20 September 1938

NRL Report No. B-1477

FR-1477

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report of

Test on Salinity Indicator Equipment

Submitted by

Control Instrument Company
Brooklyn,N.Y.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
Washington, D.C.

Number of Pages: Text - 5 Tables - 3 Plates - 9

Authorization: BuEng.let. S65-5/L5(1-24-Ds) of 2 February 1938.

Date of Test: July and August 1938.

Tested by: G.K.C. Hardesty
G.K.C. Hardesty, Sr. Engineering Aide.

Prepared by: W.B. Roberts
W.B. Roberts, Pr.Eng.Aide, Chief of Section

Reviewed by: R.A. Gano, Lieutenant, USN.

Approved: H.M. Cooley, Captain, USN, Director.

Distribution:
BuEngr. (5)

vhw

TABLE OF CONTENTS

APPENDICES

AUTHORIZATION

1. This test was authorized by reference (a), and other references pertinent to this problem are listed as references (b) and (c).

Reference: (a) BuEng.let. S65-5/L5(1-24-Ds) of 2 February 1938.
(b) Specifications 17-I-19(INT) Indicating Equipment, Salinity, of 15 February 1938.
(c) Control Instrument Company's drawing of indicator assembly, File No. 50, of 8/11/38.

OBJECT OF TEST

2. The object of this test was to determine how closely the salinity indicator complied with the specifications, reference (b), and its suitability for the Naval Service.

ABSTRACT OF TEST

3. The subject system, shown by Plates 1 to 3 inclusive, was set up at this Laboratory in suitable test circuits and carefully checked for conformance with the specifications, reference (b); all tests being made in the order specified. The test was concluded with the usual inspection of the equipment to ascertain whether it complied with the requirements in the matter of materials, design and workmanship.

Conclusions

(a) The subject salinity indicator equipment, manufactured by Control Instrument Company, Brooklyn, New York, and submitted for tests to determine its conformance with the specifications, reference (b), and its suitability for Naval use, complies except for the following:

(1) The meter scale is of white meter card instead of white enamel.

(2) No valve or packing gland assembly accompanied the cell.

(3) No nameplate or table of cell locations were furnished.

(4) A test resistor for clamping across the electrodes of a cell has not been provided.

(5) The electrodes are not supported by a molded insulator. Instead, the insulator is of stock, fabric inserted, phenolic material.

(b) An inspection of the equipment for compliance with the specifications, in the matter of materials, design and workmanship, disclosed the following:

(1) The blown fuse indicator lamps and sockets are not standard Navy equipment.

(2) The indexing feature of the compensator switch is not sufficiently positive.

(3) All line connections are made to terminal blocks mounted on the hinged panel instead of the stationary part of the case. The terminals are not properly identified.

(4) The acorn nuts securing the panel to the case do not permit free access to the equipment.

(c) It is noted that the manufacturer's drawing, reference (c), shows modifications correcting these deficiencies.

(d) As the cell furnished had an unknown constant, resistance values from the specification curves could not be used for conducting the initial accuracy test. A comparison of these curves with those furnished by the manufacturer indicated a cell constant of approximately 0.08. Resistance values taken from the manufacturer's curves were used for checking the accuracy of the indicator before any other tests and following the ruggedness test. Finally, the accuracy of the entire system was checked by immersing the cell in sea water solutions of known concentrations at several temperatures between 60°F. and 200°F. The overall accuracy was found to be within the ± 2-1/2 percent, full scale, linear distance, allowed by the specifications.

Recommendations

(a) It is recommended that this salinity indicator equipment be approved, subject to modifications to correct the deficiencies outlined under "Conclusions", providing the construction of the cell is acceptable to the Bureau.

DESCRIPTION OF MATERIAL UNDER TEST

4. The equipment submitted consists of one indicator unit and one conductivity cell and is shown by Plates 1 to 3 inclusive. It operates from a supply of 115 volts, A.C., 60 cycles, its purpose being to indicate the saline contents of the boiler feed and other water lines.

5. The indicator unit weighs 44 pounds, is 11-1/2" x 13" x 22" overall, and consists of the following parts:

(a) An indicating meter, its dial graduated to read the salt content in grains of sea salt per gallon.

(b) A transformer, ratio 115/115-15, for insulating the indicator circuits from the circuits of the ship.

(c) A rotary Navy Type J selector switch for connecting any one of seven (7) conductivity cells to the indicator.

(d) A temperature compensator rotary selector switch, having a dial graduated from 60°F. to 200°F., in steps of 5.0°F., to be set to the temperature of the water under test.

(e) A checking resistor for testing the operation of the system with compensator set at 110°F.

(f) A push button for checking the indicator when the compensator is set at 110°F.

(g) A pair of fuses, each shunted with a neon lamp which glows when a fuse is blown.

(h) A pilot light, equipped with a blue glass lens and a CS-5 lamp, for indicating when the secondary circuit of the supply transformer is energized.

