REPORT NO. P-1969

DATE 7 December 1942

FR-1969

SUBJECT

An Investigation of Infra-Red Reflecting Paints

NAVAL RESEARCH LABORATORY

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U. S. GOVERNMENT PRINTING OFFICE 16—21006

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APPENDICES

INTRODUCTION

(a) Authorization

1. This study was authorized by Bureau of Ships letter dated 8 August 1942, S19-1(6)(350).

(b) Statement of the Problem

2. The object of the study was to compare infra-red reflecting deck paints against the Bureau's standard formula 20B deck paint in order to determine the temperature differences their use would make in the compartments under the weather deck.

3. The foregoing was modified after a conference to determine the temperature of the panels only, to find out whether any lower temperature resulted by the use of infra-red reflecting paints rather than the Bureau's standard formula 20B deck paint.

(c) Known Facts Bearing on the Problem

4. Certain pigments possess a property of reflecting radiant energy in the infra-red wave lengths while appearing dark in the visible part of the spectrum. As a result of this property it was hoped that this study would indicate that the use of such pigments would reduce the radiant energy absorbed by surfaces finished with paints containing them. If the difference noted appeared to be considerable, then it followed that the temperature of all compartments beneath such painted surfaces could be reduced approximately in proportion to the differences of energy absorbed by plates painted with infra-red reflecting and non-reflecting paint. The experiments described herewith were designed to measure this difference.

METHODS

(a) Apparatus

6. The test equipment consisted of a horizontal 1/8" steel panel 18" square. In many cases this panel was provided with a reflecting panel set perpendicularly to the test panel at its edge so that sunlight striking it would reflect on the test panel. In order to support the panels a wooden rack was built from pieces of 2 x 4's made into "T" supports. These supports were held together by stringers 5/8" x 3" which provided a means of holding the test panels up off the ground and formed a vertical support for the reflecting panels. Both the test and the reflecting panels were fastened to 1" fiberglas insulating board (NC-9) with Foster's adhesive cement No. 81-15. A strip 6" wide of fiberglas was not trimmed off at the side of the panels and served as a spacer on the rack. The test panels were

fitted with three thermocouples--one at the center of the lower surface and two in grooves cut in the under side. These grooves started at the midpoint of opposite edges and extended 5" toward the center of the panel. The thermocouples were soldered in place and those in the grooves were about 4-1/2" in from the edge. This made it possible to measure the temperature of the interior of the panel at two distances from the reflecting panel and also at the lower surface.

7. The electrical set-up consisted of five boxes, each containing a ten pole multiple switch. The EMF measurements were made with a Brown potentiometer. The constantan wires from each thermocouple were connected to a common wire running directly to the ice junction. The copper wires from the thermocouples were connected to the poles on the boxes and the wire from the boxes was connected to a common wire running to the potentiometer. The boxes each had a dead point so that the circuit to them could be broken. The potentiometer was then connected by a copper wire to the cold junction completing the circuit.

(b) Materials

8. There were fifteen panels fitted with three thermocouples each, making forty-five in all. The first five panels were not provided with reflectors. The second five were finished the same as the first five and had vertical reflecting panels finished with Standard 20B deck paint, and the third set was finished like the other two but had reflectors the same as the panel for which it was reflecting. (Table I). Three infra-red reflecting formulations were tested, using the same infra-red reflecting primer on all panels painted and Standard 20B Deck Blue as the control:

(a) Pebble Ground 84A - Zinc Chromate Primer 52-P-18, Socony Paint Products.

(b) Infra-Red Reflecting 20B Deck Blue - Sherwin-Williams Co.

(c) Henry A. Gardner Infra-Red Opaque "B" - National Paint and Varnish Association

TABLE I

Arrangement of Panels on the Rack

Panel No.	Panel	Reflector
1	Polished Metal	None
2	84-A Primer	"
3	Infra-red reflecting paint*	"
4	Infra-red reflecting paint	"
5	Standard 20B deck paint	"
6	Polished Metal	Standard 20B deck paint
7	84-A Primer	" " " "
8	Infra-red reflecting paint	" " " "
9	Infra-red reflecting paint	" " " "
10	Standard 20B deck paint	" " " "
11	Polished metal	Polished metal
12	84-A Primer	84-A Primer
13	Infra-red reflecting paint	Infra-red reflecting paint
14	Infra-red reflecting paint	" " " "
15	Standard 20B deck paint	Standard 20B deck paint

*All panels having a top coat were given a primer coat of 84-A Primer immediately after pickling.

9. In each set of five panels there were duplicate infra-red reflecting panels--Sherwin-Williams in one test and Gardner "B" in another.

(c) Experimental

10. A series of readings were taken as rapidly as possible and this usually took about fifteen minutes. Then another set of readings was started one-half hour after the first reading of the previous set. The first series were usually made between 8:00 and 9:00 a.m. and the last were made about 4:00 p.m. In this way all the panels were at about the same temperature at the beginning and ended nearly the same. The thermocouples had been checked against each other beforehand and a curve of temperature -E.M.F. was prepared for converting the potentiometer readings to temperature in degrees Fahrenheit.

DATA OBTAINED

11. Since the three thermocouples on each panel all read the same within experimental error, the readings were averaged to get the temperature of the panel. The values listed are these averages.

TABLE II

Temperature Data for Sherwin-Williams Infra-Red
Reflecting Paint
Tested September 19, 1942

No Reflecting Panel - See Plate I for Curves

Polished		84-A Primer			Infra-Red Paint		Infra-Red Paint		20B Paint	Time
EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	Min.
1.20	91	1.11	87	1.15	89	1.15	89	1.15	89	0
1.36	98	1.18	90	1.21	91	1.24	93	1.31	96	30
1.49	104	1.26	93	1.35	97	1.35	97	1.49	103	60
1.85	119	1.57	107	1.63	111	1.66	111	1.90	121	93
2.36	141	1.98	125	2.07	128	2.07	128	2.41	143	123
2.54	149	2.13	131	2.20	134	2.20	134	2.51	147	150
2.88	167	2.33	140	2.41	143	2.32	139	2.64	153	182
2.88	167	2.40	142	2.47	145	2.45	145	2.79	159	212
2.76	158	2.35	140	2.46	145	2.42	143	2.69	155	240
2.86	162	2.37	141	2.47	145	2.46	145	2.82	160	275
2.83	161	2.37	141	2.39	142	2.27	137	2.57	150	302
2.13	131	1.81	117	1.82	118	1.80	117	1.95	123	360
2.34	140	2.00	125	2.12	130	2.14	131	2.40	142	393
2.27	137	1.98	125	2.03	127	2.02	126	2.27	137	420

TABLE III.

