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DEPARTMENT OF COMMERCE ★ UNITED STATES OF AMERICA ★

PERFORMANCE EVALUATION OF GUILDLINE MODEL 8400 LABORATORY SALINOMETER

Rockville, Md.
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GUILDLINE MODEL 8400
LABORATORY SALINOMETER

James E. Boyd

National Oceanographic
Instrumentation Center
Rockville, Md.
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UNITED STATES
DEPARTMENT OF COMMERCE
Elliot L. Richardson, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
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Survey
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PERFORMANCE EVALUATION OF GUILDLINE MODEL 8400 LABORATORY SALINOMETER

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National Oceanographic Instrumentation Center
National Ocean Survey
National Oceanic and Atmospheric Administration
Washington, D.C.

ABSTRACT. The performance of the Guildline Model 8400 Laboratory Salinometer (Autosal) was evaluated in detail by the National Oceanographic Instrumentation Center of the National Ocean Survey of the National Oceanic and Atmospheric Administration. The salinometer is designed to offer high accuracy (±0.003 part per thousand) and employs a measurement principle entirely different from that of other available instruments. The investigation included testing for overall accuracy, repeatability, and stability of the conductivity ratio measurements as well as the effects of variations in bath temperature, ambient temperature, and power supply voltage and frequency. The performance of the instrument was found to exceed the published specifications of the manufacturer. Results are presented in detail, notably that the conductivity ratio accuracy was better than ±1 part per million equivalent salinity. Graphs and other illustrations are included in the report.

INTRODUCTION

The Guildline Model 8400 Laboratory Salinometer (Autosal) is designed to measure the conductivity ratio of seawater samples with an equivalent accuracy of ±0.003 part per thousand (ppt) salinity. The instrument was developed by Dr. T. M. Dauphinee of the National Research Council of Canada and Guildline Instruments with the cooperation of the Bedford Institute of Oceanography. Inasmuch as the salinometer offers high accuracy and employs a measurement principle entirely different from that of other available instruments, members of the oceanographic community have expressed considerable interest in a laboratory evaluation of its performance. This study was recently carried out by the National Oceanographic Instrumentation Center of the National Ocean Survey of the National Oceanic and Atmospheric Administration. The unit is illustrated in figure 1.

The investigation included testing for overall accuracy, repeatability, and stability of the conductivity ratio measurements as well as the effects of variations in bath temperature, ambient temperature, and power supply voltage and frequency.

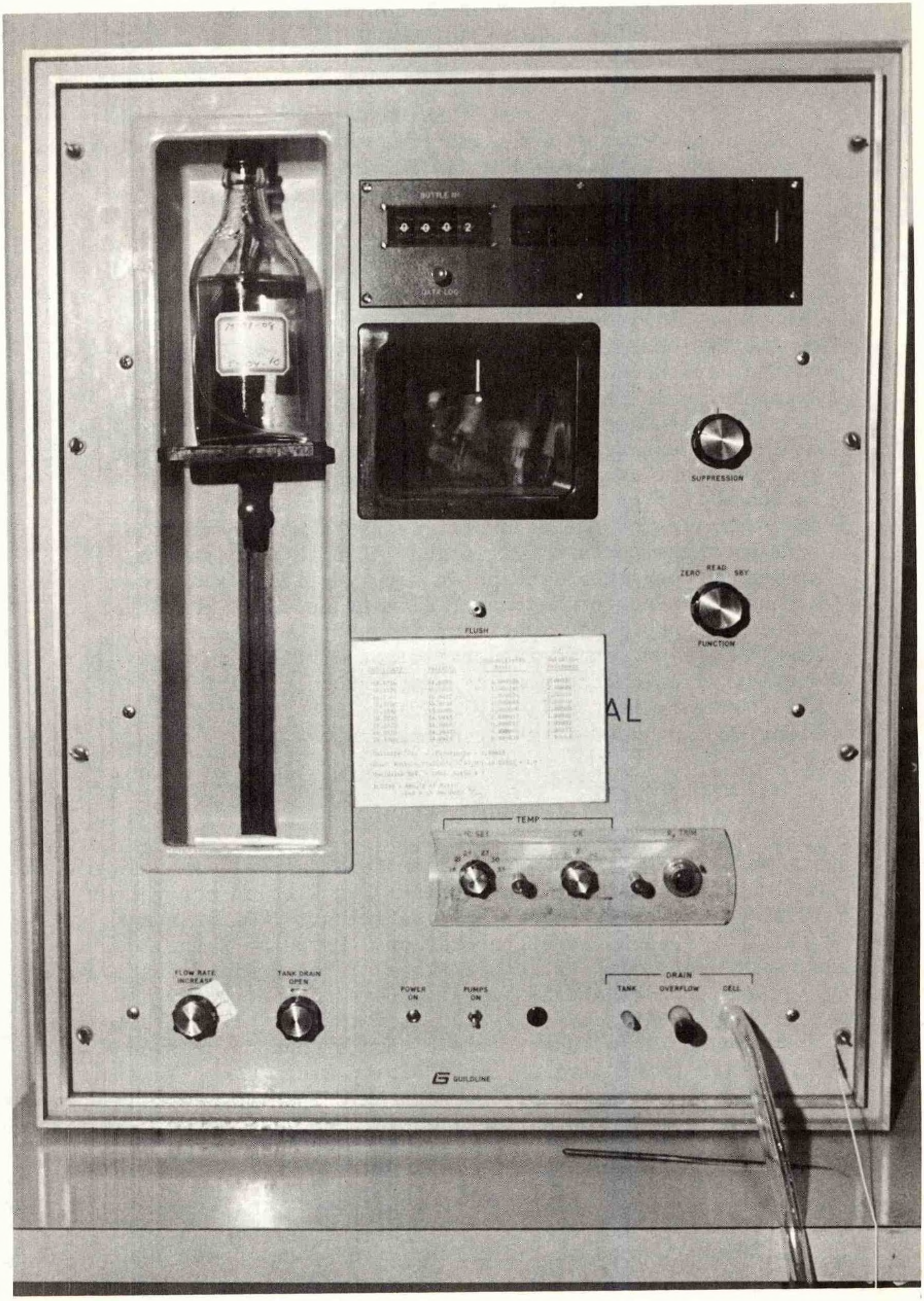

Figure 1.--Guildline Model 8400 Laboratory Salinometer

PRINCIPLES OF OPERATION

The instrument uses low air pressure (5 psi maximum) to transfer the water sample continuously from the original sample bottle to the measurement cell. A controlled temperature bath and heat exchanger bring the sample to a fixed temperature and since both the sample and standard are measured at the same temperature, there is no need for additional temperature compensation. Bath temperature, which should be chosen to be within +4° and -2°C of the ambient, can be set to control at 18°, 21°, 24°, 27°, 30°, or 33°C. Heat to the bath is provided by lamps which cycle on and off as controlled by a thermistor sensing circuit. Design accuracy of the bath is better than ±0.01°C.

