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NOAA Technical Memorandum NOS 22

PERFORMANCE EVALUATIONS OF THE ORBISPHERE LABORATORIES MODELS 2702 AND 2709 OXYGEN MEASURING SYSTEMS

Washington, D.C.
June 1979

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NOAA Technical Memorandum NOS 22

PERFORMANCE EVALUATIONS OF THE ORBISPHERE LABORATORIES MODELS 2702 AND 2709 OXYGEN MEASURING SYSTEMS

Jerald M. Peterson, Charles C. White,
Barbara S. Pijanowski, and Gary K. Ward

Test and Evaluation Laboratory
Washington, D.C.
June 1979

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ABSTRACT: Test and evaluation results are reported for two portable oxygen and temperature measuring systems. System descriptions, manufacturer's specifications, and performance results are provided with associated figures and tables summarizing accuracy, precision, stability, and environmental effects.

INTRODUCTION

The Orbisphere Models 2702 and 2709 Oxygen Measuring Systems are all-solid-state instruments designed to measure temperature in the range of 0°C to 50°C and dissolved oxygen concentrations from 0 to 20 ppm (mg/l) and 0 to 30 ppm, respectively. The electronics section may be powered by any battery possessing a voltage from 5.5 to 10 volts. A 9-volt "transistor" battery will provide 180 days of continuous operation. The detector section uses the polarographic membrane technique with a gold cathode and silver anode. Thermistors are used to provide temperature compensation to correct for the nonlinearity of the oxygen membrane permeability curve versus temperature. The temperature compensation is automatic from 0°C to 45°C. The protected sensing head has a maximum diameter of 15 mm. It may be used for measurements in NS 19 to NS 24 flasks fitted with special sleeves. The sensor has a built-in stirrer with a battery life of 8.6 hours of continuous use. A minimum of 4 minutes stabilization time is required when the plug-in sensing head is changed. The oxygen consumption is 0.1 μg/hour-ppm.

The electronics section provides a constant predetermined voltage to the oxygen sensor. The dissolved oxygen (DO) signal is applied to a current-to-voltage converter which also contains the temperature compensating circuitry. This is followed by a chopper electrometer amplifier and output amplifier which feeds both the panel meter and analog recorder output. The total current drain is 250 μA. The 2702 DO meter ranges are 0-2, 0-10, and 0-20 ppm. The 2709 DO meter ranges are 0-1, 0-3, 0-10, and 0-30 ppm.

The basic difference between the two instruments is that the Model 2709 uses a nonlinear galvanometer scale to give more precise temperature measurements than the 2702 model. The 2709 also has an improved oxygen sensor head. The 2702 and 2709 are shown in figures 1 and 2, respectively.

The manufacturer's performance specifications are summarized in appendix A.

TEST PROCEDURES AND RESULTS*

Temperature

The temperature accuracy and precision determinations were conducted in a nonmetallic, constant-temperature water bath. The temperature range for the Model 2702 evaluation was from 2°C to 40°C. The test range for the

*A performance summary is given in appendix B.

Model 2709 was from 0°C to 40°C. The bath temperature was determined with a platinum resistance thermometer in conjunction with a Mueller bridge having a combined accuracy of ±0.002°C or with a calibrated quartz thermometer having an accuracy of ±0.02°C.

The temperature calibration curves for both models are shown in figure 3. The worst cases of inaccuracy and imprecision for the Model 2702 were 2.44°C and ±0.37°C, respectively. For the Model 2709 the worst-case inaccuracy was 1.91°C* and the worst-case imprecision was ±0.13°C.