Temperature Data for Sherwin-Williams Infra-Red
Reflecting Paint
Tested September 19, 1942

Standard 20B Deck Blue Reflecting Panel - See Plate II for Curves

Polished		84-A Primer		Infra-Red Paint		Infra-Red Paint		20B Paint		Time
EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	Min.
1.28	94	1.15	89	1.15	89	1.16	89	1.22	92	0
1.41	100	1.24	93	1.24	94	1.25	93	1.31	96	30
1.59	108	1.36	98	1.40	100	1.41	100	1.53	105	60
2.04	127	1.73	114	1.80	117	1.82	118	2.00	125	93
2.61	152	2.14	131	2.21	134	2.19	133	2.42	143	123
2.80	160	2.32	139	2.41	143	2.37	141	2.58	150	150
2.99	167	2.46	145	2.58	150	2.59	151	2.81	160	182
3.13	174	2.54	149	2.67	154	2.65	153	2.88	163	212
2.97	167	2.45	145	2.60	155	2.59	151	2.83	161	240
3.11	173	2.59	151	2.76	158	2.77	158	3.00	168	275
2.82	160	2.35	140	2.50	147	2.51	147	2.74	157	302
2.21	135	1.81	117	1.92	122	1.86	119	1.96	124	360
2.52	148	2.20	134	2.34	140	2.32	139	2.51	147	393
2.47	146	2.09	129	2.37	141	2.25	136	2.44	144	420

TABLE V

Temperature Data for Gardner "B" Infra-Red Reflecting Paint
Tested September 24, 1942

No Reflector
See Plate IV for Curves

Polished		84-A Primer		Infra-Red Paint		Infra-Red* Paint		20B Paint		Time
EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	Min.
.92	79	.74	71	.73	71	.75	72	.85	76	0
1.08	86	.76	72	.77	73	.77	73	1.12	87	30
1.50	104	1.28	94	1.19	90	1.19	90	1.56	106	70
1.60	108	1.40	99	1.35	97	1.36	98	1.73	114	90
1.66	111	1.50	104	1.48	103	1.50	104	1.84	118	120
2.04	127	1.84	118	1.78	116	1.83	118	2.23	135	190
2.09	129	1.87	120	1.82	118	1.84	118	2.25	136	210
2.19	133	1.97	124	1.89	121	1.96	124	2.35	140	240
2.31	139	2.07	129	1.98	125	2.00	125	2.39	142	270
2.34	140	2.08	129	2.02	126	2.04	127	2.44	144	300
2.22	135	1.88	120	1.82	118	1.80	117	2.04	127	330
2.35	140	2.17	133	2.08	129	2.03	127	2.44	144	360
1.27	94	1.15	89	1.14	88	1.15	89	1.20	91	430

*The Gardner paint was applied over the Sherwin-Williams paint that was already on it.

TABLE VI

Temperature Data for Gardner "B" Infra-Red Reflecting Paint
Tested September 24, 1942

Standard 20B Deck Blue Reflecting Panel - See Plate V for Curves

Polished		84-A Primer		Infra-Red Paint		Infra-Red Paint*		20B Paint		Time
EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	Min.
1.00	82	.77	73	.76	72	.76	72	.84	76	0
1.26	93	.85	76	.83	75	.82	75	1.09	86	30
1.72	113	1.44	101	1.33	97	1.29	95	1.59	108	70
1.87	120	1.61	109	1.56	106	1.54	106	1.78	116	90
1.99	125	1.73	114	1.69	112	1.68	112	1.94	123	120
2.36	141	2.08	129	2.03	127	2.06	128	2.34	140	190
2.43	144	2.09	129	2.07	128	2.08	128	2.36	141	210
2.52	148	2.17	133	2.21	134	2.21	134	2.53	148	240
2.60	151	2.21	134	2.23	135	2.22	135	2.53	148	270
2.58	150	2.23	135	2.24	136	2.27	137	2.57	150	300
2.36	136	1.91	122	1.89	121	1.85	119	2.03	127	330
2.57	150	2.23	135	2.20	134	2.22	135	2.49	146	360
1.30	95	1.15	89	1.16	89	1.15	89	1.20	91	430

*The Gardner paint was applied over the Sherwin-Williams paint that was already on it.

TABLE VII

Temperature Data for Gardner "B" Infra-Red
Reflecting Paint
Tested September 24, 1942

Like Reflector
See Plate VI for Curves

Polished		84-A Primer		Infra-Red Paint		Infra-Red Paint*		Infra-Red Paint‡		20B Paint		Time
EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	EMF	T°F	Min.
.99	78	.75	72	.75	72	.75	72	.80	74	.84	76	0
1.24	93	.85	76	.83	75	.80	74	1.06	85	1.09	86	30
1.70	112	1.38	94	1.26	93	1.31	96	1.51	104	1.59	108	70
1.87	120	1.54	106	1.48	103	1.50	104	1.67	111	1.78	116	90
2.03	127	1.69	112	1.61	109	1.61	109	1.77	116	1.94	123	120
2.47	145	1.99	125	1.94	123	1.93	122	2.13	131	2.34	140	190
2.52	148	2.01	126	1.96	124	1.96	124	2.06	124	2.36	141	210
2.66	154	2.14	131	2.11	130	2.11	130	2.11	130	2.53	148	240
2.69	155	2.12	130	2.10	130	2.11	130	2.11	130	2.53	148	270
2.77	158	2.20	134	2.16	132	2.14	131	2.10	130	2.57	150	300
2.17	128	1.75	115	1.76	115	1.75	115	1.75	115	2.03	127	330
2.51	147	2.01	126	1.97	124	1.89	121	1.84	118	2.49	146	360
1.30	95	1.11	87	1.12	87	1.11	87	1.12	87	1.20	91	430

*The Gardner paint was applied over the Sherwin-Williams paint that was already on it.

‡One coat of Gardner paint was applied over the 20B on the panel and its reflector as the day's run began.

DISCUSSION

12. From these data it is evident that paints can be made that reflect more infra-red light than the Standard 20B Deck Blue now in use by the Navy. However, this is based upon the lower temperature attained by panels finished with infra-red reflecting paints and without doubt the visible light in sunlight has some heating effect.

13. In order to try to devise a simple laboratory method of testing such paints, another set of two panels was prepared, fitted with thermocouples and irradiated with an infra-red lamp. In this case the Gardner and Sherwin-Williams paints both reached higher temperatures than the polished plate did. Therefore, it must be assumed that the infra-red reflection of the paints is effective only by the light of the wave length distribution found in sunlight, and that the light produced by the infra-red lamp was of a different wave length distribution.

14. The chief question to be raised is whether the temperature lowering effected by these paints is sufficient to make an appreciable difference in the temperatures attained by the decks and compartments of a ship. There is, of course, the possibility that other paints exist or can be formulated that will effect a lowering in temperature large enough to be of greater value. Other paints have been submitted but after the Gardner paint was tested there were no days sufficiently warm and free of cloudy skies to make any tests of significance.

15. It was of interest to note that those panels which were finished with 84-A primer or infra-red reflecting paint held dew on them much longer than the polished or 20B Deck Blue panels. The polished panel with 20B reflector reached a higher temperature than that with polished reflector. This can be explained since the polished reflector absorbed more heat from the sunlight and thus less was actually reflected. From this reasoning, the panel which would reach the highest temperature would be and was the polished panel with a 20B reflector. A still higher temperature could have been attained by using a reflector finished with the Gardner "B" paint and a polished panel, because more energy would reach the panel from the reflector since absorption would be at a minimum.

16. Some error crept in because of clouds covering the sun while a set of readings was being taken. In order to see how much cooling took place, the temperatures of the polished panel with a 20B reflector was read at half minute intervals, starting just before a cloud covered the sun. Two clouds passed over the sun during the series and a plot of the temperatures is shown in Plate VII. The fact that there was a definite cooling effect when a cloud passed over the sun shows that the visible light has a heating effect since clouds are transparent to infra-red light.