The conductivity of the seawater sample at a defined temperature is compared by use of a square-wave current with an integral reference conductance that is established by calibration with standard seawater. Instrument output is a digital display and a BCD signal which is the ratio of the conductivity of the sample to that of the reference.

Mechanical - As indicated in figure 2, the water is forced from the sample bottle through a Teflon pickup tube and heat exchanger into the measurement cell without the formation of bubbles. Passing through the heat exchanger tube at a rate of approximately 1 ml/s, the sample is temperature calibrated and forced through the conductivity cell which houses four platinum-rhodium electrodes. The sample then moves through a Tygon tube to a waste bottle.

The four platinum-rhodium coil electrodes of the cell are mounted in sidearms on the upper side of the cell. In addition to the electrical leads, the top of each arm has a small Teflon air line which allows sample water to fill the arm as well as force water from the cell by introducing low pressure air.

By design, not more than 100 ml is required to measure any sample, starting with fresh water in the cell and including flushing volume. If the difference in salinity in samples is not greater than 3 ppt, 50 ml suffices to effect flushing.

After flushing, the cell refills in about 30 seconds. A window in the instrument allows the operator to check that the electrode sidearms have filled with sample water.

Electrical - A regulated current source supplies a square-wave current to the conductivity cell, R_C, and the reference resistor, R_S, in series. As shown in the block diagram of figure 3, this current source is referenced to a precisely generated 250-Hz reference voltage which also furnishes a reference for other parts of the system. A reference comparator is used to compare the square-wave voltage V_C which appears across R_C to the square-wave reference voltage and, by virtue of nulling signal, V_N, fed back to the current generator, brings the value of V_C to that of V_{REF}.

The square-wave voltage, V_S, which appears across the series reference resistor, R_S, is a linear analog of the conductivity of the seawater in the cell. By use of a linear comparator, this voltage is compared with the square-wave reference voltage, V_{REF}, which has been divided, or suppressed (on a

