PNNL-10798
UC-900

CRADA Information
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Final Project Report

CRADA with Instrumentation Northwest and Pacific Northwest National Laboratory (PNL-060): Development of an Electrochemical Sensor for Water Quality Products

P.E. Eschbach

June 1997

Prepared for U.S. Department of Energy
under Contract DE-AC06-76RLO

Pacific Northwest National Laboratory
Operated for the U.S. Department of Energy
by Battelle

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DEVELOPMENT OF AN ELECTROCHEMICAL SENSOR FOR WATER QUALITY MEASUREMENTS

Introduction

A sensor to measure water quality and characterize flow in aquifers was invented several years ago at PNNL. However, the sensor was an experimental prototype, and although it had been utilized for various field measurement activities at the Hanford Site, no commercial prototype of the instrument was available. This Cooperative Research and Development Agreement (CRADA) with Instrumentation Northwest (a small instrument manufacturing firm located in Redmond, WA) was directed at developing such a commercial prototype. Approximately $30,000 of Federal funds supplied by the Department of Energy's (DOE) Energy Research Laboratory Technology Research (ER-LTR) program were utilized to support PNNL's efforts under the CRADA. Instrumentation Northwest's contributions in labor, travel and equipment significantly exceeded PNNL's. Work on the CRADA began in late March of 1994 approximately six weeks after the proposal for the project was first submitted. The project was completed approximately seven months later in October 1994.

Instrumentation Northwest was established in 1982 by its current president, Gregg Gustafson. They have had a good track record for successfully commercializing environmental measurement technology. Instrumentation Northwest is located in Redmond, Washington and employs about twenty people.

Stephen Hall is the inventor of the ion specific sensor to be used in the water quality probe. Stephen is a senior research scientist at PNNL and provided his input to the design and testing of the instrument. Michael Hansen is a senior research engineer at PNNL and was responsible for designing the integrated probe technology. Peter Eschbach is a senior research scientist at PNNL and provided project management capabilities and input to the design of the probe, particularly the electronics and temperature measurement.

Purpose

The purpose of this CRADA was to convert an experimental electrochemical sensor invented (by Stephen Hall) at Pacific Northwest National Laboratory (PNNL) into a prototype commercial unit for sensing water quality. The water quality sensing unit will contain a pH electrode, ion specific electrochemical sensor, and a temperature sensor. This water quality sensor will be manufactured and sold by Instrumentation Northwest (INW) of Redmond, Washington. Since Instrumentation Northwest does not have a design engineer on staff, PNNL will aid in the design of the probe.

The prototype technology that will be developed in this project can benefit ongoing DOE environmental programs in three ways. Foremost, the Probe can be a central tool for use in cost-effective aquifer characterization. It was originally developed for in situ tracer measurements in a battery of single-well hydrologic tracer tests designed to yield ground water flow rate, effective porosity, and the vertical distribution of hydraulic conductivity in an aquifer. It was first used in DOE's thermal energy storage program, and is currently being used for detailed aquifer characterization at the Hanford bioremediation test site. When it is fully developed, the probe will be used in other ground water studies at Hanford, and INEL has requested the technology for ground water studies scheduled later in the year. Such tests yield the "ground truth" data necessary for realistic ground water flow modeling, and at nominal cost. With conventional hydrologic methods, collecting such data can be prohibitively expensive, and has seldom been done at Hanford.

The probe's sensing units can be designed to measure natural water quality parameters as well as introduced tracers. In Hanford's 300 Area, the ground water is known to be geochemically stratified, based on samples collected using the costly Westbay multi-level sampling system installed in a well. The probe technology can be used either instead of the Westbay (or similar) installation, or as a means to geochemically log a well to optimize placement of permanent sampling ports. Finally, the probe can be used for continuous monitoring in the vicinity of known waste disposal sites.

Summary of Activities Performed

Successful achievement of the purpose of this CRADA required the establishment of a project team with diverse backgrounds. The members of the PNNL team were as follows: Lisa Stoetzel (financial matters), Michael Hansen (design engineer), Stephen Hall (inventor and electrochemicst), and Peter Eschbach (project manager). Instrumentation Northwest Staff that were involved with the project were: Gregg Gustafson (Inventor and Company President), Jay Kuga (draftsman, and manufacturing engineer), and Mike Kirsch (electrical engineer).

In late March, funding was allocated for the project and design of the probe was started by Michael Hansen. On April 7th a preliminary design was sent to Instrumentation Northwest (INW). INW team members then read through Michael Hansen's design draft and made comments to Peter Eschbach of PNNL. The comments were discussed with Michael Hansen and Stephen Hall and a second revised draft was completed by Michael Hansen on April 22. In early May, INW team member Jay Kuga arrived in Richland and stayed two weeks. During his stay, Kuga detailed the second design and made the drawings shop ready. The drawings are attached in Appendix A as Protected CRADA Information.

The shop ready drawings finalized in May 1994 were sent to various machine shops in the Seattle area by Jay Kuga of Instrumentation Northwest. Bids on the job were received back approximately one and one half weeks later. The job was awarded and parts were received from the machine shop in early July.

The probes were assembled at PNNL with the help of Mike Kirsch and Jay Kuga of Instrumentation Northwest. During the assembly, Stephen Hall guided the coating of the electrodes, proper reference electrode assembly, and expected outputs from the probe. During the pressure test, water leakage around the Ph electrode was discovered. This was corrected by machining the Ph electrode O ring grove and replacing the O ring with an O ring of larger cross section. We also discovered that the cases on the transistors were shorting to the stainless steel housing and causing a current to flow between the reference electrode and the stainless housing. By replacing these transistors with ceramic body transistors we were able to eliminate this current.

Stephen Hall has been performing a long term stability test of the reference electrode. At the time this report was developed, the reference electrode had been stable (constant voltage output) for two months, which is substantially longer than commercially available reference electrodes. The stability of the reference electrode is due to the patented design where capillary action along the threads causes slow diffusion of the reference solutions. The stability of the hydroprobe reference electrode makes it possible to leave the unit underwater for months without maintenance.

At the time of this report, a complete probe had been under test for several weeks. Data from the probe is collected every ten minutes by the data logger and stored in the computer. So far we have not seen significant changes in the outputs from the Ph electrode, Ion selective electrode (Bromine) or the thermistor. We plan on letting the data logger run for up to another year, until the probe output changes. Information on the operation of probe is provided as Protected CRADA Information in Appendix B.

Significant Accomplishments

A commercial prototype of a new instrument for sensing water quality was designed, manufactured and tested during the seven month duration of this Cooperative Research and Development Agreement (CRADA). The probe contains elements to measure temperature, PH, and ion concentrations assembled into a one inch diameter probe. The probe uses a patented design to achieve a very stable reference electrode that should allow the probe to be run continuously for a period of up to eight months without significant drift in either PH, temperature or ion selective signal. A product brochure/instruction manual for the TempHion™ commercial product developed in this project is provided in Appendix C.

This result could not have occurred without the contributions of PNNL staff to successfully address the technical problems described previously. The probe, now being sold by Instrumentation Northwest, the CRADA partner, is called TempHion™. The first customer, located in Oregon, purchased a TempHion™ to characterize groundwater; they were very pleased with the performance of hydroprobe and have since ordered another.

