Control No. RSD3

RESULTS OF THE EVALUATIONS OF HYDROLAB'S MULTIPARAMETER LOGGER

by

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INTRODUCTION

A specialized data logger, produced by Hydrolab Corporation, Austin Texas, was evaluated for its suitability as a field logger to be used to gather environmental data from rivers and lakes. The parameters are temperature, conductivity, oxygen and hydrogen ion. The logger is intended to remain in one location, is self contained and battery operated. The data are stored in a memory while most control functions are microprocessor based. Further information on the system can be seen in Appendix A.

This report is intended for internal purposes at the National Water Research Institute and should not be considered an endorsement of the instruments described. No liability will be assumed for actions arising from this report.

Two loggers, of the type shown in Figure 1, were purchased and compared to measurement standards using instruments and apparatus operated and maintained by the Calibration Unit of the Engineering Section of the Research Support Division in the National Water Research Institute (NWRI). Appendix B has excerpts from the laboratory's quality assurance manual and gives evidence of the care taken to control the accuracy of the standards and test apparatus.

The loggers come with a generally well prepared manual and a kit to calibrate the loggers. The calibration procedure is actually a means for the loggers to sense a known standard then set its own coefficients to give the correct values for further readings. The kit includes supplies for refurbishing and standardizing the sensors. A plastic cup is supplied to surround the sensors with the standardizing solutions. In all cases, the direct instructions in the manual were followed for coefficient settings and operations. In some cases additional things were tried. These are noted. The temperature channel is an exception because it cannot undergo a coefficient setting procedure.

The two loggers underwent the handbook procedure for setting the coefficients then a set of comparisons were made with the NWRI standards. The units were placed in the field for one week while they logged data on the Canagagigue Creek. After recovery, a second comparison was made with NWRI standards without cleaning the electrodes or resetting the calibration coefficients. Other comparisons were made after the electrodes were cleaned and the coefficients reset.

TEMPERATURE COMPARISONS

The accuracy and stability of the temperature channels were measured in a water bath that is controlled to a stability of /10 millidegrees celsius. Total uncertainties of the standard, including the Guideline thermometer errors, are expected to be less than /20 millidegrees celsius.

Figures 2 and 3 summarize the differences between the standards and the data from the loggers. The earliest comparison labelled AF (prefield) and PF (postfield) were done with the interrogator connected to the sonde. Later comparisons labelled PF#3, AS (preshock) and PS (postshock) were done in the logging mode with the interrogator disconnected and the loggers fully submerged. The reference to shock is the mechanical shock tests that were applied to the loggers to simulate field conditions. These amounted to pulling a one inch block from under one end of the logger while the other end rested on the bench. The shocks were repeated three more times in different planes. This was done in an attempt to locate the source of inconsistent readings within a calibration run and between calibration runs. No test was conclusive but the consistency appeared to improve when the logger was not connected to the interrogator and fully submerged. There appears to be no affects from the shocks.

CONDUCTIVITY COMPARISONS

The conductivity measurement standards were based on the Beckman Conductivity Bridge, Model RC-18A having a published error of less than /0.05% of reading. The cell was the Beckman BB1-Y87-CERT, certified to an error of 0.5 percent. Distilled water was dosed with sea salt to make up the various conductivities. The temperature was held constant at 23 +0.007 -0.000 degrees celsius in a Guideline bath having a stability similar to the bath used for temperature comparisons. The Guideline bath is non-metallic but its plumbing is metallic and grounded to the 115 volt outlet.

There appeared to be interference between the ground circuits of the bath and the interrogator. An offset error occurred if the calibration setpoint was done in the bath water. As a result, the plastic calibration cup had to be used to get correct results in the logged data compared to the standards. Presumably, the cup served to isolate the ground circuits.

An operational error was made when the raw (not standardized to 25 degrees celsius) conductivities were given to the interrogator in the coefficient setup procedure. The effect is estimated to introduce an error of -5.6% of reading. The manual was unclear in this instruction.

Figures 4 and 5 summarize the results of the comparisons. The prefield and postfield differences appear reasonable (labelled AF and PF respectively) because the electrodes had been badly fouled in the field with a flocculent material. However, after cleaning the electrodes according to the manual, the errors increased in one logger (S/N 5001) as seen in the traces labelled PC. A second try at cleaning and stabilizing S/N 5001, including the use of a wetting agent, did not improve the accuracy much but did cause a change in the errors labelled PEC. It is also remarkable that S/N 5001 has its maximum errors at the set point used to establish the logger's slope coefficient (1.4 mS/cm). As an added precaution, the loggers were operated in the logging mode without being connected electrically to anything to gather data for the PC and the PEC traces. This was to avoid the possibilities of interfering ground circuits. Both loggers were operating at the same time in the same bath. The PEC trace is a repeated run after the electrodes were cleaned again and the coefficients reset with the CAL routine. When asked about these errors, the manufacturer emphasized that the electrodes must soak overnight to stabilize before the coefficients are set. This was described as optional in the manual but should be considered manditory.

Figure 6 shows the results of a comparison between the standards and athe data from both loggers in the same bath at 23 and 5 degrees celsius. It is not clear what has happended with S/N 5001 at 5 degrees because both agreed well at 23 degrees and both presumably have the same temperature correction algorithm. It is not the effects of the temperature sensing errors of the two loggers because that accounts for one tenth of the difference.

OXYGEN COMPARISONS

The usual care was taken in establishing standard sources of oxygenated water. The method uses natural air or precise ratios of oxygen to nitrogen gasses which are factory mixed (0.05% nominal accuracy). These are bubbled through a small, well mixed water bath which is temperture controlled with a heat exchanger. The actual temperature and barometric pressures are accurately known (/20 millidegrees celsius and /0.003 kPa respectively). From this, the oxygen content of the water is calculated according to M.L. Hitchman in his book, Measurement of Dissolved Oxygen, Wiley 1978.

Upon arrival from the manufacturer, the two units had their coefficients set according to the instructions without a change in membranes or electrolyte, then their readings were compared with the standard gas solutions. After the field deployment, the comparisons were repeated without changing anything or even cleaning the membranes. Figures 7 and 8 show the differences in oxygen readings compared to the expected values. The AF traces are the prefield comparisons while the PF are the postfield comparisons. Some of the positive bias can be attributed to the flow effect correction algorithm that is used by the loggers to compensate for the lack of agitation around the sensor. The logger assumes a moderate value of agitation. If high agitation is expected, as it was in the comparisons, the coefficients must be changed with a software command. This was not done, so the readings are 4% high in the prefield and postfield comparisons (AF and PF). An unexpected result was the increase in sensitivity of the sensors after a week in the field. There is no explanation for the apparent zero offset in the prefield comparisons. Unfortunately zero oxygen tests were not done to confirm this trend.

The zero oxygen readings varied according to the method used. Boiled water which was cooled then constantly bubbled with pure nitrogen did not produce zero readings. Further tests with other probes showed that the oxygen content was within 0.11 mg/L of zero. Sodium sulphite solutions in the calibration cup produced negative readings in the loggers, for example -0.13 mg/L. The readings 15 minutes after introducing the sulphite varied according to the amount used in the cup. Logger, S/N 5000 exhibited an odd effect when sodium sulphite was used. Unless the pH electrodes were kept out of the solution, abnormally high readings were indicated. For example the oxygen readings fell from 9.44 to a minimm of 3.08 mg/L then began to rise. A change of membrane did not cure the problem. Only by keeping the pH electrodes out of the solution could the zero be approached. This was not the case with S/N 5001.

Figure 9 shows the time response of the loggers to a sudden drop in oxygen as they are transferred to a nitrogen-bubbled water bath.

An important characteristic is the response to an oxygen cycle that goes from high to low and back again. This approximates the diurnal conditions in small or shallow rivers. Tests were done to check for lag effects by logging the oxygen readings over one cycle of decreasing then increasing oxygen levels. Each reading was made after about an hour and a half which is adequate time for the gas to equilibrate in the bath. The zero oxygen reading was done with nitrogen bubbling overnight. The minimum reading was taken as the zero value. This reading coincides well with the expected oxygen level in the nitrogen bath. The cycle was done at 23 and 5 degrees celsius. Figure 10 shows the results from logger S/N 5000. The date and time are shown for each comparison. The lag produces errors of about 0.05 mg/L at 23 degrees and 0.1 mg/L at 5 degrees.

HYDROGEN ION COMPARISONS

Buffers provided by Hydrolab or those purchased from Fisher Scientific were used to compare the output of the loggers. The buffers were contained in the calibration cup which was immersed in a stable temperature bath. It was difficult to get the interrogator to accept the buffers, in the coefficient setting operation, if they were not fresh or very stable in temperature. Both the prefield and postfield comparisons were done with the interrogator attached for interrogations.

Figures 11 and 12 show the differences between the loggers' readings and the buffers used. The prefield (AF) and the postfield (PF) errors are reasonable within the span between the two buffers that were used to set the coefficients, however, the linearity was poor outside this range. The postfield comparisons were made without cleaning the electrodes or resetting the coefficients.

The effects of cleaning and resetting coefficients were not good for S/N 5000 as seen in the PC trace. This is the logger with the interaction between the oxygen and pH sensors described earlier.

The 5C and the 5C' traces on the graphs show the results of setting coefficients at 25 degrees celsius then comparing the loggers' readings to the buffer values at 5 degrees celsius. The buffers came with a temperature correction table which was applied. The Hydrolab manual does not give the temperature correction formula used for the temperature effect on the probes themselves. The 5C' trace is a second run (including a resetting of coefficients at 25 degrees celsius) at 5 degrees. No changes were made to the procedure except to include the two setpoint buffers (pH 7.0 and 10.0) in the low temperature comparisons.

OTHER OBSERVATIONS

Other items to consider for future planning include the following.

The interrogation procedure is very prone to operator error at the time the units are coupled. On one occasion the order was reversed by mistake which caused a malfunction. What was more disturbing was that the malfunction was not fully evident and the units appeared to operate except some coefficients were changed somewhat. As well, on two occasions, S/N 5001 has spuriously lost the coefficients during the interrogation operation with a "TIMED OUT" message.

The communications between the interrogator and the personal computer is facilitated by a package called Crosstalk. If Crosstalk does not find the interrogator ready (on), it cancels out of its terminal mode. If the interrogator is turned on before Crosstalk is enabled, the initial header and the first question are missed. This will cause a hangup unless the operator responds to a question that is not on the screen. The manufacturer points out that this can happen if the wire for the Data Terminal Ready signal is not correct in our cable.

The date code format should be offered as an option because of the confusion it may cause in stripped files where the Hydrolab column headers are missing. The Canadian standard being urged is the ISO form YYYY-MM-DD however the older standard DD-MM-YY is still much in use. The years 2001 to 2012 will be a problem in the data banking disciplines.

Part Four of the Hydrolab manual on the subject of deployment is not specific enough about the precautions needed to avoid mistakes such as leaving the cap on the pH reference electrode. The manual should include a section on recovery procedures and sensor protection. Points made in other sections should be repeated there.

One potential user feels that a battery operated interrogator should be available for operating and refurbishing in remote locations. The present difficulties in getting some standardizing solutions accepted by the interrogator for field calibrations will detract from the usefulness of the battery interrogator.

DESIREABLE FEATURES

The loggers have several good features that have not been available elsewhere to our knowledge.

The large experience base that Hydrolab has had with environmental monitoring instruments has contributed to what appears to be a reasonably stable set of sensors. One potential user was pleased with the data retrieved from the field deployment. The data appeared adequate to gain useful inference about the dynamic processes in a creek. See Figures 13 and 14. The limits on the ranges of the readings were set in our software not the loggers'.

The mechanical package layout is compact and very functional for field work. With higher capacity batteries becoming available, the risk of opening and reclosing the underwater case can be lessened in the future.

The interrogation procedure is very well supported with prompts for the operator. This is important in lessening the learning time for new operators and maintainers.

The flexibility and rapidity in accessing the data through a personal computer will make the loggers very adaptable for short term studies and spot checks.

The feature of excluding some sensors to extend the life of the batteries is excellent. The capability to program the start and stop times, as well as the scanning interval, is a good feature.

The manufacturer and representative have been very attentive and appear to be supportive in the application of the loggers.

RECOMMENDATIONS FOR IMPLEMENTATION AT NWRI

To achieve the maximum benefit and return from these loggers the following is recommended.

