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NAVY DEPARTMENT
BUREAU OF ENGINEERING

Report of
Test on Salinity Indicator Equipment

Submitted by
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Brooklyn, New York

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WASHINGTON, D.C.

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Conclusions

(a) The subject salinity indicator system complies with the specifications, reference (b), except for the following deficiencies:

- (1) The dial should read "Grains of Sea Salt per Gallon" instead of "Grains of Chlorine per Gallon". In addition, the specifications require a white enamel background for the dial. The one furnished is of the usual paper meter card type, having black graduations on a white background.
- (2) The projecting hinge screws will eventually cut into the lead wires.
- (3) The self-indexing feature of the temperature compensating switch is not positive. The ball-faced contact has the tendency to rest between the switch contacts.
- (4) Replacement of the pilot lamp is very difficult.
- (5) Soldering lugs are provided on the transformer instead of the required terminal strip for Navy standard wire terminals.
- (6) The value in the furnished checking resistor corresponds to a salinity of 1 gr. per gal. at 100° F. instead of 1 gr. per gal. at 110° F. as required. There is no 100° F. position on the compensator.
- (7) The gas emanating from the electrode assembly while submerged in the 284° F. paraffin bath is believed to indicate improper molding.

Recommendations

(a) It is recommended that the subject salinity system be approved subject to the correction of the deficiencies outlined under "Conclusions", and submission to this Laboratory for material inspection.

(b) It is further recommended that the Bureau consider having a check mark placed on the dial at 1 gr. per gal., as there is now nothing on the equipment to show what position the pointer should assume when the check button is depressed. It would also be desirable to provide the checking resistor with suitable clamps for attaching to the cell electrodes without injury.

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 52 pounds, 5 ounces, is 8-1/2" x 12-1/2" x 21", and consists of the following parts:

- (a) A power factor meter, its dial graduated to read the salt content in grains of chlorine per gallon.
- (b) A transformer, ratio 115/100-60, 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 50° F. to 200° F., in steps of 7.5° 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 Navy Type VG-2-N 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 brass cover of a steel case of drip-proof construction finished in black. Flexible lead wires, flame resistant, connect the units to a terminal block located in the back of the case.

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

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

<u>Dial Reading</u>	<u>Indications</u>
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 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 Chlorine Per Gallon". The cell consists of two platinum sheathed electrodes in a molded phenolic insulator housed in a cylindrical brass tube. This assembly is housed in a second brass tube which is equipped with a gate-valve so that the cell may be withdrawn for inspection. The electrodes are protected from injury by a cylindrical guard. The cell is not equipped with the usual six feet of portable rubber cord, extending through a 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 power factor 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 standard salinity solutions, Plate 4. 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 chlorine 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. 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.

16. The electrode assembly was removed from the salinity cell and

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

17. 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

18. Tables 1 and 2 give the results of the accuracy tests. Plates 5 to 8 are curves taken from tables 1 and 2. If there were any errors caused by variations of ± 5 cycles in frequency or ± 10 volts, they could not be read on the indicator.

19. The shock test had no apparent effect on the indicator.

20. The conductivity cell successfully withstood the required hydrostatic test.

21. The immersion of the electrode assembly in the hot paraffin bath produced no detectable change in dimensions or appearance. However, a stream of gas bubbles emanated from the joint between the phenolic material and the knurled brass sleeve for the greater period of the test.

22. The insulation resistance between all current-carrying parts and ground was 100 megohms by 500 volt Megger, following the application of a dielectric test of 1500 volts, A.C., 60 cycles, for one minute.

CONCLUSIONS

23. The subject salinity indicator system complies with the specifications, reference (b), except for the following deficiencies:

- (1) The dial should read "Grains of Sea Salt per Gallon" instead of "Grains of Chlorine per Gallon." In addition, the specifications require a white enamel background for the dial. The one furnished is of the usual paper meter card type, having black graduations on a white background.
- (2) The projecting hinge screws will eventually cut into the lead wires.
- (3) The self-indexing feature of the temperature compensating switch is not positive. The ball-faced contact has the tendency to rest between the switch contacts.
- (4) Replacement of the pilot lamp is very difficult.
- (5) Soldering lugs are provided on the transformer instead of the required terminal strip for Navy standard wire terminals.
- (6) The value in the furnished checking resistor corresponds to a salinity of 1 gr. per gal. at 100° F. instead of 1 gr. per gal. at 110° F. as required. There is no 100° F. position on the compensator.
- (7) The gas emanating from the electrode assembly while submerged in the 284° F. paraffin bath is believed to indicate improper molding.