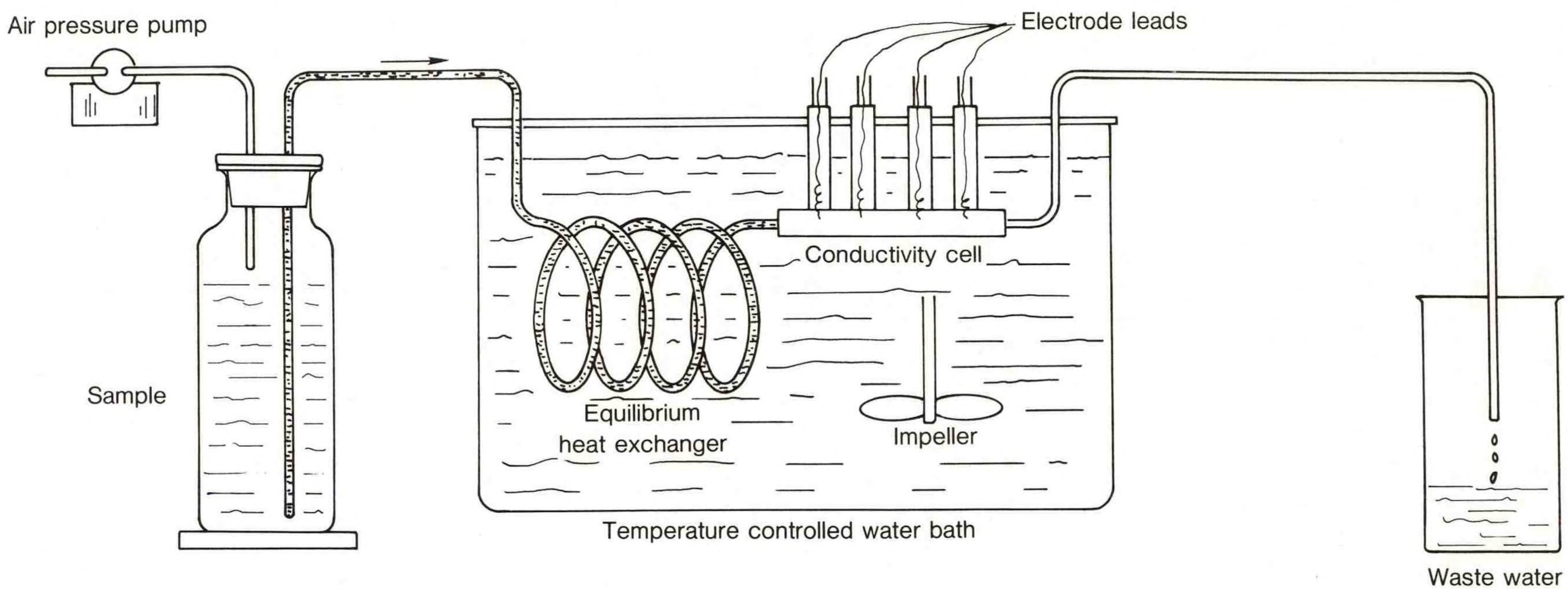

Figure 2.--Conductivity measuring apparatus

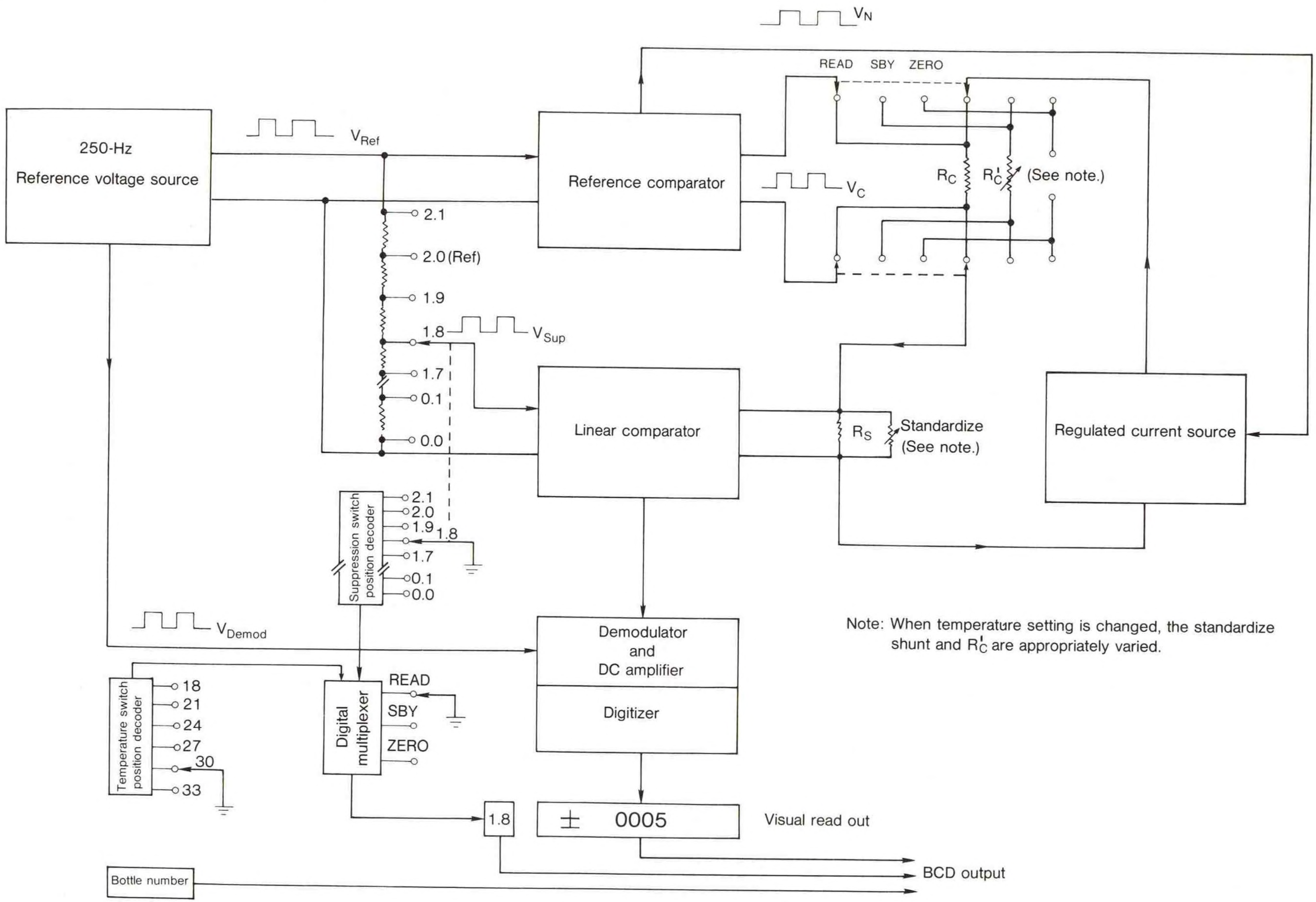

Figure 3.--Conductivity measuring circuit

linear scale) to a level within 5% of the voltage V_S. This setting is made manually with a front-panel control and is required only once for each sample since the approximate conductivity is usually known. The dial setting is read out on the panel meter as the first two digits of the conductivity ratio.

The linear comparator produces a signal proportional to the difference between the divided square-wave reference voltage and V_S and feeds this difference to a demodulator and DC amplifier. The difference passes through an analog-to-digital converter and then to the read out to provide the last four figures of the resolution. The sign of the difference is also displayed as illustrated in the block diagram.

The conductivity ratio as well as the temperature setting from the BCD output signal may be fed to external units for computing salinity. Bottle number may be identified by use of a 4-digit thumb-wheel switch on the front panel and logged via the BCD output signal.

In the standby position (SBY), the first two digits on the digital display are the bath temperature setting and the last four digits are derived from a precision resistive network, R_C'. The other four digits (to the right of the decimal point) are established when the instrument is standardized with Copenhagen water; any subsequent change indicates a shift in electrical operation which must be corrected.

In the ZERO position, the cell circuitry is open so that no potential should reach the DC amplifier, resulting in a series of zeros on the readout.

Standardization - The instrument is standardized by running a Copenhagen sample through the cell and trimming R_S to give a reading of

$$2 \left(\frac{G_{ts}}{G_{t,35}}\right)$$

where G_{ts} is the conductivity of a particular bottle of Copenhagen water and $G_{t,35}$ is the conductivity of 35-ppt water, both at temperature t. (Thus, a reading of 2.00000 corresponds to exactly 35 ppt.)

By design, standardization with Copenhagen water should be required no more than weekly for routine measurements.

MANUFACTURER'S SPECIFICATIONS

Accuracy	Better than 0.003 ppt equivalent salintiy
Short term stability	Better than 0.002 ppt equivalent salinity for 24 hours without restandardization
Maximum resolution	Better than 0.0002 ppt equivalent salinity at 35 ppt

Sample volume	A maximum of 100 milliliters (starting from fresh water in cell) including flushing volume. About 50 milliliters for a difference of 3 ppt in samples.
Scale suppression (conductivity range select)	Linear scale of conductivity ratio having 22 steps from 0 to 2.2 where 2.0 corresponds to seawater of 35-ppt salinity. Maximum reading is 2.29999, corresponding to approximately 42 ppt.
Temperature	Selectable from 18° to 33°C in 3° steps with an accuracy of ±0.01°C and a stability of ± 0.001° per day. Selected temperature should be within (ambient + 4)°C and (ambient - 2)°C.
Water bath volume	4.4 U.S. gallons (16.7 liters)
Dimensions	
Height	24 in. (61 cm)
Width	19 in. (48.3 cm)
Depth	21 in. (53.3 cm)
Weight	
Bath empty	115 lb (52 kg)
Bath full	150 lb (68 kg)
Shipping	193 lb (88 kg)
Power required	115 or 230 volts ± 10% at 50/60 Hz (200 watts maximum)

PERFORMANCE SUMMARY

Following is a summary of the performance of the salinometer. Details of the testing methodology are presented further below.