The loggers should remain with the field instrument maintenance personnel between field seasons. Periodically, on a rotation basis the loggers should be routinely refurbished and calibrated in the laboratory when field operations are proceeding. One scientist or technologist should be recruited to review the data as soon as possible to make sure it is valid. Field measurements should be taken with independent instruments to assist in confirming the data. The frequency of these measurements depends upon the degree of credibility in the data that is necessary for the study.

In the early stages, concern must exist for establishing the timing patterns for the various phases of upkeep. This will require careful review of the field data and the verification results received from the laboratory and field instrument comparisons.

The circulation of this logger amongst several operators, calibrators, maintainers and verifiers is not recommended, however, backup personnel must be established for each discipline.

Since the data are readily available on a personal computer, the need for a data base support structure seems slight, however, if a large study is undertaken serious thought must be given to data banking and manipulation on central computer facilities.

If the measurements must be made in more than one location and be continuous for a period beyond two weeks, then another pair of loggers are ncessary to meet the refurbishing cycle.

The present data set suggests that the error bands be as follows:

Temperature:	+0.4 / -0.4AC
Conductivity:	/0.03 mS/cm @ room temperature
	+0/-0.2 mS/cm @ 5AC.
Oxygen:	+1.0/-0.0 mg/L @ room temperature
	+0.2/-0.8 mg/L @ 5AC
Hydrogen Ion:	/0.2 pH @ room temperature
	+0.0/-0.5 pH @ 5AC

The bands likely will have to be opened for field conditions for the oxygen, conductivity and pH channels. It is expected that the bands will narrow as some of the sources of error are eliminated. In some cases this may involve the exchange of the Read-Only-Memory chips used by the system.

Although the errors seem large compared to the advertized specification (Appendix A), it is not unusual to encounter this in field instrumentation. The accuracies are achieved if everything goes right. It is common for vendors to advertise the best performance or typical performance under good conditions. The best example might be radio range specifications. These often read "... up to x miles" but rarely read "... not less than x miles". Therefore, it is most important to do crosschecks in the field with accurate instruments and methods. The history of these crosschecks will ultimately set the limits on the error bands.

ACKNOWLEDGEMENTS

The bulk of the work on this study has been done by L. Peer and J. Cooper who have painstakingly done all the comparisons. The positive support of Dr. Brownlee and his contribution of placing the loggers in the field for a trial was an important part of this evaluation. Finally, the support of members of the Scientific Equipment Development Working Group who sponsored this study is gratefully acknowledged.