Dissolved Oxygen

The dissolved oxygen accuracy and precision data were obtained from instrument readings in a constant-temperature water bath in which the concentration of dissolved oxygen was established as follows. The water bath was saturated with a gas mixture of O_2 and N_2 in a temperature cycle of 20°C, 10°C, 0°C, 20°C, 30°C, 40°C, and 20°C. This saturation process and temperature cycling was repeated two or more times in baths of 0-ppt and 35-ppt salinity. The artificial seawater was prepared from American Society for Testing and Materials (ASTM) Formula A sea salt at a temperature of 40°C. Three different gas mixtures (4, 8, and 21 percent O_2 in N_2)$^+$ were used to saturate the test bath that was temperature cycled to obtain a complete range of dissolved oxygen concentrations. Literature values for dissolved oxygen in saturated seawater as functions of temperature and

*The 2709 had a 1.0°C offset over the entire temperature range. If corrected for the offset, the worst-case inaccuracy would be 0.91°C.

+Actual gas mixture oxygen concentrations were obtained to within ±0.08 mole percent from analyses performed by the National Bureau of Standards.

salinity were obtained from Gilbert, et al. (1967)*. Water samples were also taken at each test point to be analyzed by the modified Winkler method and gas chromatographic techniques.

Figure 4 shows the freshwater dissolved oxygen calibration curves for the Model 2702 for the three gas mixtures. (The Model 2709 did not arrive until after the freshwater tests were completed and, therefore, was not tested for dissolved oxygen in freshwater.) The worst-case inaccuracy was 0.92 ppm (4 percent O_2 mixture at 2°C), and the worst-case imprecision was ±0.26 ppm (4 percent O_2 at 20°C). Figure 5 presents the seawater (35-ppt salinity) dissolved oxygen calibration curves for both instruments. The worst-case inaccuracy for the Model 2702 in seawater was 0.50 ppm (4 percent O_2 mixture at 0°C), and the worst-case imprecision was ±0.50 ppm (21 percent O_2 mixture at 20°C). For the Model 2709 in seawater the worst-case inaccuracy and imprecision were 0.60 ppm (4 percent O_2 mixture at 0°C) and ±0.10 ppm (4 percent O_2 mixture at 10°C), respectively.

Response Times

The response times for each parameter (temperature and dissolved oxygen) were obtained by subjecting the sensor to a step change in measurand and monitoring the output on an analog recorder. The results of the 95 percent response tests are summarized in table 1. It should be noted that the temperature measuring thermistor and the two temperature compensating thermistors are thermally connected directly to the cathode of the detector, which results in faster temperature response times.

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*Gilbert, Pawley, and Park, 1967: Carpenter's oxygen solubility table and nomograph for seawater as a function of temperature and salinity. Oceanographic Society of Japan, 23 (5), p. 252-255.

Table 1.--Measured response times (seconds)*

Measurand	At 0°C	At 20°C	At 40°C
Dissolved oxygen	106	21	7
Temperature	124	132	140

Environmental Effects

To examine the effects of temperature and humidity variations on the electronics portion of the system, the sensor inputs were simulated and the electronics package was placed in an environmental chamber where the temperature was cycled from 10°C to 45°C. Two cycles were conducted at 25 percent relative humidity and one cycle at 85 percent relative humidity. The sensor-simulation circuitry was isolated from these temperature variations. The worst-case temperature error during the environmental evaluation was ±1.9°C for the Model 2709. The worst-case dissolved oxygen error was ±0.9 ppm for the Model 2709. The Model 2702 was not tested for environmental effects, because the electronics circuitry is the same for both instruments.

Power Supply Variation Effects

A DC power supply was substituted for the instrument's internal battery, and the voltage was varied from the "normal fresh-battery" voltage down to 65 percent of the battery voltage. No detectable errors were observed in the outputs of either instrument.

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*Response time is herein defined as the time required for the system output to attain 95 percent of the asymptotic value when subjected to a step input. This 95 percent response time is three times the time constant [$(1-e^{-1})$ value] for a pure exponential response.

Long-Term Stability

The long-term stability tests were conducted for 24 days to determine the instrument's reliability for monitoring applications. For this test, the sensors were once again placed into the nonmettalic bath containing freshwater saturated with a gas mixture of 21 percent oxygen in nitrogen. The bath was resaturated, and readings recorded each day. Figure 6 depicts the dissolved oxygen error for each instrument as a function of time in days.