17. The air temperatures for the two days during which the runs were made are shown graphically in Plate VIII.

18. Plates IV, V, VI, curves 3 and 4, show that the paint may be applied over any surface and the reflectivity is the same as when it is applied to a fresh surface of primer. Table IV, curve 6, shows very clearly that only one coat of infra-red reflecting paint applied over Standard 20B Deck Blue is necessary to get the maximum reflectivity of the paint.

19. The two photographs on Plate IX show the panels taken with both ordinary and infra-red film.

CONCLUSIONS AND RECOMMENDATIONS

20. From the foregoing results it is evident that the paints tested have the ability to decrease the temperature attained by a steel panel when exposed to sunlight. However, it is not clear as to whether this effect is large enough to warrant its use in service.

21. The test can by no means be considered complete since only two out of a number of commercial preparations could be tested while the sun was hot enough to heat the panels appreciably. However, the method has been shown to be of use in evaluating such paints. Therefore, no recommendations can be made on the basis of this test but further tests on other paints using this method are suggested.

22. The superiority of the Gardner "B" infra-red reflecting paint over the Sherwin-Williams infra-red reflecting paint is clearly demonstrated.

23. In future tests it is suggested that the polished and 84-A panels be omitted and all paints submitted for tests be exposed simultaneously with a Standard 20B Deck Blue control panel included. Each panel should be provided with a reflecting panel finished in the same way in order to exaggerate the effect as much as possible.

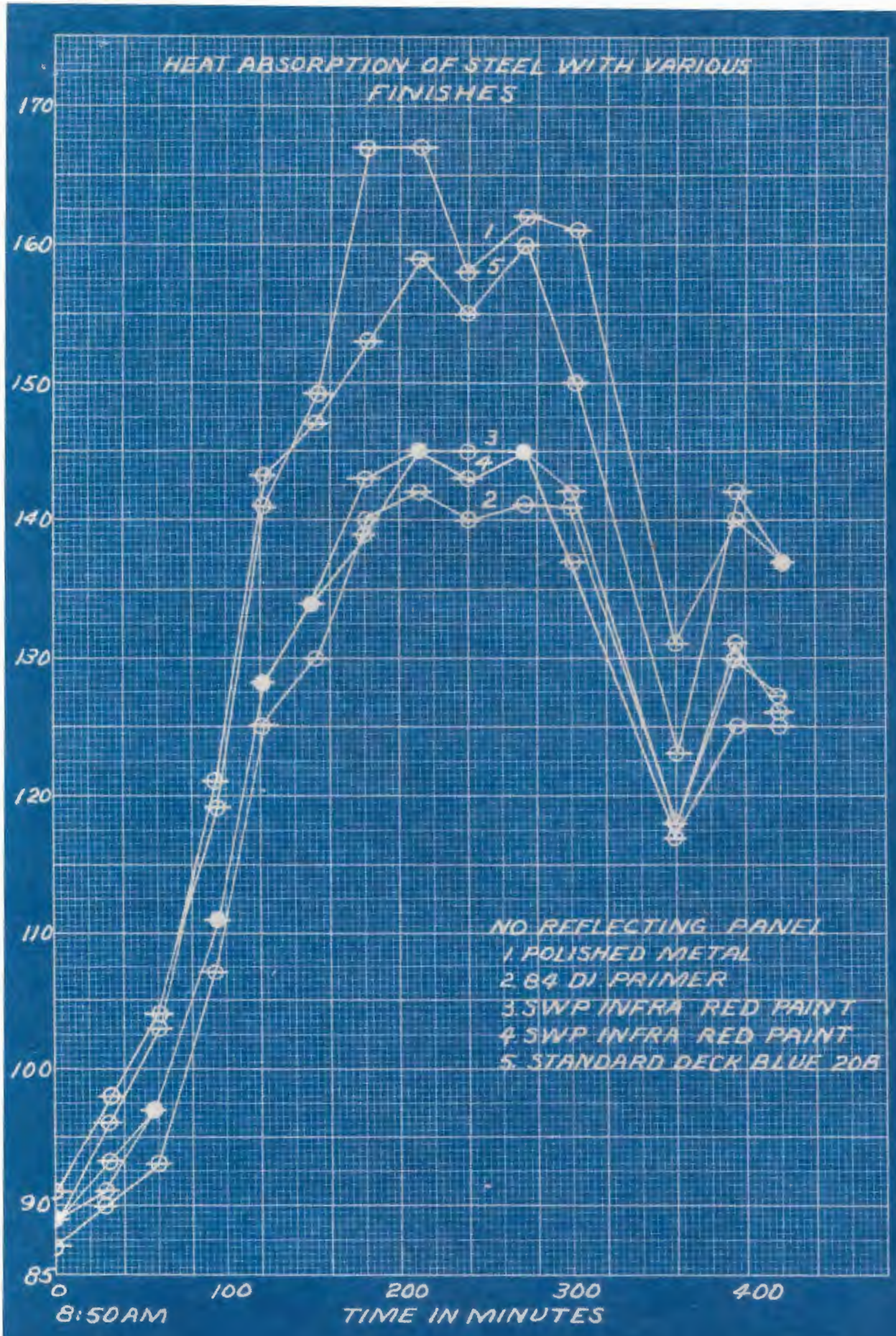

HEAT ABSORPTION OF STEEL WITH VARIOUS FINISHES
170
160
150
140
130
120
110
100
90
85
0
100
200
300
400
8:50 AM
TIME IN MINUTES
1
5
3
4
2
NO REFLECTING PANEL
1 POLISHED METAL
2 84 DI PRIMER
3 SWP INFRA RED PAINT
4 SWP INFRA RED PAINT
5 STANDARD DECK BLUE 208