6. All of these parts are mounted on a hinged aluminum panel of a steel case of drip-proof construction finished in grey. Flexible lead wires, flame resistant, connect the units to terminal blocks located in the back of the cover.

7. Four shock absorbing units, located in the back of the case, are provided for mounting the indicator unit on a bulkhead.

8. The indicator dial is divided into three sections, the markings and graduations being as follows:

Dial Reading	Indications
0 to 0.5 grain	White
0.5 to 1.0 grain	Green
1.0 to 10.0 grains	Red

CONDUCTIVITY CELL

9. The conductivity cell, shown by Plate 3, is designed for installation in the boiler feed line, or others as desired, and is electrically

connected to the indicator unit from which salinity indications may be read in "Grains of Sea Salt Per Gallon". The cell consists of two platinum sheathed electrodes in a phenolic insulator housed in a cylindrical brass tube. The electrodes are protected from injury by a cylindrical guard. The cell is not equipped with the usual valve and stuffing gland.

OPERATION OF SYSTEM

10. When a cell circuit is closed, the deflecting coil in the meter, being connected in series, moves a pointer across a graduated dial; the displacement of the coil and pointer with respect to the fixed coil being proportional to the current flowing in the cell circuit. The meter, used as an indicator, self-compensates for variations in the voltage and frequency, and the ambient temperature.

METHOD OF TEST

11. The indicator was first tested for accuracy by substituting resistors of suitable values taken from temperature resistance curves for salinity solutions, Plate 5. The readings were taken at every compensator position. It was checked for accuracy at 105 volts at 65 cycles and 125 volts at 55 cycles.

12. An endurance test was next conducted by successively connecting the correct values of resistance in a cell circuit causing the pointer to indicate 0.1, 0.5, 1.0, 2.0 and 5.0 grains of sea salt per gallon. This change occurred at the rate of ten (10) readings per minute, and was continued for fifty hours.

13. The endurance test was then interrupted for the purpose of conducting the shock and vibration tests. The shock test consisted of 20 blows of 250 foot pounds each while the indicator was mounted on a Bureau of Engineering shock stand and operating as under endurance. Under vibration, the indicator was placed on a vibrating machine and subjected to shocks of 3 foot pounds at frequencies of 100, 150, 200, 250, 300, and 350 vibrations per minute for periods of 30 minutes each. During this test, the indicator was operating as under endurance.

14. Following the shock and vibration tests, the indicator was again checked for accuracy, as outlined under paragraph 11. The remainder of the 500 hour test then followed.

15. Next followed a test for accuracy conducted by immersing the manufacturer's cell in sea water solutions of 0.5, 1.0, 2.0, 5.0 and 10 grains per gallon, at temperatures ranging from 60°F. to 200°F.

16. The conductivity cell was subjected to a hydrostatic pressure of 150 pounds per square inch for a period of one hour. The temperature of the water was held at 150°F.

17. The electrode assembly was immersed in a paraffin bath at 284°F. for 1 hour, after which it was removed and inspected.

18. The insulation resistance and dielectric strength tests, and an inspection of the material to ascertain whether it was in conformance with the specifications, concluded the test.

RESULTS OF TEST

19. The test results which follow were obtained when the equipment was tested in the order required by the specifications.

Requirements	Test Values
Accuracy: Error shall not exceed 2-1/2 percent of full scale linear distance at any time during the test.	Complied; see Tables 1 and 2, and Plates 6, 6a, 7, 7a, 8, 8a, 9, and 9a.
Endurance: The indicator shall be operated continuously for 500 hours at rated voltage and frequency (115 V., 60 cycles) except for an interruption after the first 50 hours for conducting the shock, vibration, and accuracy tests.	Complied.
Shock integrity: Shall withstand 20 shocks of 250 foot pounds each while the indicator is mounted on a Bureau of Engineering shock stand and operating as under the endurance test.	Complied.
Vibration integrity: The indicator shall withstand shocks of 3 foot pounds at frequencies of 100, 150, 200, 250, 300 and 350 vibrations per minute for periods of 30 minutes each while operating as under the endurance test.	Complied.
Hydrostatic test: The cell assembly shall withstand a pressure of 150 pounds per square inch for a period of 1 hour with a water temperature of 150°F.	Complied. (Only the electrode assembly tested.)
Paraffin bath test: The electric assembly shall be immersed in a 284°F. paraffin bath for 1 hour without physical changes.	Complied.
Operation at over and under voltage and frequency: Shall cause no error when operating at 105 V., 65 cycles or 125 V., 55 cycles.	Complied.
Indicator pointer: The pointer shall return to zero with system energized and selector switch in the off position.	The pointer fails to return to zero by an amount varying with the position of the compensator dial (1/8" max.).
Dielectric strength: Shall withstand 1500 volts, A.C., 60 cycles, applied between live parts and ground for 1 min.	Complied.
Insulation resistance: Shall be not less than 10 megohms at 500 volts.	Complied.