GENERAL COMMENTS

1. The 2104.01 sensor head in the Model 2709 failed prior to the environmental testing and was replaced by the manufacturer.

2. The manual supplied with the instruments does not contain a system description and includes only a very brief circuit description. The manual does contain an excellent section on polarographic oxygen measurements, and the sections on operation, care and maintenance, and trouble-shooting are quite detailed. The manual also contains a parts list and circuit schematics.

ACKNOWLEDGMENT

The authors wish to acknowledge the dedicated efforts of Paul Eichelberger without whose expertise, perseverance, and attention to testing detail, the data in this report could not have been gathered.

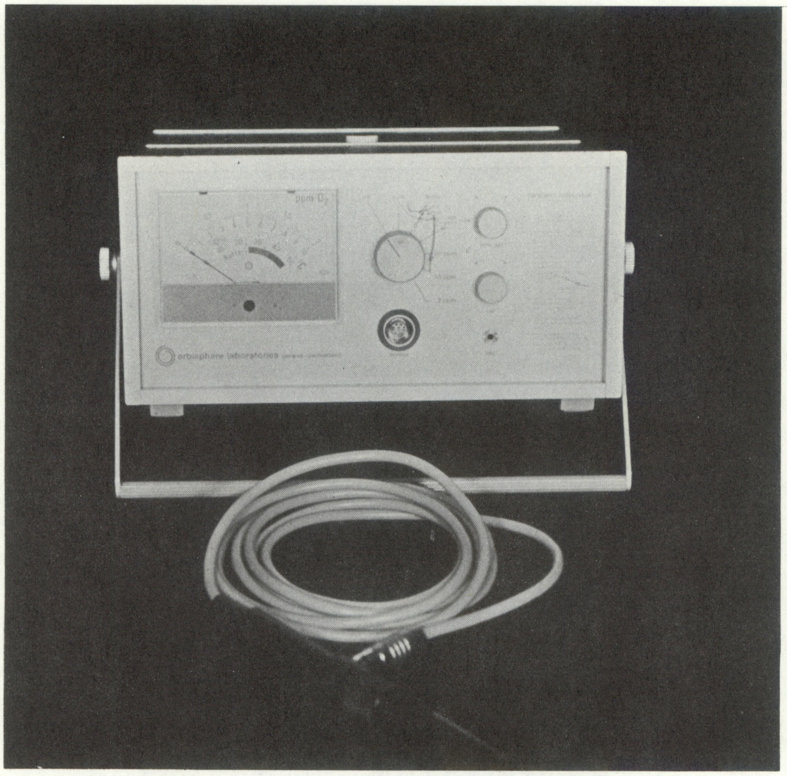

Figure 1.--Orbisphere model 2702 oxygen measuring system.

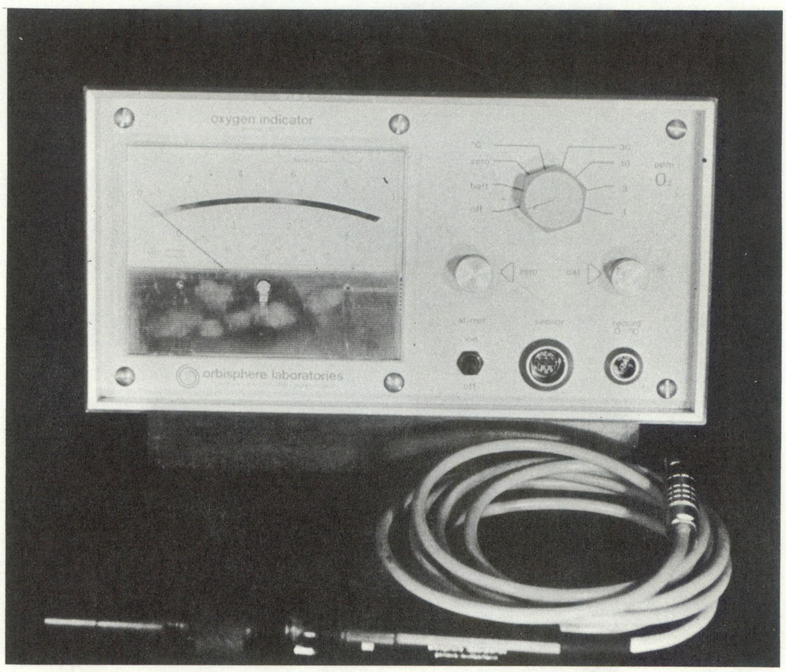

Figure 2.--Orbisphere model 2709 oxygen measuring system.