TABLE 1

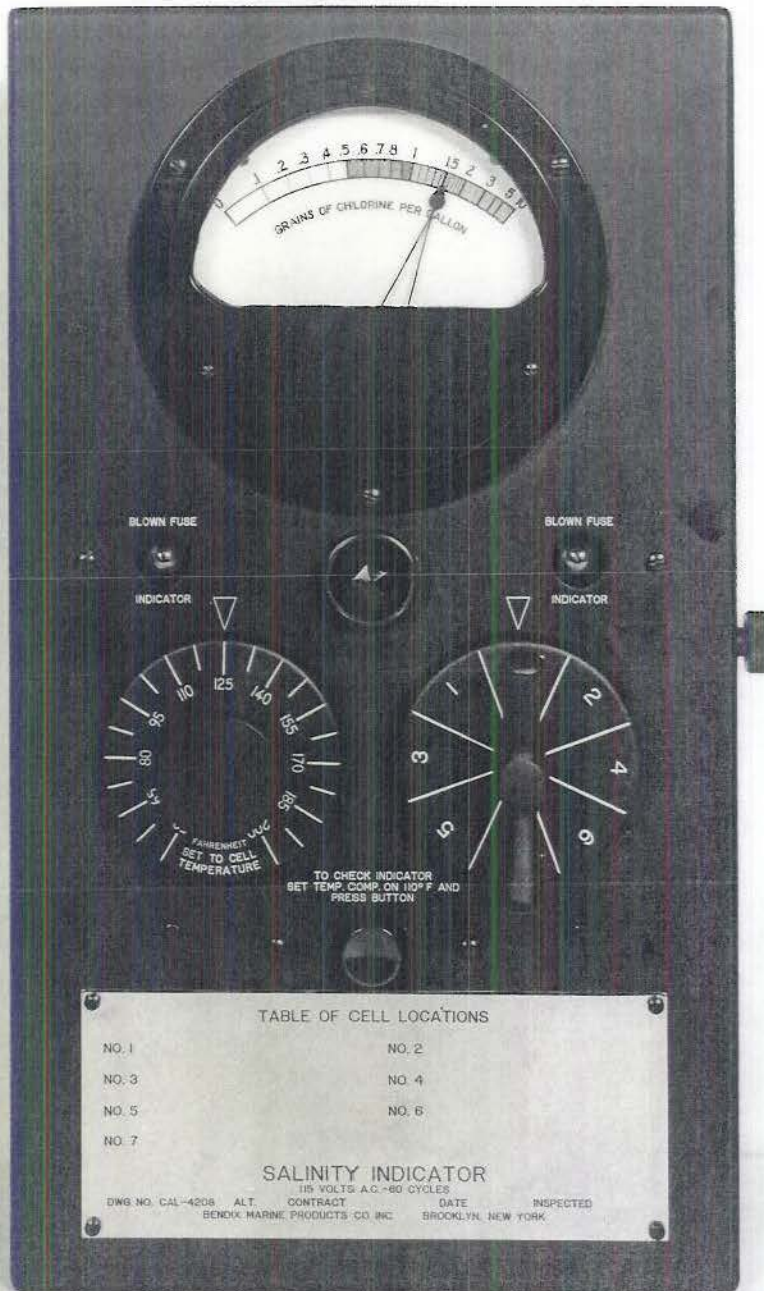
Initial Accuracy Test at 115 Volts, A. C. 60 Cycles

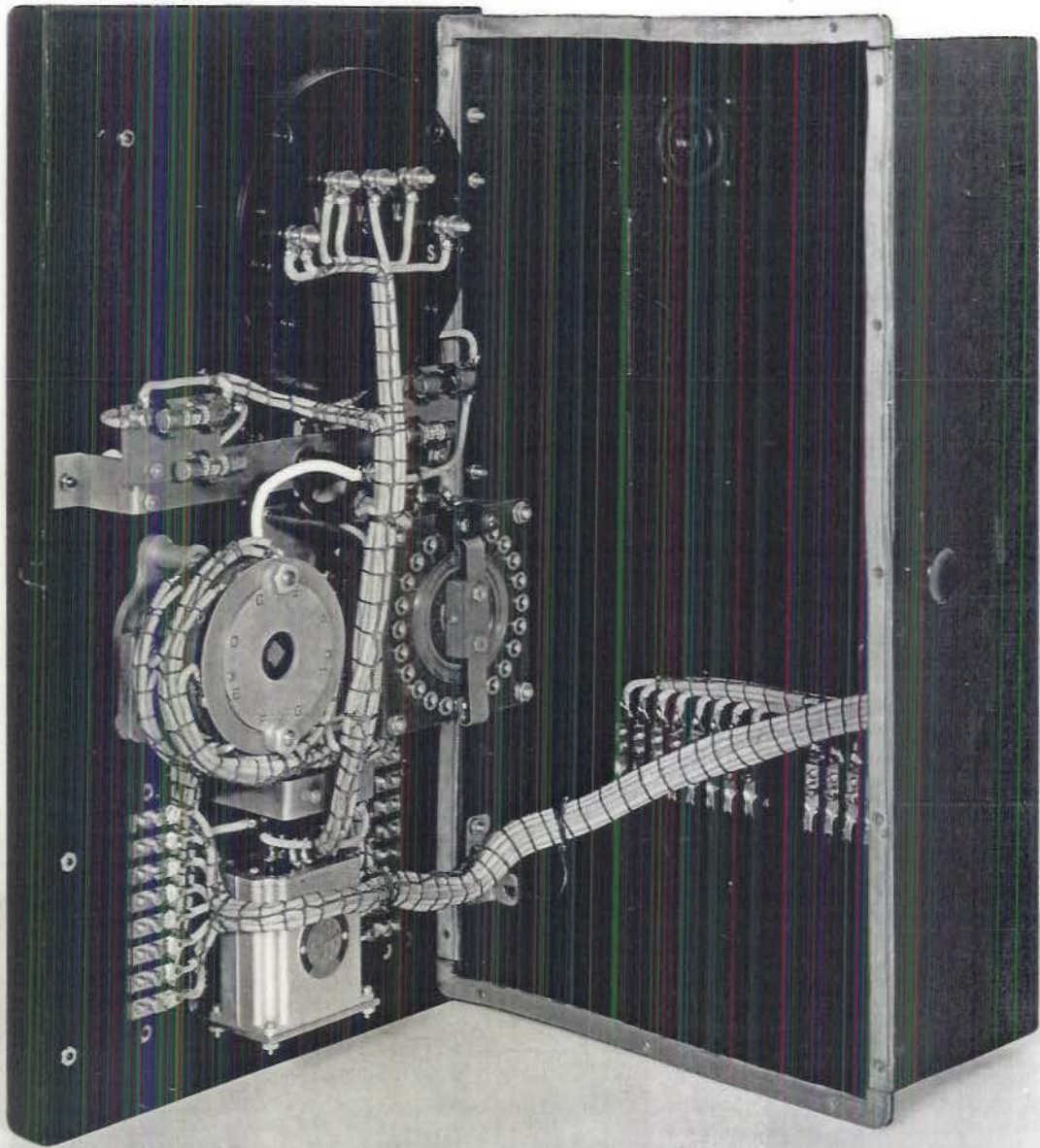
Compen- sator Setting °F	Temp.(°F) for values of resist- ances taken from curves	% error	% error	% error	% error	% error	% error
		0.1 gr/ gal	0.3 gr/ gal	0.5 gr/ gal	1.0 gr/ gal	2.0 gr/ gal	5.0 gr/ gal
57.5	61.25	+ .5	+ .7	+1.2	+1.3	+2.0	+1.0
65.0	61.25	- .8	-1.6	-1.6	-1.7	+ .2	0
65.0	68.75	+1.2	+ .9	+ .9	+1.6	+1.8	+ .6
72.5	68.75	- .3	-1.4	-1.7	-1.3	+ .2	- .3
72.5	76.25	+ .8	+1.0	+1.2	+1.4	+1.7	+ .7
80.0	76.25	- .4	-1.1	-1.4	-1.4	0	- .3
80.0	83.75	+ .6	+ .5	+ .7	+1.4	+1.5	+ .6
87.5	83.75	- .7	-1.4	-1.5	-1.2	- .2	- .3
87.5	91.25	+ .6	+ .2	+ .5	+1.4	+1.3	+ .5
95.0	91.25	-1.0	-1.5	-1.7	-1.1	- .2	- .4
95.0	98.75	+ .3	+ .2	+ .6	+1.3	+1.2	+ .2
102.5	98.75	- .8	-1.6	-1.4	-1.0	- .3	- .6
102.5	106.25	+ .3	+ .4	+ .5	+1.2	+1.7	+ .1
110.0	106.25	- .8	- .7	-1.4	-1.1	+ .4	- .6
110.0	113.75	+ .2	+ .2	+ .7	+1.0	+1.0	- .3
117.5	113.75	- .8	-1.4	-1.4	-1.3	- .4	-1.1