PLATE 1

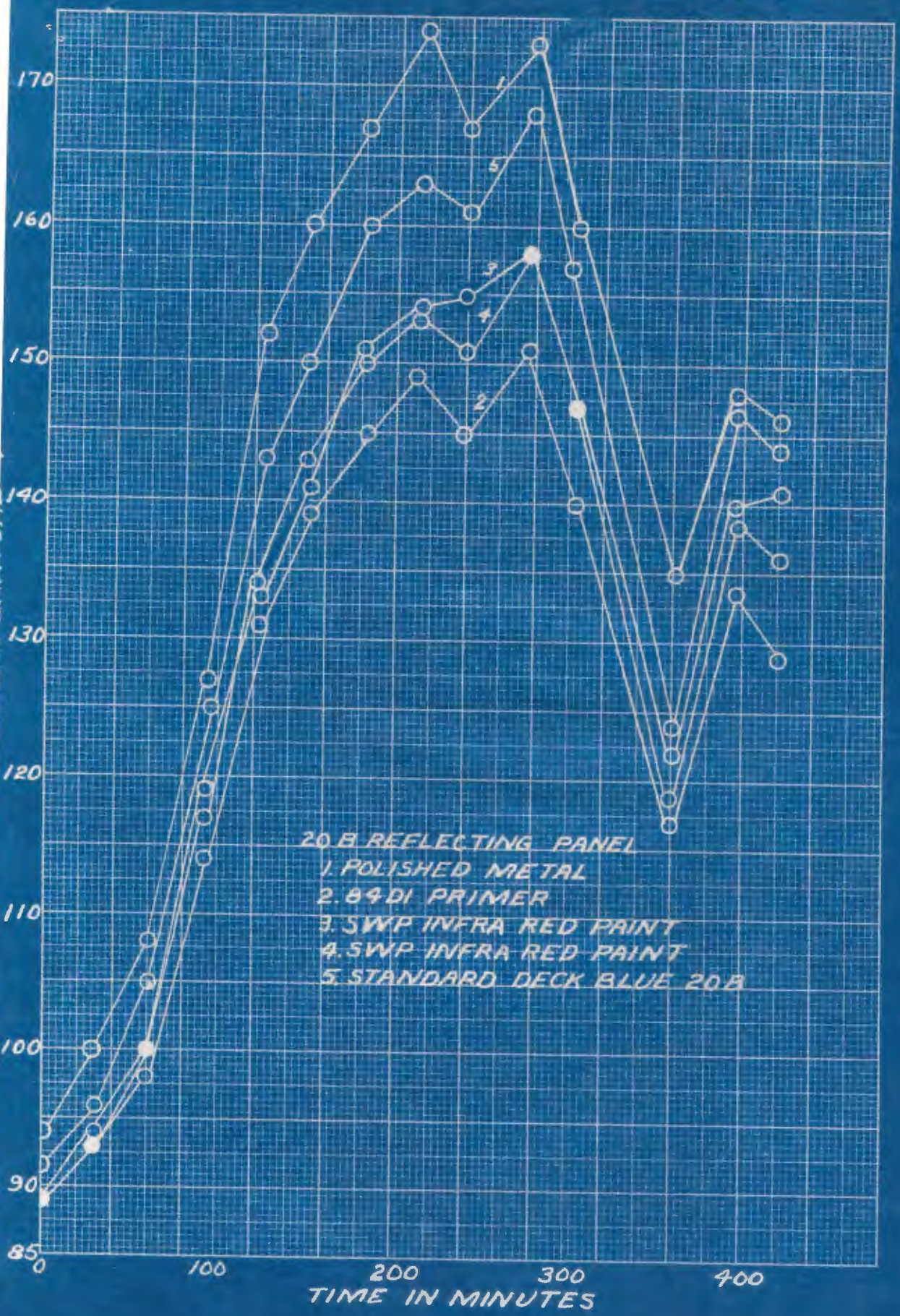

170
160
150
140
130
120
110
100
90
85
0
100
200
300
400
TIME IN MINUTES
1
5
3
4
2
20 B REFLECTING PANEL
1. POLISHED METAL
2. 84 DI PRIMER
3. SWP INFRA RED PAINT
4. SWP INFRA RED PAINT
5. STANDARD DECK BLUE 20 B

PLATE 2

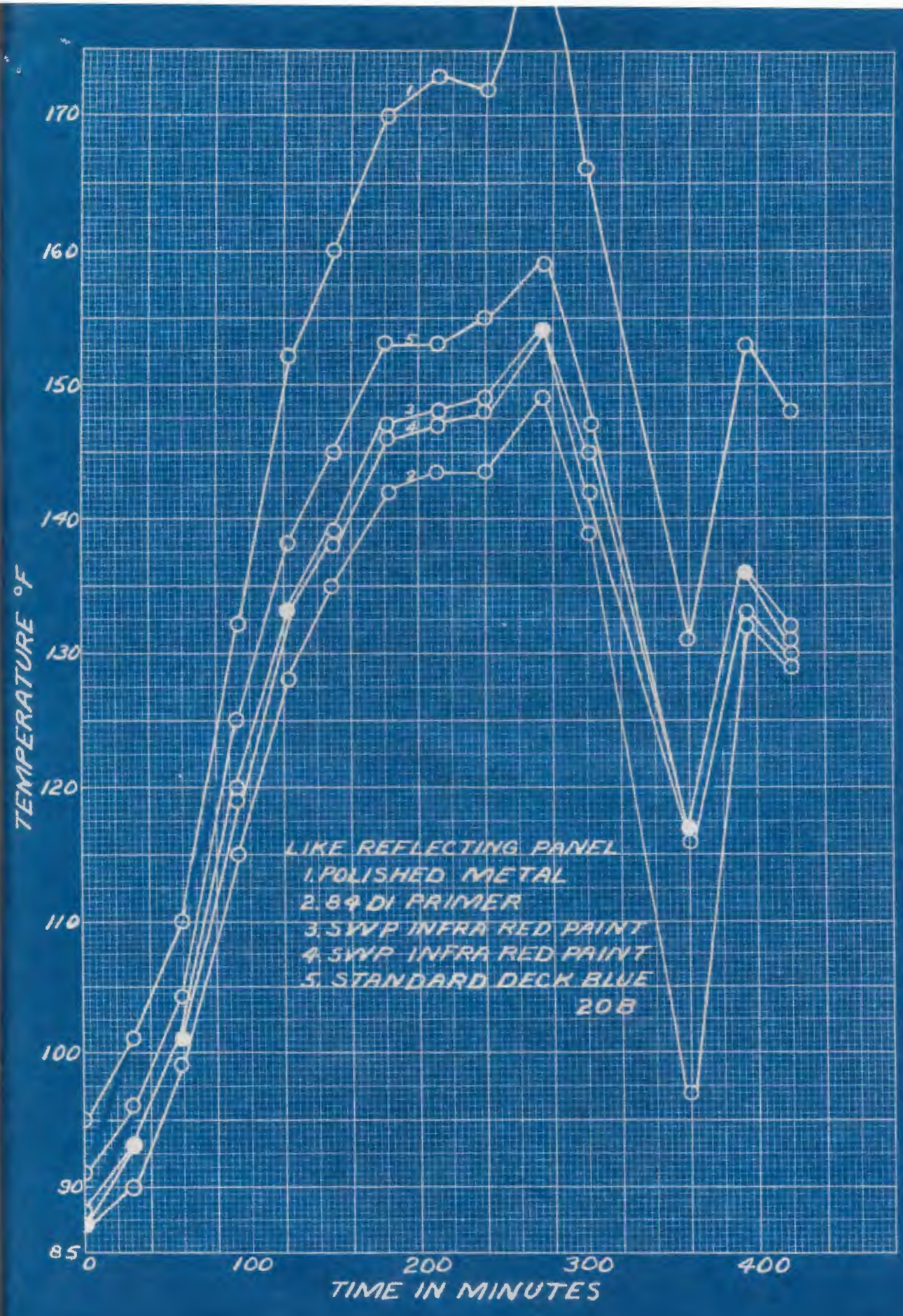

TEMPERATURE °F
170
160
150
140
130
120
110
100
90
85
0
100
200
300
400
TIME IN MINUTES
LIKE REFLECTING PANEL
1. POLISHED METAL
2. 84 DI PRIMER
3. SWP INFRA RED PAINT
4. SWP INFRA RED PAINT
5. STANDARD DECK BLUE
20B