CONCLUSIONS

20. The subject salinity indicator equipment, manufactured by Control Instrument Company, Brooklyn, New York, and submitted for tests to determine its conformance with the specifications, reference (b), and its suitability for Naval use, complies except for the following:

(a) The meter scale is of white meter card instead of white enamel.
(b) No valve or packing gland assembly accompanied the cell.
(c) No nameplate or table of cell locations were furnished.
(d) A test resistor for clamping across the electrodes of a cell has not been provided.
(e) The electrodes are not supported by a molded insulator. Instead, the insulator is of stock, fabric inserted, phenolic material.

21. An inspection of the equipment for compliance with the specifications, in the matter of materials, design and workmanship, disclosed the following:

(a) The blown fuse indicator lamps and sockets are not standard Navy equipment.
(b) The indexing feature of the compensator switch is not sufficiently positive.
(c) All line connections are made to terminal blocks mounted on the hinged panel instead of the stationary part of the case. The terminals are not properly identified.
(d) The acorn nuts securing the panel to the case do not permit free access to the equipment.

22. It is noted that the manufacturer's drawing, reference (c), shows modifications correcting these deficiencies.

23. As the cell furnished had an unknown constant, resistance values from the specification curves could not be used for conducting the initial accuracy test. A comparison of these curves with those furnished by the manufacturer, indicated a cell constant of approximately 0.08. Resistance values taken from the manufacturer's curves were used for checking the accuracy of the indicator before any other tests and following the ruggedness test. Finally, the accuracy of the entire system was checked by immersing the cell in sea water solutions of known concentrations at several temperatures between 60°F. and 200°F. The overall accuracy was found to be within the ± 2-1/2 percent, full scale, linear distance, allowed by the specifications.

Table 1

Initial Accuracy Test at 115 Volts, A. C. 60 Cycles

Temp.(°F) for values of resistances taken from mfr's curves	Compensator Setting °F	% error 0.1 gr/gal	% error 0.3 gr/gal	% error 0.5 gr/gal	% error 1.0 gr/gal	% error 2.0 gr/gal	% error 5.0 gr/gal
62.5	60	+1.6	-.2	-1.0	+1.4	+1.3	+.5
62.5	65	+.7	-1.5	-2.8	-.9	+.3	0
67.5	65	+1.2	+.8	+2.4	+1.2	+1.3	+.5
67.5	70	+.7	0	+1.6	0	+.9	0
72.5	70	+1.2	+.2	0	+1.4	+1.5	+.6
72.5	75	+.2	-.5	-2.0	-.8	+.2	0
77.5	75	+1.0	0	-.2	+.9	+1.1	+.7
77.5	80	+.7	-.6	-1.0	0	+.7	+.4
82.5	80	+1.3	+1.0	+.7	+1.8	+1.5	+.4
82.5	85	0	-1.2	-1.8	-.9	0	-.3
87.5	85	+.2	-.2	+.5	+1.0	+.3	+.6
87.5	90	-1.1	-2.0	-1.1	0	-.1	0
92.5	90	+.2	0	0	+.5	+1.0	0
92.5	95	-.6	-1.2	-1.1	-.5	+.4	-.2
97.5	95	+.7	+1.0	+.5	+.9	+1.0	+1.1
97.5	100	+.2	0	-.7	0	-.4	+.9
102.5	100	+.7	+1.5	+1.0	+1.4	+1.3	+.4
102.5	105	-.2	-.4	-1.0	-.7	0	-.2
107.5	105	+.2	+.5	+.4	+.7	+.8	+.2
107.5	110	-.2	-.4	-.9	-.5	0	-.2
112.5	110	+.5	0	+.6	+.6	+.8	+.4
112.5	115	-.2	-1.2	-1.2	-1.0	-.4	0
117.5	115	+.5	-.2	-.4	+.5	+.8	+.2
117.5	120	-.2	-1.4	-2.0	-1.0	-.2	-.2
122.5	120	+.2	+.5	0	+.8	-.5	+.2
122.5	125	-.2	-.5	-.2	-.4	+.2	-.2
127.5	125	+.3	0	+.7	+1.0	+.7	+.2
127.5	130	0	-.6	-.3	+.2	0	0
132.5	130	0	+.2	+.8	+1.0	+1.0	-.4
132.5	135	-.6	-.9	-.8	-.4	0	0
137.5	135	+.8	+.3	+1.0	+1.0	+1.0	+.4
137.5	140	+.3	-.5	0	0	+.3	0
142.5	140	+.5	+.4	+1.0	+1.2	+1.0	+.3
142.5	145	-.3	-1.0	-1.0	-.8	+.2	-.1
147.5	145	+.4	-.2	+.6	+.7	+.3	0
147.5	150	-.3	-1.4	-1.2	-1.0	-.7	-.4
152.5	150	+.4	-.5	0	+.3	-.7	-.3
152.5	155	0	-1.4	-1.1	-.8	-1.3	-.7
157.5	155	+.4	-.4	+.2	+.7	+.5	-.4
157.5	160	0	-1.0	-.5	0	+.9	-.7
162.5	160	+.8	+.3	+1.0	+1.5	0	-.2
162.5	165	-.2	-1.0	-1.0	-.3	-1.0	-.8
167.5	165	+.2	-.5	0	+.8	-.6	-.7
167.5	170	-.4	-1.5	-1.4	-.4	-1.2	-1.0