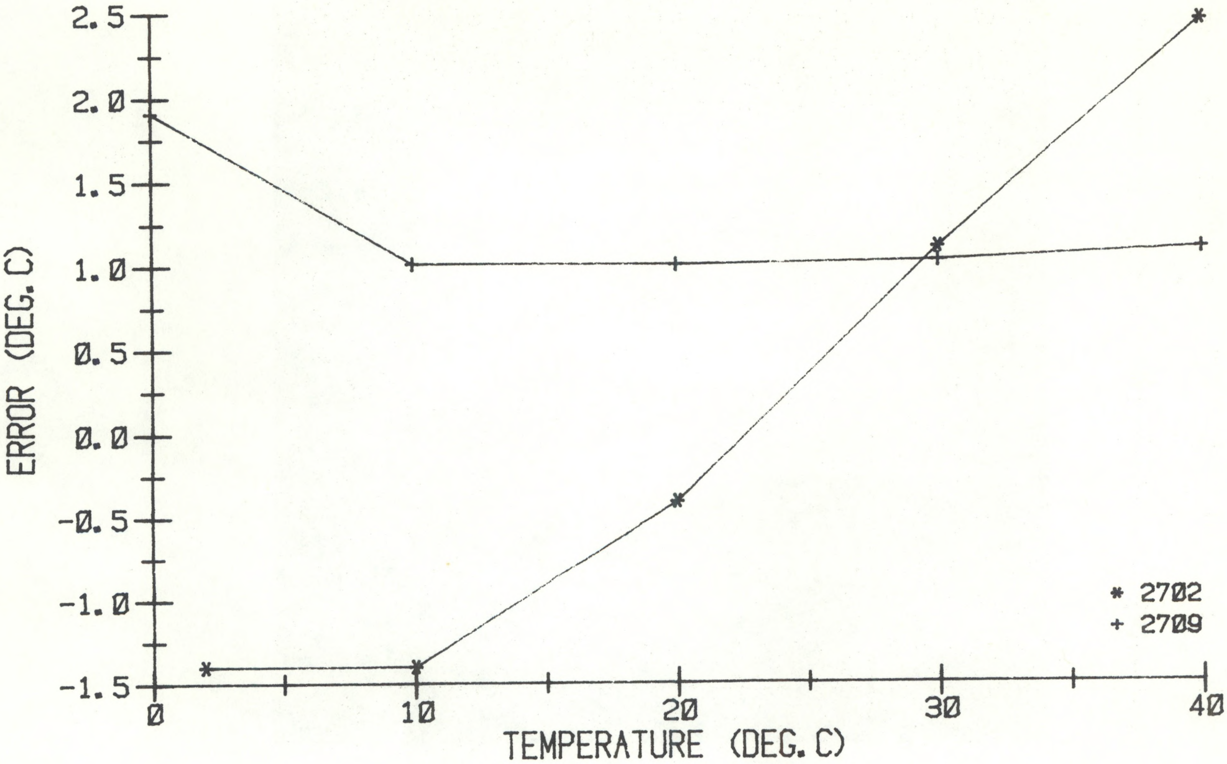

Figure 3.--Temperature accuracy for models 2702 and 2709.

