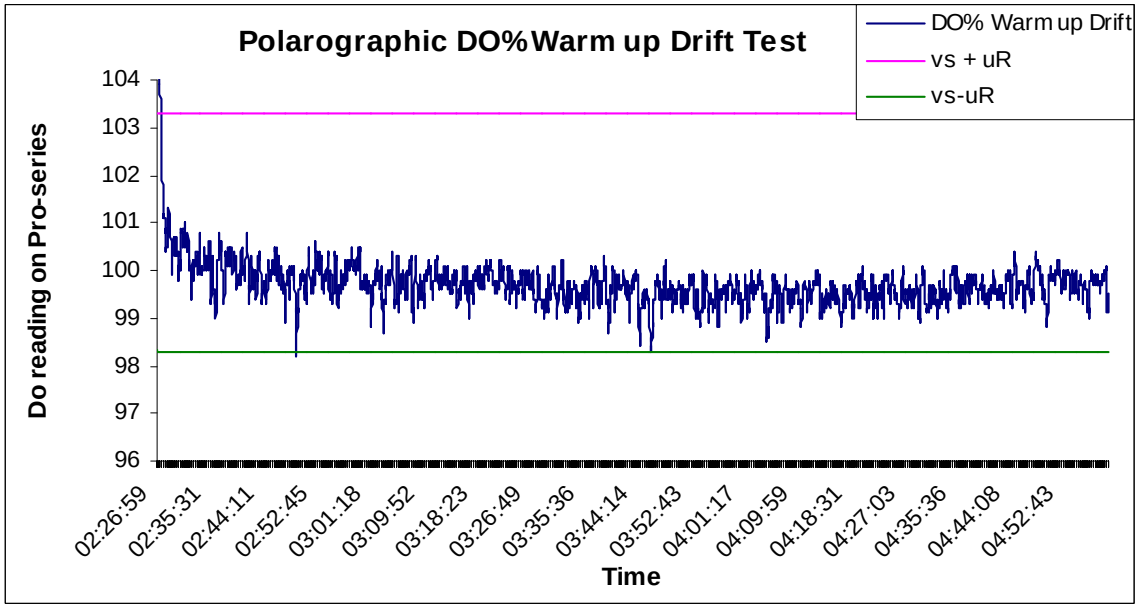


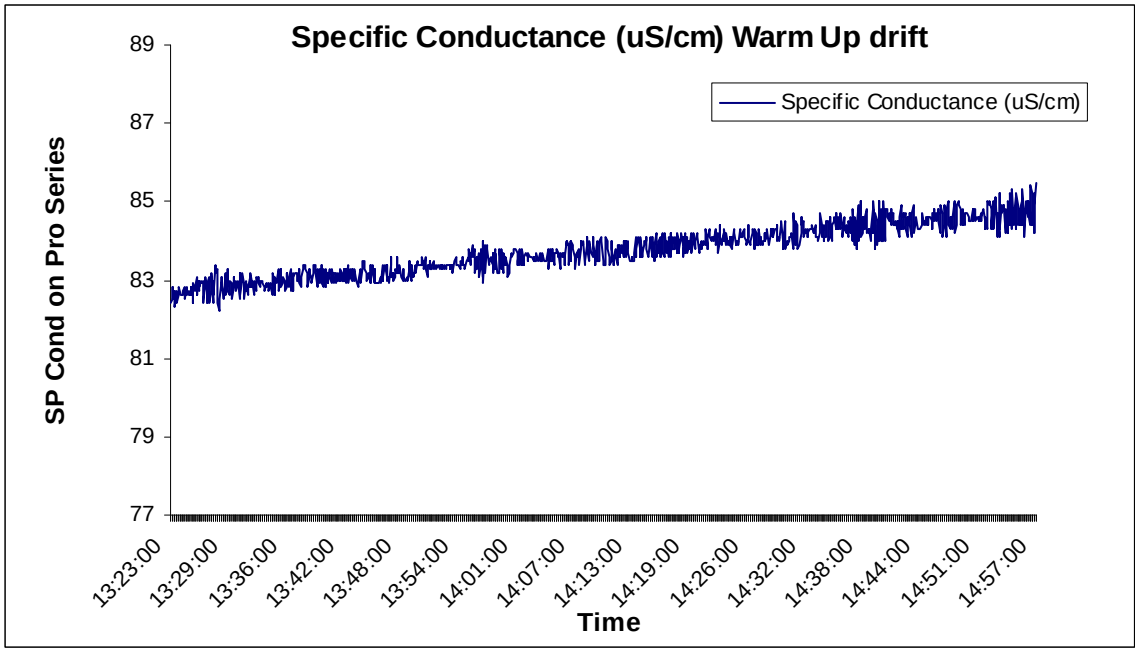
6.6.5 Linearity regression graph Ammonia (TAN)