PLATE 3

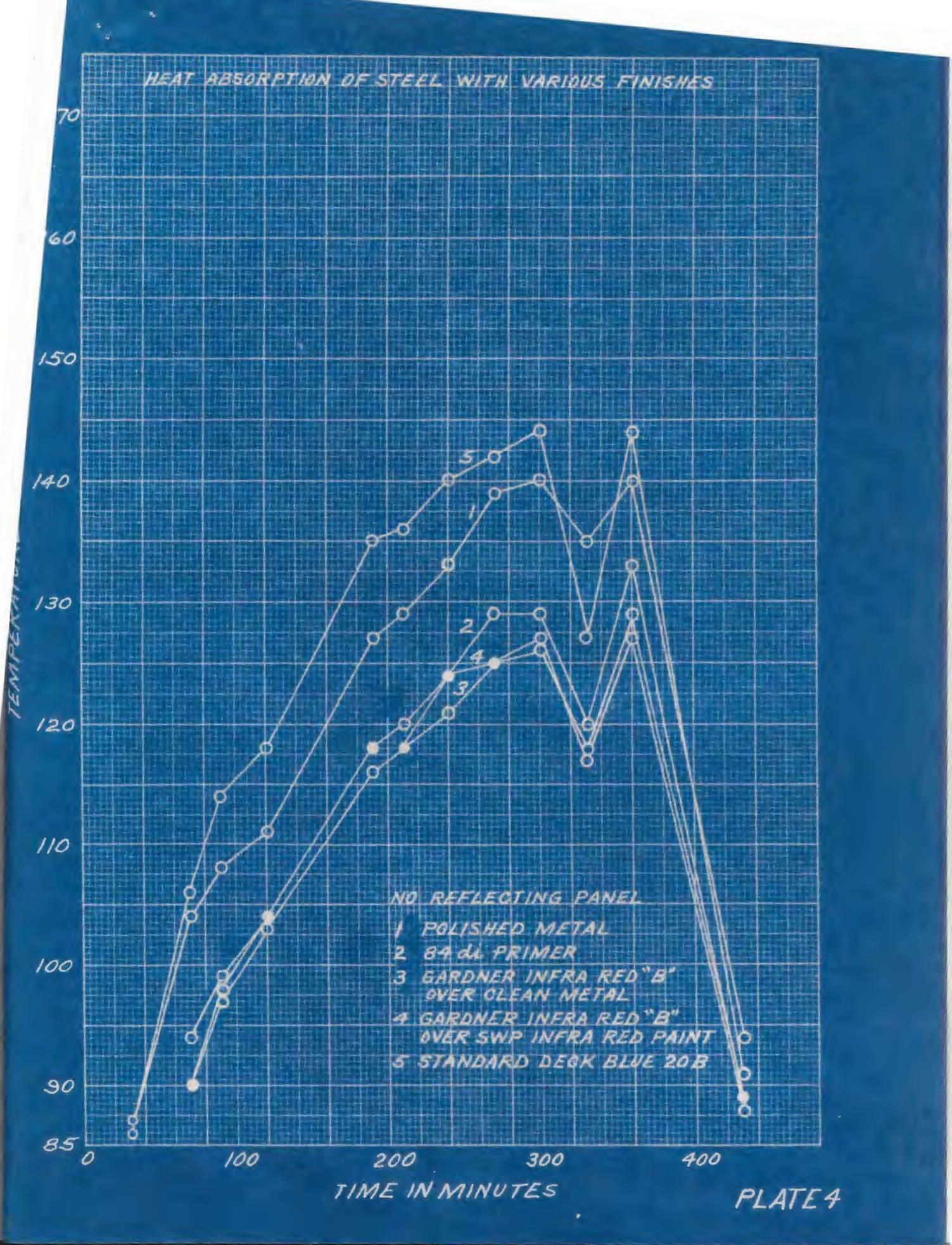
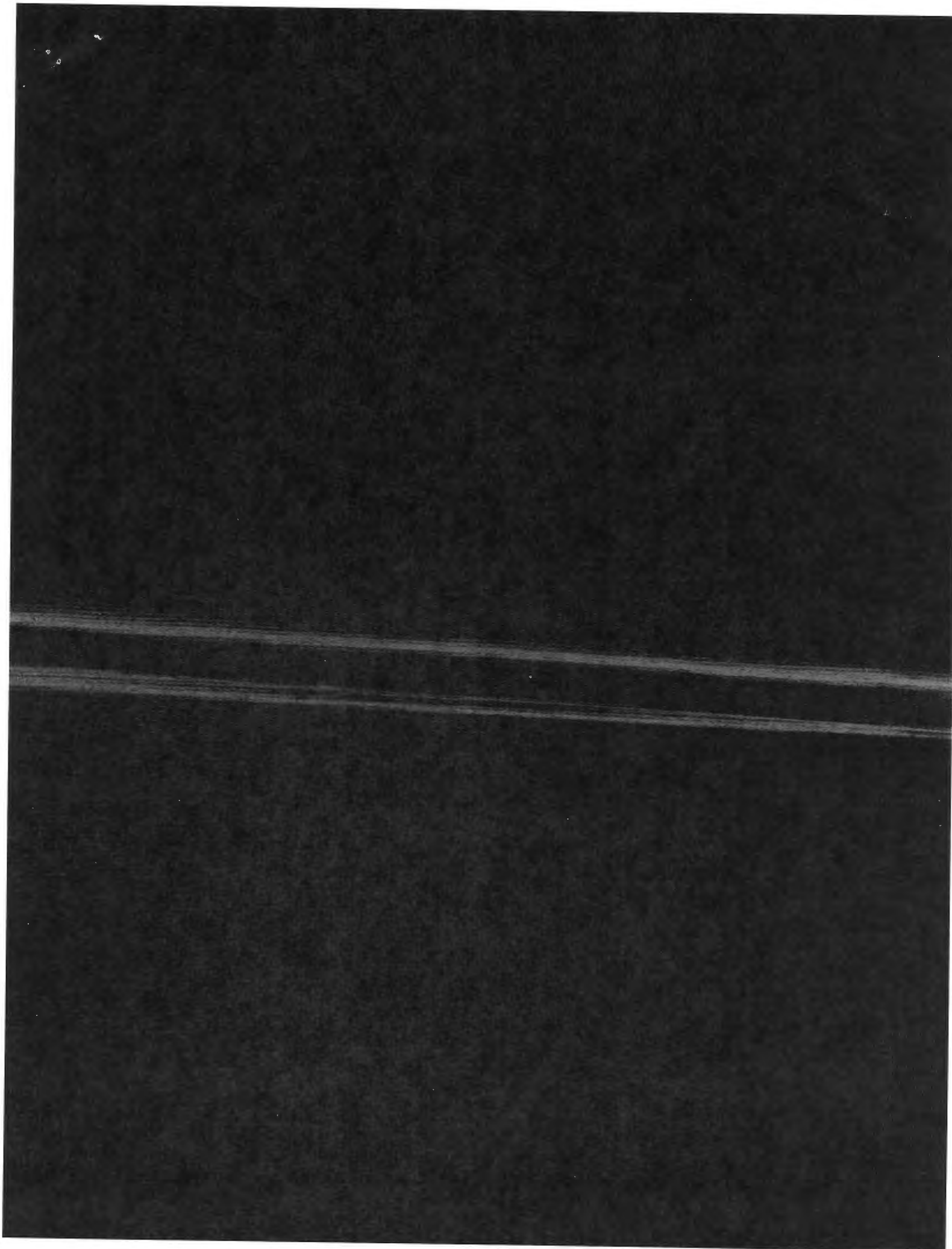