Table 1 (cont'd)

Temp.(°F) for values of resistance taken from mfr's curves	Compensator Setting °F	% error 0.1 gr/gal	% error 0.3 gr/gal	% error 0.5 gr/gal	% error 1.0 gr/gal	% error 2.0 gr/gal	% error 5.0 gr/gal
172.5	170	+.3	-.8	-.4	+.7	-1.0	-.8
172.5	175	0	-1.6	-1.5	-.5	-1.8	-1.1
177.5	175	+.3	-.7	0	+.3	-.8	-1.0
177.5	180	0	-1.3	-1.0	-.6	-1.2	-1.2
182.5	180	+.5	-.4	0	+.5	-.9	-1.0
182.5	185	+.2	-1.0	-.8	-.1	-1.3	-1.2
187.5	185	+.4	-.5	+.1	+1.0	-.7	-.7
187.5	190	0	-1.2	-1.0	0	-1.2	-1.1
192.5	190	+.4	-.7	+.4	+.9	-.8	-1.0
192.5	195	0	-1.7	-1.0	-.4	-1.3	-1.2
197.5	195	+.4	-.8	0	+.4	-.7	-1.0
197.5	200	-.3	-2.0	-.6	-1.0	-1.6	-1.3
202.5	200	+.2	-1.0	-.6	0	-1.0	-1.1
202.5	205	0	-1.5	-1.0	-.5	-1.3	-1.2

Table 2

Accuracy Test at 115 Volts, A.C., 60 Cycles
Following Shock and Vibration Tests

Temp.(°F) for values of resistance taken from mfr's curves	Compensator Setting °F	% error 0.1 gr/gal	% error 0.3 gr/gal	% error 0.5 gr/gal	% error 1.0 gr/gal	% error 2.0 gr/gal	% error 5.0 gr/gal
62.5	60	+1.0	+.4	-.2	+1.6	+2.0	+1.0
62.5	65	+ .3	-1.2	-2.2	-.4	+.8	+.5
67.5	65	+1.0	-.5	0	+1.5	+2.0	+1.0
67.5	70	+.5	-1.5	-1.5	+.2	+1.0	+.5
72.5	70	+1.2	+.7	+.6	+2.0	+2.0	+1.0
72.5	75	0	-1.0	-1.9	-.2	+.5	+.3
77.5	75	+1.0	+.2	0	+1.5	+1.5	+.9
77.5	80	+.5	-.4	-1.0	+.8	+1.0	+.5
82.5	80	+1.2	+1.2	+1.0	+2.0	+2.0	+1.0
82.5	85	0	-1.0	-1.6	-.4	+.3	+.2
87.5	85	+.5	+.2	-.2	+1.0	+1.4	+.8
87.5	90	-.5	-1.3	-1.9	-.9	+.3	+.1
92.5	90	+.5	0	0	+.8	+1.1	+.5
92.5	95	0	-.6	+1.0	-.2	+.7	+.2
97.5	95	+.5	+.8	+.6	-1.0	+1.3	+.7
97.5	100	0	-.2	-.5	+.2	+.6	+.4
102.5	100	+.5	+1.0	+1	+1.5	+1.6	+.8
102.5	105	-.5	-.7	-1.1	-.7	+.3	+.2
107.5	105	+.3	+.4	+.2	+1	+1	+.6
107.5	110	-.2	-.6	-1.0	0	+.2	+.2
112.5	110	+.5	+.6	+.7	+1	+1	+.8
112.5	115	-.5	-.8	-1.2	-1.6	-.2	+.2
117.5	115	+.3	+.3	+.2	+1	+.9	+.5
117.5	120	-.7	-1.0	-1.4	-.5	-.2	0
122.5	120	0	0	0	+1	+.5	+.5
122.5	125	-.7	-.8	-1.1	0	-.3	0
127.5	125	+.5	+.2	+.4	+1.0	+.5	+.5
127.5	130	0	-.5	-1.5	-.3	0	+.2
132.5	130	+.5	+.8	+1	+1.5	+.8	+.5
132.5	135	0	-.5	-.5	0	-.2	0
137.5	135	+.5	+.5	+1	+1.0	+.6	+.5
137.5	140	0	-.4	-.2	0	0	0
142.5	140	+.5	+.8	+1.1	+1.5	+.6	+.4
142.5	145	-.5	-.8	-.8	-.2	-.5	-.1
147.5	145	0	0	+.5	+1.0	0	+.2
147.5	150	-.8	-1.1	-1.3	-.8	-1.0	-.2
152.5	150	0	-.3	0	+.5	-.3	0
152.5	155	-.5	+1.1	-1.1	-.6	-1.0	-.3
157.5	155	0	-.3	+.2	+.5	-.2	0
157.5	160	-.5	-.6	-.4	0	-.7	-.3