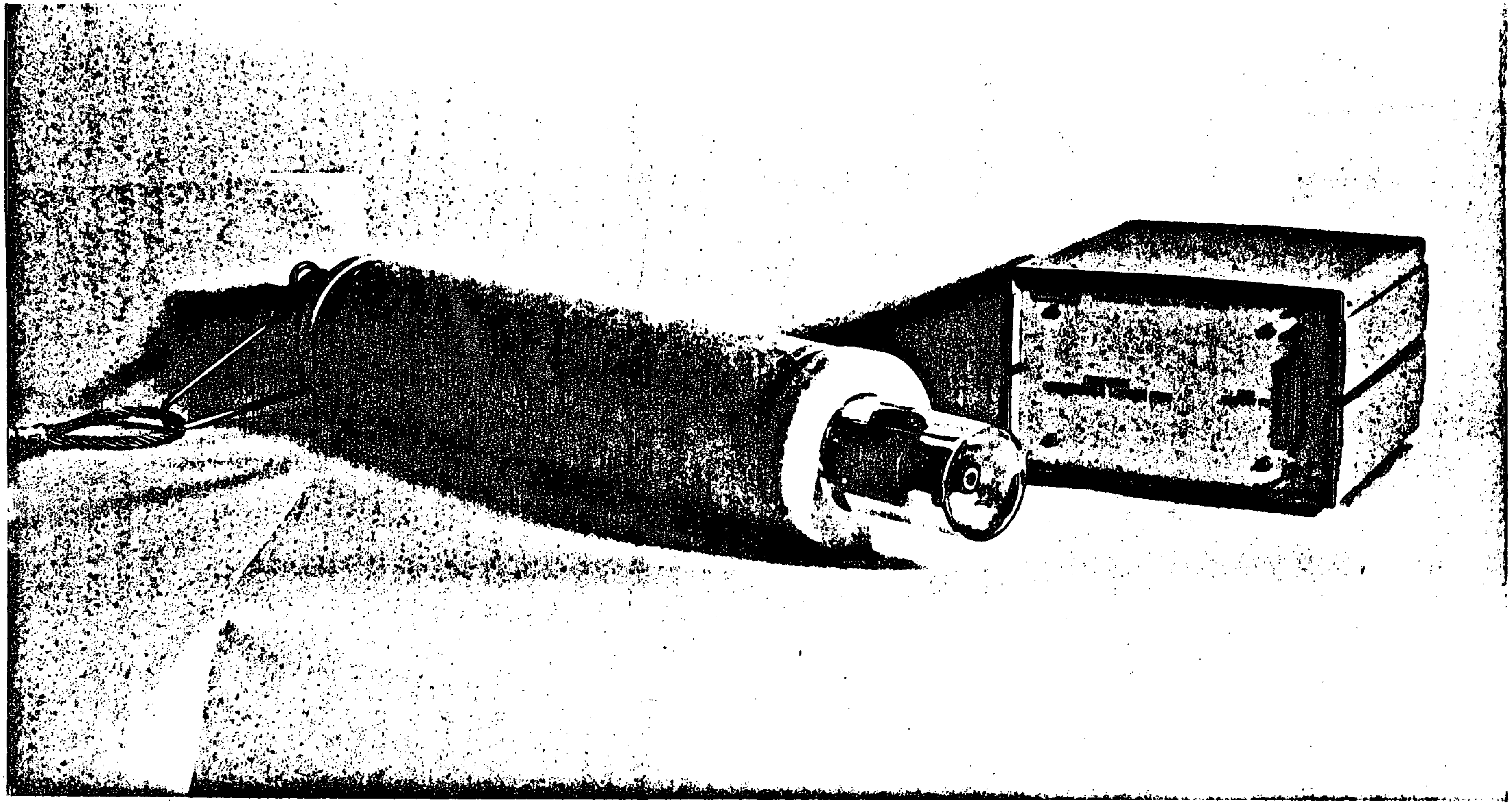


Figure 1 VIEW OF THE MULTIPARAMETER LOGGER AND ITS INTERROGATOR

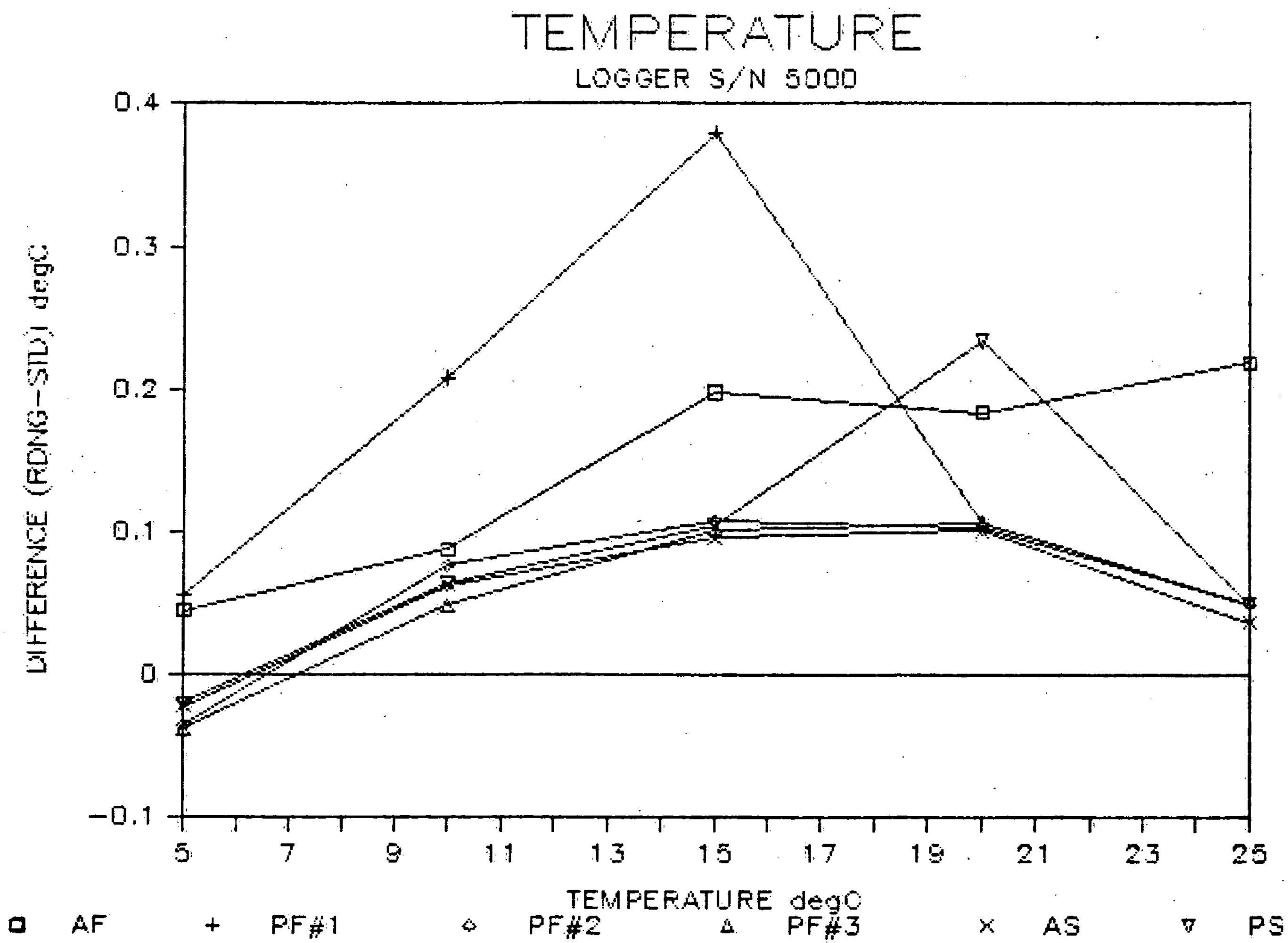


Figure 2 TEMPERATURE READING COMPARISONS FOR THE LOGGER S/N 5000

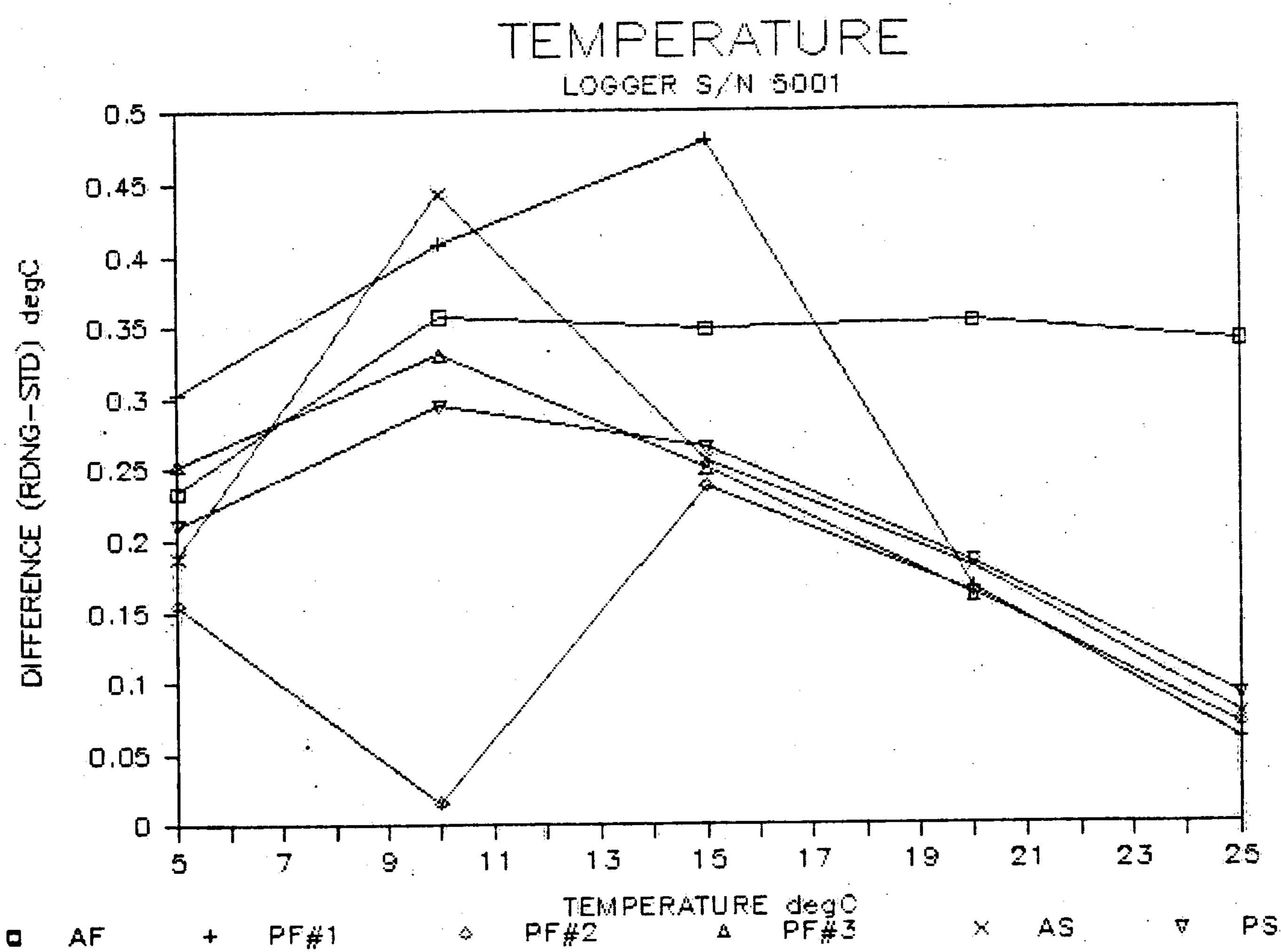


Figure 3 TEMPERATURE READING COMPARISONS FOR LOGGER S/N 5001

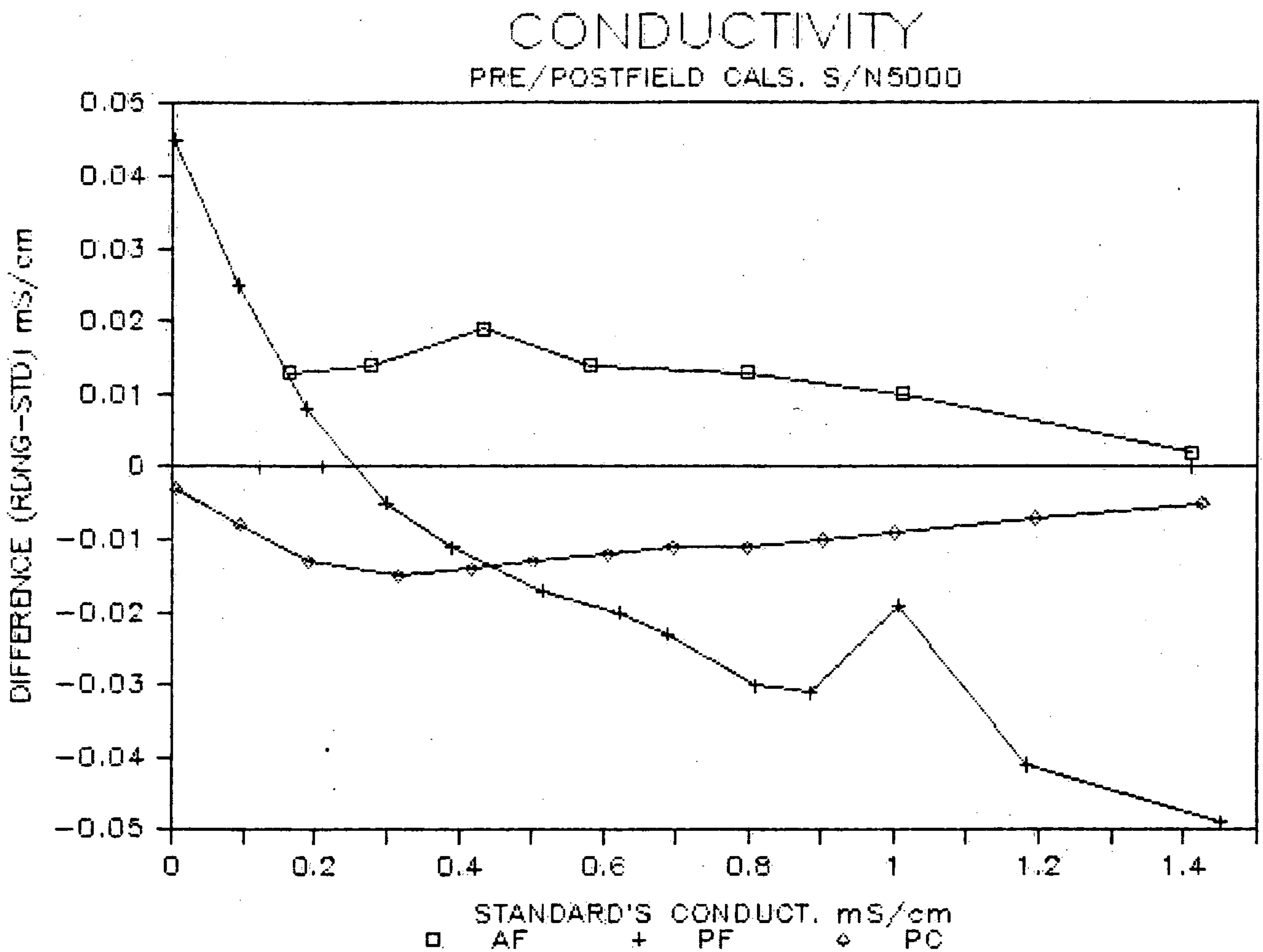


Figure 4 CONDUCTIVITY READING COMPARISONS FOR LOGGER S/N 5000

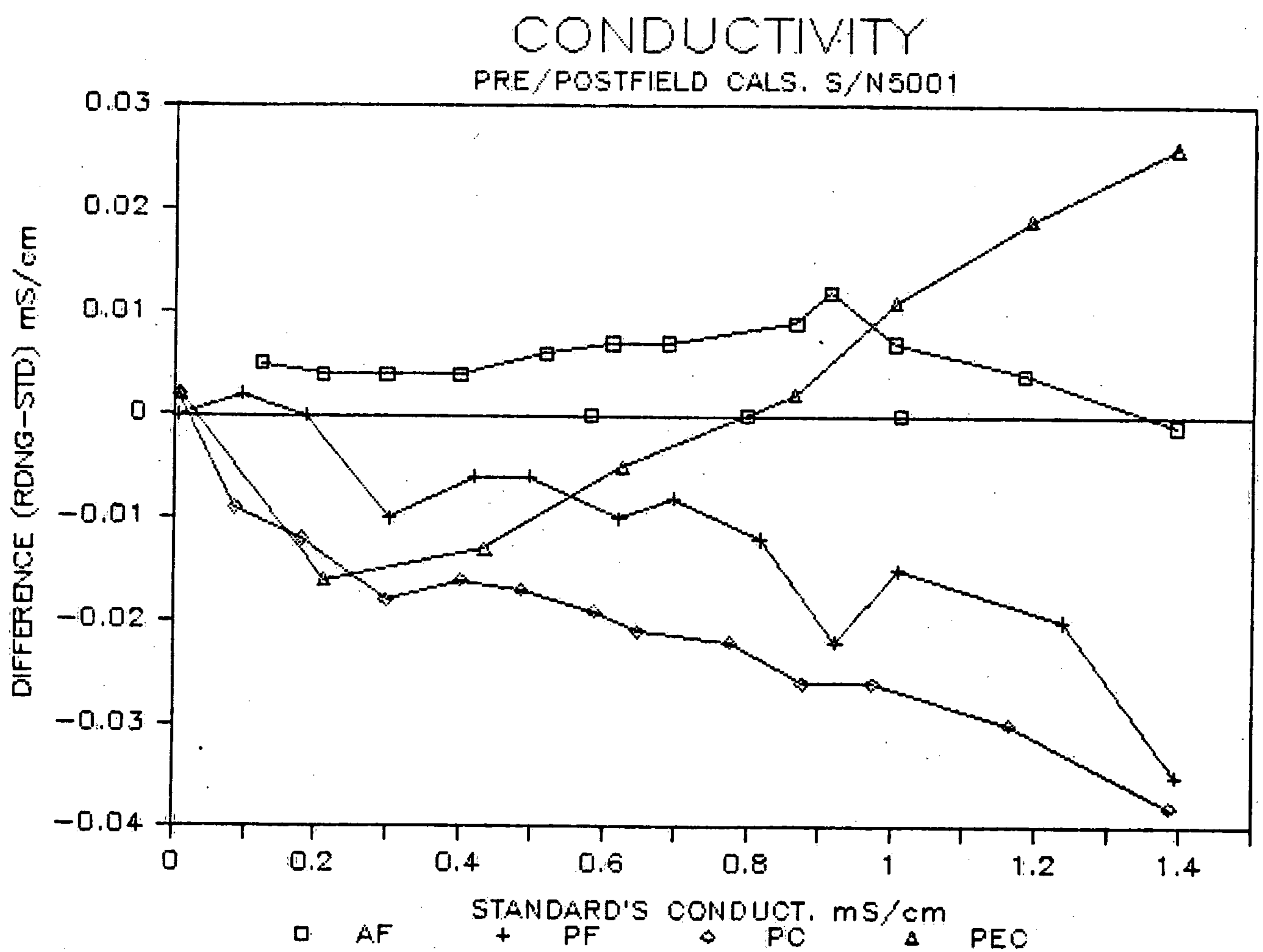


Figure 5 CONDUCTIVITY READING COMPARISONS FOR LOGGER S/N 5001

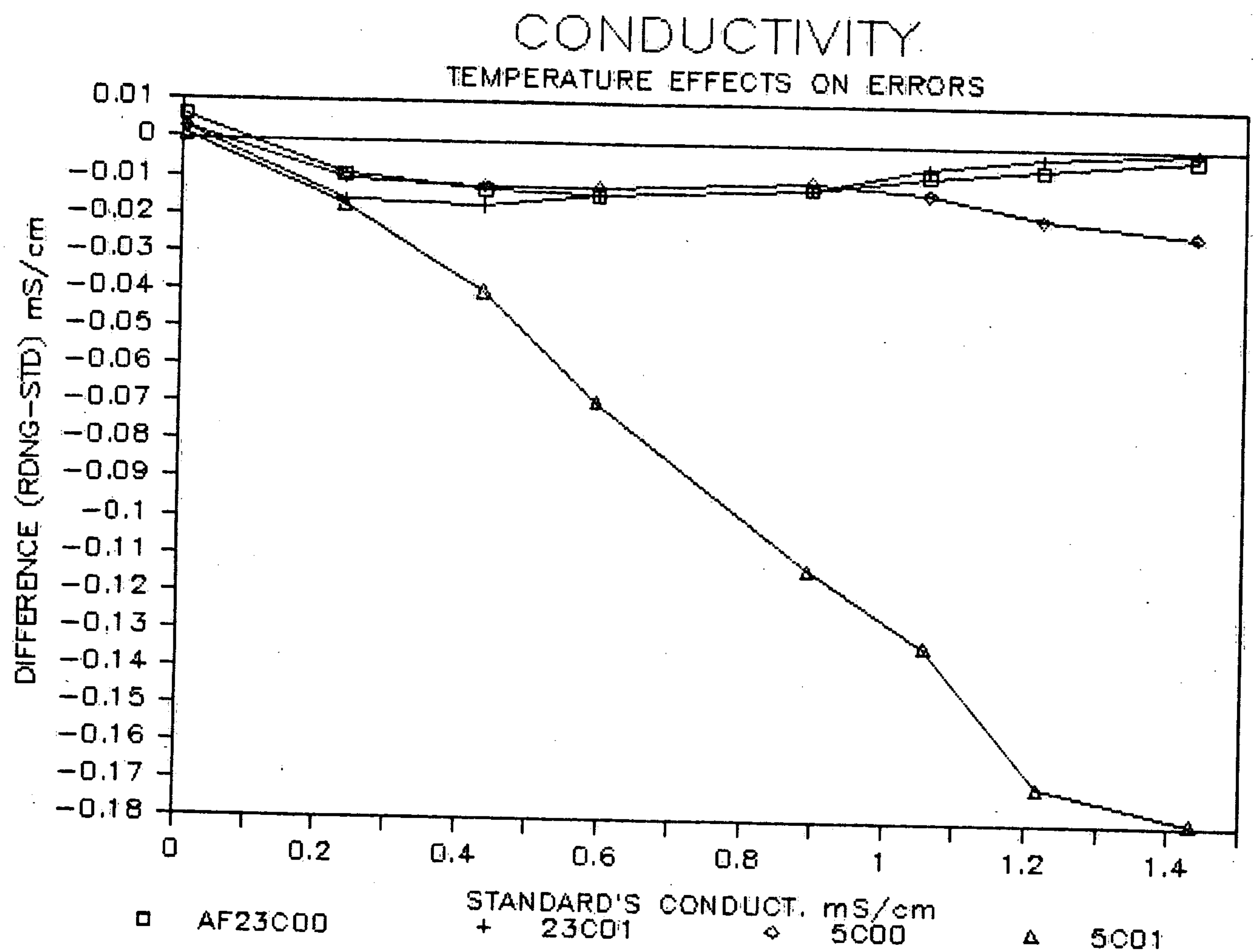


Figure 6 CONDUCTIVITY READING COMPARISONS AT 23 AND 5 DEGREES CELSIUS FOR LOGGERS S/N 5000 AND 5001

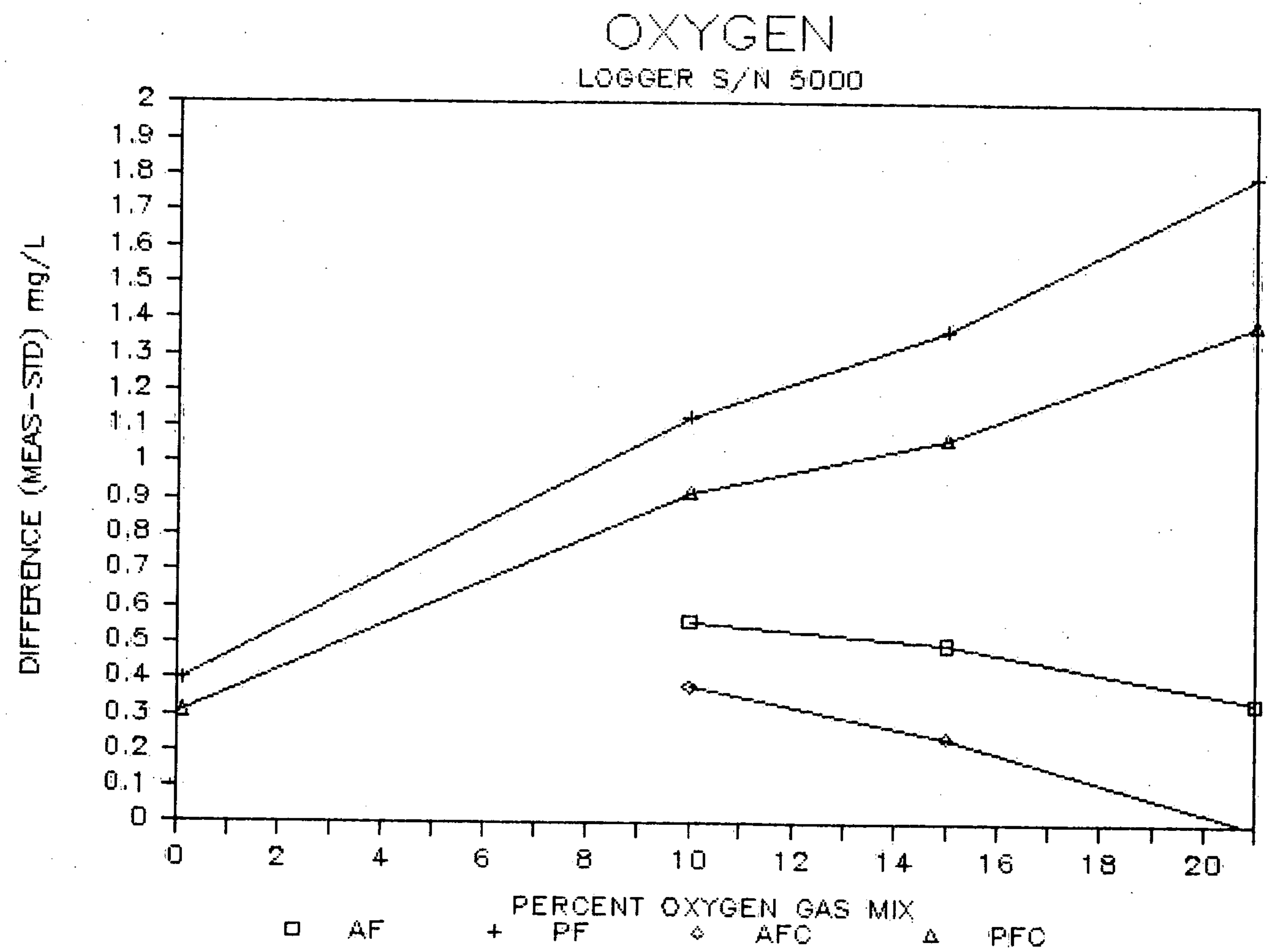


Figure 7 OXYGEN READING COMPARISONS FOR LOGGER S/N 5000

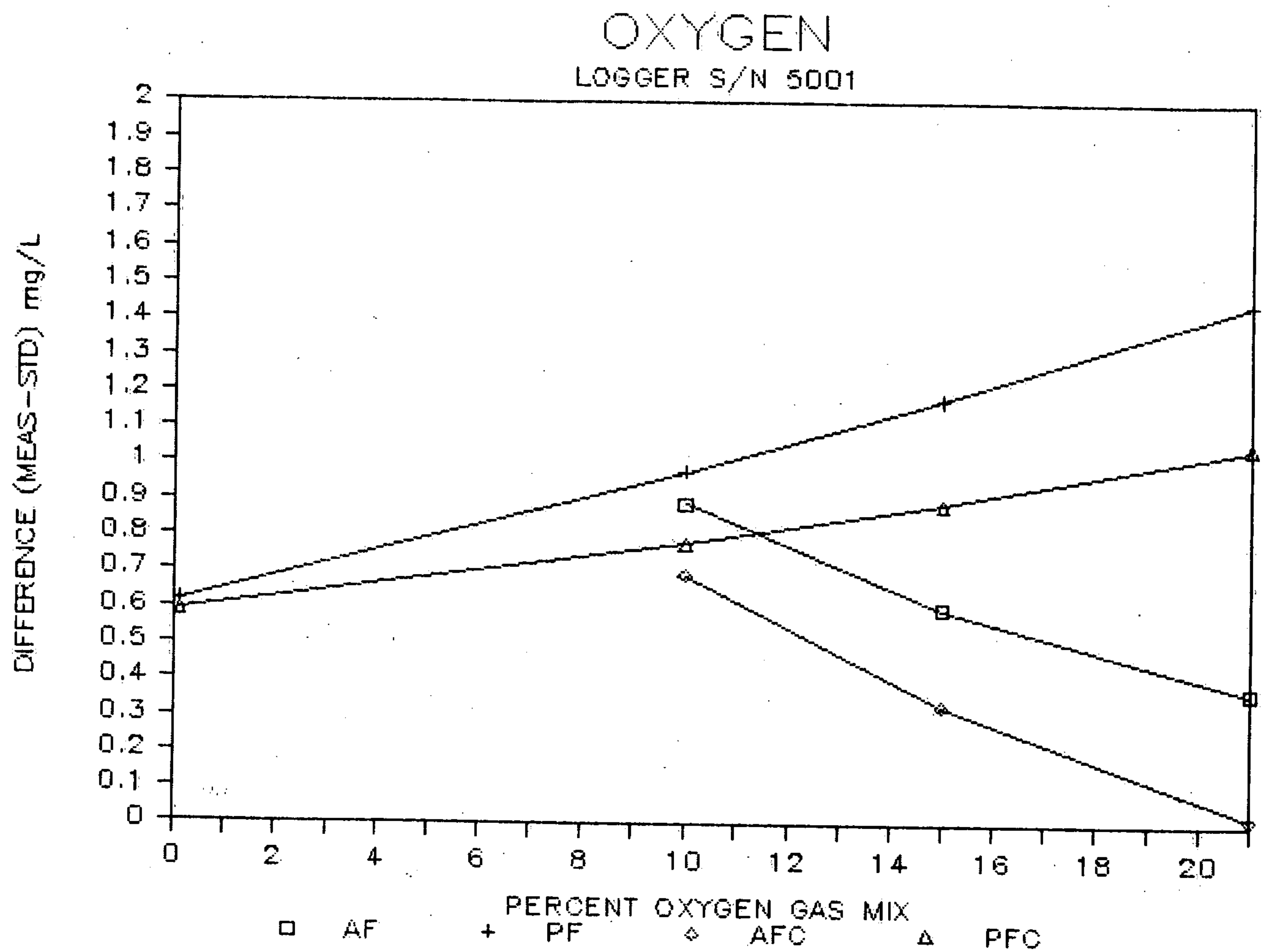


Figure 8 OXYGEN READING COMPARISONS FOR LOGGER S/N 5001

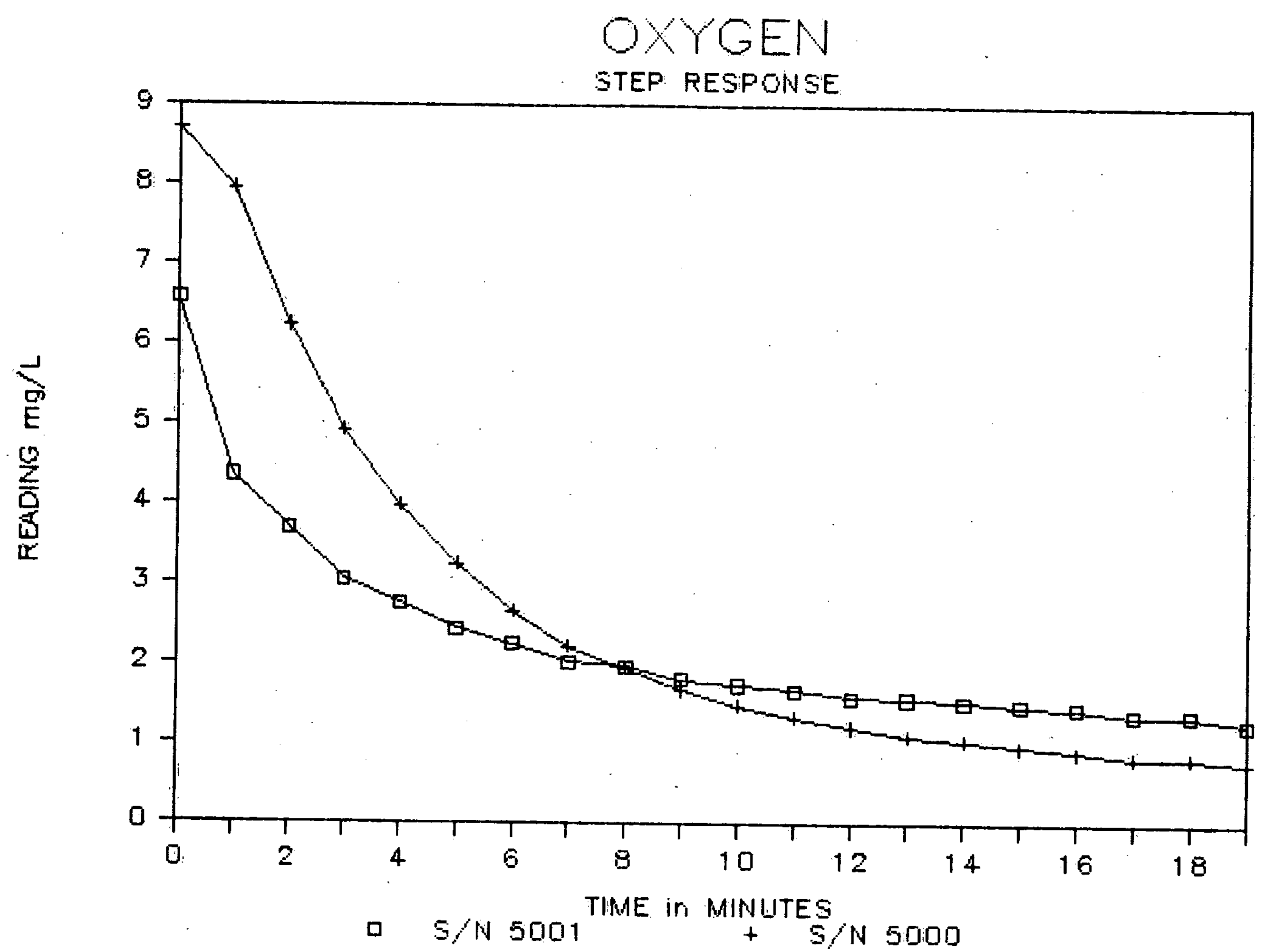


Figure 9 OXYGEN SENSOR'S RESPONSE TO A STEP CHANGE IN CONCENTRATION