Significant Problems

The only significant problems encountered in the course of this project were the water leakage and electrical shorting problems with the initial prototype that were described previously. PNNL team members were able to successfully solve these problems prior to the completion of the project.

Industry Benefits Realized

The Hydroprobe provided an instrument that was much smaller than the other instruments on the market. This allows testing in wells that could not be tested previously, and in vertical wells where other instruments "stirred" the well and consequently could not provide the needed readings. In addition to the new applications made available by the Hydroprobe, the cost ($500-$1000 per instrument) is nearly half of the cost of competing probes on the market.

With the conclusion of the testing program in late September, Instrumentation Northwest's attention has been focused on marketing the probe. During the month of November 1994, two units were sold and the customer has reported only a two percent drift in the ion selective electrode (Bromine concentration) output in the aquifer they are testing. Thus, Instrumentation's Northwest's first customer is observing the same stability with the hydroprobe that we have observed in our idealized lab setting. In the colloquial of industry, the first customer is a Beta test site. We understand that they have been very pleased with the two hydroprobe units.

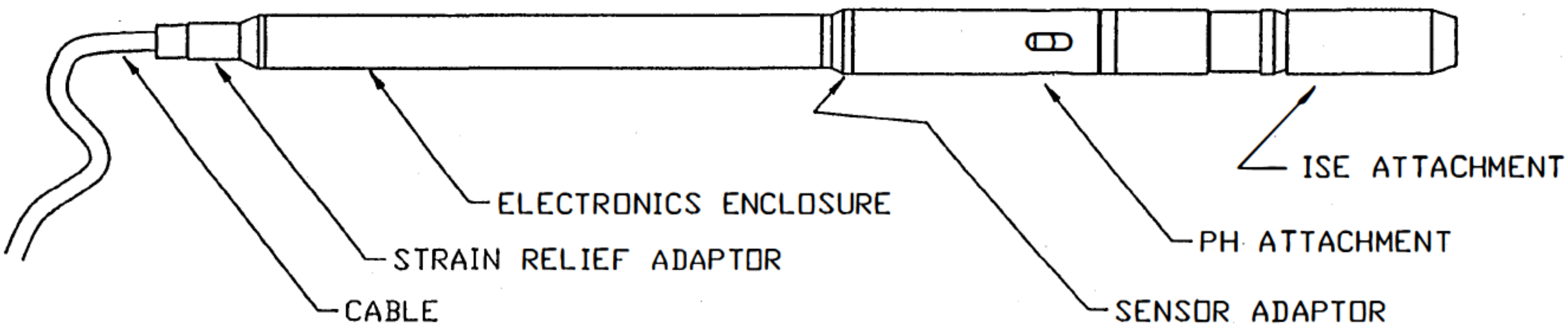
Instrumentation Northwest plans to have fifty more hydroprobes built for inclusion in their loan pool which will allow customers to "rent" the probes and potentially encourage sales. It is highly probable that some of these customers will be DOE sites (including Hanford) that have a need for an inexpensive way to monitor groundwater quality within the sites.

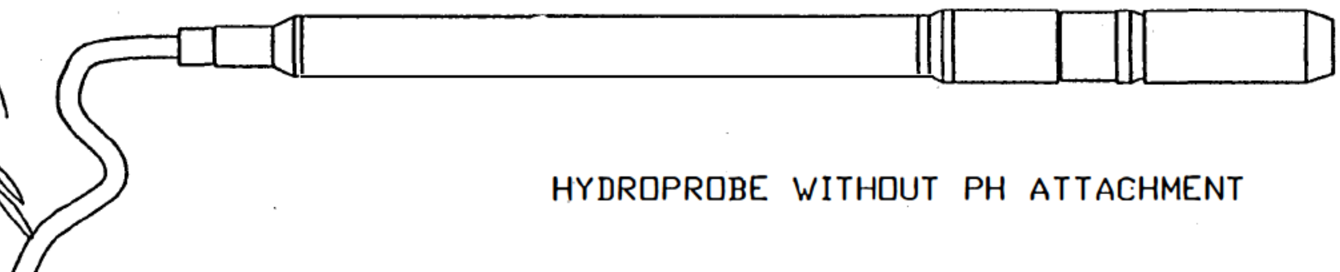
Recommended Follow-On Work

Because a commercial prototype was able to be successfully developed and transferred to industry within the $30,000 of funding provided by DOE for this CRADA, no follow-on work supported by the ER-LTR program is proposed. It is recommended that the results of this CRADA (including additional testing results from the Hydroprobe) continue to be tracked to measure the long-term benefits to both Instrumentation Northwest and DOE of the apparently successful outcome.