HEAT ABSORPTION OF STEEL WITH VARIOUS FINISHES
TEMPERATURE
70
60
150
140
130
120
110
100
90
85
0
100
200
300
400
TIME IN MINUTES
1
2
3
4
5
NO REFLECTING PANEL
1 POLISHED METAL
2 84 dl. PRIMER
3 GARDNER INFRA RED "B" OVER CLEAN METAL
4 GARDNER INFRA RED "B" OVER SWP INFRA RED PAINT
5 STANDARD DECK BLUE 20B

PLATE 4



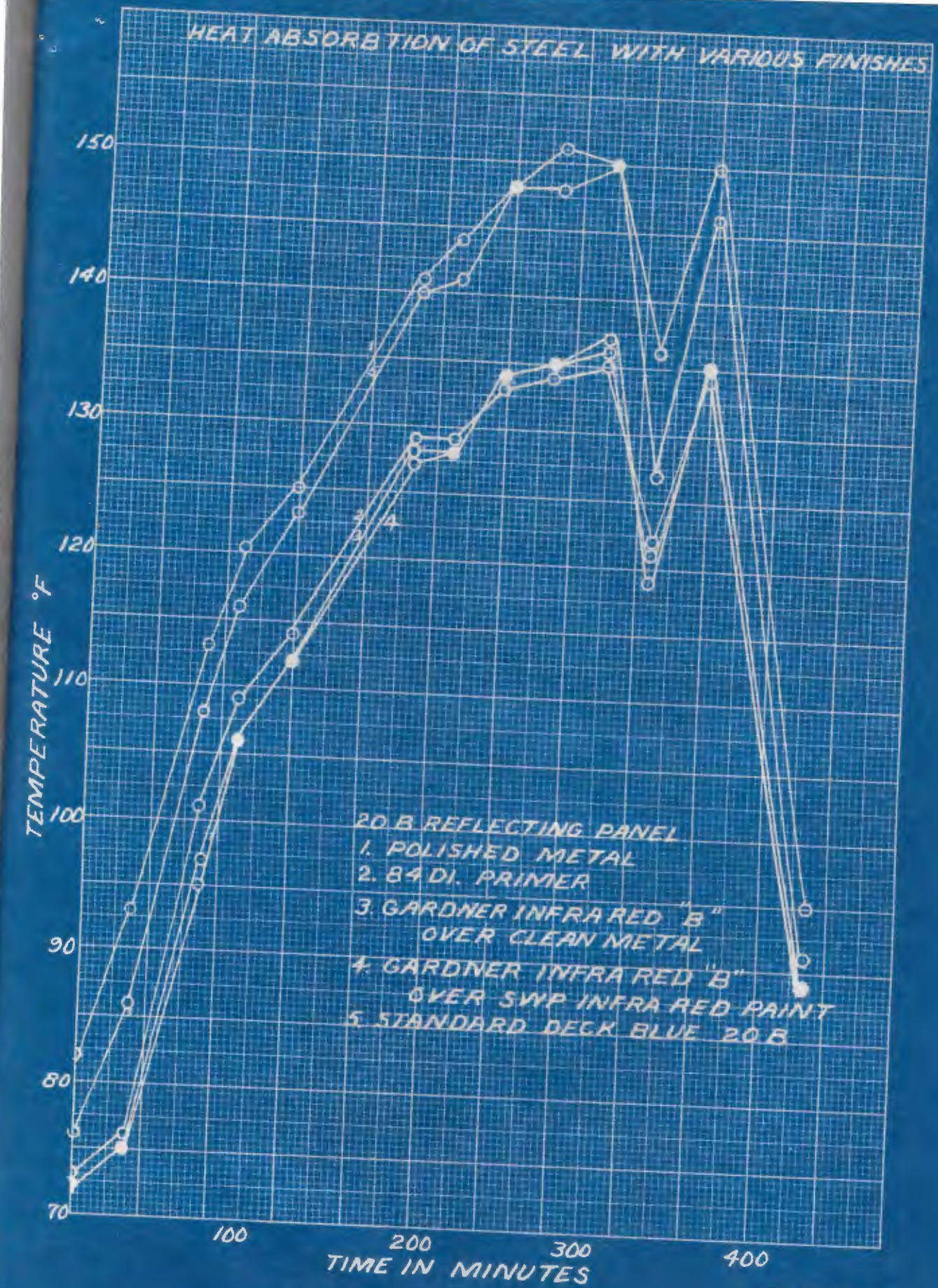

HEAT ABSORBTION OF STEEL WITH VARIOUS FINISHES
TEMPERATURE °F
150
140
130
120
110
100
90
80
70
100
200
300
400
TIME IN MINUTES
20 B REFLECTING PANEL
1. POLISHED METAL
2. 84 DI. PRIMER
3. GARDNER INFRA RED "B" OVER CLEAN METAL
4. GARDNER INFRA RED "B" OVER SWP INFRA RED PAINT
5. STANDARD DECK BLUE 20 B