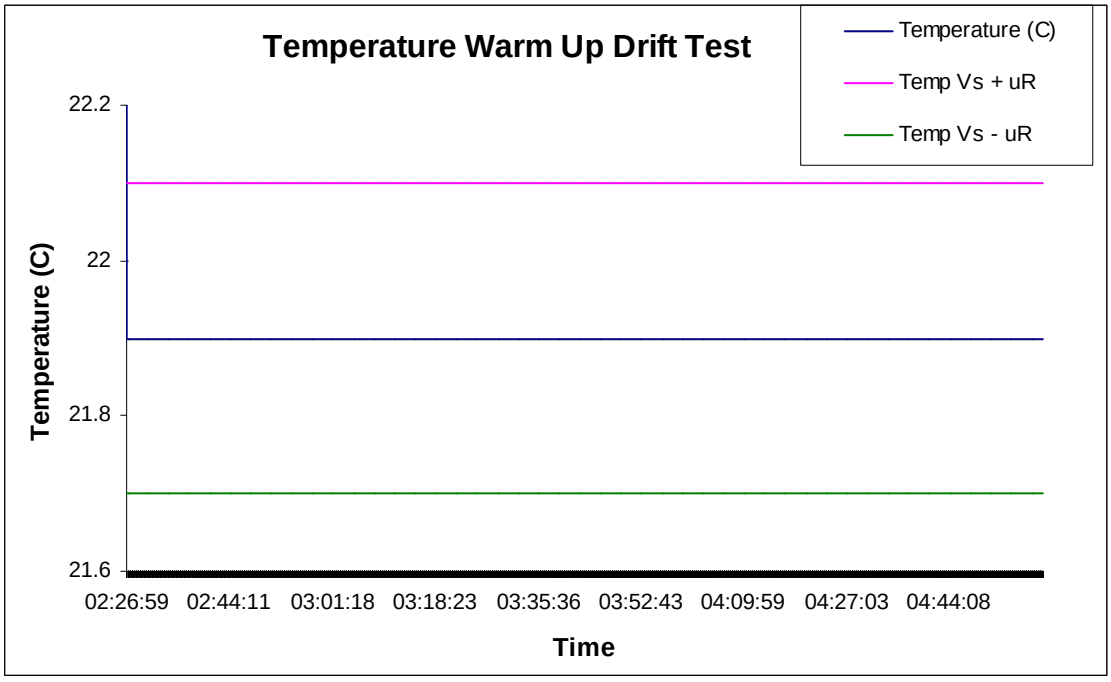


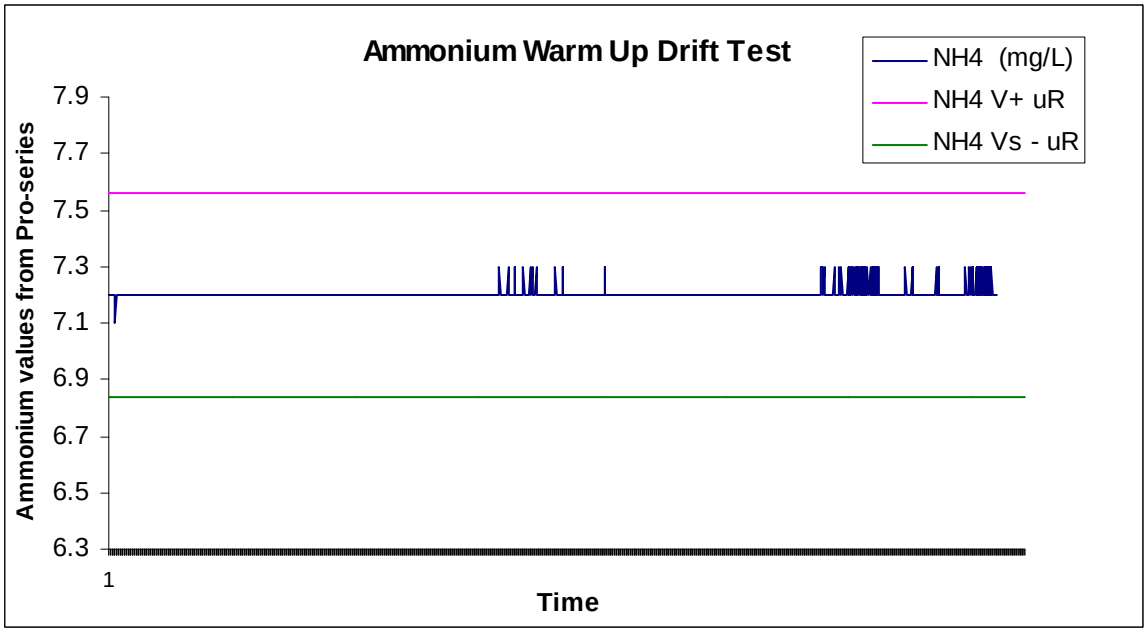
6.6.6 Warm up Drift Graphs



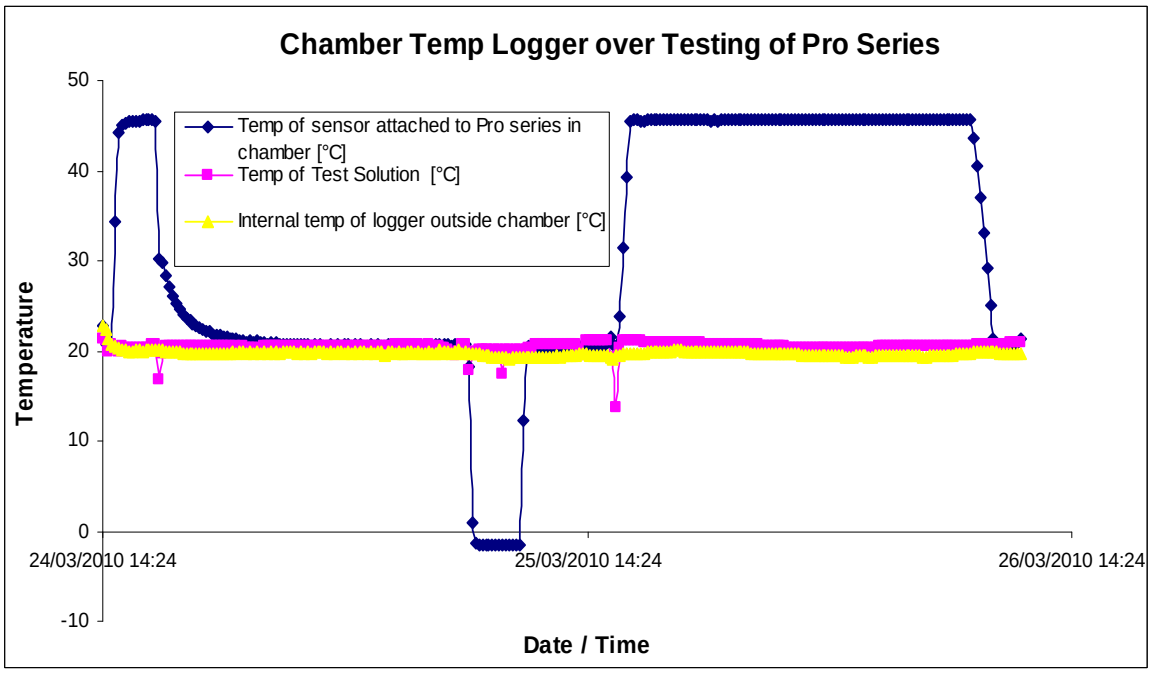



Specific Conductance (uS/cm) Warm Up drift
Specific Conductance (uS/cm)