Bath-temperature accuracy and control stability

Worst-case inaccuracy: 0.048°C

Worst-case instability ±0.004°C/24 hours

Line-voltage and frequency-variation effect on bath temperature

The power transformer was adversely affected at 138 VAC and 50 Hz, causing a fuse to blow. The manufacturer changed his specifications accordingly. Other than this, no effects were noted on bath temperature.

Conductivity-ratio standardization repeatability

The worst-case change in standardization was ±0.000027/30 days.

Line-voltage and frequency-variation effect on ratio measurement

The worst-case change in conductivity ratio was +0.00009.

Conductivity-ratio accuracy, repeatability, and stability

The change in conductivity ratio was less than ±1 ppm equivalent salinity over the measurand range of the instrument.

Sample-temperature and fill-rate variation effect on conductivity ratio

The effect on conductivity ratio was negligible within the specified operating conditions.

Comparison of Guildline and UNESCO equations

The worst-case difference found when the Guildline and UNESCO equations were compared was -3.9 ppm salinity between 18° and 33°C.

LABORATORY EVALUATION TESTS[1]

1. BATH-TEMPERATURE ACCURACY AND CONTROL STABILITY

The system was tested for accuracy and control stability of six selectable bath-temperature control settings.

Method - The Autosal was placed in an environmental temperature chamber and the bath temperature monitored with a temperature standard with a resolution of 0.0001°C. Each bath temperature setting was maintained for 24 hours and recorded continuously as ambient temperature was held for 12 hours at -4°C from the setting and then 12 hours at +2° from the setting. In addition, overrange and underrange tests were run with the Autosal bath temperature setting at 24°C. The overrange test was performed at ambient temperature of -8°C and +4°C; the underrange ambient temperatures were -2°C and +1°C. During all of the above tests, the gain and zero-reference levels were also recorded.

[1]During the laboratory evaluation tests, the Autosal was energized continuously unless otherwise noted.

Results - Results for each test condition are summarized in table 1 in terms of bath-temperature accuracy and 12- and 24-hour control stability. Changes in gain and zero reference values are also provided. The worst-case bath-temperature inaccuracy and instability values (excluding overrange and underrange tests) are noted below.

Test Conditions		
Ambient Temperature (°C)	Bath Temperature (°C)	Results
14	18	Inaccuracy: 0.048°C
32	30	24-Hour Instability: ±0.004°C

The maximum change in gain was one count in the least significant of the four digits on the display. The maximum change in the zero-reference was four counts in the least significant of the four digits on the display.

2. LINE-VOLTAGE AND FREQUENCY-VARIATION EFFECTS ON BATH STABILITY

Accuracy and control stability of the bath temperature were tested for the effect of varying line voltage and frequency.

Method - The Autosal was set up using the same testing arrangement employed for Test 1 with the bath and ambient temperature maintained at 24°C. The instrument was energized by a power source of variable potential and frequency. The Autosal was first operated at 120 VAC and 60 Hz as a reference. Performance was then observed under the voltage and frequency conditions cited below.

Line Potential (VAC)	Line Frequency (Hz)	
102	60	
138	60	
120	60	Reference
120	50	
102	50	
138	50	
129	50	

Results - No discernible changes in the reference bath temperature control condition (±0.0005°C) were noted. However, at 138 VAC and 50 Hz, the laminations in the power transformer began vibrating and several minutes later the power fuse blew. When the manufacturer was apprised of this behavior, the original specifications (120 or 240 volts, 50/60 Hz, 200 watts maximum) were revised to reflect the finalized specifications of 115 or 230 volts ±10%, 50/60 Hz, 200 watts maximum.

3. CONDUCTIVITY-RATIO STANDARDIZATION REPEATABILITY

The system was tested for repeatability of the conductivity ratio measurement at standardized conditions over a period of 30 days.

Table 1.--Guildline Model 8400 Salinometer test results

Temperature (°C)		Instrument bath-temperature tests							
Instrument bath set point	Ambient ±0.3	Mean	Error set point (mean)	12-hour stability	24-hour stability	Gain ref. number	Change in gain	Zero	Change in zero
18°	14	17.9515	+0.0485	±0.0010		18 + 6921		0.0 + 0008	
	20	17.9541	+0.0459	±0.0011	±0.0024	18 + 6921	0	0.0 + 0004	-0.00004
21°	17	20.9667	+0.0333	±0.0008		21 + 7329		0.0 + 0006	
	23	20.9679	+0.0321	±0.0011	±0.0016	21 + 7329	0	0.0 + 0002	-0.00004
24°	20	23.9703	+0.0297	±0.0010		24 + 7775		0.0 + 0004	
	26	23.9720	+0.0280	±0.0012	±0.0020	24 + 7775	0	0.0 + 0000	-0.00004
27°	23	26.9749	+0.0251	±0.0010		27 + 8190		0.0 + 0002	
	29	26.9770	+0.0230	±0.0010	±0.0021	27 + 8191	+1	0.0 - 0001	-0.00003
30°	26	29.9783	+0.0217	±0.0011		30 + 8614		0.0 + 0000	
	32	29.9807	+0.0193	±0.0045	±0.0040	30 + 8615	+1	0.0 - 0004	-0.00004
33°	29	32.9905	+0.0095	±0.0035		33 + 9044		0.0 - 0002	
	35	32.9932	+0.0068	±0.0012	±0.0037	33 + 9044	0	0.0 - 0006	-0.00004
Overrange test									
24°	16	23.9678	+0.0322	±0.0008		24 + 7777		0.0 - 0007	
	28	23.9737	+0.0263	±0.0015	±0.0041	24 + 7778	+1	0.0 - 0001	+0.00006
Underrange test									
24°	22	23.9705	+0.0295	±0.0015		24 + 7778		0.0 + 0003	
	25	23.9719	+0.0281	±0.0015	±0.0022	24 + 7778	0	0.0 + 0001	-0.00002

Method - Ampoules of Copenhagen standard seawater were combined and then bottled to provide 36 separate standard test samples. The conductivity ratio of two of these samples was measured on NOIC's Precision Conductivity Comparator (PCC); a value of 0.999724 was determined for each. (The relative inaccuracy of the PPC in salinity units was estimated to be ±1.5 ppm with an imprecision of ±0.5 ppm.) The ambient instrument temperature and bath control temperatures were set at 24°C. The Autosal was standardized with the first test sample on Day One and one additional sample of the series was measured each subsequent day of the test for a total of 32 days.