PLATE 5

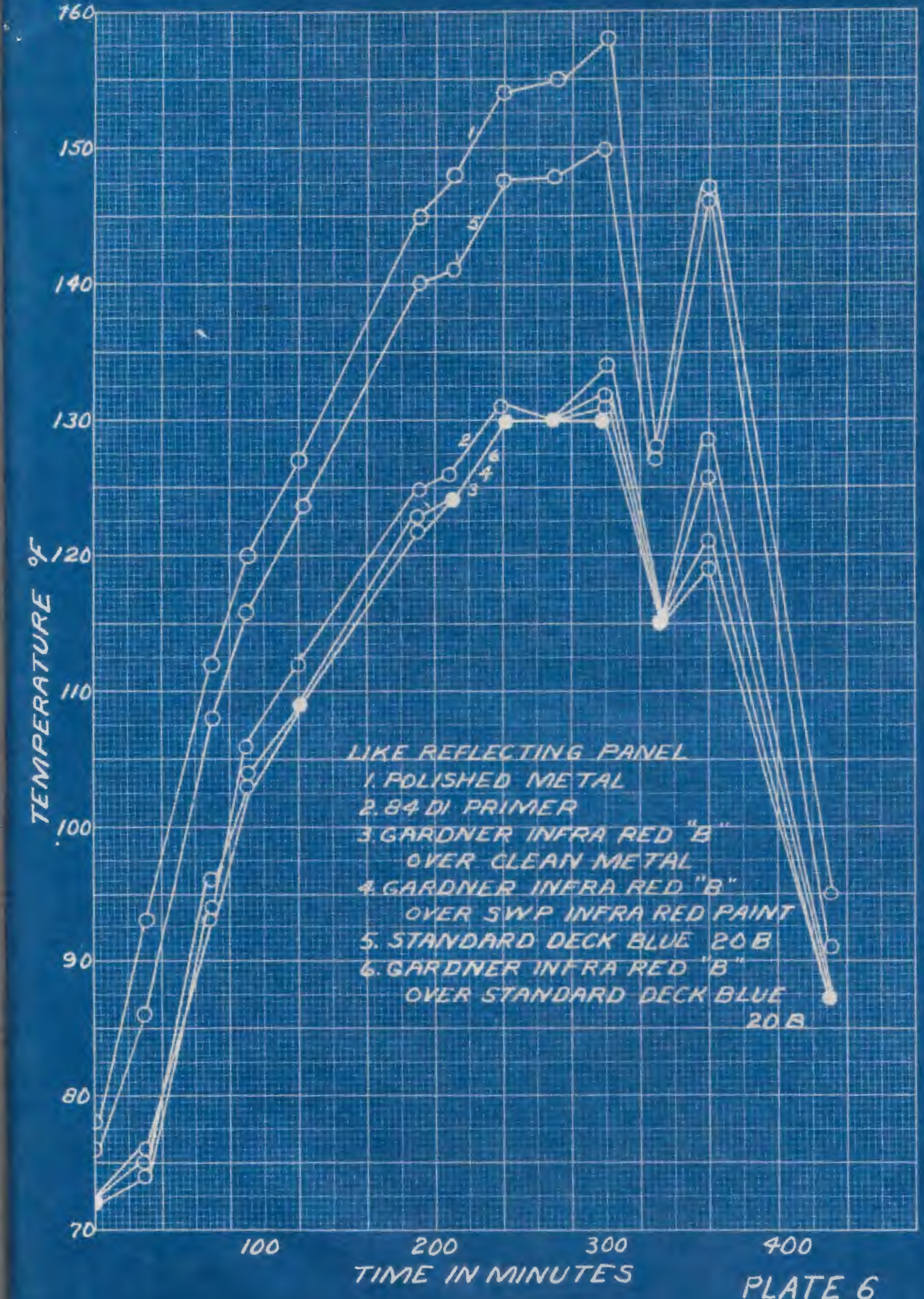

160
150
140
130
120
110
100
90
80
70
TEMPERATURE °F
100
200
300
400
TIME IN MINUTES
1
2
3
4
5
6
LIKE REFLECTING PANEL
1. POLISHED METAL
2. 84 DI PRIMER
3. GARDNER INFRA RED "B" OVER CLEAN METAL
4. GARDNER INFRA RED "B" OVER SWP INFRA RED PAINT
5. STANDARD DECK BLUE 20 B
6. GARDNER INFRA RED "B" OVER STANDARD DECK BLUE 20 B

PLATE 6

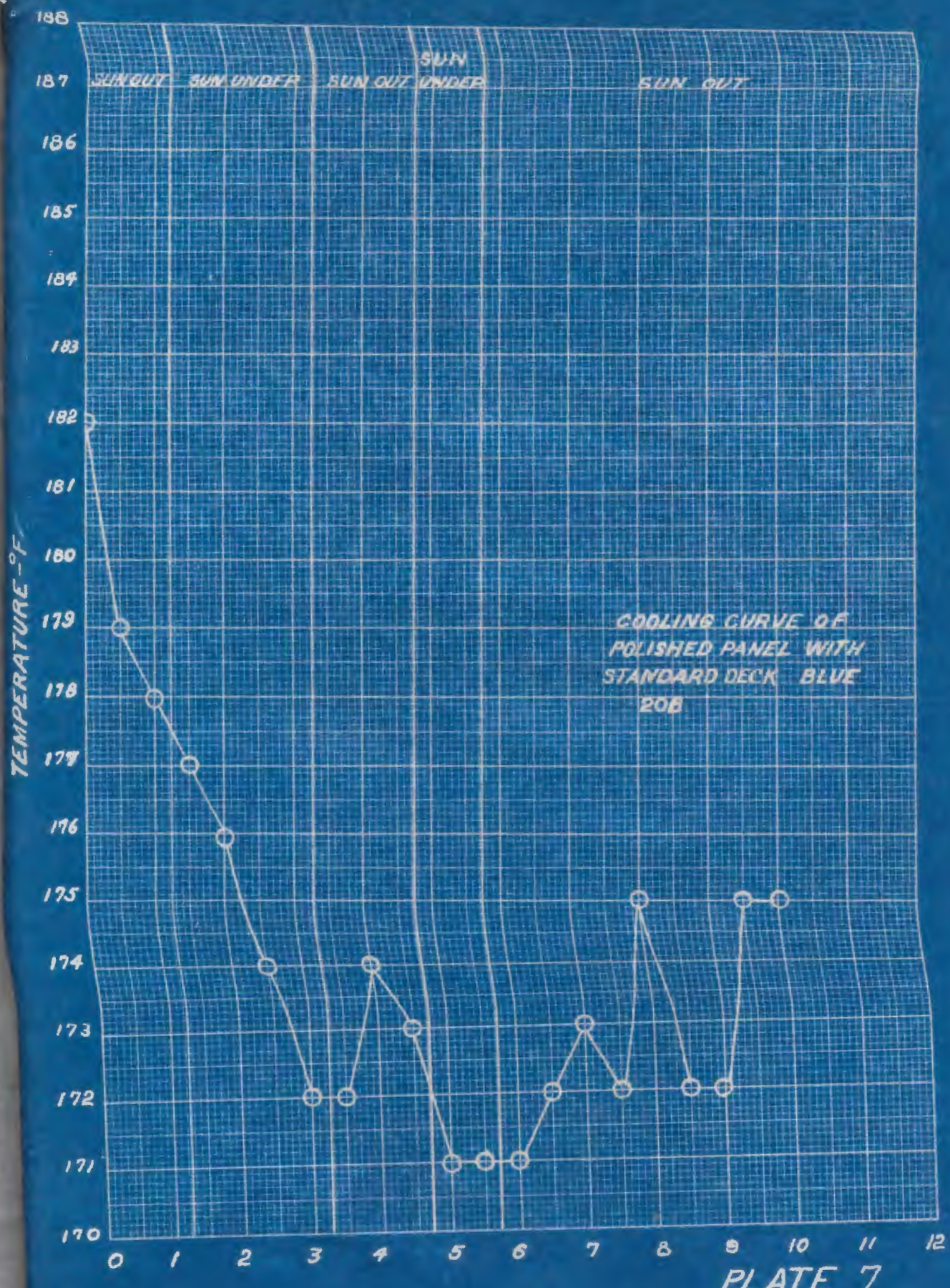

SUN
SUN OUT
SUN UNDER
SUN OUT
UNDER
SUN OUT
TEMPERATURE - °F.
188
187
186
185
184
183
182
181
180
179
178
177
176
175
174
173
172
171
170
0
1
2
3
4
5
6
7
8
9
10
11
12
COOLING CURVE OF POLISHED PANEL WITH STANDARD DECK BLUE 208