117.5	121.25	0	+ .2	+ .3	+1.0	+1.0	+ .2
125.0	121.25	- .9	- .4	-1.6	-1.1	- .3	- .5
125.0	128.75	+ .1	+ .5	+ .6	+ .8	+ .7	- .5
132.5	128.75	- .8	-1.0	-1.3	-1.3	- .6	-1.2
132.5	136.25	0	+ .8	+1.0	+1.3	+ .5	- .6
140.0	136.25	- .8	- .6	- .6	- .5	- .6	-1.1
140.0	143.75	+ .1	+ .5	+ .5	+1.2	+ .6	- .8
147.5	143.75	- .6	- .8	-1.0	- .5	- .7	-1.4
147.5	151.25	+ .1	+ .4	+ .4	+1.1	+ .4	-1.0
155.0	151.25	- .7	- .8	-1.2	- .8	- .6	-1.5
155.0	158.75	+ .2	+ .5	+ .4	+1.0	+ .2	-1.2
162.5	158.75	- .6	- .7	- .9	- .3	- .7	-1.6
162.5	166.25	+ .2	+ .7	+ .5	+ .8	+ .3	-1.0
170.0	166.25	- .6	- .5	- .8	- .7	- .7	-1.6
170.0	173.75	+ .5	+ .8	+ .7	+ .8	+ .3	-1.4
177.5	173.75	- .3	- .4	- .6	- .6	- .7	-1.9
177.5	181.25	+ .1	+ .8	+ .5	+ .8	- .1	-1.4
185.0	181.25	- .6	- .3	- .7	- .6	-1.0	-1.8
185.0	188.75	+ .1	+ .8	+ .6	+ .9	+ .6	-1.7
192.5	188.75	- .5	- .3	- .5	- .4	-1.3	-2.1
192.5	196.25	+ .3	+1.1	+ .9	+ .8	- .6	-1.8
200.0	196.25	- .4	+ .2	0	- .3	- .3	-2.2
200.0	203.75	+ .3	+1.4	+1.4	+1.1	- .5	-1.8