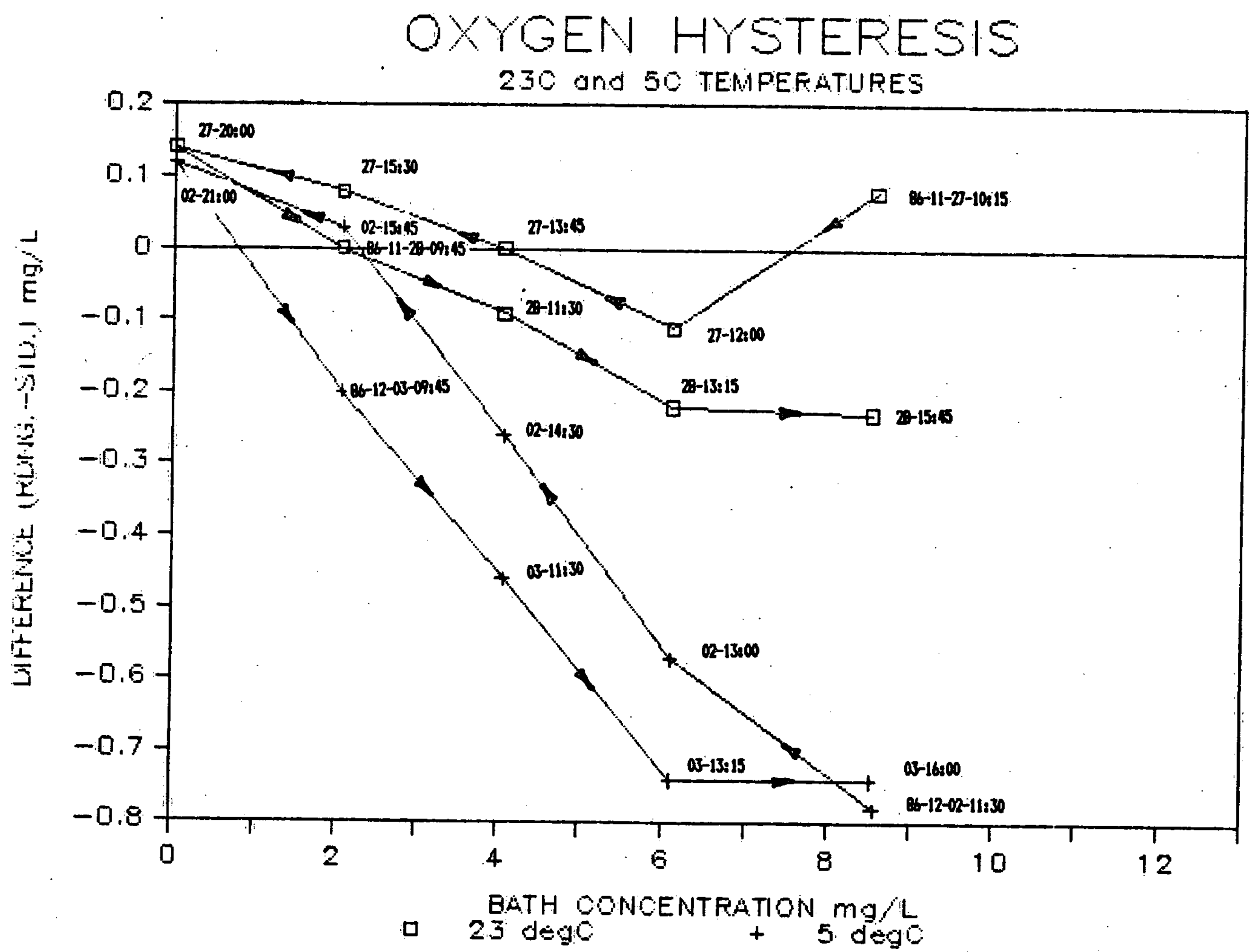


Figure 10 OXYGEN SENSOR'S ERRORS IN SIMULATED DIURNAL CHANGES

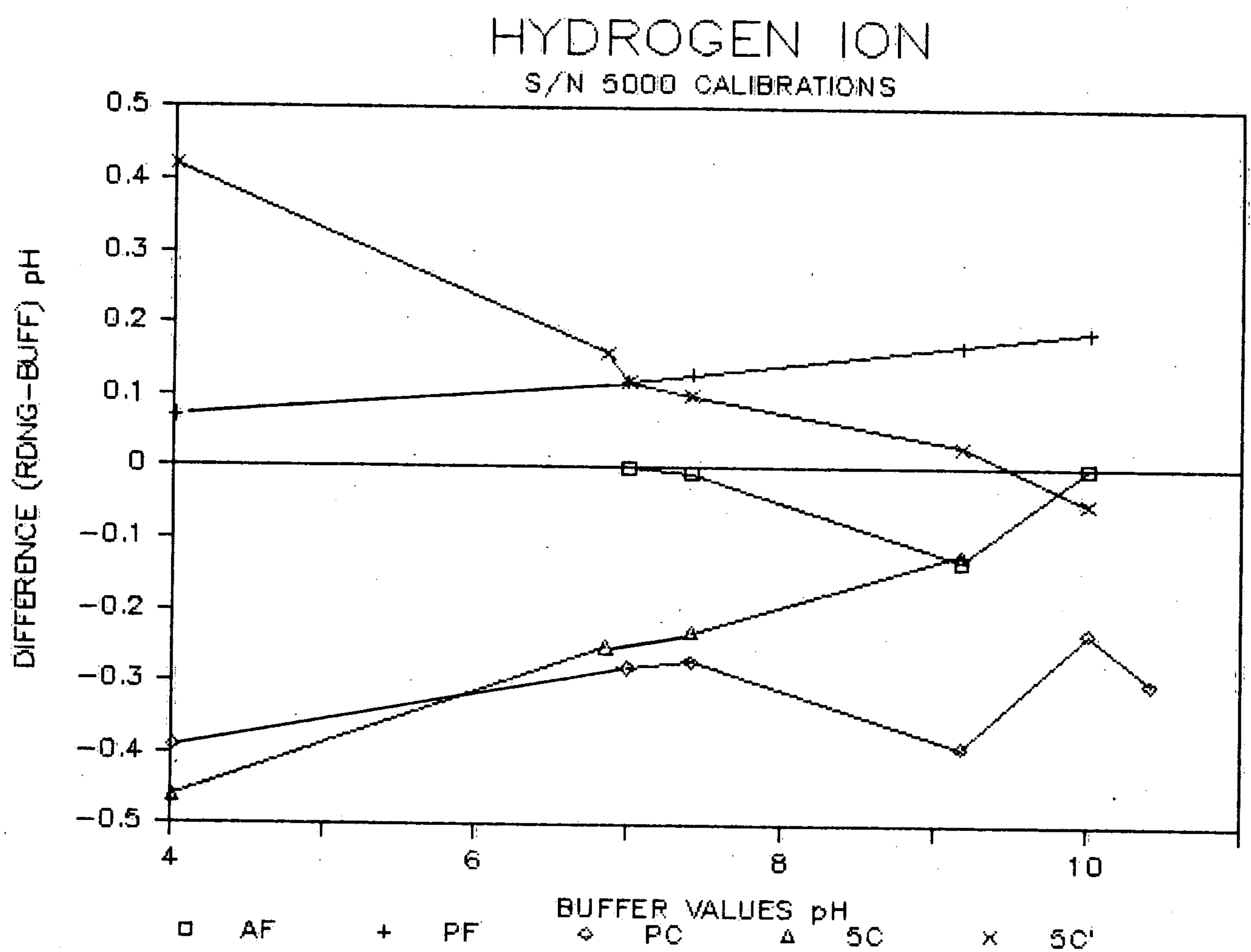


Figure 11 HYDROGEN ION READING COMPARISONS FOR LOGGER S/N 5000

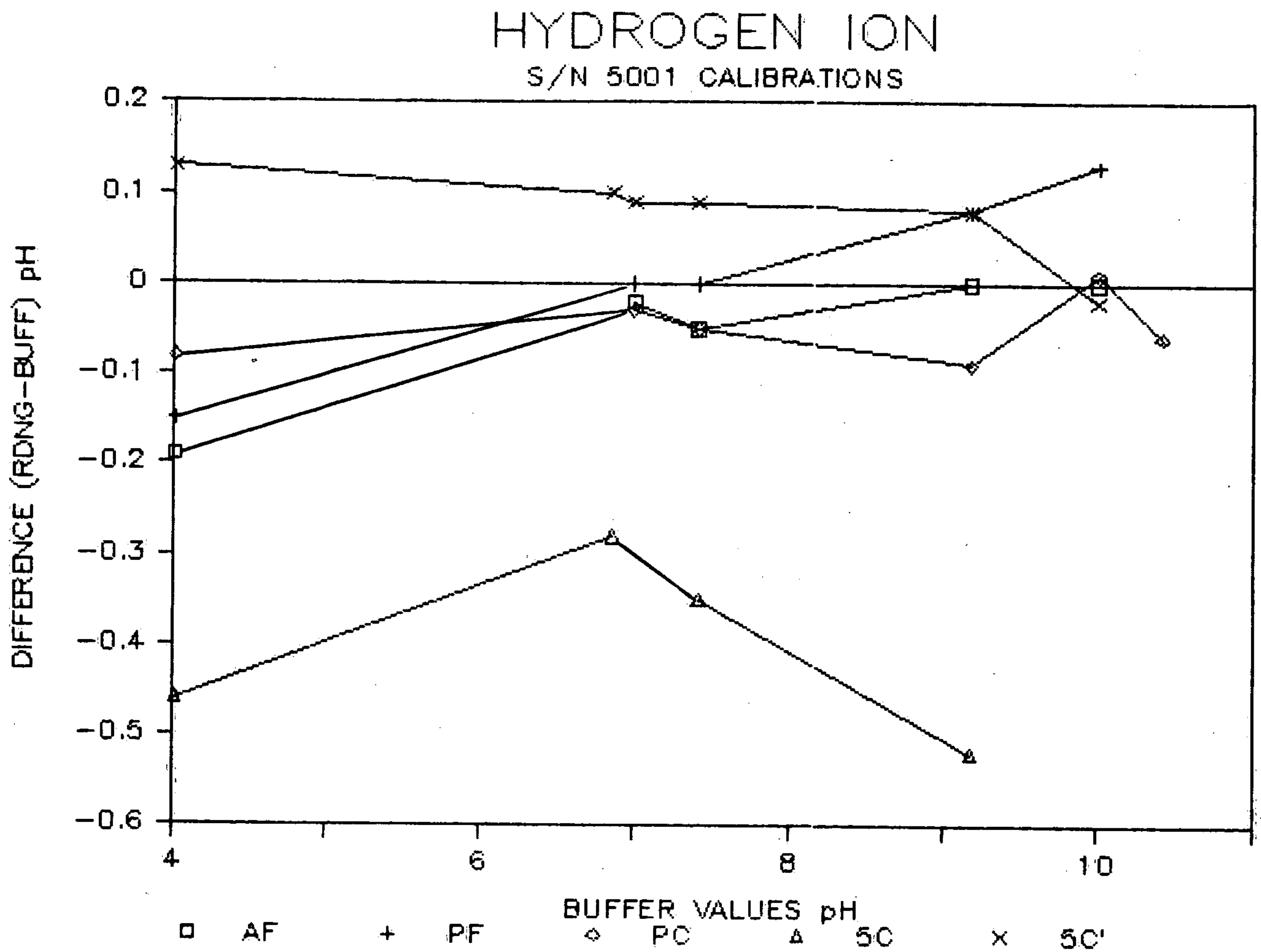


Figure 12 HYDROGEN ION READING COMPARISONS FOR LOGGER S/N 5001

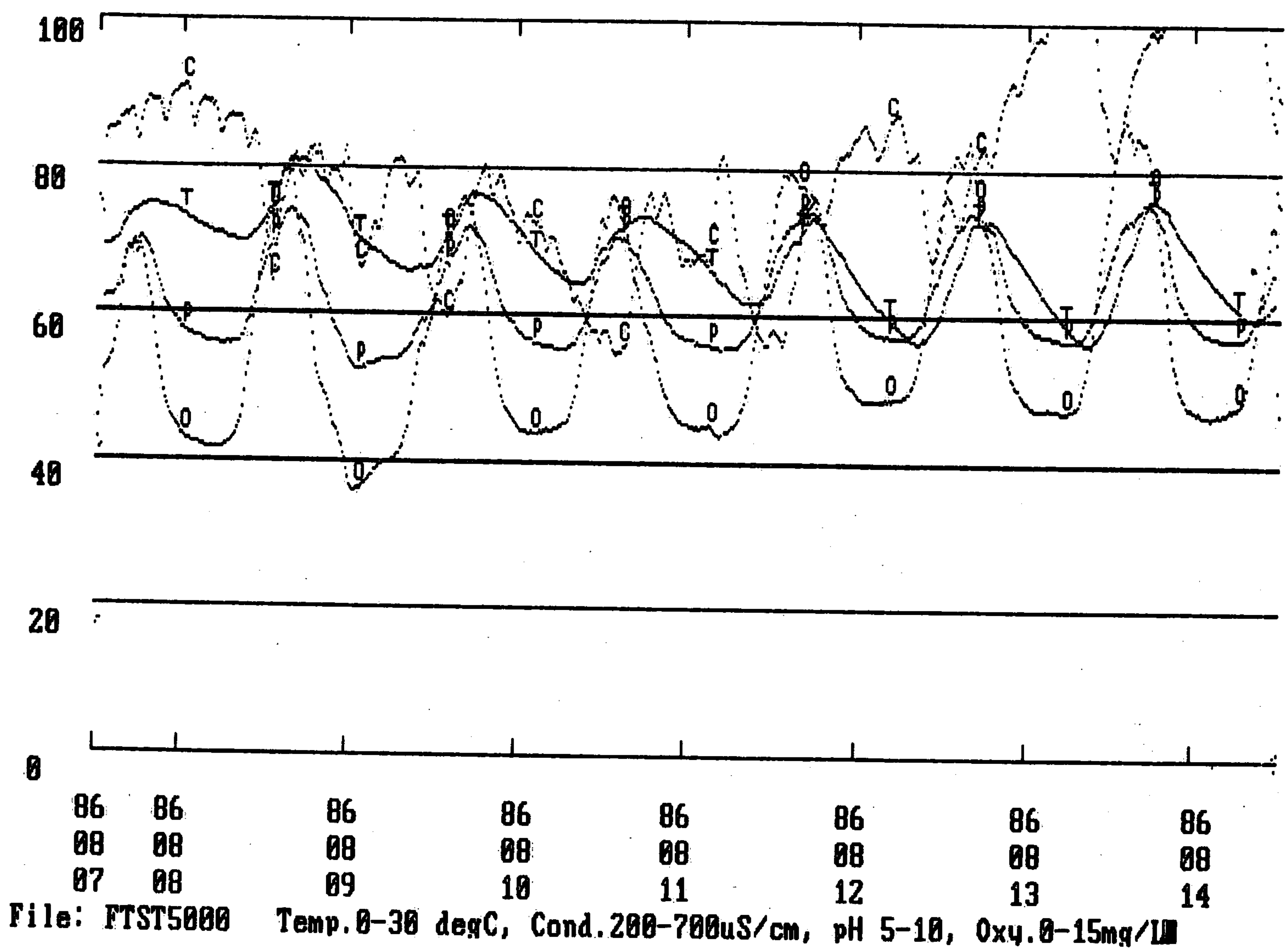


Figure 13 EXAMPLE OF THE FIELD DATA FROM CANAGAGIGUE CREEK, ONTARIO OBTAINED BY LOGGER S/N 5000

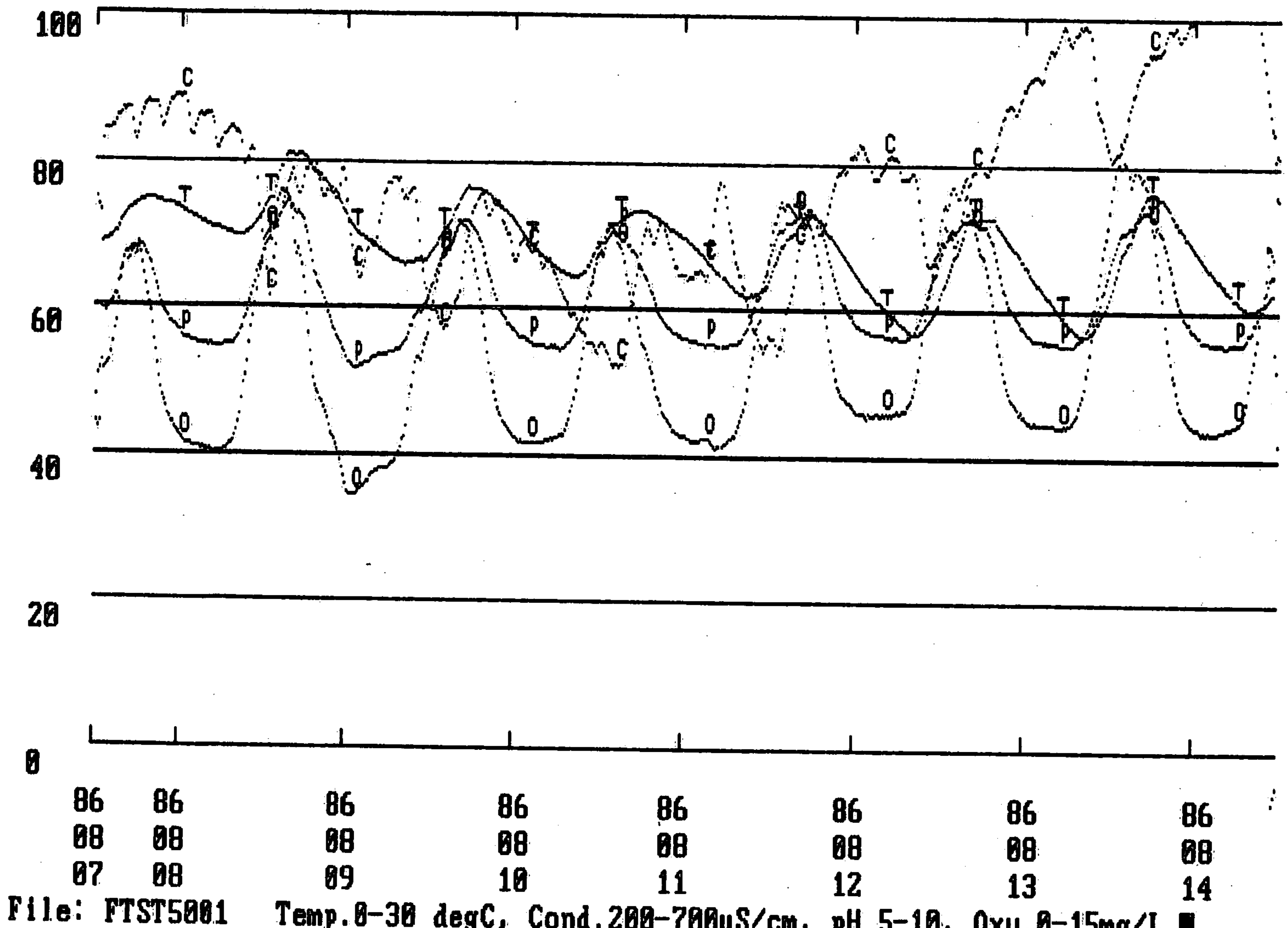
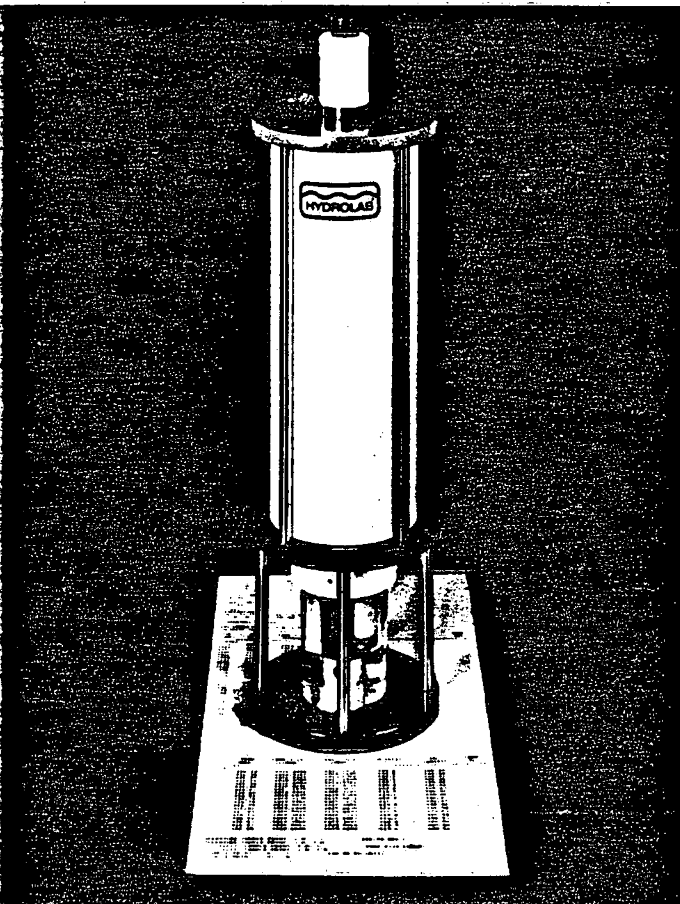


Figure 14 EXAMPLE OF THE FIELD DATA FROM CANAGAGIGUE CREEK, ONTARIO OBTAINED BY LOGGER S/N 5001

APPENDIX A

HYDROLAB CORP. DESCRIPTIVE LITERATURE



DataSonde™

The Water Quality Data Logger With No Strings Attached

HYDROLAB™

Fully submersible automated water quality data systems with totally self-contained solid-state "intelligence"—an exciting field-proven breakthrough in automated *in situ* datalogging technology. . . .