Results - The average and standard deviations for each test sample measured during the 32-day period are listed in table 2; the gain (SBY) and zero-reference values are also included. The algebraic maximum and minimum differences from the initial standardization value were +0.00005 and -0.00006, respectively. The worst-case standard deviation was ±0.000027. The variations in the gain and zero-reference values (one-half peak-to-peak) for the entire test period were ±1 and +0.000005, respectively.

4. LINE-VOLTAGE AND FREQUENCY-VARIATION EFFECT ON RATIO MEASUREMENT

The system was tested for the effects of varying line voltage and frequency on conductivity ratio measurement.

Method - The Autosal was set up using the same arrangement employed for Test 2. A salt water solution of approximately 3 ppt was prepared and bottled to provide eight test samples. For reference purposes, the Autosal was first energized at 120 VAC and 60 Hz and standardized. The conductivity ratios of these samples were measured on the Autosal at the energized voltage and frequency conditions specified below.

Line Potential (VAC)	Line Frequency (Hz)	
102	60	
138	60	
120	60	Reference
120	50	
102	50	
138	50	
129	50	

Results - The algebraic maximum and minimum differences of the measured ratios from the average value at reference conditions were 0.00009 and 0.00000, respectively.

5. CONDUCTIVITY-RATIO ACCURACY, REPEATABILITY, AND STABILITY

The system was tested to determine the conductivity-ratio measurement accuracy, repeatability, and stability over the measurand range of the instrument.

Method - Eleven batches of different salt water solutions were prepared. Seven samples from each batch were extracted and bottled, thus providing

Table 2.--Autosal stability and repeatability

Day	STBY	ZERO	Average deviation*	Standard deviation x 10^{-5}	Change
1	24 + 8379	0.0 + 0002	1.99944	0.254	Ref.
2	24 + 8379	0.0 + 0002	1.99943	2.664	-0.00001
3	24 + 8378	0.0 + 0002	1.99942	0.568	-0.00002
4	24 + 8379	0.0 + 0002	1.99940	0.434	-0.00004
7	24 + 8378	0.0 + 0002	1.99944	1.192	0.00000
8	24 + 8379	0.0 + 0002	1.99941	0.498	-0.00003
9	24 + 8379	0.0 + 0002	1.99941	0.568	-0.00003
10	24 + 8379	0.0 + 0002	1.99941	0.490	-0.00003
11	24 + 8379	0.0 + 0002	1.99940	0.507	-0.00004
14	24 + 8379	0.0 + 0001	1.99949	0.460	+0.00005
15	24 + 8379	0.0 + 0002	1.99943	0.450	-0.00001
16	24 + 8379	0.0 + 0002	1.99941	0.504	-0.00003
17	24 + 8378	0.0 + 0002	1.99938	0.648	-0.00006
18	24 + 8379	0.0 + 0002	1.99938	0.320	-0.00006
22	24 + 8378	0.0 + 0002	1.99940	0.651	-0.00004
23	24 + 8377	0.0 + 0001	1.99945	0.592	+0.00001
24	24 + 8377	0.0 + 0001	1.99948	0.531	+0.00004
25	24 + 8377	0.0 + 0002	1.99949	0.827	+0.00005
28	24 + 8378	0.0 + 0001	1.99949	0.481	+0.00005
29	24 + 8378	0.0 + 0001	1.99948	0.728	+0.00004
30	24 + 8378	0.0 + 0001	1.99948	0.681	+0.00004
31	24 + 8378	0.0 + 0001	1.99944	0.504	+0.00000
32	24 + 8377	0.0 + 0001	1.99944	0.556	0.00000

*The standardization dial was set at 1.99944 for all readings.

seven identical samples of 11 different salt water solutions. The conductivity ratios of three samples from each batch were measured on the Precision Conductivity Comparator; the average ratio of the three samples from each batch was computed and these are listed below along with desired salinity using the UNESCO equation. These values were used as standard reference values for this test.

Batch No.	Conductivity Ratio (24°C)	Salinity (ppt)
1	1.136224	40.4356
2	1.063638	37.5222
3	1.001928	35.0760
4	0.936512	32.5134
5	0.872070	30.0194
6	0.739124	24.9681
7	0.602082	19.8940
8	0.462974	14.8918
9	0.319048	9.9053
10	0.168297	4.9569
11	0.016856	0.3868

The Autosal bath-temperature control was set at 24°C and the ambient temperature of the unit was controlled at 24°C. The Autosal was standardized with Copenhagen standard seawater. The remaining four samples from each batch were divided into four groups (11 samples each). The conductivity ratios of groups 1 and 2 were measured with the Autosal, where group 1 was measured in descending salinity values and group 2 was measured in ascending salinity values. Approximately one month later, the Autosal was restandardized and the conductivity ratios of groups 3 and 4 were measured using the technique described above for batches 1 and 2.

Results - On a series of 30 sensor samples as recorded at each test point, the worst-case standard deviation of conductivity ratio was ±0.0000072. The average ratio values were converted to salinity values using the UNESCO equation. These values were compared to the reference standard values listed above as obtained from the PCC and a difference was computed.

The difference (error) versus salinity for test sample groups 1 and 2 and groups 3 and 4, respectively, are shown in figures 4 and 5. The average errors of groups 1 and 2 and groups 3 and 4 versus salinity are shown in figure 6. The differences between these two errors at any salinity were within 1 ppm.

6. SAMPLE TEMPERATURE AND FILL RATE VARIATION EFFECT ON CONDUCTIVITY RATIO

The system was tested to determine the effects on the Autosal conductivity-ratio measurement of different temperatures and varying fill rates.