PLATE 7

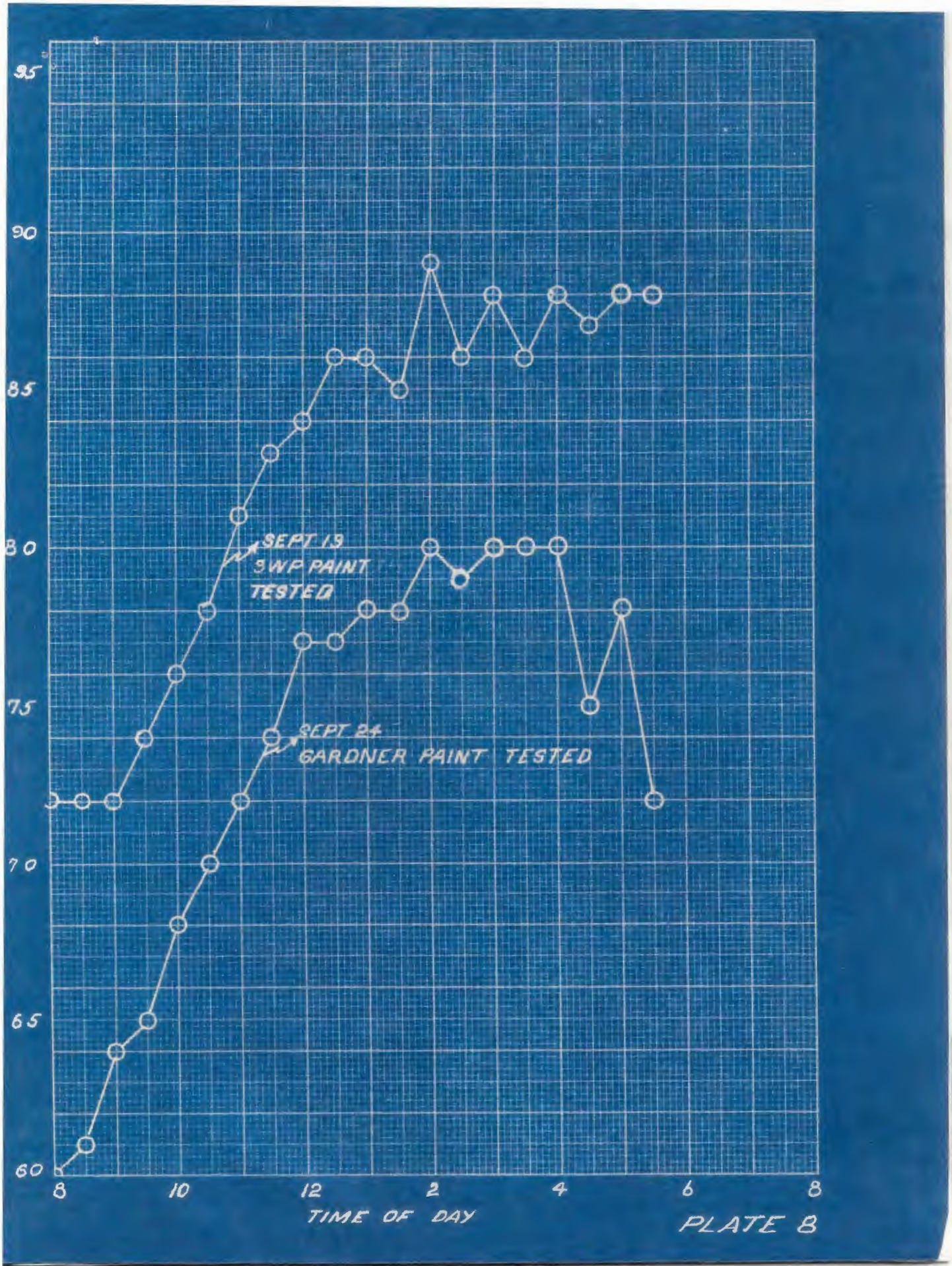

95
90
85
80
75
70
65
60
8
10
12
2
4
6
8
TIME OF DAY
SEPT 19
SWP PAINT
TESTED
SEPT 24
GARDNER PAINT TESTED

PLATE 8

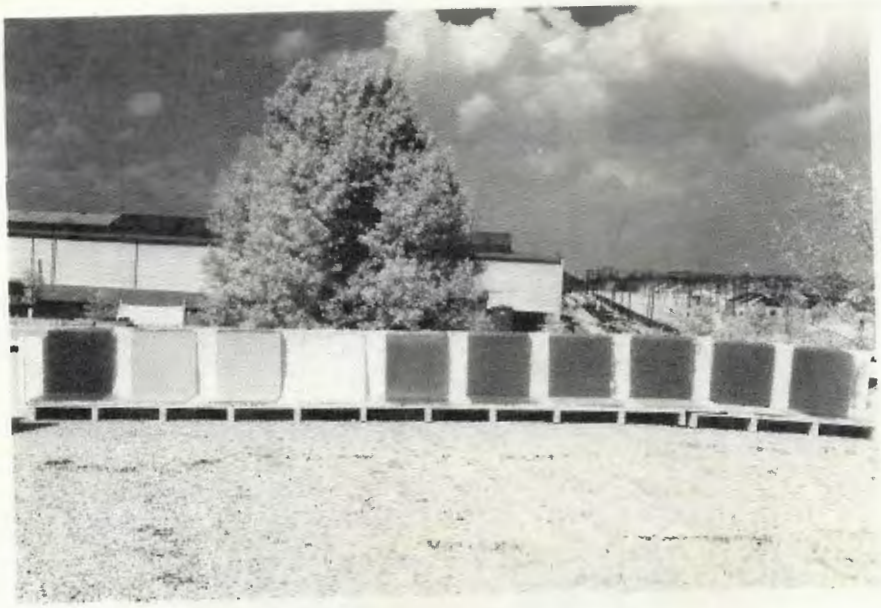


FIG. 1

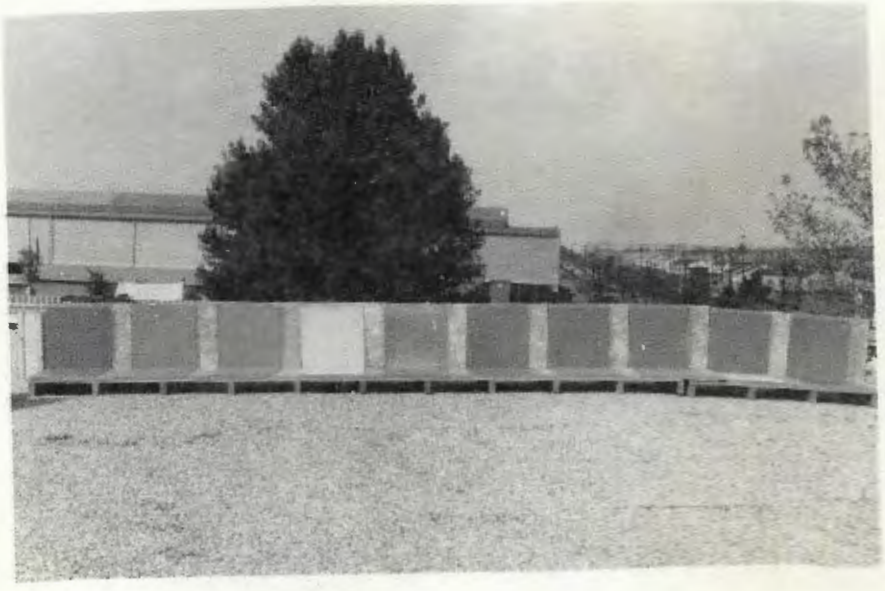


FIG. 2