All-in-One Efficiency

What if you could have incredibly accurate water quality data, collected with the highest possible reliability, brilliantly organized, and transferred and/or typed with cybernetic precision?

With its new DataSonde 2000 series water quality data systems, Hydrolab Corporation has made such a dream a reality . . . once more earning its reputation as the leading edge of the microprocessor revolution within the water quality datalogging industry. Containing all necessary measuring circuits, processing, data storage and power supply batteries within one simple, portable, watertight housing, the DataSonde is a completely integral, completely solid-state, completely *self-dependent* submersible data system representing the achievement of a new plateau in water quality monitoring technology.

Unlike other water quality monitoring systems which require cumbersome cable hook-ups tying underwater sondes to expensive, vandal-prone, land-based equipment such as recording instruments and power supplies, the robot-like, submersible DataSonde system functions underwater automatically—without moving parts, without land-based instrumentation, without cable attachments . . . literally, ***with no strings attached.***

Originally developed for Florida Power & Light Company to monitor cooling water intake and discharge temperatures, the DataSonde has been expanded in capability and made available to meet the needs of the entire community of water quality monitoring professionals . . . and has found immediate and enthusiastic acceptance by such agencies as the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the Utah State Department of Health in water quality investigation programs.

What appeals to agencies such as these is a spectrum of remarkable features which distinguishes the DataSonde as the leading technological advance in its field.