APPENDIX A

Design Drawings for Probe Technology

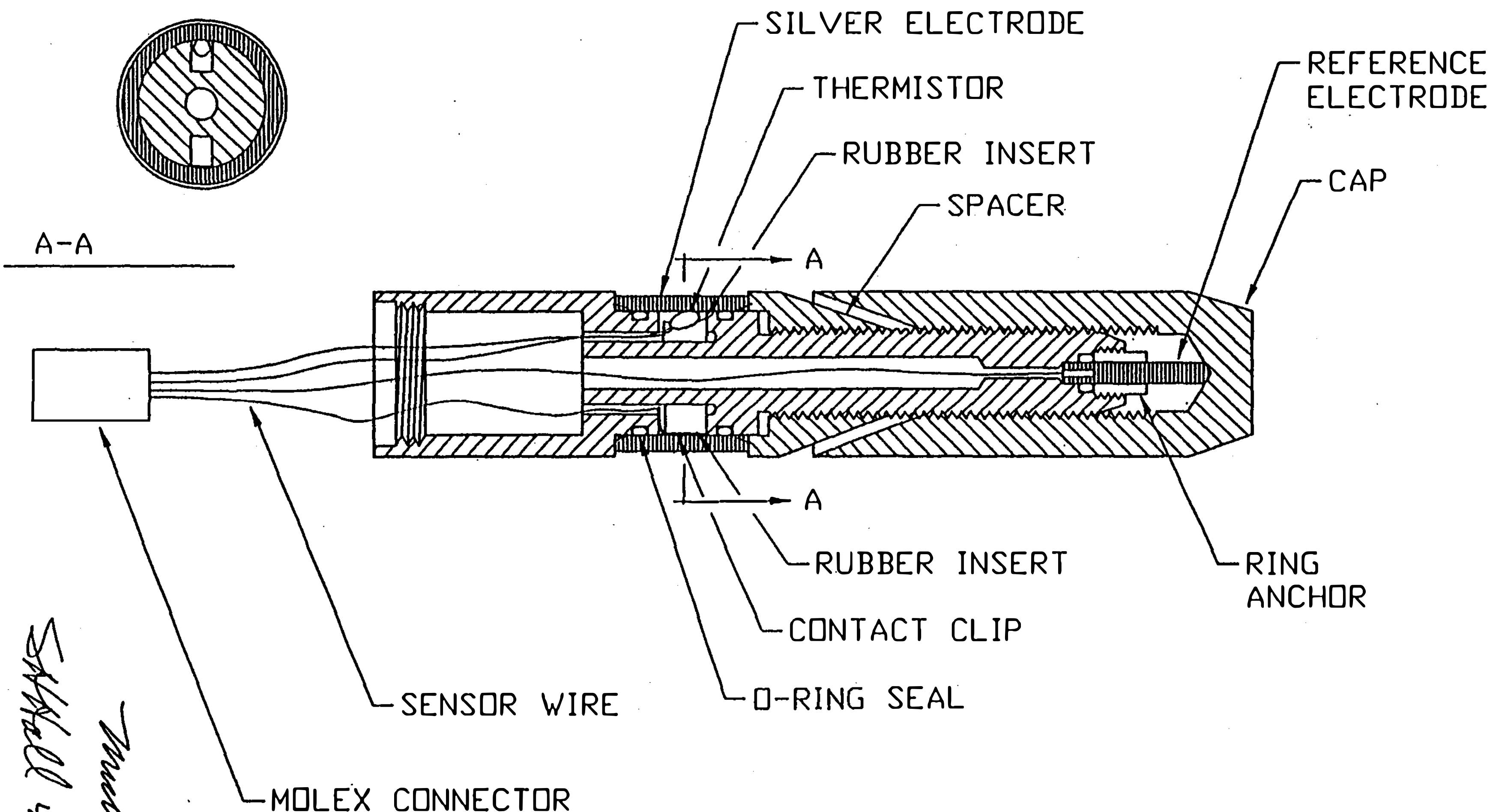




HYDROPROBE WITHOUT PH ATTACHMENT

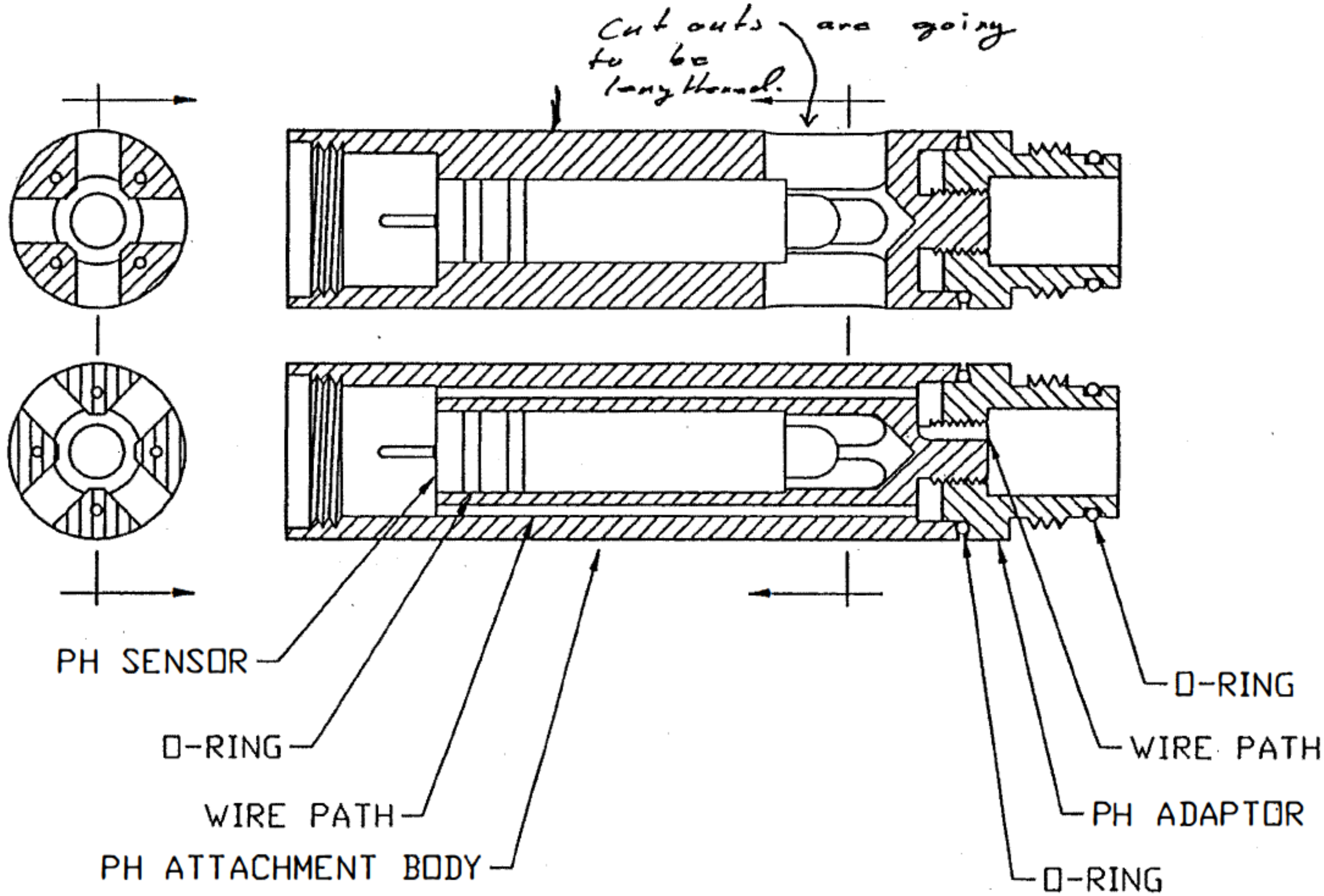
INW HYDROPROBE - ASSEMBLY

DRAWN: MA HANSEN
BATTELLE
DATE: 4-27-94
REV. 0
HPROBE1.DWG
SHEET 2 OF 5



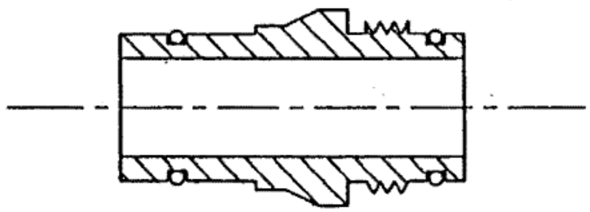
INW HYDROPROBE - ISE ATTACHMENT

DRAWN: MA HANSEN
BATTELLE
DATE: 4-27-94
REV. 0



INW HYDROPROBE - PH ATTACHMENT

DRAWN: MA HANSEN
BATTELLE
DATE: 4-27-94
REV. 0
HPROBE1.DWG
SHEET 4 OF 5



INW HYDROPROBE - SENSOR ADAPTOR

DRAWN: MA HANSEN
BATTELLE
DATE: 4-27-94
REV. 0
HPROBE1.DWG
SHEET 5 OF 5

NOTES

THE O-RING GROOVES SHOULD BE MADE ACCORDING TO PARKER DIMENSIONS AND FINISHES FOR INDUSTRIAL STATIC SEAL GLANDS

MATERIALS USED IN CONSTRUCTION OF PROBE COMPONENTS SHOULD BE DELRIN, WITH THE EXCEPTION OF THE SENSOR ADAPTOR WHICH SHOULD BE MADE OF 300 SERIES STAINLESS

THE SILVER ELECTRODES SHOULD HAVE A FINISH AS SPECIFIED FOR PARKER INDUSTRIAL STATIC O-RING SEAL GLANDS ON THEIR SEALING SURFACES