TABLE 2

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

Compen- sator Setting °F	Temp.(°F) for values of resis- tance taken from curves	% 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
57.5	61.25	+1.2	+ .6	+1.0	+1.8	+2.0	+ .9
65.0	61.25	- .5	-1.8	-2.0	-1.0	+ .5	0
65.0	68.75	+1.1	+ .2	+1.0	+2.0	+2.0	+ .8
72.5	68.75	- .4	-1.9	-1.9	- .8	+ .4	- .2
72.5	76.25	+1.1	0	+ .4	+1.5	+1.7	+ .4
80.0	76.25	- .7	-2.0	-2.0	-1.1	+ .1	- .3
80.0	83.75	+1.2	- .1	+ .5	+1.8	+1.8	+ .2
87.5	83.75	- .2	-2.0	-2.0	- .9	+ .1	- .6
87.5	91.25	+ .8	0	+ .5	+1.7	+1.3	+ .1
95.0	91.25	- .2	-1.9	-1.9	- .8	- .1	- .5
95.0	98.75	+ .7	- .6	+ .2	+1.3	+1.0	0
102.5	98.75	-1.0	-2.1	-2.0	- .9	- .1	- .8
102.5	106.25	0	- .3	+ .2	+1.2	+1.7	- .1
110.0	106.25	-1.0	-2.0	-1.9	-1.0	+ .5	- .9
110.0	113.75	+ .1	- .4	+ .3	+1.1	+1.0	- .3
117.5	113.75	- .7	-2.0	-2.0	-1.1	- .1	-1.1
117.5	121.25	0	- .2	0	+1.2	+ .9	- .8
125.0	121.25	- .9	-1.8	-1.9	- .9	- .1	-1.2
125.0	128.75	- .4	+ .1	+ .3	+1.2	+ .8	- .6
132.5	128.75	-1.1	-1.2	-1.6	- .9	- .3	-1.1
132.5	136.25	0	- .1	+ .1	+1.1	+ .3	- .8
140.0	136.25	- .8	-1.3	-1.4	- .5	- .6	-1.2
140.0	143.75	+ .1	0	+ .3	+1.2	+ .9	-1.0
147.5	143.75	- .7	-1.3	-1.4	- .3	- .1	-1.4
147.5	151.25	0	0	+ .2	+1.3	+ .3	-1.0
155.0	151.25	- .8	-1.1	-1.3	- .1	- .7	-1.5
155.0	158.75	0	0	+ .3	+1.2	+ .3	-1.2
162.5	158.75	- .6	-1.0	-1.1	0	- .6	-1.9
162.5	166.25	0	+ .2	+ .5	+1.1	+ .3	-1.3
170.0	166.25	- .7	- .9	-1.0	- .3	- .5	-1.9
170.0	173.75	+ .6	+ .3	+ .8	+1.2	+ .2	-1.7
177.5	173.75	0	- .7	- .7	- .1	- .5	-2.1
177.5	181.25	- .1	+ .1	+ .4	+1.0	+ .1	-1.9
185.0	181.25	- .9	- .8	-1.0	- .1	- .9	-2.2
185.0	188.75	- .9	+ .3	+ .5	+1.0	- .2	-2.0
192.5	188.75	-1.7	- .7	- .9	0	-1.0	-2.2
192.5	196.25	+ .2	+ .5	+ .8	+1.0	- .7	-2.0
200.0	196.25	- .3	- .3	- .4	0	-1.1	-2.2
200.0	203.75	0	+ .8	+ .9	+1.1	- .3	-2.2