Table 2 (cont'd)

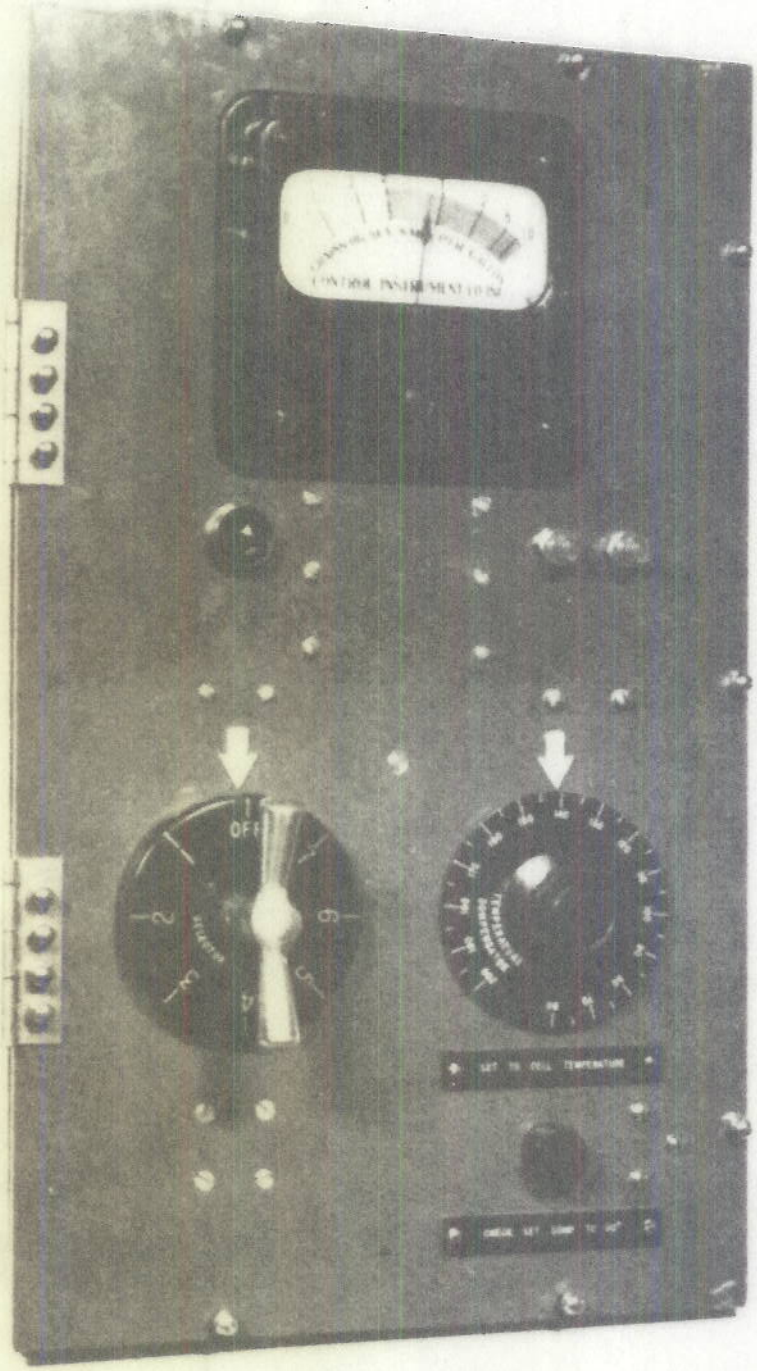
Temp. (°F) for values of resistance taken from mfr's curves	Compensator Setting °F	% error 0.1 gr/gal	% error 0.3 gr/gal	% error 0.5 gr/gal	% error 1.0 gr/gal	% error 2.0 gr/gal	% error 5.0 gr/gal
162.5	160	0	0	+.6	+1.0	0	0
162.5	165	-.8	-1.2	-1.2	-.5	-1.0	-.4
167.5	165	0	-.4	+.2	+.8	-.2	0
167.5	170	-.8	-1.4	-1.2	-.5	-.9	-.5
172.5	170	0	-.6	-.3	+.5	-.7	-.2
172.5	175	-.6	-1.4	-1.3	-.5	-1.2	-.7
177.5	175	0	-.5	0	+.1	-.5	-.3
177.5	180	-.5	-1.2	-1	-.8	-1.0	-.7
182.5	180	0	-.4	0	+.4	-.7	-.3
182.5	185	-.5	-1.0	-.8	-.3	-1.0	-.5
187.5	185	+.2	-.2	0	+.9	-.5	-.2
187.5	190	-.2	-1.0	-1.0	0	-1.0	-.6
192.5	190	+.2	-.4	+.3	+.8	-.5	-.4
192.5	195	-.2	-1.3	-1.0	-.5	-1.1	-1.0
197.5	195	+.2	-.5	0	+.2	-.7	-.4
197.5	200	-.6	-1.7	-1.5	-1.1	-1.4	-1.0
202.5	200	-.4	-1.0	-.6	0	-1.0	-.7
202.5	205	-.8	-1.4	-1.0	-.5	-1.3	-1.0