Foolproof Accuracy

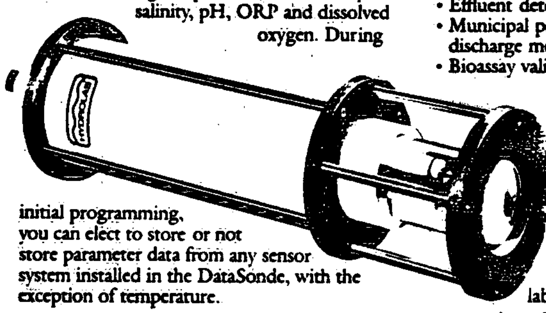
DataSonde's solid-state reliability and precision, plus automatic preprogrammed operation, result in a new level of confidence for the water quality monitoring professional. Precise parameter measurements are automatically temperature compensated (ATC) over a range of −2 to 50°C (with temperature calibrated to an accuracy of ±0.1°C with NBS traceability).

Moreover, once calibrated and programmed in the laboratory or office, the DataSonde needs only to be deployed at a desirable field location—preset to start collecting the data desired by lab personnel. All that field personnel do is anchor the DataSonde and later retrieve it—since all data transfer is handled electronically in the lab, data management professionals get machine-pure data they can fully trust . . . totally free of the errors possible through human transfer.

Programmable Flexibility

Easily programmable via an external standard keyboard terminal, the DataSonde can be set to log only the parameters you wish, when you wish. The unit can even be set to turn itself on (delayed start) and shut itself off under control of an internal real time clock recording exact time and date. Sample intervals can be programmed in multiples of five minutes . . . to as long as 9 days!

An assortment of DataSonde versions are available providing various measurement capabilities, including temperature, conductivity/salinity, pH, ORP and dissolved oxygen. During initial programming, you can elect to store or not store parameter data from any sensor system installed in the DataSonde, with the exception of temperature.



Rugged Durability

Engineered and crafted with Hydrolab's renowned insistence on quality materials and superior workmanship, the DataSonde's hermetically sealed, watertight integrity and solid-state ruggedness ensure that each unit will withstand incredibly abusive environmental extremes. Built with a heavy-duty, nonmetallic pressure housing, each unit is at home in 3 feet or 1,000 feet of water, saline or fresh, from −2° to 50°C. Weighing just 10.5 lbs. (4.8 kg.) and readily portable, the DataSonde can be toted anywhere—from the Arctic to the Amazon, the North Sea to the Everglades—by truck, boat, or plane . . . even by dog-sled, balloon, or canoe!

Long-Life Endurance

Utilizing an energy-efficient CMOS RAM memory, the DataSonde can store over 3,600 parameter readings during each deployment period. With no energy-gulping moving parts, each unit is powered on-board by just four long-life D-cell alkaline batteries, and can thus stay in the field as long as 6 months before retrieval.

Versatile Applications

The potential water quality monitoring applications of the DataSonde are virtually limitless. Some of the more typical include:

Analyses
- Biological
- Limnological
- Ichthyological
- Hydrological
- Petrological
- Benthological
- Oceanological

Deployment
- Lakes, creeks, rivers, and other inland waterways
- Oceanic sites
- Salt marshes
- Sewerage and wastewater systems
- Industrial discharge sites
- Under ice

Purposes
- Baseline surveys
- Water quality surveys, from tropical to arctic/antarctic
- Effluent detection
- Municipal power plant cooling water discharge monitoring
- Bioassay validation
- Municipal water quality monitoring
- Industrial water quality monitoring

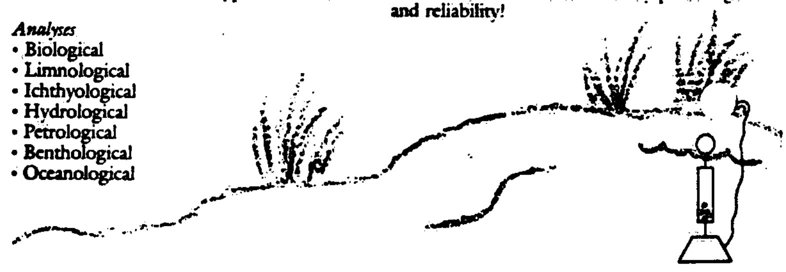
Simple, Easy Operation

Handled entirely in the lab, calibration and programming of the DataSonde are literally a snap—effected by simply snapping in the Hydrolab 5200-20XX DMU (Data Management Unit), itself connected to your EIA RS-232-C compatible keyboard terminal. Opening the DataSonde's heavy-duty housing isn't needed—and there's no need to fool with knobs, pots, etc. Moreover, once the unit leaves the lab, all your field personnel h[illegible] is transportation and placement—the Dat[illegible]nde functions automatically.

Back in the lab, the unit can be easily debriefed in virtually the same way—dumping its CMOS-stored water quality data, via the DMU, into your CRT or printer for immediate printout, or into your computer's mass-memory file storage . . . or both. Lab personnel will be pleasantly amazed by the system's sophistication—an "intelligence" which can even detect whether inputted calibration values are reasonable!

Manpower and Deployment Savings

Since deployment of the DataSonde is so simple, field manpower needs are minimized—and the unit can be left unattended for days, weeks, or months . . . until it's time for retrieval. Moreover, the system's automatic electronic data transfer means tremendous savings in dataprocessing manpower and a significant increase in personnel efficiency—together with a drastic increase in data recovery percentage and reliability!



In addition, since the DataSonde functions *in situ with no strings attached*, expensive vandal-proof shelters for housing land-based equipment aren't needed. And since the system's data management and data display/transfer functions are separate from the data collection and data storage unit, a single investment in just one DMU and display set up in the lab can service any number of DataSondes, which can be rotated between field and headquarters.

Higher Quality at Lower Cost

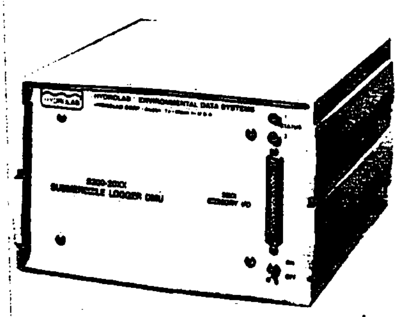
Fully incorporating the spectacular benefits of state-of-the-art microprocessor technology, the DataSonde provides a major enhancement in water quality data systems performance together with a significant reduction in instrumentation cost—a fraction of the price of competitive systems. In effect, investment in the DataSonde system literally and immediately means greater quality and performance for the money.

An Invaluable Management Tool

Competent, dependable, electronically accurate, and centrally programmed, the DataSonde is a powerful, versatile management tool responding totally and reliably to your instructions—letting *you* know exactly *what* monitored environmental conditions it encountered and *when* . . . eliminating "in between" human data reporting and transmission. Even equipment management is enhanced via convenient diagnostics which yield a complete lab record of every DataSonde in service.

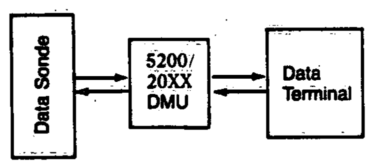
In short, the submersible, self-contained, fully automatic DataSonde is a water quality data system you can have total confidence in . . .

WITH NO STRINGS ATTACHED!



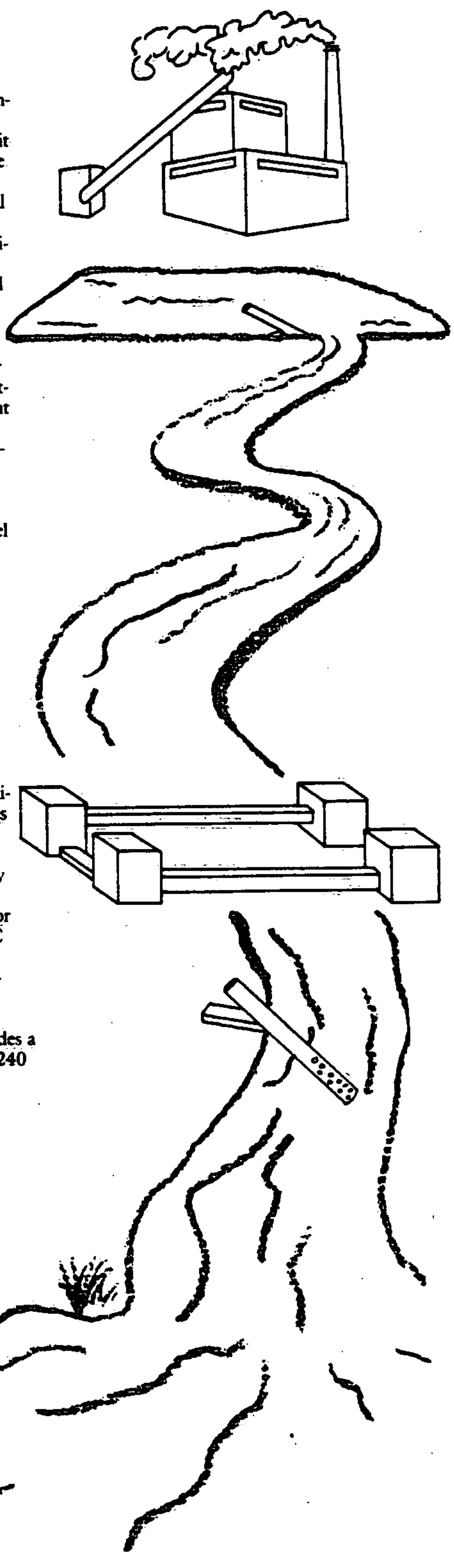
Hydrolab 5200-20XX Data Management Unit

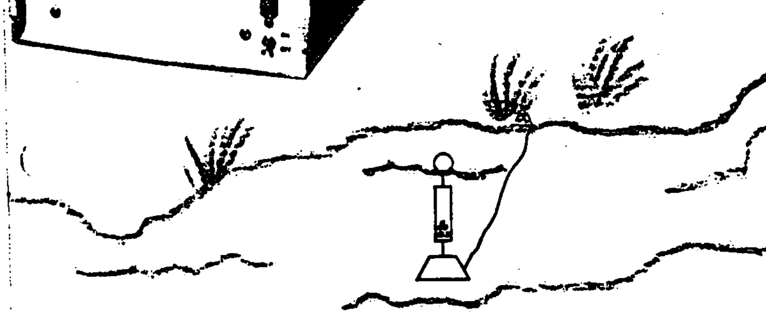
What enables each DataSonde to communicate with you—and, if desired, your computer and its mass-storage medium—is the Hydrolab 5200-20XX Data Management Unit (DMU), a solid-state, laboratory-based device which plugs into the DataSonde as well as your RS-232-C compatible keyboard terminal (e.g., CRT, TTY) and/or computer system. With the DMU, calibration, programming, diagnostics, and data read-out (i.e., outputting data from each DataSonde) can all be handled conveniently and efficiently in the laboratory via a dialogue with the keyboard operator. A series of questions and answers enables the operator to communicate pertinent parameter calibrations as well as test the DataSonde's battery, memory, and the ability of the instrument to perform in relation to the calibration standard. Further flexibility in data analysis is provided by the DMU's "intelligence," which allows for rudimentary conversions to be performed (e.g., conductivity to salinity and/or raw conductivity) as required by lab personnel and effected via keyboard command.



Operating via its own permanent internal software like each DataSonde, the DMU eliminates the need for expensive software packages (as well as tapes, disks, etc.) usually required to format data for understandability. Instead, output from the DataSonde's CMOS memory is automatically analyzed, organized, and formatted by the DMU, making it readable for your easy interpretation. Dual EIA RS-232-C ports on the unit allow this output to be printed out, transmitted via modem to a computer for permanent storage and/or further processing, or both.

The Hydrolab 5200-20XX DMU includes a plug-in power supply switchable for 120/240 VAC, 60/50 Hz.