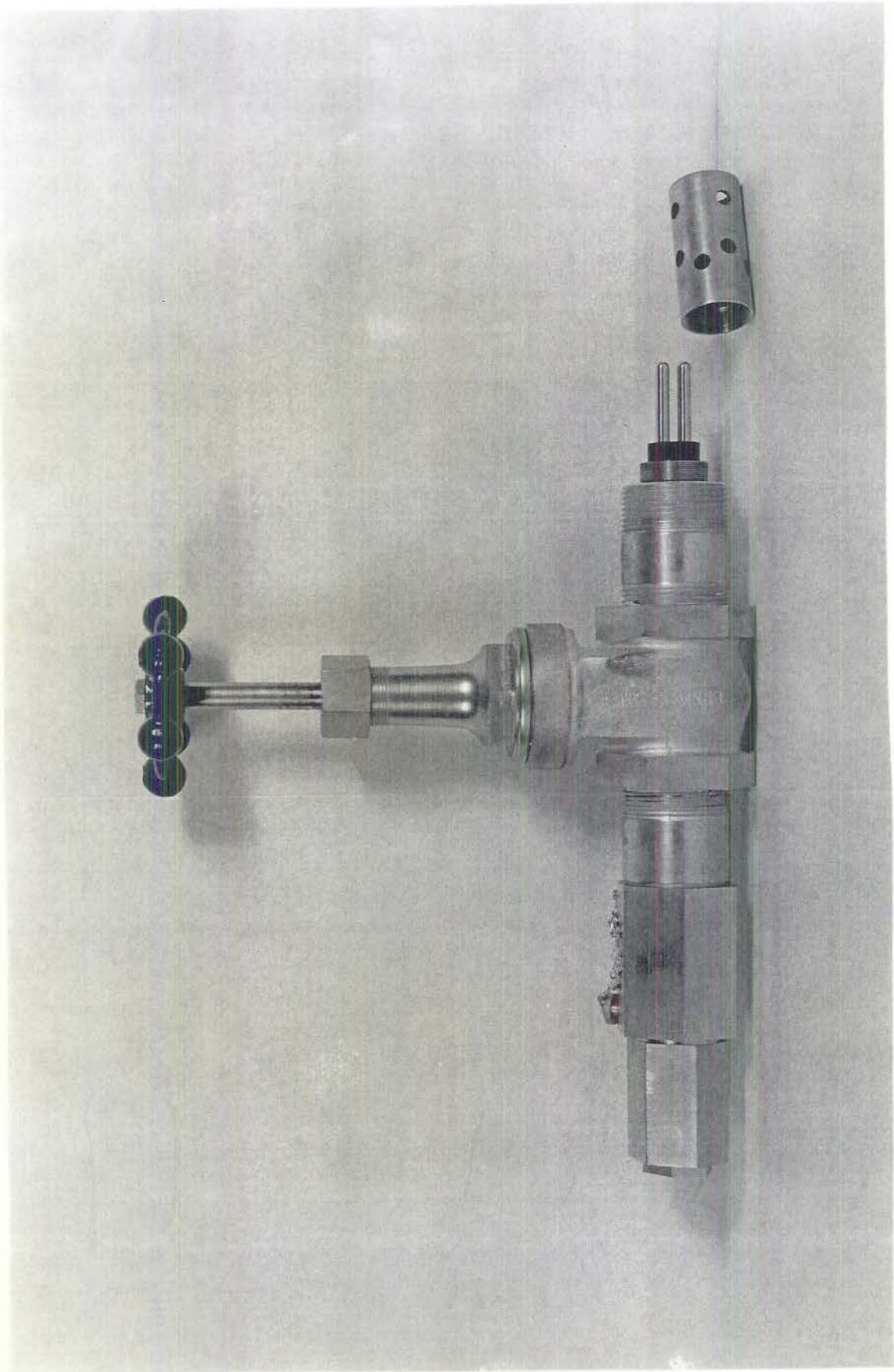
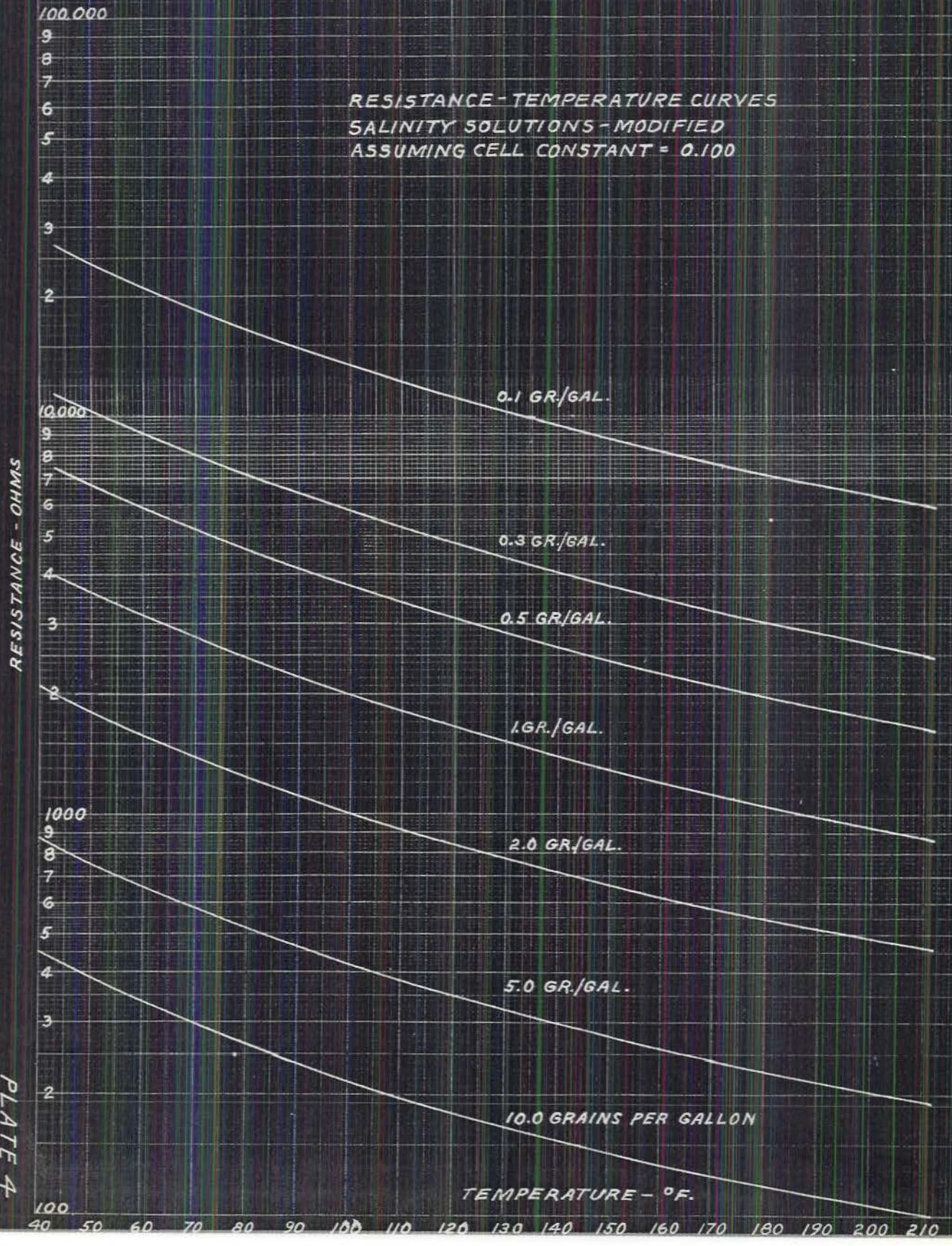