SP Cond on Pro Series
89
87
85
83
81
79
77
13:23:00
13:29:00
13:36:00
13:42:00
13:48:00
13:54:00
14:01:00
14:07:00
14:13:00
14:19:00
14:26:00
14:32:00
14:38:00
14:44:00
14:51:00
14:57:00
Time

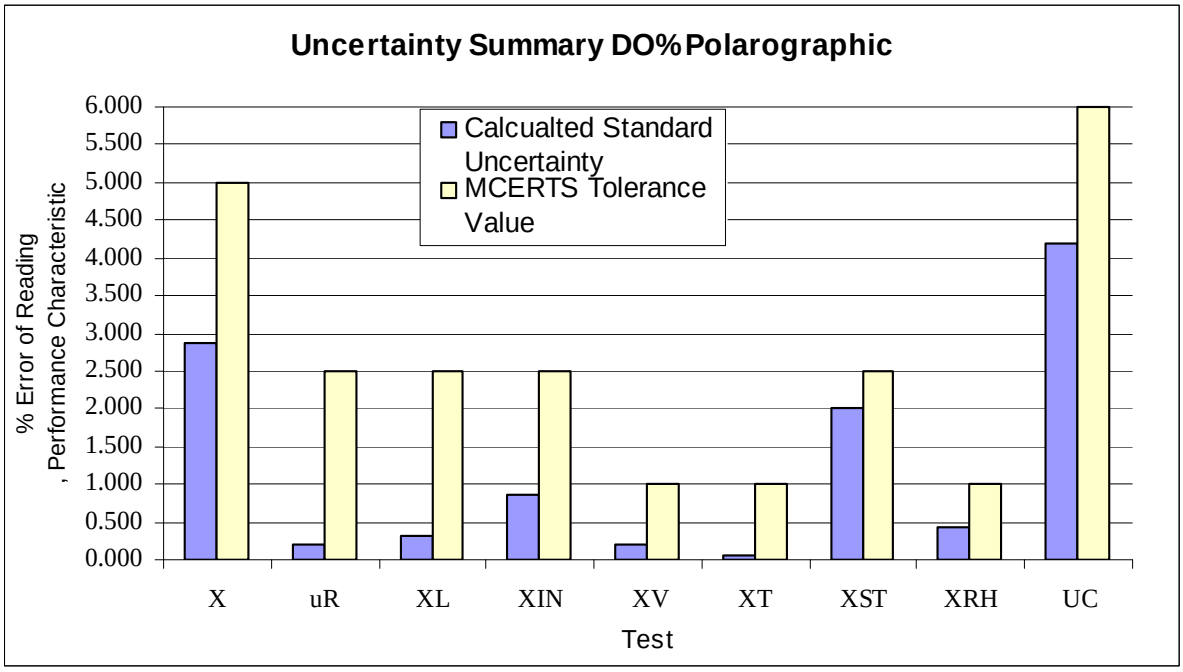

Temperature Warm Up Drift Test
Temperature (C)
Temp Vs + uR
Temp Vs - uR
Temperature (C)
22.2
22
21.8
21.6
02:26:59
02:44:11
03:01:18
03:18:23
03:35:36
03:52:43
04:09:59
04:27:03
04:44:08
Time