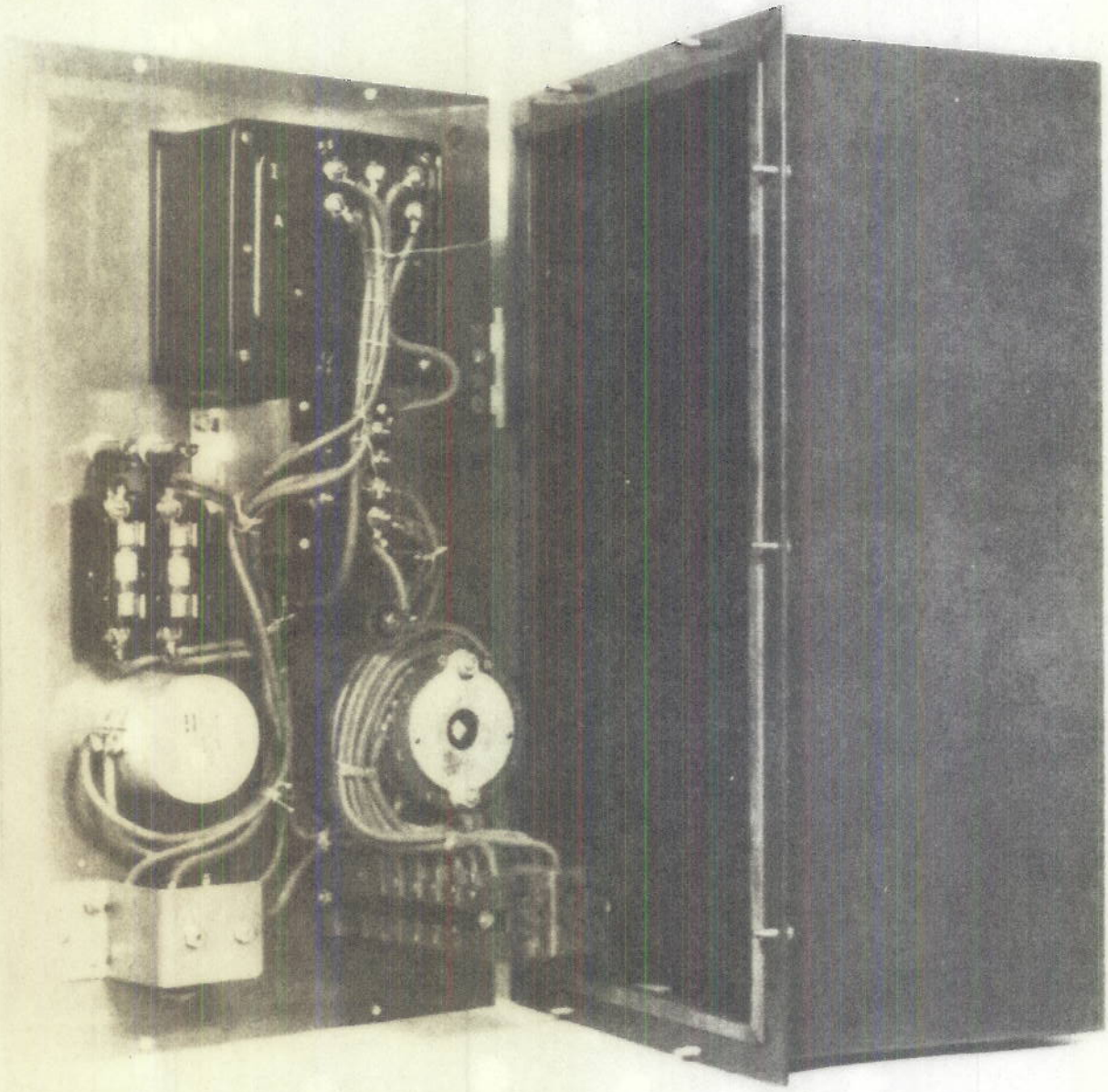
Table 3

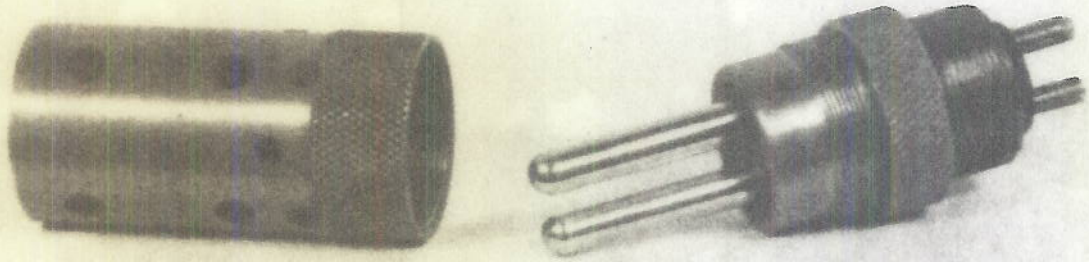
Table of Resistance of Solutions in Ohms