Plate 3

RESISTANCE-TEMPERATURE CURVES
SALINITY SOLUTIONS - MODIFIED
ASSUMING CELL CONSTANT = 0.100



RESISTANCE - OHMS

PLATE 4

INITIAL ACCURACY TESTS

COMPENSATOR
SET AT 80° F

COMPENSATOR
SET AT 102.5° F

5

SOLUTION AT 76.25° F

SOLUTION AT 85.75° F

SOLUTION AT 98.75° F

SOLUTION AT 106.25° F

2

1

.5

.3

.1

-3

-2

-1

0

+1

+2

+3

-3

-2

-1

0

+1

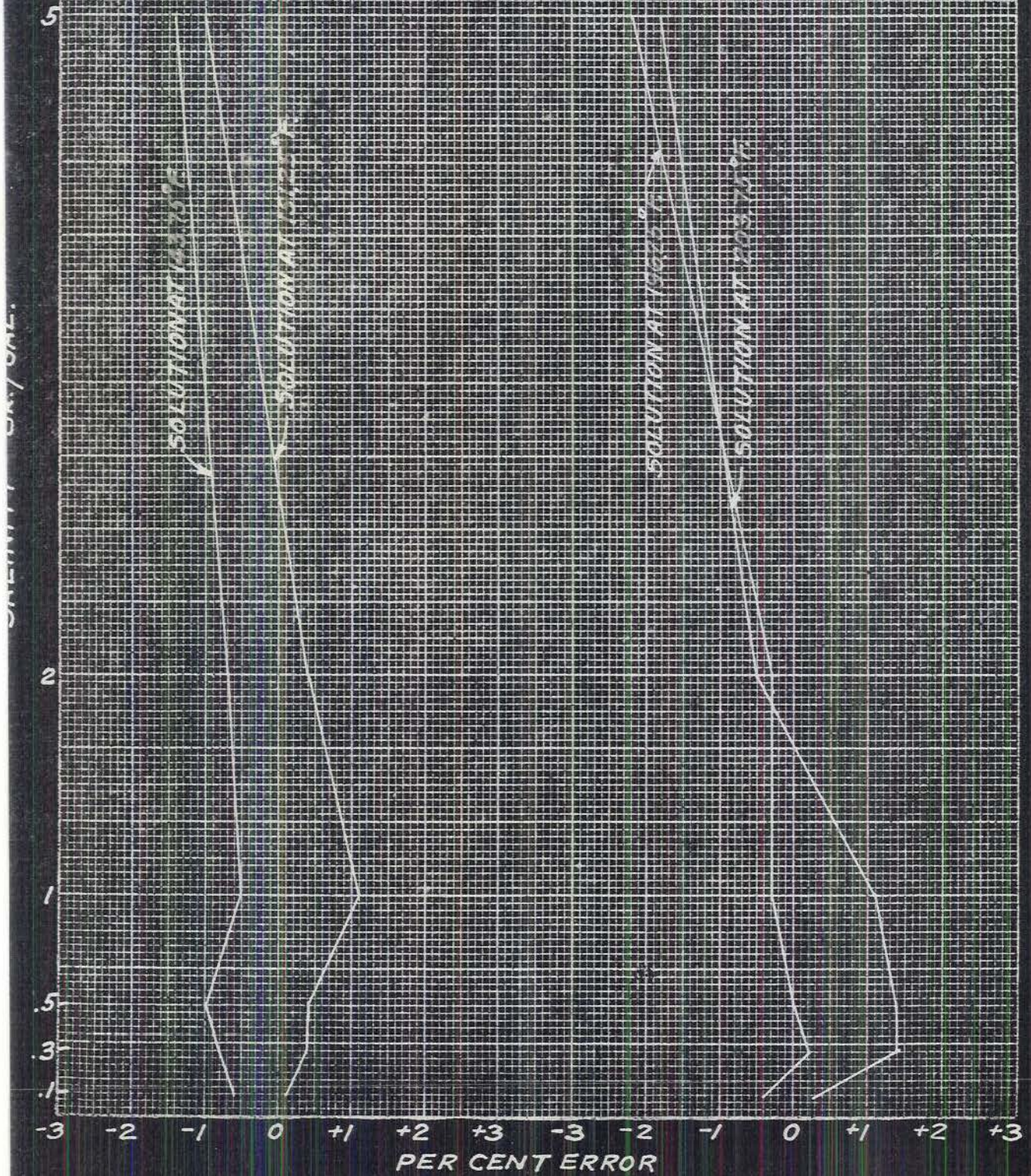
+2

+3

INITIAL ACCURACY TESTS

COMPENSATOR
SET AT 147.5°F