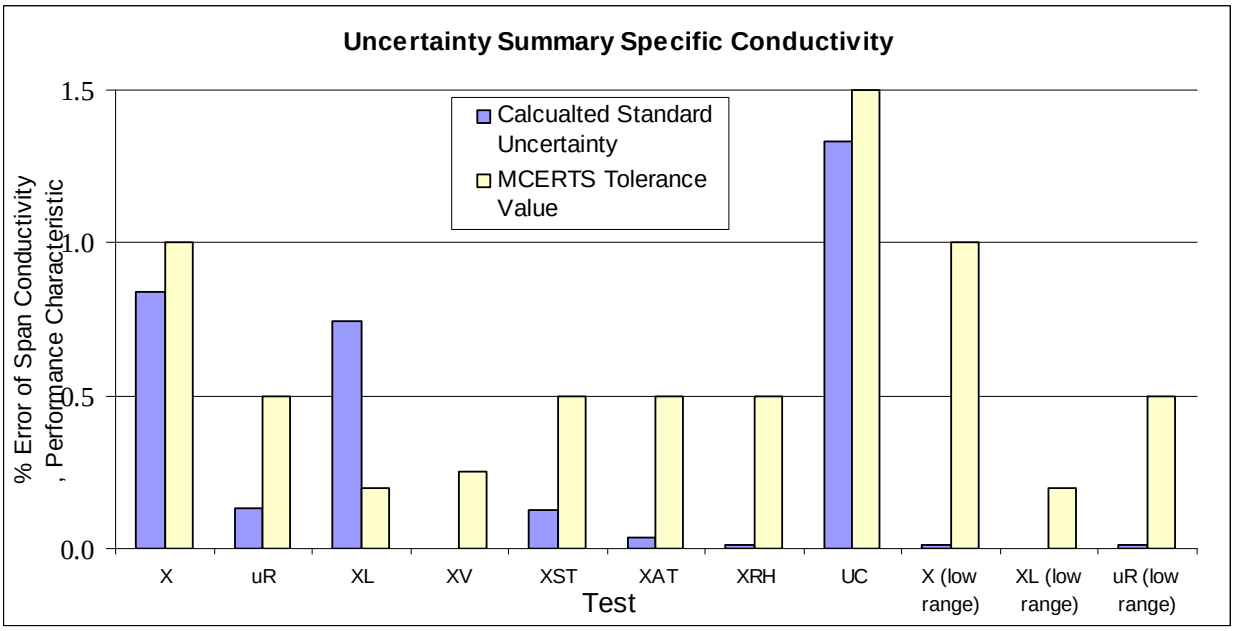
6.6.7 Temperature logs for Ambient Temp and Relative Humidity Tests in the Chamber