Method - A batch of salt water solution was prepared by mixing four ampoules of Copenhagen standard seawater; from this batch four samples were bottled for the test. The Autosal bath-temperature control was set at 24°C

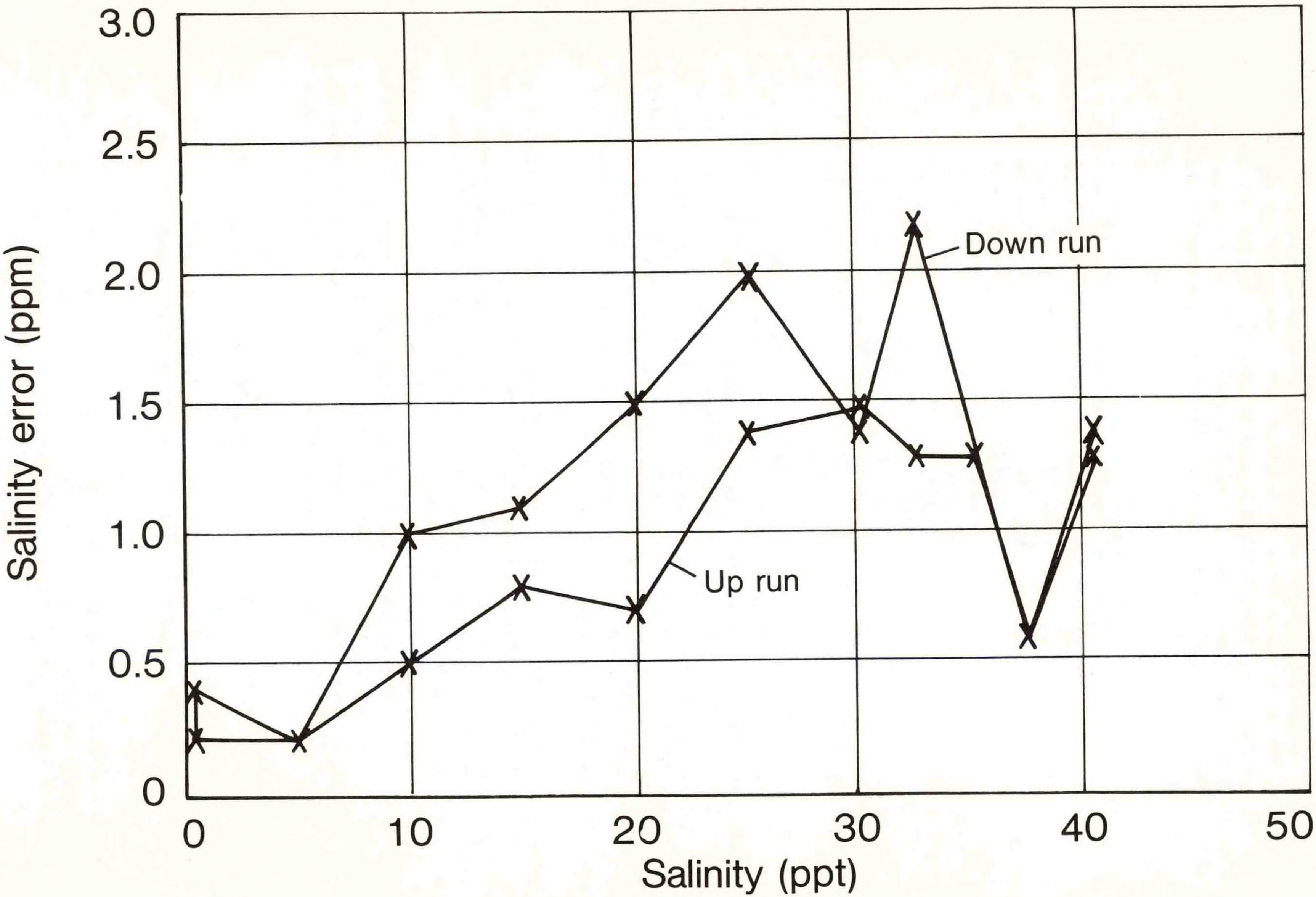

Figure 4.--Salinity versus salinity error

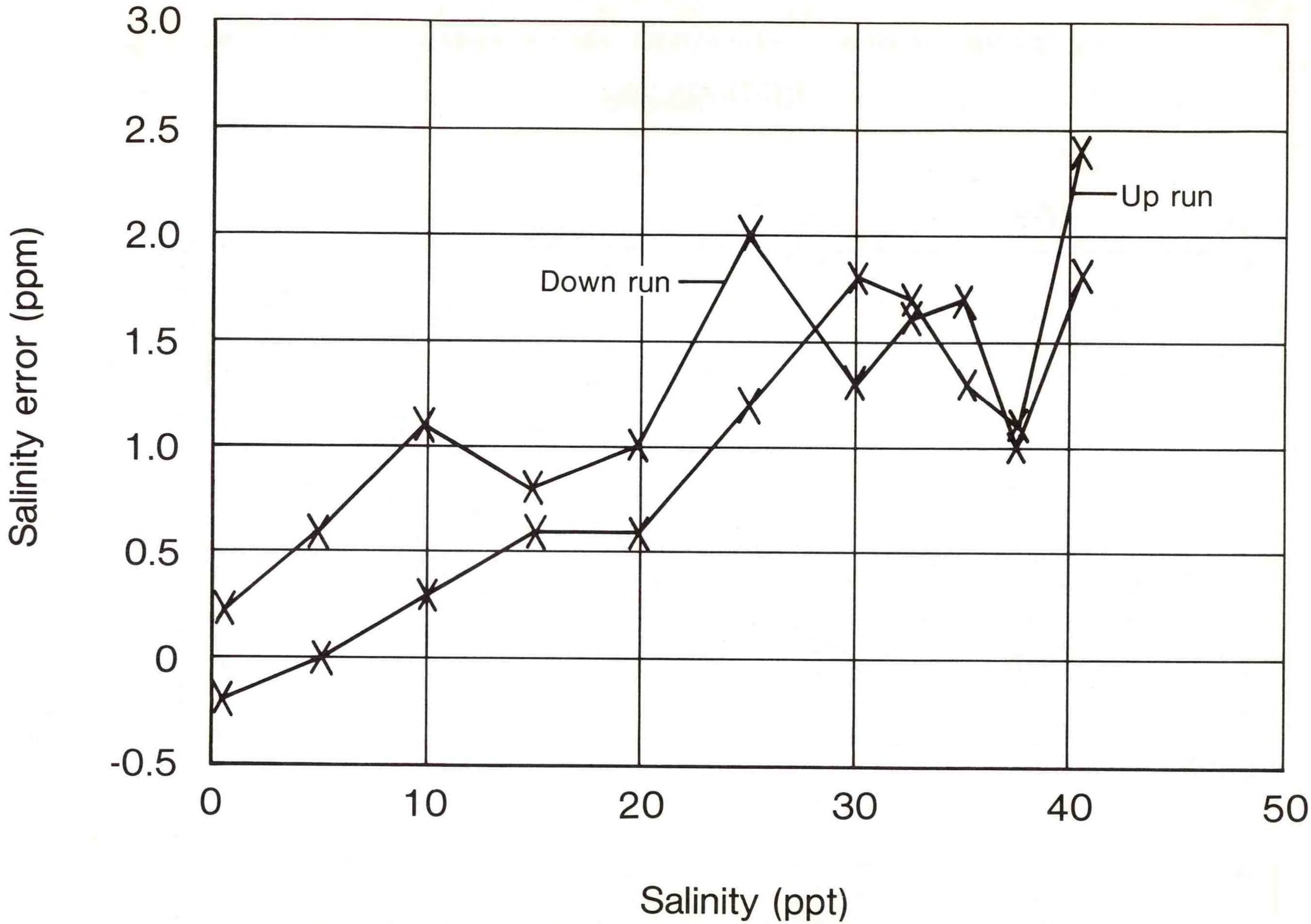

Figure 5.--Salinity versus salinity error after 32 days

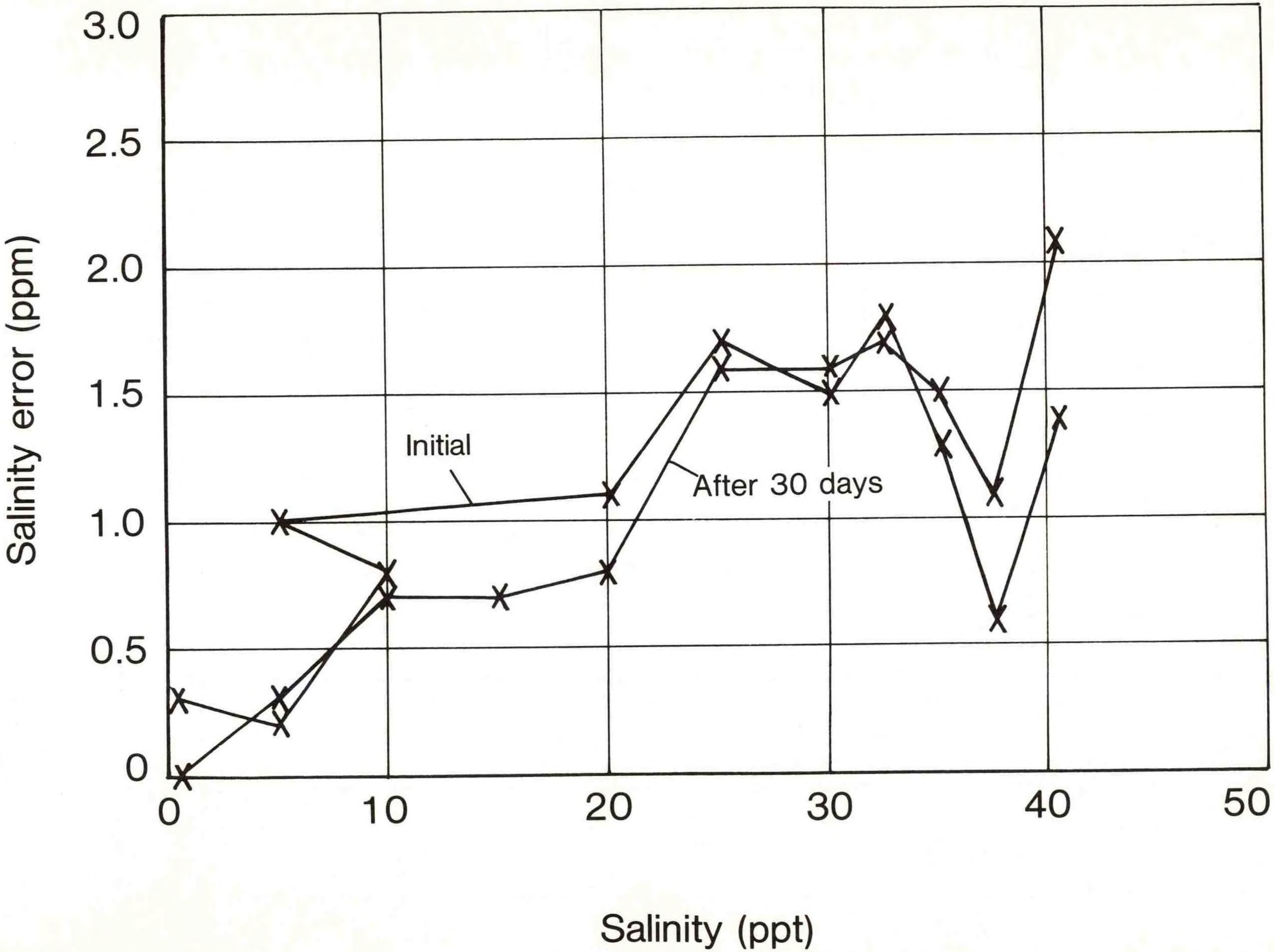

Figure 6.--Salinity versus average salinity error, initial and after 32 days

and the ambient temperature of the Autosal was controlled at 24°C. The four sample bottles were preconditioned at 18°, 24°, 27°, and 30°C. The conductivity ratios of these samples were measured at cell-fill rates of 16, 24, and 59 seconds.

Results - Ratios were converted to salinity using the UNESCO equation. The table below shows the Autosal measurements at various test-sample temperatures and cell-fill rates.

Sample Temperature (°C)	Fill Rates (seconds) 16	24	59
18	35.007 ppt	35.007 ppt	35.007 ppt
24	35.008	35.008	35.008
27	35.005	35.007	35.005
30	Out of control*	35.008	35.007

7. COMPARISON OF GUILDLINE AND UNESCO SALINITY EQUATIONS

Purpose - A comparison was made between the salinity equation developed by Dr. A. Bennett, Bedford Institute of Oceanography, Dartmouth, Nova Scotia (furnished in the Autosal manual) and the UNESCO equation.

Method - A computer was used to generate a table of differences (Bennett - UNESCO) between the 2 equations for a combination of 6 temperatures and 26 ratios.