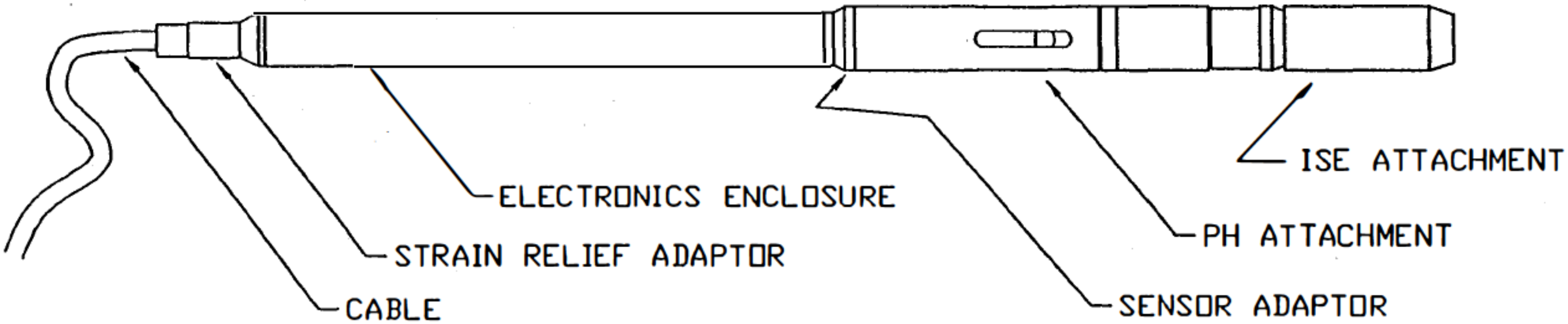
CERTAIN ASSUMPTIONS WERE MADE AS TO THE SIZE OF THE MOLEX CONNECTORS THAT INW WOULD LIKE TO USE. CLEARANCE SHOULD BE CHECKED BEFORE THE FINAL DETAILED DRAWINGS ARE ISSUED

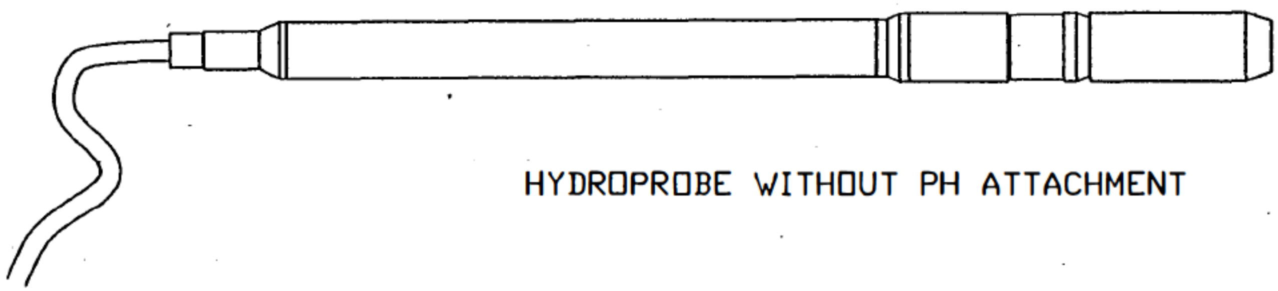
THE WIRE USED TO HOOK UP THE PROBE SENSORS SHOULD BE MULTI STRAND WIRE, WITH A GAGE OF 26 TO 30