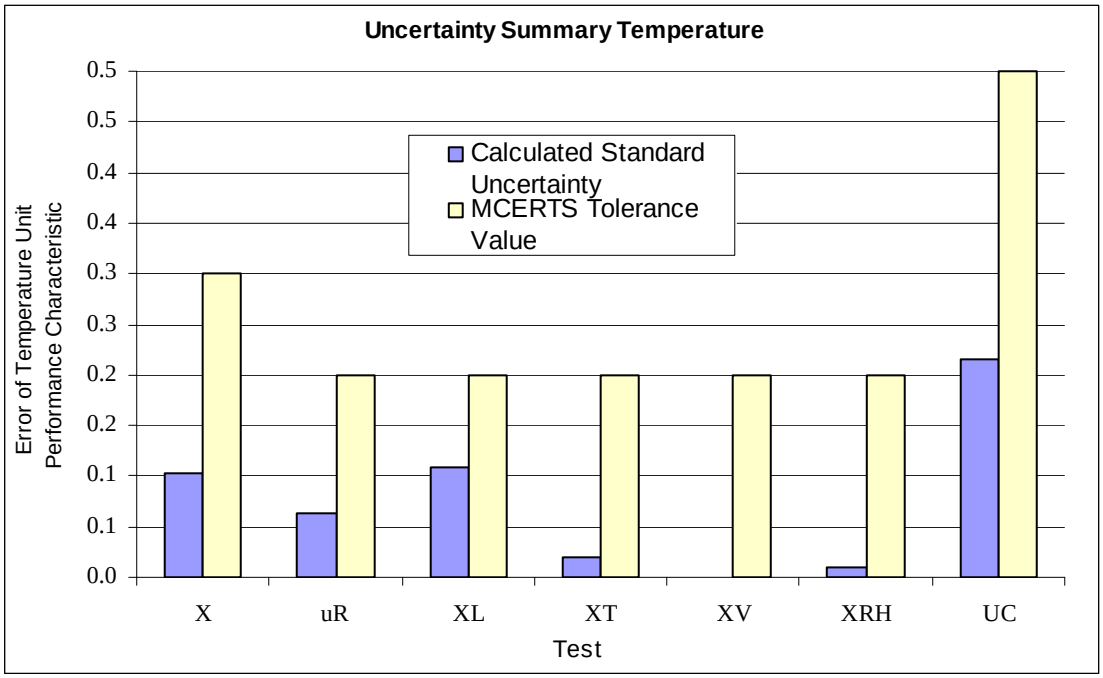
6.6.8 Uncertainty Summary DO%



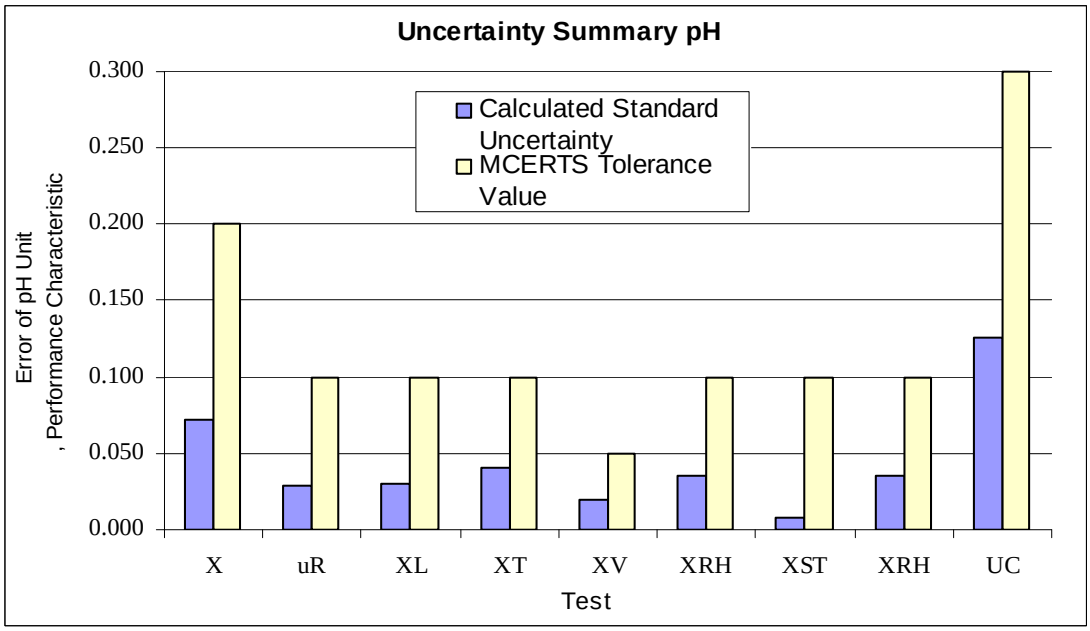
6.6.9 Uncertainty Summary Conductivity



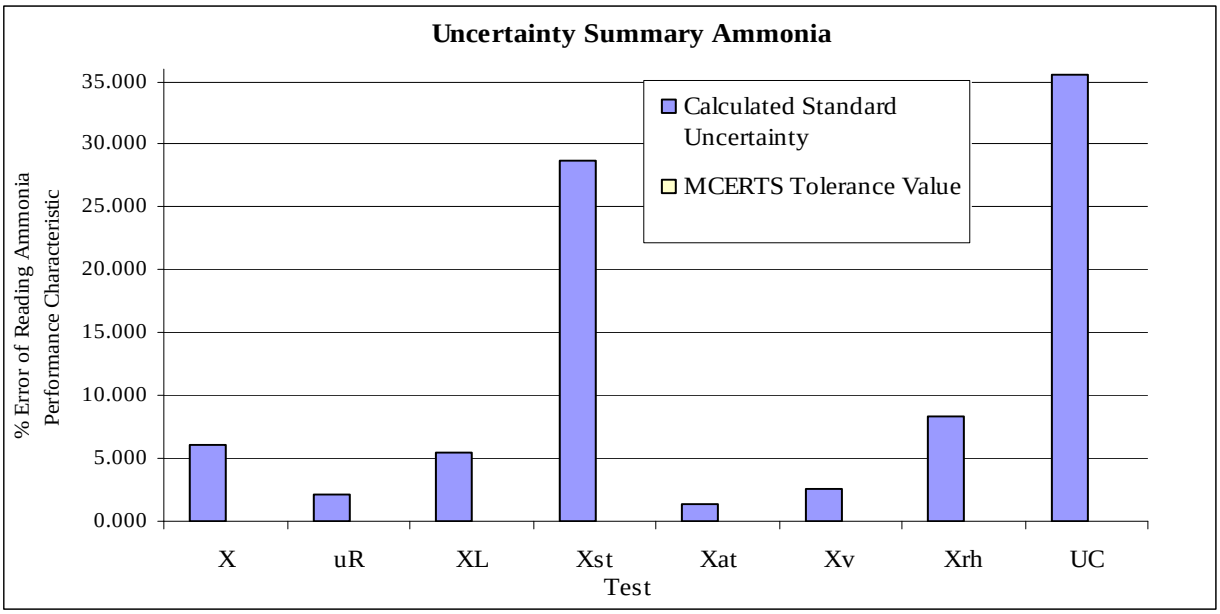
6.6.10 Uncertainty Summary Temperature



6.6.11 Uncertainty Summary pH



Uncertainty Summary Ammonia (TAN)



Appendices

Appendix A: Raw data from the tests

1. Spreadsheet containing all raw data and calculations – See disk

Appendix B: Operating instructions

1.	Professional Series Manual	See Disk
2.	Radiometer PHM220 pH Meter Lab SOP 7.3/C1	See Disk
3.	DO by Titrimetry 7.3/D5 Laboratory Method	See Disk
4.	Operation of Environmental Chamber lab SOP 5.4 B1	See Disk
5.	CPX200 TTI Variable Power Supply lab SOP 5.4 B2	See Disk
6.	pH Buffer details and MSDS data	See Disk
7.	Conductivity Standards and MSDS data	See Disk
8.	Gas System Lab SOP B8	See Disk
9.	Hach Laboratory Spectrophotometer Manual	See Disk
10.	Radiometer Conductivity Meter Manual	See Disk
11.	TTI 2 Accurate Temperature Measuring instrument (refs: Cal 032 and Cal 071 for Platinum Resistance Thermometer used. Man 032 and SOP 7.3/B9 for instructions).	See Disk
12.	ASL F100 PRT Temperature measuring devices (ref Cal 074 and Cal 075) SOP 5.4 B13 and MAN 029.	See Disk