DataSonde™ 2000 Series Performance Specifications

Specification	Temperature	Conductivity	Salinity	pH	ORP	D.O.
Range	−2° to 50°C	0–1K, 10K, 100K µS/cm (std range) or 0–100, 1K, 10K µS/cm (Acid Rain System) (Selectable by keyboard)	20–60‰ (approx.) N/A	0–14pH	−1,000 to +1,000 mv	0–20 mg/l (ppm)
Calibrated Accuracy	±0.1°C (NBS traceability)	±1% of range selected	0.75‰	±0.1pH over 3–11pH range	Within ±10mv of platinum electrode potential	±0.2 mg/l (ppm)
Resolution	±0.025°C	0.1% of range	0.1‰	0.01pH	1 mv	0.01 ppm
Sensor Type	Linear Thermistor	6-electrode cell	See Conductivity	Glass electrode, sealed reference with refillable flowing junction	Platinum electrode	Polargraphic cell
Temperature Compensation (ATC)	N/A	Automatic 25°C reference	N/A	Automatic	N/A	Automatic
Calibration	Factory (NBS traceability)	By keyboard entry with sensor immersed in quality KCl or seawater standard solutions	See Conductivity	pH7 and 4 or 10 buffer	Quinhydrone standard	Saturated water or Winkler titration

DataSonde 2000 Series Physical Specifications

Length Overall	20.5" (521 mm.)
Diameter Overall	5.75" (146 mm.)
Weight	10.5 lbs. (4.8 kg.)
Maximum Depth	1,000 feet (300 meters)
Temperature Tolerance Range	−2 to 60°C
Construction Materials	PVC, delrin, stainless steel

DataSonde 2000 Series Operational Specifications

Data Storage	Solid-state CMOS RAM
Data Capacity	3,600 parameter readings plus station identification, initial time and date, ending time and date, calibration standard values, sample time interval, parameters selected
Data Recovery	By means of any EIA RS-232-C compatible terminal or printer via Hydrolab 5200-20XX DMU
Sampling Interval	Programmable; selectable by keyboard entry in multiples of five minutes up to 9 days. (Note: to be used in slowly varying sample investigations—minimum sample rate is 5 minutes)
Clock	Quartz reference (accuracy: 2 min./month)
Power Supply	6 VDC from 4 D-cell alkaline batteries (operating life: approx. 6 months)

HYDROLAB™
P.O. Box 50116
Austin, Texas 78763
512-255-8841 Telex II 910-874-1335

APPENDIX B

EXCERPTS FROM THE QUALITY ASSURANCE PROGRAM MANUAL

NWRI CALIBRATION LABORATORY

ES 1136

Approved for Implementation by: [signature]
S.D. Baird, Head
MANTEC Section

Date: MARCH 11'86

QUALITY ASSURANCE PROGRAM MANUAL

FOR MANTEC CALIBRATION UNIT

by

L.R. Peer

Manufacturing and Technical
Development Section
Hydraulics Division
National Water Research Institute
Canada Centre for Inland Waters
Burlington, Ontario

December 1985

Revised: L.R. Peer 1986March06   Revision Approved: [signature]

MARCH 11'86

5.0 ENVIRONMENT DESCRIPTION

The environment of the calibration, standards laboratories shall be controlled in keeping with ISA standard RP52.1 (1975).

Lighting shall be by neon with a minimum light level of 1000 Lux at all work areas. Electrical power shall be supplied at 115 VAC and 220 VAC. The primary standards 115 VAC supply shall be backed up by the CCIW building emergency supply which runs off a diesel generator. Regular tap water and distilled water shall be supplied, the latter for making ice baths for temperature references. Temperature shall be held between 21 and 23 degrees celcius, with humidity held between 40 and 60 percent. Dust particle count shall be maintained in keeping with guidelines set by the Standards Council of Canada. The lab conditions for temperature, humidity and barometric pressure shall be continuously recorded on a Weathermeasure Meteorograph with a 31 day chart. The primary barometric pressure standard shall be a digiquartz pressure transducer with frequency output to a counter and calculator to convert to kPa. A benchmark shall be installed in the floor of the Calibration Laboratory R101. A sign above it shall display the values of latitude, longitude, and gravity. Every five years these values are to be rechecked and the sign updated. Heat sensor alarms mounted at various points in the ceiling shall be used to provide a warning of fire.

A layout of the labs is given in Appendix D.

6.0 LABORATORY STAFF

The Supervisor of the Calibration Unit shall be responsible for the day to day operation of the Unit and will report directly to the Head, Manufacturing and Development Section. The Calibration Unit shall also have a fulltime assistant metrologist who will report to the Supervisor. Both the Supervisor and assistant metrologist shall be certified electronic technologists.

7.0 RULES ON MEASUREMENT SYSTEMS AND DATING

The International System of Units (SI) shall be used for all work, measurements and reports per Hydraulics Division Operational Guidelines (Dr. T.M. Dick, Division Chief, 1979 October). CSA standards CAN3-Z234.2-76 and CAN3-Z234.1-79 apply.

All dating shall be in the form, year, month, day (YYMMMDD). Year will be the last two numerals, month the first three letters in capitals and the day the two numerals, i.e., 85NOV06 for 1985 November 06. This closely follows the CSA standard CAN3-Z234.4-79 except to avoid confusion with the many other dating standards used in our country we have chosen to display the month as three letters instead of numerals. Eventual changeover to all numeric is intended as soon as it is more commonly used in the rest of the country, hopefully this will be before the year 2001.

8.0 INTERNAL OPERATION OF CALIBRATION UNIT

The internal organization is described in the following categories:

8.1 Traceability of standards
8.2 Calibration procedures
8.3 Computer automated calibration procedures
8.4 Report documentation
8.5 Security
8.6 Work order flow
8.7 Equipment control
8.8 Technical documents
8.9 Future measurement requirements
8.10 Handling complaints

8.1 Traceability of Standards

A three-stage hierarchy of standards is to be maintained to ensure lab traceability to the National Research Council.

Standards are to be divided into three categories. These are Primary, Secondary and Working standards. Table 1 lists these standards and their calibration intervals. These intervals shall be adjusted as instrument histories dictate.

Primary standards are to be either calibrated directly by NRC or in our lab using other NRC calibrated standards.

Secondary standards are to be calibrated by us against our Primary standards.

Working standards are to be calibrated also by us against our Secondary standards then used in general instrument repair and calibration.

Control charts are to be used to monitor the standard cells used as the primary voltage standard, the primary standard oscillator and the primary resistors, and to ensure confidence in them. Lists of the standards in each of these three categories shall be kept along with the calibration procedures for the standards, in a dedicated three-ring binder entitled Standards Calibration Procedures.

The calibration status of internal calibration equipment shall be indicated by a green calibration sticker on each piece. This sticker is to carry the date of last calibration, the name of the performing metrologist and date when next calibration is due.

Completed client equipment is to have a green tag attached which has the calibration date and name of performing metrologist. Next calibration due date is not indicated as it is determined by the client and is normally not known by the Calibration Unit.

Other than being listed in this book, the standards have no markings on them to indicate their category. They are only used by the metrologists in the Calibration Unit who are aware of their status and limits of use.

In cases such as DWT pressure testing, humidity and temperature, the primary standards are also the working standards. With volts, ohms and frequency the primary standards are maintained in a separate section of R122B called the Electrical Standards Laboratory. Here clear cut levels of primary, secondary and working standards prevail.

8.2 Calibration Procedures

Calibration procedures are to be written for all the lab standards plus the routine transducer calibrations performed in the lab. These procedures are to be kept in three three-ring binders. The titles will be: Transducer Calibration Procedures, Computer Based Transducer Calibration Procedures and Standards Calibration Procedures. All three are to be kept on the Calibration Laboratory bookshelf.

They shall list equipment required, pertinent operating instructions, computer programs, diagrams for interconnection, an example of a typical report form and relevant supporting documents from outside authorities.

These procedures are to be used whenever they exist for the work being performed.

There shall be an ongoing program of internal monitoring for the assurance of continued accuracy of measurements. The following outlines some minimum ways this shall be done:

Temperature:
- ice bath checks monthly
- comparisons of the two temperature bridge systems yearly
- calibration at NRC of one bridge thermometer every three years

Pressure:
- using a precision transducer crossscheck between the Ruska DWT and the Mansfield and Green DWT yearly
- calibration at NRC of one DWT every five years

9.4 Temperature Calibration Facility

9.4.1 Purpose

The calibration and testing of temperature sensors and their associated electronics. Investigating response times and the effects of temperature on a variety of submersible devices.

9.4.2 General

To meet the range of water/air related temperatures (-15°C to +40°C) required by the Institute, two variable temperature baths provide stable temperature sources from -25°C to +45°C. Two direct reading bridges with platinum probes calibrated at NRC ensure calibrations to an accuracy of 10 m°C and special calibrations to less than 5 m°C.

The smaller bath has a 24 litre capacity and uses #200 silicone oil. This tank is used to calibrate most air and water temperature sensors as it has a fast rate of change and is quick to stabilize. The larger bath has a capacity of 150 litres, uses water and accommodates larger units such as CTD's, EBT's and current meters where sensors cannot be removed.

9.4.3 Specifications

Rosemount Oil Bath Model 910AC

Range	-	-30°C to +50°C
Capacity	-	24 litres
Stability	-	better than ±3 mC
Medium	-	#200 Silicone oil, 1.5 cS

Constant Temperature Controls Water Bath

Range	-	-30°C to +50°C (with antifreeze)
Capacity	-	150 litres
Stability	-	better than ±10 m°C
Medium	-	water

Guildine Direct Reading Dauphinee Thermometer Bridge Model 9500

Range	-	-50°C to +500°C
Accuracy	-	±0.001% + 1 m°C

Rosemount Platinum Resistance Thermometer Model 162C

Range	-	-189°C to +500°C

Guildline Digital Thermometer Model 9535

Range	-	-189°C to +500°C
Accuracy	-	±0.030m°C

Fluke Digital Thermometer Model 2180A abd 2030A Printer

Range	-	-20°C to +200°C
Accuracy	-	±0.1°C

Distilled Water Ice for Ice Baths

Triple Point of Water Cell

9.5 Frequency and Time

9.5.1 Purpose

The acquisition of data requires a precise time reference. Calibration of frequency measuring instruments requires an accurate frequency source. The National Water Current Meter Calibration Service requires an NRC traceable reference frequency for its tow carriage speed indicator. The Marine Sciences Division of the

Department of Fisheries and Oceans requires this same traceable reference frequency for calibraiton of frequency measuring instruments. These are used to calibrate hydrographic vessel position indicating systems.

9.5.2 General

This facility is based on the Fluke VLF receiver, comparator, standard oscillator Model 207-5 described under Primary Standards. The receiver is tuned to receive WWVB at the NBS facility in Bolder, Colorado, U.S.A. This provides a frequency traceable to NBS/NRC standards. The frequency output of 1 MHz is also routed to the other CCIW labs previously mentioned. For time keeping and display an HP 59309A Digital Clock is referenced to this frequency. Audible time signals are received from NRC by a Specific Products CHU/WWV HF receiver.

9.5.3 Equipment specifications

Fluke VLF receiver, comparator, standard oscillator
Model 207-5
Range 8kHz to 60 kHz
Standard frequency 1 mHz
Accuracy $\pm 1 \times 10^{-9}$
Calibration Capability $\pm 1 \times 10^{-11}$ on a 24 h basis

10.0 RANGE AND UNCERTAINTIES OF CALIBRATION SYSTEMS

10.1 Temperature Calibration

Using the Rosemount model 910AC oil bath in the standard configuration, transducers can be calibrated over the range of -15 to 40°C with an uncertainty of ±0.015 °C. Standard configuration means using Dow Corning type 200 dimethyl silicon fluid with a viscosity of 1.5 centistokes (MIL-S-21568A).

This uncertainty is worse case. It assumes all contributing errors are maximum and occur at the same time and in the same direction. Contributing errors include bath non-uniformities (gradients and stability), thermometer calibration and non linearity, temperature bridge calibration and non-linearity.

In calibrating a typical Rosemount temeperature transducer as used in the Electrobathythermograph (EBT) systems, the uncertainty would be the 0.015 °C from above, plus the uncertainty of the transducer readout device, which is typically a Fluke model 8500A DMM.

For example, experience shows that the Fluke's published accuracy specs can be taken as worse case. This means an uncertainty of 200 μV when measuring 5 Vdc on the 10 V range. For a Rosemount model 171ED temperature transducer covering the range 0 to 50°C with an output of 0 to 5 Vdc

total uncertainty = voltmeter + temp. facility uncertainties
= trans sens in °C/μV x 200 μV + 0.015°C
= (50°/5V) x 200 μV + 0.015 °C
= ± 0.017°C

10.2 Pressure Calibration

10.2.1 Ruska DWT

Using the Ruska model 2465-751 dead weight tester (DWT), transducers can be calibrated over the range of 14 kPa to 5.2 MPa (2 to 750 psi) gauge or absolute with an uncertainty of ±0.01506 percent of reading.

This uncertainty is worse case. It assumes all contributing errors are maximum and occur at the same time and in the same direction. Contributing errors include the Ruska DWT and vacuum gauge with an NRC confirmed uncertainty of 0.015 percent of reading, plus an