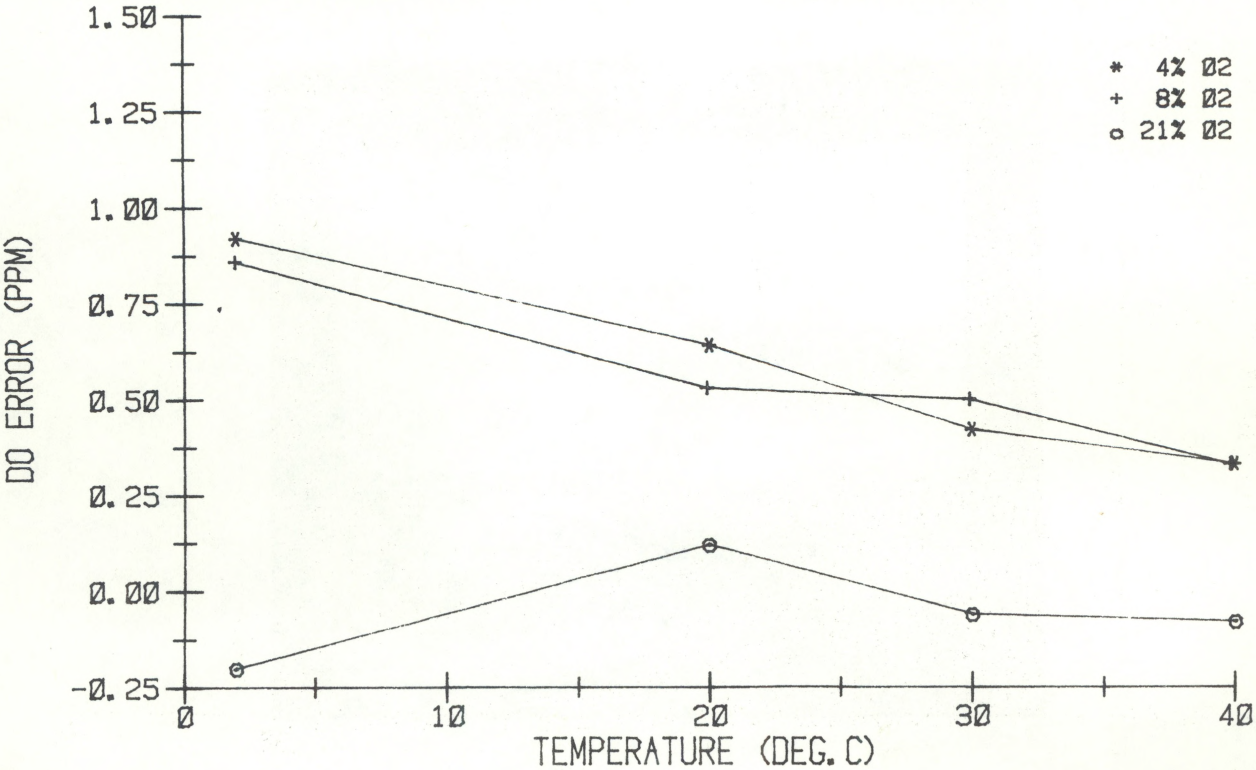

Figure 4.--Dissolved oxygen accuracy in freshwater for the model 2702.