ALL SHARP CORNERS SHOULD BE BROKEN ON ACCOUNT OF THE O-RING SEALS

DRAWN: MA HANSEN
BATTELLE
DATE: 4-27-94
REV 1
HPROBE1.DWG
SHEET 1 OF 5

Michael A Hansen 5/29/95
Peter C Eschbach 5/25/95



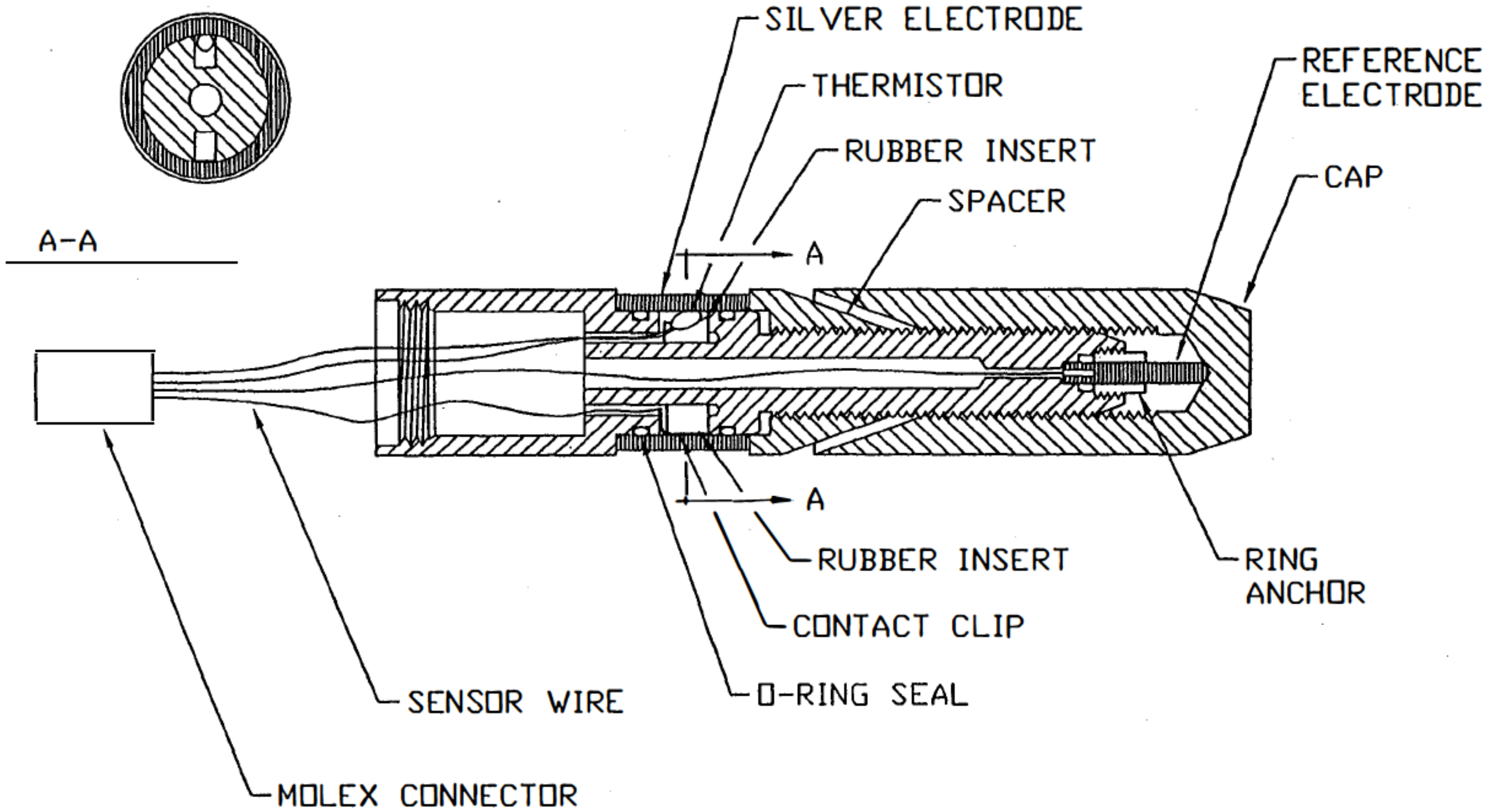


HYDROPROBE WITHOUT PH ATTACHMENT

INW HYDROPROBE - ASSEMBLY

DRAWN: MA HANSEN
BATTELLE
DATE: 4-27-94
REV 1
HPROBE1.DWG
SHEET 2 OF 5

~~Protected CRADA Information~~



INW HYDROPROBE - ISE ATTACHMENT

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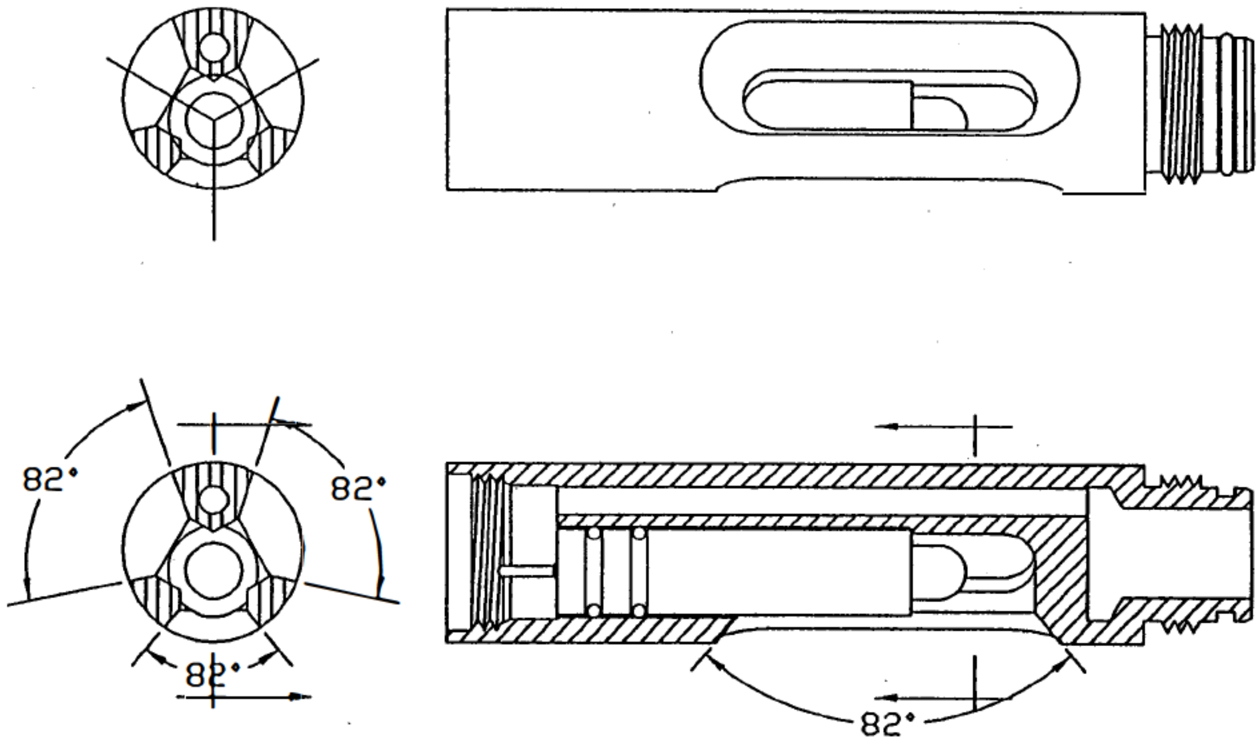
BATTELLE
DATE: 4-27-94
REV 1
HPROBE1.DWG
SHEET 3 OF 5

Protected CRADA Information

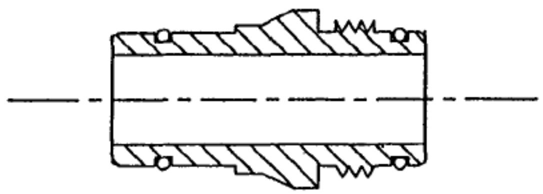


INW HYDROPROBE - PH ATTACHMENT

FINAL DESIGN 1

DRAWN: MA HANSEN
BATTELLE
DATE: 5-16=94
REV 1
HPROBE1.DWG
SHEET 4 OF 5

~~Protected CRADA Information~~



INW HYDROPROBE - SENSOR ADAPTOR

DRAWN: MA HANSEN
BATTELLE
DATE: 4-27-94
REV 1
HPROBE1.DWG
SHEET 5 OF 5

APPENDIX B

Operating Information for the Probe Technology

APPLICATION NOTE

WATER QUALITY SENSOR

October 1994

INTRODUCTION

The Ion Specific sensor has three outputs, Ion Specific (Bromide), PH, and Temperature, each with their own 4-20 ma outputs.

The purpose of this note is to help in the interpretation of the sensors data. Since there are three independent outputs, a discussion of each will follow.

TEMPERATURE

Temperature sensor is a thermistor with a range of 0 - 40 deg C over an output signal of 4 - 20 ma. It has an accuracy of +/- 1%, uses the Yellow wire as the output connection. When used with the Aquistar DL4a, it uses the following Conversion Multiplier and Offset:

T = 10v - 10 where, T = Temp deg C
v = 1-5 volt (4-20ma) datalogger input

pH

pH sensor has a range of 0 - 14 pH over an output signal of 20 - 4 ma. The conversion multiplier and offset takes the form:

y = mv + b m = conversion multiplier (slope), b = offset

pH = -9.23 v + 34.46 where, pH = level 0 - 14 pH
v = 1-5 volt (4-20ma) datalogger input

Temperature correction is attained by using the following formula and proceedure. Temp calibration (Tc) is the room temperature at time of calibation in deg K (Kelvin). This sensor was calibrated with a temperature Tc = 295.15 deg K. Temperature measured Tm, is that instantaneous temperature around the sensor, measured by the thermistor output.

pH' = (m/Tc)(Tm)v + b
= (-9.23/295.15)(Tm)v + 34.46
= .03127(Tm)v + 34.46

Note that all temperatures in this conversion need to be in deg K. Therefore, be sure and derive Tm from the T temperature output and add 273.15.

deg K = deg C + 273.15

SPECIFIC ION (BROMIDE)

Bromide sensor has a range of 0 - 300 ppm Br over an output signal of 4 - 20 ma. The conversion multiplier and offset takes the form:

y = mv + b   m = conversion multiplier (slope), b = offset

Two conversions need to take place. The datalogger converts the signal to cell volts vs ma output,

cell volts (millivolt) = 18.75v + 225

???? or ma = 18.75v + 225

then, external from the datalogger we need to sovlve for Br- (conc),

Br (conc) = 10 exp ((ma - 20.13)/-2.925)

derived from, ma = 20.13 - 2.925 log(Brconc)

Temperature compensation:

Br (conc) = 10 exp ((ma - 20.13)/ -2.925(.003388Tm))

or, ma = 20.13 - 2.925(.003388Tm) log (Br)

where, Temp coefficient is Tm/Tc = Tm/295.15 = .003388Tm deg K

WIRING

This wiring layout is for use with the Aquistar DL4a datalogger.
The datalogger powers all 4 channels together, so we only use channel #1's power and ground (Red and Black). Heat shrink tubing should be used on channel's 2 & 3 Red and Black wires and not used.