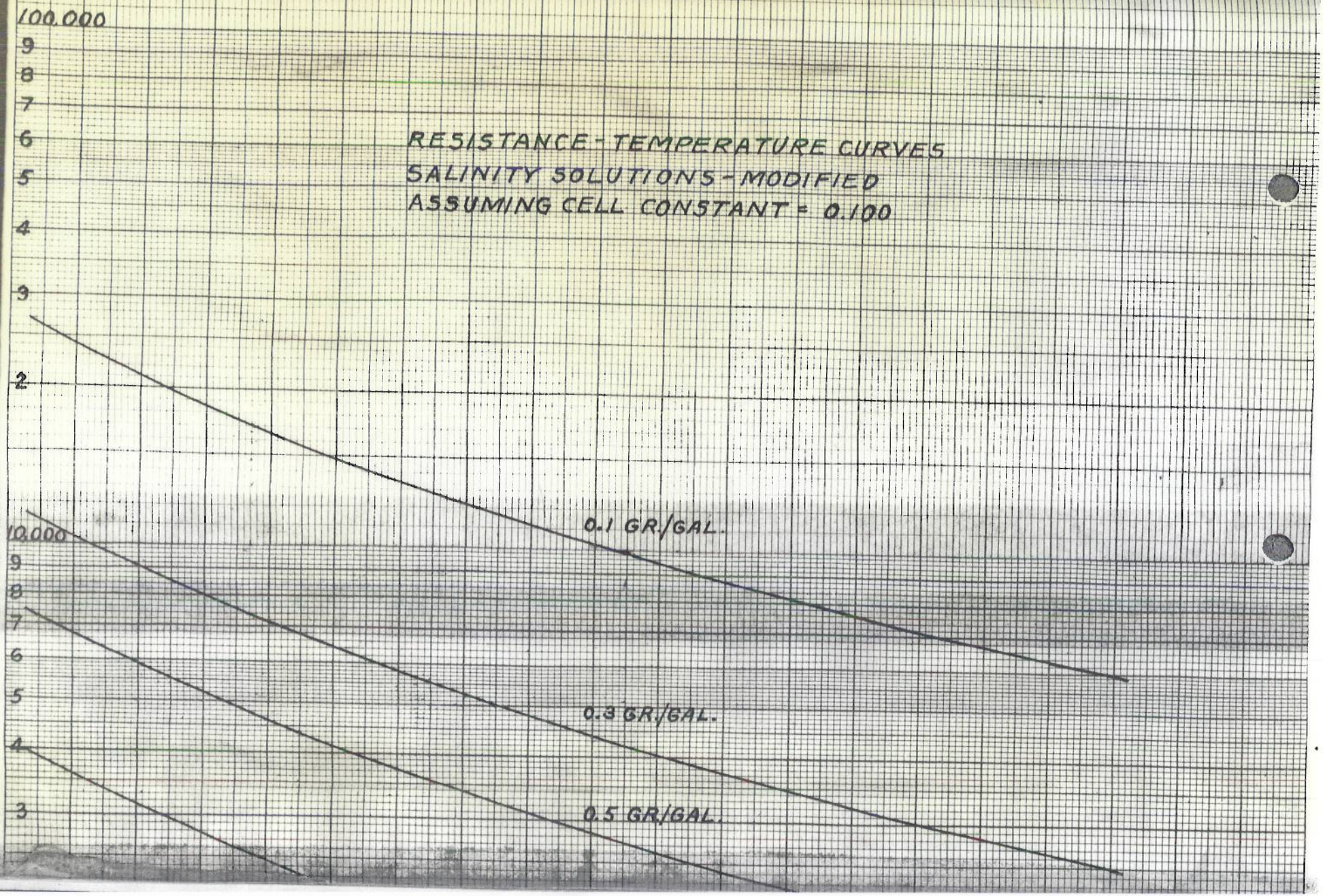
(Furnished by Control Instrument Company)