COMPENSATOR
SET AT 200°F

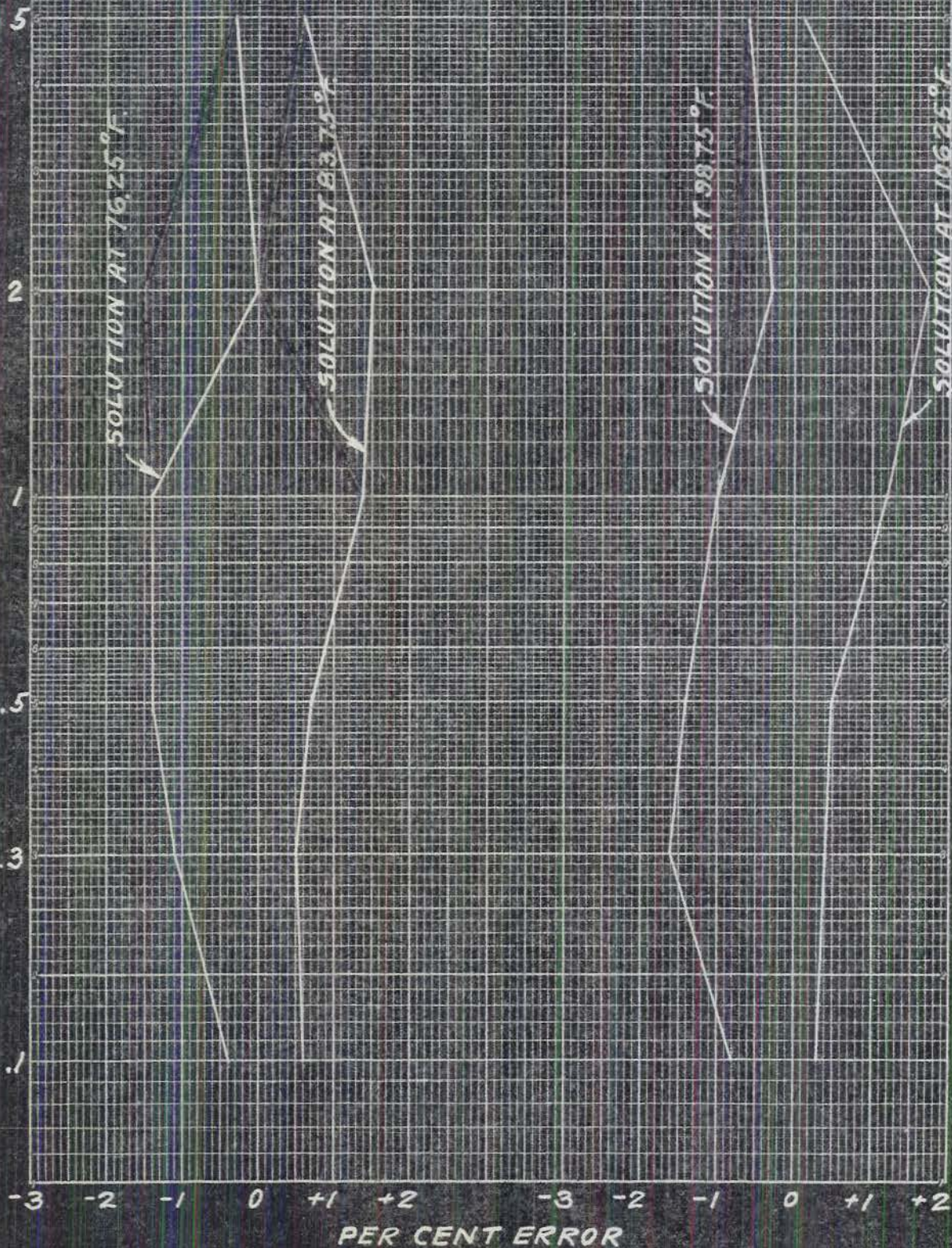


INITIAL ACCURACY TESTS

COMPENSATOR
SET AT 80°F

COMPENSATOR
SET AT 102.5°F

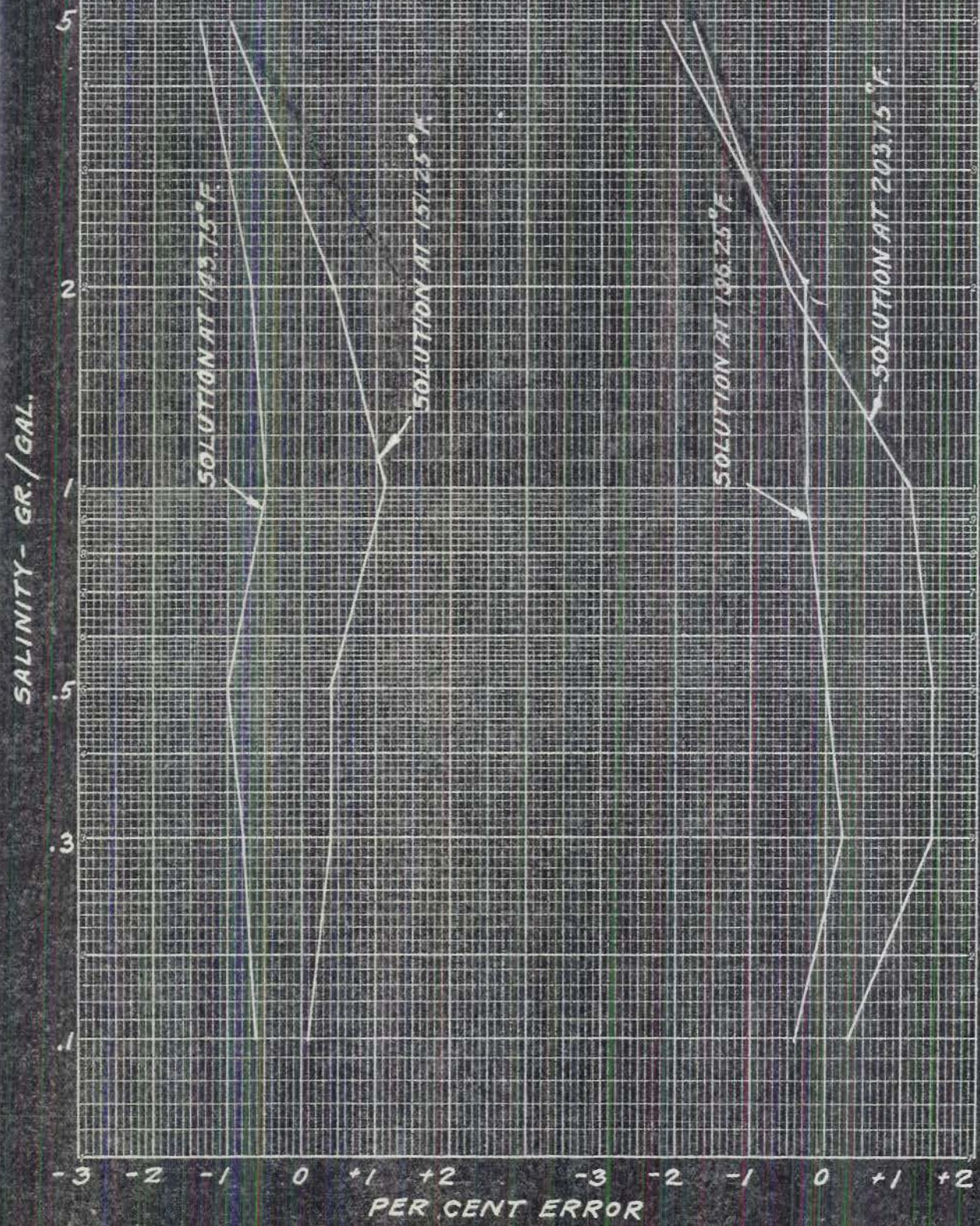
SALINITY - GR./GAL.



INITIAL ACCURACY TESTS

COMPENSATOR
SET AT 147.5°F.

COMPENSATOR
SET AT 200°F.



FINAL ACCURACY TESTS

COMPENSATOR
SET AT 80° F.

COMPENSATOR
SET AT 102.5° F.

5

SOLUTION AT 76.25° F.
SOLUTION AT 83.75° F.

SOLUTION AT 91.25° F.
SOLUTION AT 106.25° F.