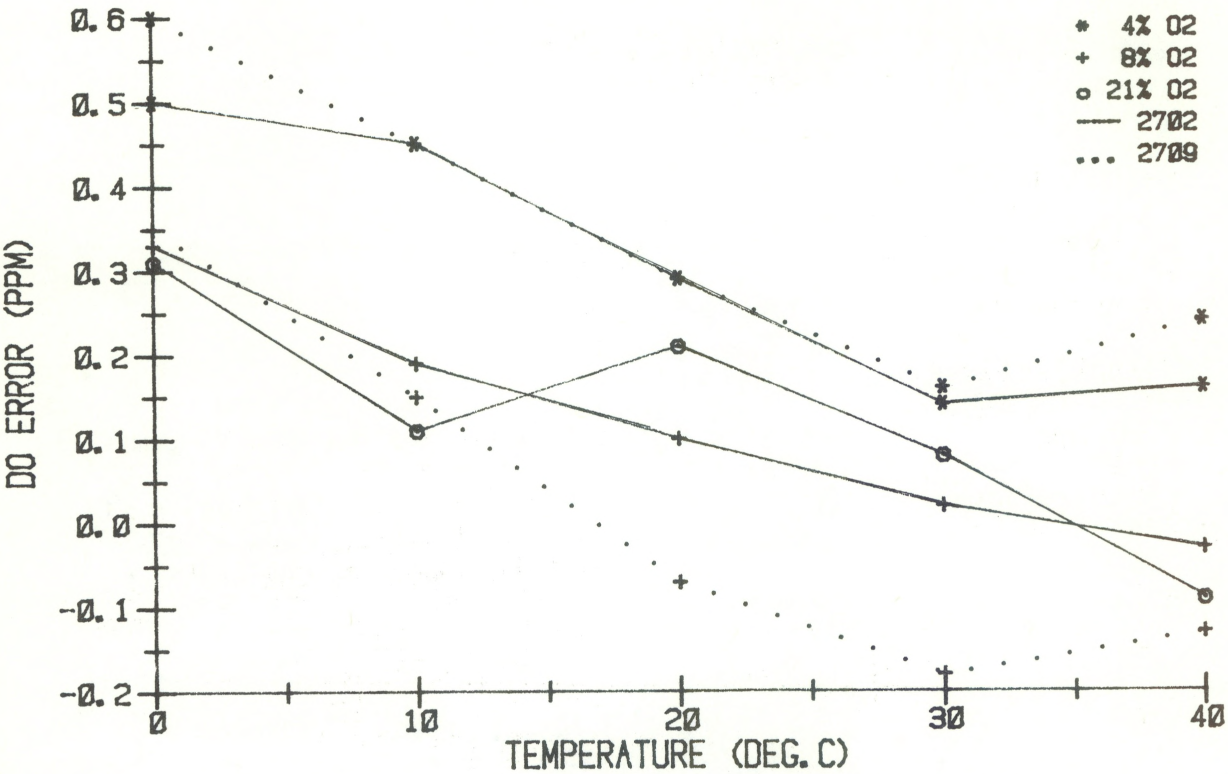

Figure 5.--Dissolved oxygen accuracy in seawater (35-ppt) for models 2702 and 2709.