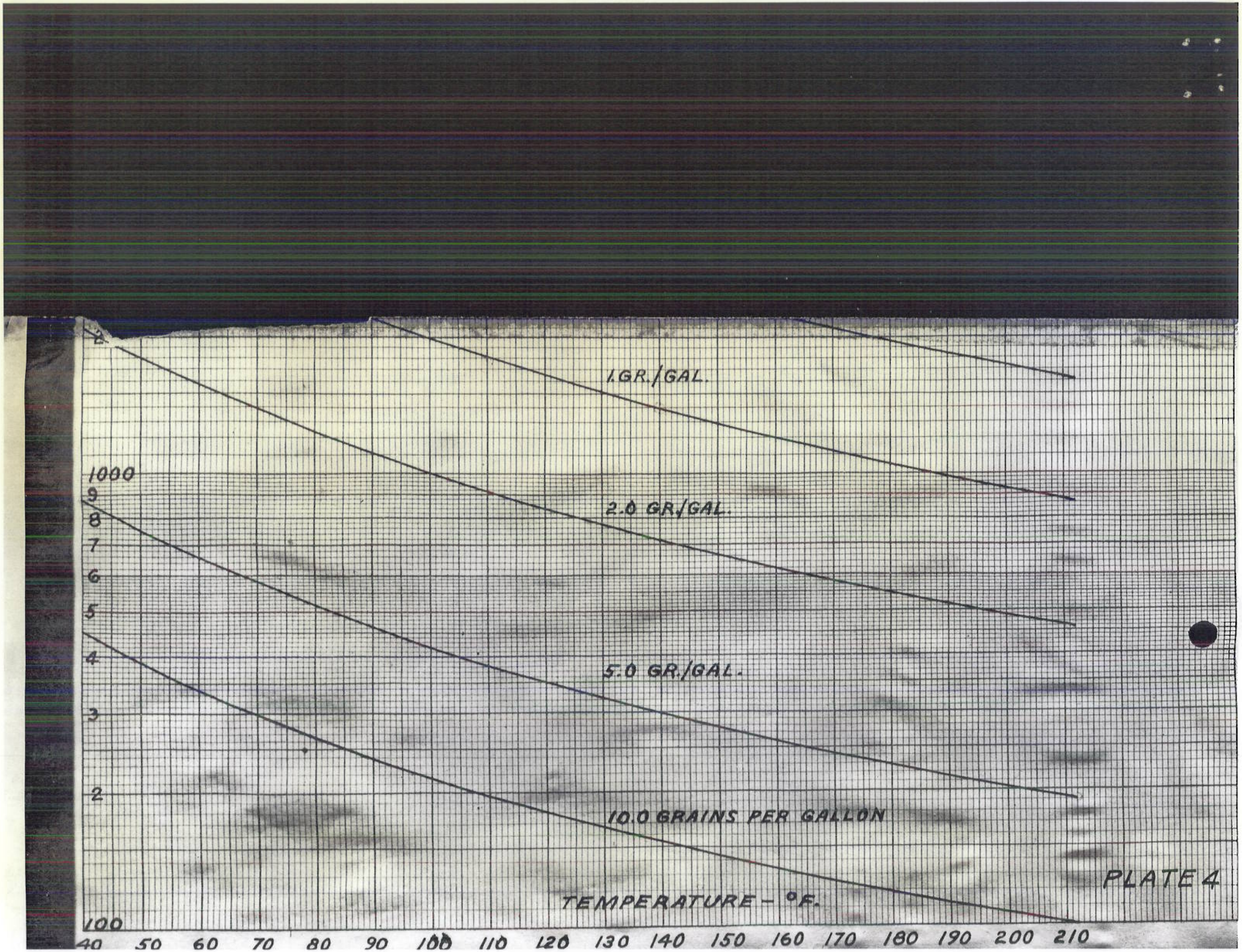
Solution Temp. °F	0.1 gr/gal	0.3 gr/gal	0.5 gr/gal	1.0 gr/gal	2.0 gr/gal	5.0 gr/gal
62.5	17500	7700	5150	2530	1210	500
67.5	16400	7120	4700	2350	1135	470
72.5	15300	6640	4400	2200	1070	445
77.5	14300	6200	4125	2060	1015	420
82.5	13600	5800	3850	1950	960	400
87.5	12900	5500	3625	1850	905	375
92.5	12100	5160	3400	1750	858	360
97.5	11600	4870	3225	1660	820	340
102.5	11000	4600	3050	1575	780	322
107.5	10500	4380	2900	1490	750	308
112.5	9950	4150	2750	1425	720	290
117.5	9400	3950	2625	1350	682	280
122.5	9000	3770	2500	1275	658	268
127.5	8550	3610	2375	1225	630	258
132.5	8200	3430	2250	1175	605	248
137.5	7800	3280	2150	1125	580	239
142.5	7500	3120	2050	1075	560	230
147.5	7170	3000	1975	1025	540	221
152.5	6850	2890	1890	980	520	212
157.5	6600	2780	1800	940	500	207
162.5	6360	2680	1740	900	480	198
167.5	6050	2580	1675	860	460	193
172.5	5820	2490	1625	830	450	188
177.5	5560	2390	1550	810	430	183
182.5	5400	2300	1500	780	420	177
187.5	5200	2230	1460	750	408	172
192.5	5050	2180	1400	730	394	168
197.5	4870	2100	1360	710	380	162
202.5	4700	2020	1320	682	370	158


OFF






100.000
9
8
7
6
5
4
3
2
10.000
9
8
7
6
5
4
3
RESISTANCE - TEMPERATURE CURVES
SALINITY SOLUTIONS - MODIFIED
ASSUMING CELL CONSTANT = 0.100
0.1 GR/GAL.
0.3 GR/GAL.
0.5 GR/GAL.


1.GR./GAL.
2.0 GR/GAL.
5.0 GR./GAL.
10.0 GRAINS PER GALLON
TEMPERATURE – °F.
PLATE 4
1000
9
8
7
6
5
4
3
2
100
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210