2

1

.5

.3

.1

-3 -2 -1 0 +1 +2 +3 -3 -2 -1 0 +1 +2 +3

PER CENT ERROR

FINAL ACCURACY TESTS

COMPENSATOR
SET AT 141.5 °F

COMPENSATOR
SET AT 200 °F

5

SOLUTION AT 143.75 °F

SOLUTION AT 151.25 °F

SOLUTION AT 196.25 °F

SOLUTION AT 201.25 °F

2

1

.5

.3

.1

-3

-2

-1

0

+1

+2

+3

-3

-2

-1

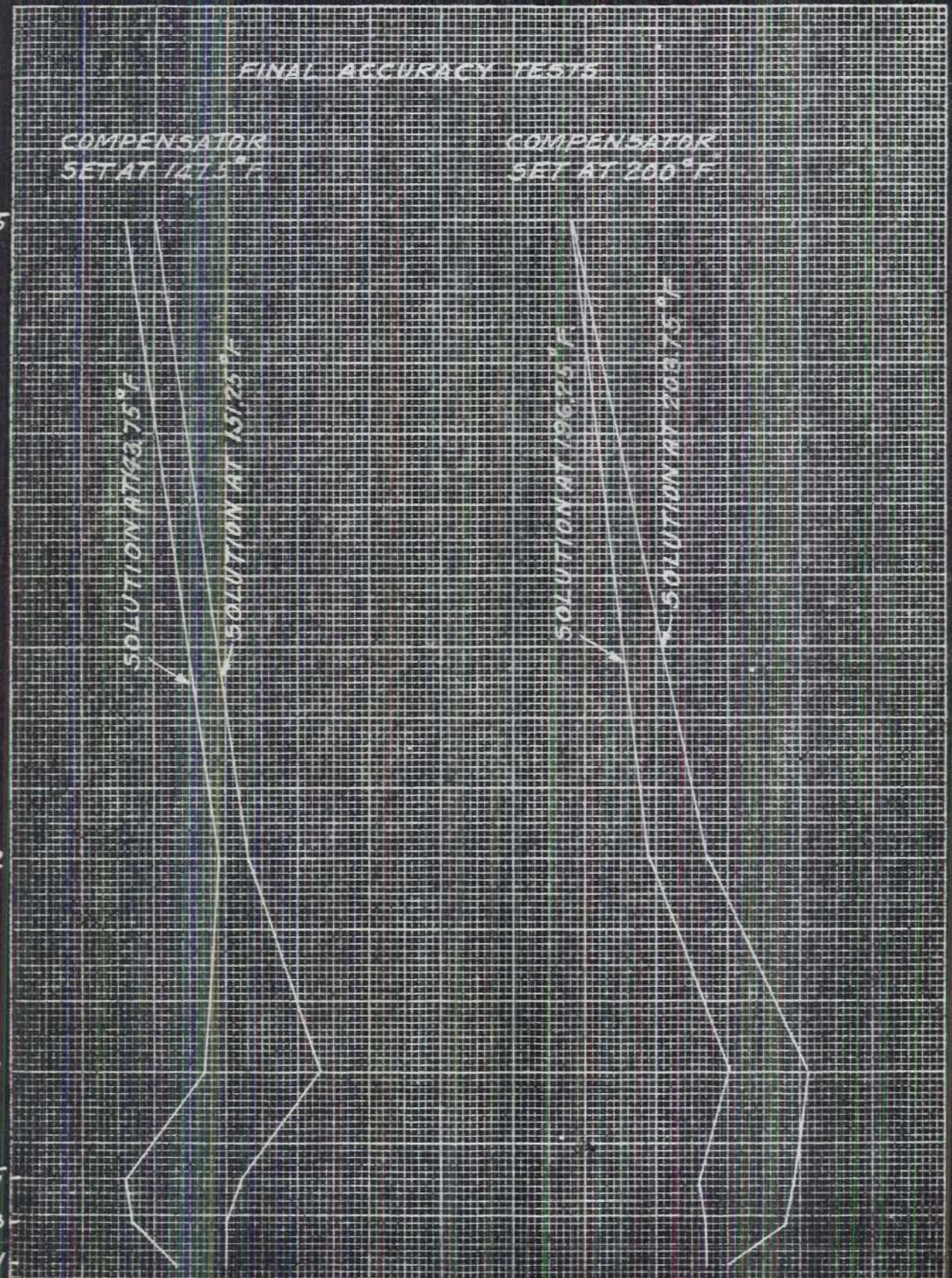
0

+1

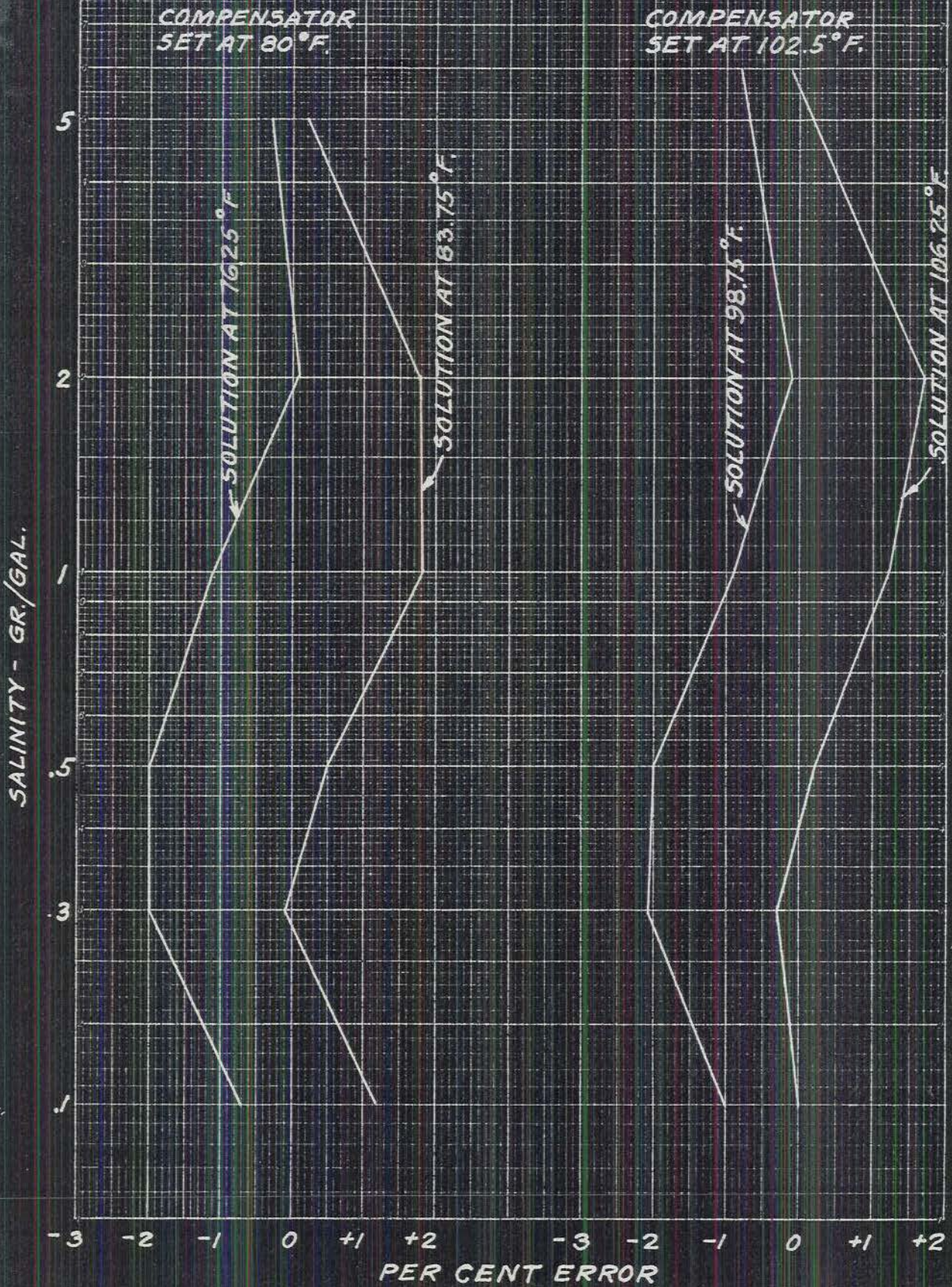
+2

+3

PER CENT ERROR



FINAL ACCURACY TESTS



FINAL ACCURACY TESTS

COMPENSATOR
SET AT 147.5° F.

COMPENSATOR
SET AT 200° F.