DATALOGGER		TRANSDUCER
Channel #1 Red (+PWR)	o---------o	Orange (+PWR)
Channel #1 Black (GRD)	o---------o	Black (GRD)
Channel #1 Orange (RETURN)	o---------o	Red (ISE RETURN)
Channel #2 Orange (RETURN)	o---------o	Brown (PH RETURN)
Channel #3 Orange (RETURN)	o---------o	Yellow (TEMP RETURN)

ION SPECIFIC SENSOR OVERVIEW AND OPERATION FOR BROMIDE MEASUREMENT

January 1995

OBJECTIVE

The purpose of this document is to provide an overview of the Ion Specific Sensor (ISS) when configured for bromide measurement.

BACKGROUND

The ISS measures temperature and the concentration of a specific ion. In this application, bromide is the ion of interest. The ISS is constructed as a voltaic cell and as such its operation is described by the Nernst equation. Specifically, we observe a linear cell output voltage over the log of the bromide concentration. In simplified form, the Nernst equation appears as follows:

$$V_{cell} = E^{\circ}_{tot} - aT \log(C) \qquad \{1\}$$

where,

V_{cell} is the voltage generated by the voltaic cell
E°_{tot} is the standard voltage
a is a reaction constant
T is the temperature in Kelvin
C is the bromide concentration in PPM

For bromide measurement, the electronics within the ISS amplify the cell voltage and transmit an industry standard 4 - 20 mA signal. The circuit is calibrated such that a -150 to +150 mV cell voltage corresponds to a 4 to 20 mA current, respectively. With this in mind, the following relationships are defined:

$$I = (8/150)V_{cell} + 12 \qquad \{2\}$$

$$V_{cell} = (150/8)I - 225 \qquad \{3\}$$

where I is in mA and V_{cell} is in mV

For sample date taken at approximately 20°C, we have the following relationship:

$$V_{cell} = 161 - 55 \log C \qquad \{4\}$$

Substituting equation 4 into equation 2, we have

$$I = 20.587 - 2.993 \log C \qquad \{5\}$$

or

$$C = \exp[I - 20.587)/-2.993] \qquad \{6\}$$

Equation 4 is a benchmark cell voltage equation developed from actual test data taken at room temperature (-20°C). That is, an offset voltage of approximately 143 mV is typical but varies from unit to unit (on the order of +/- 20mV). In the case of equation 4, the offset voltage (1PPM output) is 161 mV. Equation 4 also shows that the cell output voltage decreases by 55 mV per decade increase in bromide concentration.

Equation 5 maps the cell voltage to look current transmitted by the ISS. For this particular device, the offset current is 20.587 mA. Also a decrease in look current of about 3 mA per decade increase in bromide is indicated by equation 5.

SET UP FOR OPERATION

The electrical wiring and logger parameters for the Aquistar DL4a are discussed in the INW Water Quality Sensor Application Note which was released in October, 1944. At this time, more discussion of the probe set-up is in order.

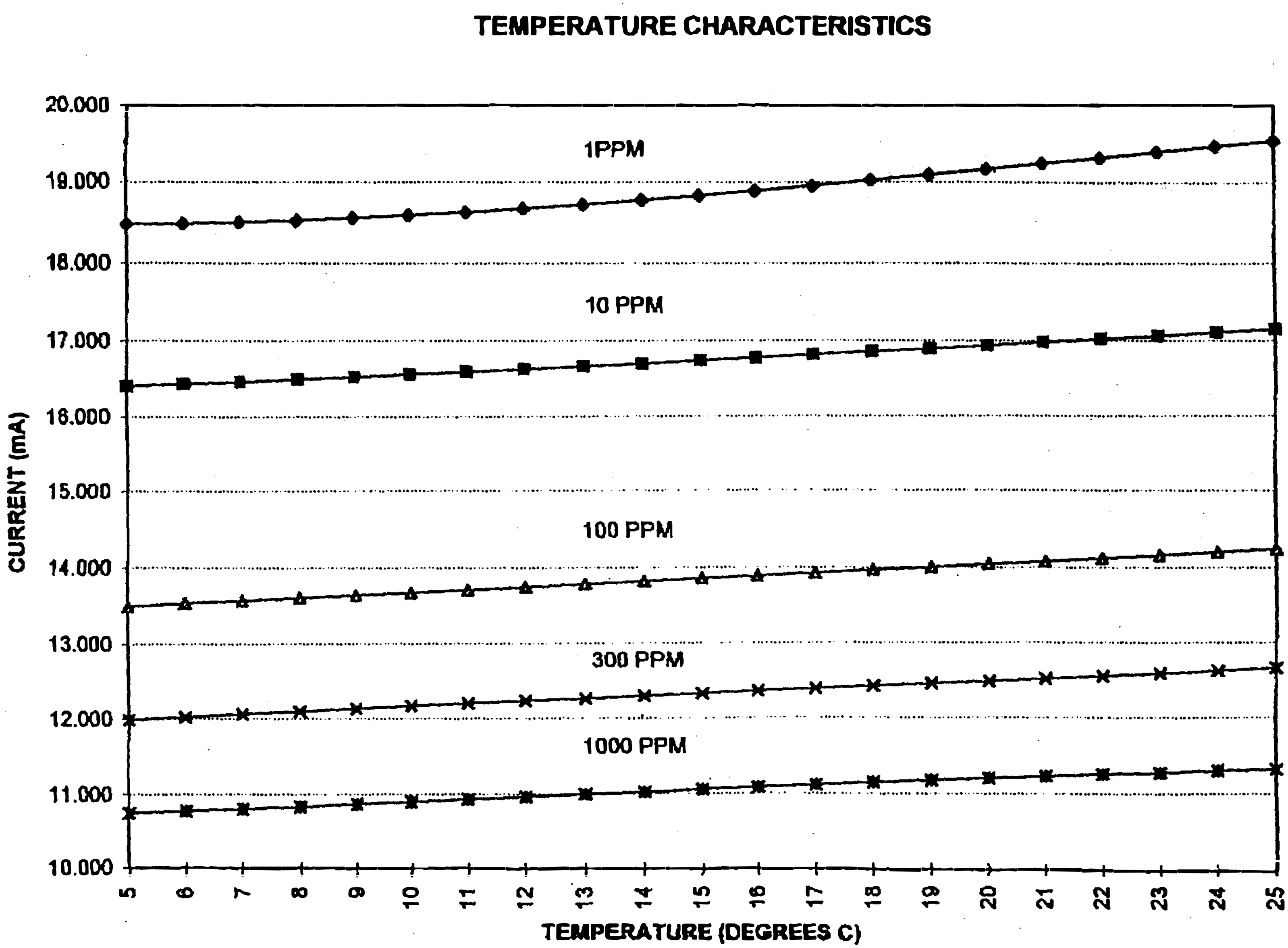
Before using the probe, the Ag| |AgC1 reference solution must be added. In addition, a fresh wrap of Teflon tape is required on the capillary threads. The recommended frequency for this procedure is every two weeks or whenever the probe is removed from the well. To accomplish this, refer to the following steps:

1. Unscrew the reference solution reservoir. Be careful not to touch or damage the reference electrode (silver lug). This unit is plated and should appear light, flat gray. At this time, inspect the plated silver band. It should appear brownish-gray.