The Bennett and UNESCO equations are shown below; a value of P equal to 0 was used in the Bennett equation for the comparison.

Bennett Equation

$$S\ [\text{ppt}] = -0.08996 + 28.8567R + 12.1888r^2 - 10.61869R^3$$
$$+5.98624R^4 - 1.32311R^5 + R(R - 1)\ \ [0.442 \times 10^{-1}\ T$$
$$-0.46 \times 10^{-3}\ T^{-2} - 4 \times 10^{-3}\ RT + (1.25 \times 10^{-4} - 2.9 \times 10^{-6}\ T)P]$$

where R = Conductivity ratio measured at temperature T

T = temperature (°C)

P = pressure (dbar)

*A stable measurement could not be obtained at this temperature and fill rate because the bath temperature was out of control.

UNESCO Equation

$$\Delta 15^{(t)} = R_{15} - R_t = 10^{-5} R_t (R_t - 1) (t - 15) [96.7 - 72R_t + 37.3R_t^2$$

$$(0.63 + 0.21 R_t^2) (t - 15)]$$

$$S\ [\text{ppt}] = -0.8996 + 28.2972 R_{15} + 12.80832R_{15}^2 - 10.67869R_{15}^3$$

$$+ 5.98624R_{15}^4 - 1.32311R_{15}^5$$

where Δ_{15} = correction factor to bring ratio at t°C to ratio at 15°C

R_{15} = conductivity @ 15°C

R = conductivity ratio measured at temperature t

t = temperature (°C)

Results - The difference in computed salinity (Bennett - UNESCO) in parts per million at the various ratio and temperature combinations is shown in table 3.

GENERAL COMMENTS

A number of problems were encountered during the test and evaluation of the Autosal. These are discussed below along with some general observations.

1. The wiring diagram for the BCD output for the 10^2 digit was in error. The 2 and 4 lines for this BCD digit were shown going to data log connector pins 26 and 25, respectively. The reverse is correct.

2. A ZERO reference shift of 149 counts occurred when the data log output was connected to a Hewlett Packard 5050B digital printer. This occurred because the Autosal data log bottle grounds (pins 29 and 30) were connected to the power ground (pin 50) and to the low level reference input (pin 24) of the printer. Evidently, connecting pins 29 and 30 of the data log plug to pin 50 of the printer created a ground loop. This problem was remedied by connecting pins 29 and 30 only to pin 24 and connecting pin 50 to the Autosal power ground at the power cord.

3. A wiring discrepancy was noted in the heater control circuit. In accordance with the wiring diagram supplied, the signal return from the thermistors should have been directly connected to pin 24 (ground) of the power supply board; instead, it was connected to a ground on a terminal block located on the top of the bath. This connection was removed and the signal return of the thermistors was wired directly to pin 24 of the power supply.

4. The drive belt of the stirrer broke four times during the course of the evaluation (six months). In each case, the condition was noted by the failure of the heater lamps to cycle.

Table 3.--Difference in computed salinity (ppm) at various ratio and temperature combinations (°C)

Ratio	18°	21°	24°	27°	30°	33°
0.05	-0.3	-0.3	-0.1	0.3	1.0	1.9
0.10	-0.5	-0.5	-0.1	0.7	2.0	3.7
0.15	-0.7	-0.7	-0.2	1.0	2.7	5.0
0.20	-0.8	-1.0	-0.3	1.0	3.1	5.9
0.25	-1.1	-1.3	-0.7	0.8	3.0	6.1
0.30	-1.3	-1.7	-1.1	0.3	2.7	5.9
0.35	-1.5	-2.1	-1.7	-0.3	2.0	5.3
0.40	-1.7	-2.5	-2.3	-1.1	1.2	4.4
0.45	-1.9	-2.9	-2.8	-1.8	0.2	3.3
0.50	-2.1	-3.2	-3.3	-2.5	-0.7	2.1
0.55	-2.2	-3.4	-3.7	-3.0	-1.5	1.1
0.60	-2.2	-3.4	-3.9	-3.4	-2.0	0.2
0.65	-2.1	-3.4	-3.8	-3.5	-2.4	-0.5
0.70	-1.9	-3.1	-3.6	-3.4	-2.5	-0.9
0.75	-1.7	-2.8	-3.2	-3.1	-2.3	-1.0
0.80	-1.4	-2.3	-2.7	-2.6	-2.0	-0.9
0.85	-1.0	-1.7	-2.0	-1.9	-1.4	-0.6
0.90	-0.7	-1.1	-1.2	-1.2	-0.8	-0.2
0.95	-0.3	-0.5	-0.6	-0.5	-0.3	0.0
1.00	0.0	0.0	0.0	0.0	0.0	0.0
1.05	0.2	0.3	0.2	0.1	-0.2	-0.5
1.10	0.2	0.2	0.0	-0.4	-1.0	-1.8
1.15	0.0	-0.2	-0.8	-1.6	-2.8	-4.2

5. At one point in the evaluation, the conductivity cell could not be properly filled with a test solution. This was attributed to drying out of the leather piston in the fill pressure pumps. A few drops of lightweight oil applied to the leather restored the pump to normal operation. The purge pump was also inspected and found to be in the same condition; it was repaired in a like manner.

6. Discussion with other Autosal users has indicated that they were experiencing algae growth in the temperature bath which was obstructing the view of the cell through the bath window. This problem was not experienced at NOIC where the same bath, filled with de-ionized water, was used through the evaluation.

7. The manufacturer recommends that fresh water be stored in the conductivity cell when not in use. However, at NOIC, it was noted that approximately 10 flushes were required to obtain a stable conductivity ratio measurement after storage of de-ionized water in the cell. It is now recommended by the manufacturer that water be forced out of the heat exchanger by replacing the sample bottle with a small empty test tube and activating the pumps.

SUMMARY

The results of the tests performed on the Autosal indicate that the instrument will provide conductivity ratio measurements of seawater solutions with accuracies of ±3 ppm in equivalent salinity units as advertised. If specified operating conditions are observed, effects on the instrument performance due to variations in ambient temperature and power voltage and frequency are negligible.

(Continued from inside front cover)

NOS 16 Deep Sea Tide and Current Observations in the Gulf of Alaska and Northeast Pacific. Carl A. Pearson, December 1975.

NOS 17 Deep Sea Tide Observations Off the Southeastern United States. Carl A. Pearson, December 1975.