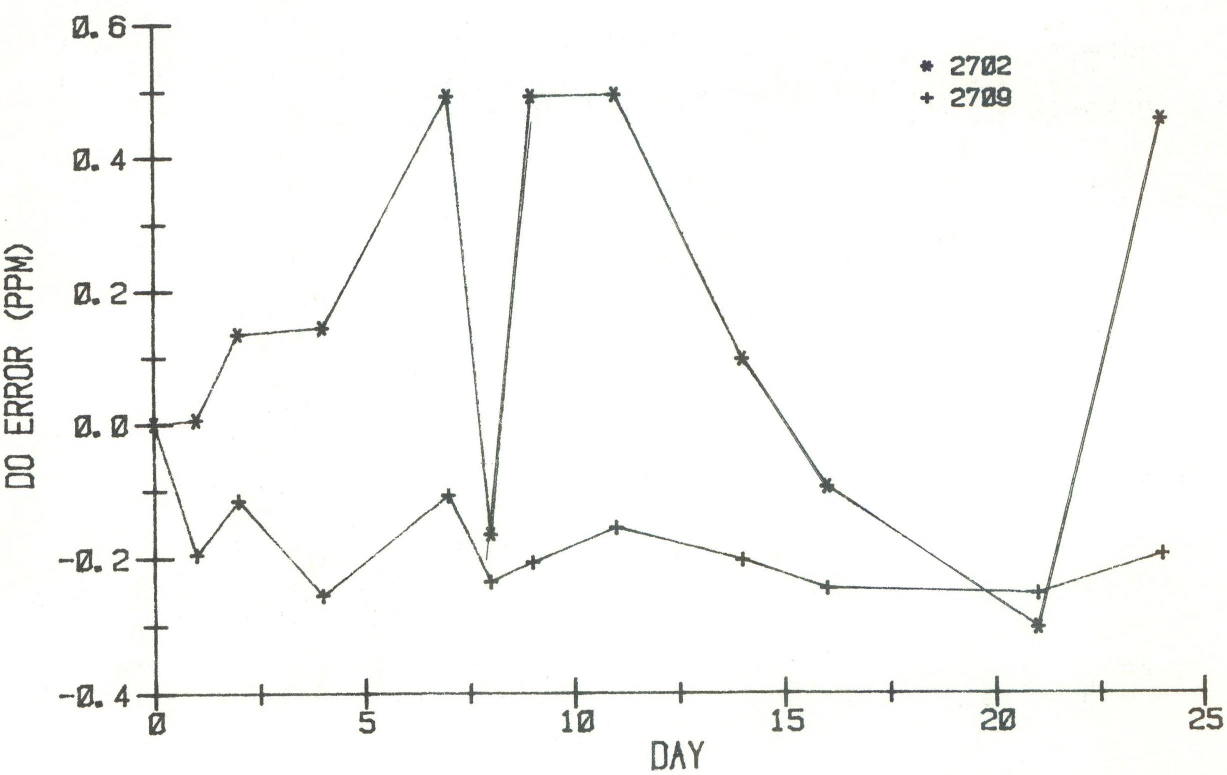

Figure 6.--Dissolved oxygen error vs. time (days) for models 2702 and 2709.

APPENDIX A -- MANUFACTURER'S PERFORMANCE SPECIFICATIONS

Temperature	
Range	0°C to 50°C
Accuracy	±0.5°C
Dissolved oxygen	
Ranges	0 to 2, 0 to 10, 0 to 20 ppm
Accuracy	±1 percent when temperature of unknown sample is within ±5°C of calibration temperature
Response time	10 s to reach 90 percent of true value
	30 s to reach 99 percent of true value
O_2 consumption	0.1 μg/hour-ppm
Linearity	±1 percent
Temperature compensation	0°C to 45°C

APPENDIX B -- PERFORMANCE SUMMARY*+

	2702	2709
Temperature		
Range tested	2°C to 40°C	0°C to 40°C
Accuracy	2.44°C	1.91°C**
Precision	±0.37°C	±0.13°C
Dissolved oxygen		
Range tested	1 to 14 ppm (mg/l)	1 to 14 ppm
Accuracy, freshwater	0.92 ppm	--
Accuracy, seawater	0.50 ppm	0.60 ppm
Precision, freshwater	±0.26 ppm	--
Precision, seawater	±0.50 ppm	±0.19 ppm

*Abbreviated from the Test Procedures and Results and associated graphs.

+All test results are worst-case values averaged from two or more cycles unless otherwise specified.

**Includes a 1°C calibration offset

APPENDIX C - GLOSSARY

Measurand - A physical quantity, property, or condition which is measured.

Error - The algebraic difference between the indicated value and the true value of the measurand, usually expressed in percent of the full-scale output, somtimes expressed in percent of the output reading of the instrument.

Accuracy - The ratio of the error to the full-scale output (usually expressed as "within ± ---- percent of full-scale output") or the ratio of the error to the output, expressed in percent. Accuracy may also be expressed in terms of units of measurand.

Precision (repeatability) - The ability of an instrument to reproduce output readings when the same measurand value is applied to it repeatedly, under the same conditions, and in the same direction. Precision is expressed as the maximum difference between output readings or as "within ---- percent of full-scale output." Three calibration cycles are used to determine precision unless otherwise specified.

Throughout this report, the values for errors, accuracies, and precisions are reported in terms of units of measurand. Accuracies are the average errors from the true value determined from two or more calibration cycles and are reported as + or - biases. Precisions are averages of the worst-case high and low values obtained with the same measurand input value under the same conditions over two or more calibration cycles unless otherwise noted. These precision averages are reported in measurand units as ± (highest value - lowest value)/2.

(Continued from inside front cover)

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NOS 19 Test Results on an Electromagnetic Current Sensor With an Open Design. David R. Crump, August 1976. (PB-260444)

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NOS 21 National Ocean Survey Abstracts - 1976. October 1977, 20 pp. (PB-275293)

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