2. Remove any Teflon tape from the male threads.

3. Place a new, continuous single wrap of tape on the male threads by starting at the bottom (reference lug end) of the threads and working upward. Be sure to overlap half the width of the Teflon tape. This results in a double layer of tape on the male threads. Terminate the wrap approximately 1/4" below the black taper nut (i.e., only tape the threads that will be engaged when the reference solution reservoir is installed).

4. Fill the reservoir approximately 1/3 of the way and screw onto the male capillary threads finger tight. **DO NOT TORQUE** the reference solution reservoir. This can damage the reference electrode and induce a leak. If installed properly, there should be a 1/8" gap between the inside taper of the reservoir and the black taper nut.


TEMPERATURE CHARACTERISTICS
1PPM
10 PPM
100 PPM
300 PPM
1000 PPM
CURRENT (mA)
20.000
19.000
18.000
17.000
16.000
15.000
14.000
13.000
12.000
11.000
10.000
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
TEMPERATURE (DEGREES C)

APPENDIX C

Product Brochure/Instruction Manual for Probe Technology

Instrumentation Northwest®

Manufacturer of Groundwater Monitoring Equipment and Submersible Sensors

TempHion™

Submersible Water Quality Sensor

INSTRUCTION MANUAL

LIMITED WARRANTY

Seller warrants that products manufactured by Seller when properly installed, used and maintained, shall be free from defects in material and workmanship. Seller's obligation under this warranty shall be limited to replacing or repairing the part or parts or, at Seller's option, the products which prove defective in material or workmanship within ONE (1) year from the date of delivery, provided that Buyer gives Seller prompt notice of any defect or failure and satisfactory proof thereof. Any defective part or parts must be returned to Seller's factory or to an authorized service center for inspection. Buyer will prepay all freight charges to return any products to Seller's factory, or any other repair facility designated by Seller. Seller will deliver replacements for defective products to Buyer (ground freight prepaid) to the destination provided in the original order. Products returned to Seller for which Seller provides replacement under this warranty shall become the property of Seller.

This limited warranty does not apply to lack of performance caused by abrasive materials, corrosion due to aggressive fluids, mishandling or misapplication. Seller's obligations under this warranty shall not apply to any product which (a) is normally consumed in operation, or (b) has a normal life inherently shorter than the warranty period stated herein.

In the event that equipment is altered or repaired by the Buyer without prior written approval by the Seller, all warranties are void. Equipment and accessories not manufactured by the Seller are warranted only to the extent of and by the original manufacturer's warranty.

THE FOREGOING WARRANTIES ARE IN LIEU OF ALL OTHER WARRANTIES, WHETHER ORAL, WRITTEN, EXPRESSED, IMPLIED OR STATUTORY. IMPLIED WARRANTIES OF FITNESS AND MERCHANTABILITY SHALL NOT APPLY. SELLER'S WARRANTY OBLIGATIONS AND BUYER'S REMEDIES THEREUNDER (EXCEPT AS TO TITLE) ARE SOLELY AND EXCLUSIVELY AS STATED HEREIN. IN NO CASE WILL SELLER BE LIABLE FOR CONSEQUENTIAL DAMAGES, LABOR PERFORMED IN CONNECTION WITH REMOVAL AND REPLACEMENT OF THE SENSOR SYSTEM, LOSS OF PRODUCTION OR ANY OTHER LOSS INCURRED BECAUSE OF INTERRUPTION OF SERVICE. A NEW WARRANTY PERIOD SHALL NOT BE ESTABLISHED FOR REPAIRED OR REPLACED MATERIAL, PRODUCTS OR SUPPLIES. SUCH ITEMS SHALL REMAIN UNDER WARRANTY ONLY FOR THE REMAINDER OF THE WARRANTY PERIOD ON THE ORIGINAL MATERIALS, PRODUCTS OR SUPPLIES.

With respect to products purchased by consumers in the United States for personal use, the implied warranties including but not limited to the warranties of merchantability and fitness for a particular purpose, are limited to twelve (12) months from the date of delivery.

Some states do not allow limitations on the duration of an implied warranty, so the above limitation may not apply to you. Similarly, some states do not allow the exclusion or limitation of consequential damages, so the above limitation or exclusion may not apply to you. This limited warranty gives you specific legal rights; however, you may also have other rights which may vary from state to state.

I. INTRODUCTION

This preliminary document is provided for informational purposes only and describes proper procedures for installing, operating and maintaining an INW TempHion™ beta unit. It may be changed substantially prior to final commercial release. The entire risk of the use or the results of the use of this document remains with the user.

To encourage the exchange of information and facilitate the development process of a new product, INW sells beta units at a discount in exchange for product feedback. Designed for experimental use only, this sensor will stand up to the rigors of field use if reasonably operated as outlined in this manual. The sensor is eligible for repair or replacement as described in INW's limited warranty for one year. If commercial release occurs within one year of purchase, the beta unit may be upgraded to final product specifications at a reduced price.

II. INITIAL INSPECTION AND HANDLING

Upon receiving the TempHion, inspect the device for obvious and concealed damage, such as cut cable. Also check the packaging for damage. If damage is apparent, note the signs on the appropriate shipping form and immediately report the information to the carrier. It is the responsibility of the shipping company to pay for any damage incurred during transit.

Check the etched label on the sensor to ensure the proper range and type was provided. Also, check the label attached to the cable at the connector end to guarantee proper cable length.

III. DOS AND DON'TS

- √ **Do** handle the device with care.
- √ **Do** store the device (without reference solution) in a dry, inside area when not in use.
- ☒ **Don't** handle the plated electrode ring or reference electrode.
- ☒ **Don't** store the device in sub-freezing temperatures.
- ☒ **Don't** install the device below 300 feet.
- ☒ **Don't** allow the device to free-fall down a well at high velocities as impact damage can occur.
- ☒ **Don't** bang or drop the device.
- ☒ **Don't** disassemble the device. ***(Warranty is void if sensor is disassembled.)***

IV. INITIAL SET-UP

Prior to installing and operating the TempHion, Ag/AgCl solution must be installed in the reference electrode.

Step 1

Unscrew and remove the reference solution reservoir. Be careful to minimize handling or damaging the ring plating or reference electrode plating. If the reference reservoir is too tight to remove, simply insert a 1/8" round stock into the hole just above the reservoir and grasp it while unscrewing the reservoir.

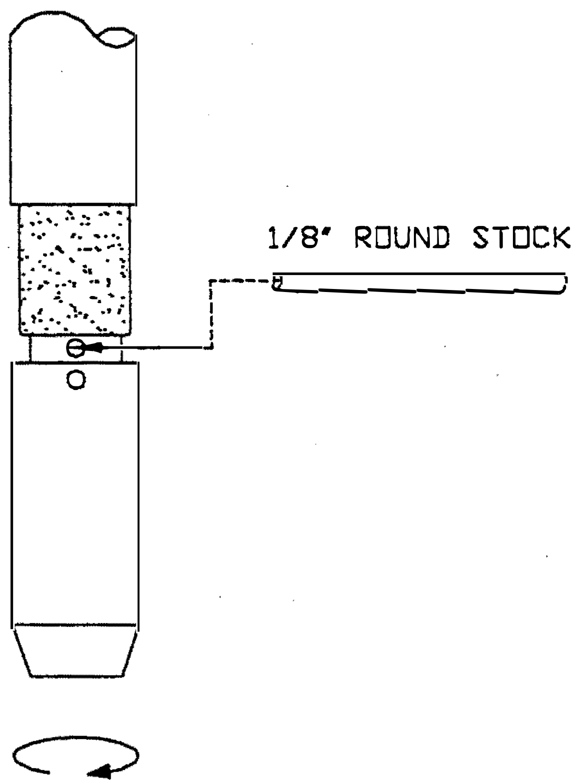


Figure 1.0

Step 2

Fill the reference reservoir about one-third of the way with Ag/AgCl solution and thread onto the male capillary threads finger tight. **Do not torque the reference reservoir.** Excess reference solution should bleed out the reservoir's four (4) port holes, indicating the proper amount was installed.

V. INSTALLATION

Note: The TempHion™ must be installed within 30° of vertical for proper operation.

Lower the probe downhole below the liquid level. While submersed, raise and lower it several times to remove any trapped air in the reference reservoir. Then lower the probe to the desired depth. Next, fasten the cable to the well head using tie straps or a weather-proof strain-relief system. Take a measurement to ensure the probe is installed below the liquid level. INW recommends several test readings to verify proper operation after installation.

VI. MAINTENANCE

INW recommends the TempHion be returned for factory re-calibration and general maintenance check once a year or sooner if difficulties with stability or accuracy develop. **Do not return sensor without first receiving INW's authorization. INW will provide the proper instructions for returning equipment for service.**

Electrode Plating

If damage occurs to the plating of the ring electrode or the reference electrode, return the sensor to INW for cleaning and re-plating.

Cable

Cable can be damaged by abrasion, sharp objects, twisting, crimping or crushing and pulling. Take care during installation and use to avoid damage. If a section of cable is damaged, return the sensor for cable harness assembly replacement.

End Connections

The contact areas (pins and sockets) of mil-spec connectors will wear out with extensive use. If the application requires repeated connections (in excess of 5,000) other types of connectors can be provided. INW connectors are not submersible but are designed to be splash-resistant.

VII. TROUBLESHOOTING

Erratic or unstable readings can occur from improper installation or operation, a damaged probe or cable, poor connections, improper readout equipment or omitted solution. Assuming that the readout equipment is working correctly, first check sensor installation. Make sure the sensor is fully submerged and that the connections are working and dry. If it is still giving unstable readings, remove the probe from the well and change the reference solution. If unstable readings continue, most likely the cable or the probe is damaged. In either case consult INW.

VIII. TEMPHION™ COMPONENTS AND WIRING INFORMATION

The following outlines the TempHion's components.

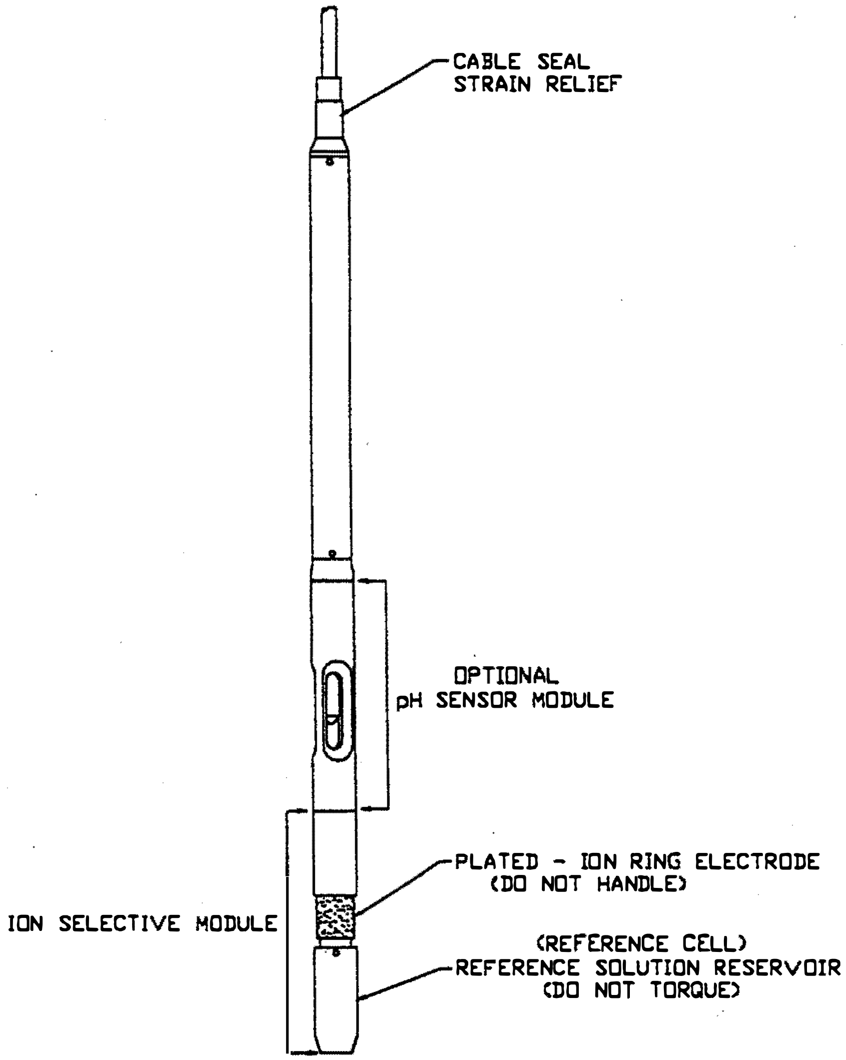


Figure 2.0

IX. TEMPHION™ WIRING INFORMATION

For 9000-Series Transmitters (4 - 20 mA)

Cable Type	=	6-Conductor
Orange	=	(+) Excitation (Channel 1)
Black	=	(-) Ground (Channel 1)
Red	=	ISE Signal Return (Channel 1)
Brown	=	pH Signal Return (Channel 2)
Yellow	=	Temperature Signal Return (Channel 3)

For 9105-Series Transmitters (mV) with 30KΩ Thermister Temperature Output

Cable Type	=	6-Conductor
Orange	=	(+) Excitation
Black	=	Ground
Red	=	ISE Signal Return (mV)
Brown	=	pH Signal Return (mV)
Yellow	=	Temperature Lead—1
White	=	Temperature Lead—2

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Redmond, WA 98052
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