February 1944

NRL Report No. P-2250

NAVY DEPARTMENT

Report

on

THE EFFECT OF VARIOUS PIGMENTS ON THE ELECTRICAL PROPERTIES OF SYNTHETIC RESIN INSULATION

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Number of Pages: Text - 6 Tables - 2 Plates - 16

Authorization: BuShips ltr S62-(1)(350) of 26 August 1943 to NRL.

Date of Tests: October 1943 to February 1944.

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Distribution: BuShips (8)

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ABSTRACT

In multi-conductor cables of the synthetic resin type it is necessary to incorporate various pigments into the insulation in order that each conductor can be readily identified. Since this incorporation of a dye or pigment into a resin might adversely affect electrical properties, it was considered desirable to investigate the problem.

A series of measurements were made on each of eight colors of two types of vinyl chloride-acetate copolymers (Vinylites). The results showed that none of the colors studied caused a marked lowering in electrical properties of the resin, although two of them (white and blue) appeared to improve the formulations in respect to insulation resistance and power factor at the higher temperatures.

INTRODUCTION

(a) Authorization

1. This work was authorized by Bureau of Ships letter S62-(1)(350) of August 26, 1943 to NRL.

(b) Statement of Problem

2. The purpose of this work is to establish any difference in the electrical properties of plasticized polyvinyl chloride when various pigments are incorporated into otherwise identical formulations.

(c) Known Facts Bearing on the Problem

3. No systematic study of the effect of coloring matter on the electrical properties of plasticized polyvinyl chloride is known to this Laboratory, although there has been work published by F. G. Clark of the Carbide & Carbide Chemicals Corporation in which the effect of many different coloring materials on the physical and chemical properties of copolymer vinyl chloride-acetate compounds are discussed.

4. It is to be expected that the incorporation of a conducting material like carbon black in an insulator will have a deleterious effect on the electrical properties of that insulator. Likewise, the use of a chloride ion adsorbing material such as basic lead carbonate (white lead) could be expected to improve the electrical properties of polyvinyl chloride type insulation in the higher temperature range. Because many factors are involved, the exact effect of such materials on electrical insulation cannot always be predicted, but must be determined experimentally.

METHODS

(a) Materials

5. Samples of eight different colors of Vinylite 5900 and like colors of Vinylite 5901 were furnished by the Carbide and Carbon Chemicals Corporation. All the VE 5900 samples were said by the manufacturer to have the same chemical composition except for the added colors. The same was true for the VE 5901 samples. Chemical analysis showed these samples to be as claimed by the manufacturer except for the percentage of plasticizer in the 5900 blue. This value was found to be low (see Table I).

(b) Equipment and Procedure

6. The 60 cycle power factor measurements were made with a G. R. Type 740 BG bridge, while the 10,000 cycle measurements were made with a G. R. Type 716 A bridge. The leads of both bridges were of the guarded type so they could be run through oven walls without electrical interference. Guard electrodes were not used on the specimens themselves in this case since such electrodes have no appreciable effect on the power factor of dry samples (negligible surface leakage). Insulation resistance measurements were made on both wet and dry samples with a General Radio Type 544-BS8 special megohm bridge at 25°C using 500 volts potential across the specimen. Guard electrodes were used in these measurements. The dry specimens were conditioned in a drying oven for 6 hours at 100°C while the wet specimens were conditioned 100 hours at 50°C and 95% relative humidity. The specimens in all cases were 3.75" square by 0.035" thick with test electrodes 2.5" in diameter (grounded electrodes were 3.75" square).

7. The numerous points on the power factor temperature curves were obtained by using a procedure involving constant rate of temperature rise for the specimen. To accomplish this the specimens were placed in a cold forced draft oven and the heat input adjusted to give a rate of temperature increase of about two degrees per minute. Electrical measurements were made continuously on the specimens, one after another, while the temperature was rising. The temperature was recorded with a recorder having a roll type chart (chart speed one inch per minute) and the electrical data written directly on the chart opposite the correct points on the temperature curve. This procedure made it possible to obtain quickly points at intervals of not more than five degrees apart over the entire temperature range. The rate of temperature rise of the oven is not very critical in that measurements on identical specimens using rates of rise of one degree per minute and three degrees per minute respectively showed satisfactory agreement.

8. The dielectric strength measurements were made at 25°C (specimens conditioned at 40% relative humidity) under oil using a 1 kva transformer and aligned electrodes one inch in diameter by one inch in height with corners rounded to a radius of 1/8 inch. Voltages were measured directly on the high potential side of the transformer using a calibrated vacuum tube voltmeter in conjunction with high voltage resistance units. A constant rate of

voltage rise of 500 volts per second was applied until breakdown occurred.

DATA OBTAINED

(a) Curves or Plots of Data

9. On Plates 1 through 16 are given curves of dissipation factor versus temperature at 60 cycles and at 10,000 cycles for the various colors of VE 5900 and VE 5901. Each curve for each frequency represents two independent sets of data taken at different times on different specimens. The circles represent specimen #1 and the triangles represent specimen #2.

(b) Data in Tabular Form

10. In Table I is given chemical analyses made on 4 colors of each Vinylite resin (5900 and 5901). Table II gives a summary of the electrical properties of all the materials under investigation.

(c) Probable Errors

11. The good checks shown by the circular and triangular points on the curves, Plates 1 to 16, show the power factor-temperature data to be quite reproducible. The #2 samples (triangles) were always cut from a different place in the roll than the #1 samples (circles) and were always conditioned independently and measured on different days than the #1's.

12. The insulation resistance and dielectric strength data are not as reproducible as the power factor determinations but are within the limits usually expected for those types of measurements. The dielectric strength values represent an average of 6 punctures and the insulation resistance measurements represent the average of measurements on two independent samples. The average of the deviation from the mean was 2.8% for all the dielectric strength measurements and 16% for all the insulation resistance measurements.

13. The variation in the percent plasticizer obtained for the various VE 5901 samples (see Table I) might be within the total experimental error of the method although this variation is greater than that usually encountered in multiple determinations on identical material. The variation obtained for the VE 5900 samples is definitely beyond experimental error. The blue sample has too low

a plasticizer content. It is closer to that of VE 5901 material than it is to the VE 5900. Six analyses were made of this material with results as follows (the other colors were analyzed in triplicate):

	Type	Color	Filler % wt.	Resin % wt.	Plasticizer % difference
1	VE 5900	blue	4.3*	65.6	30.1
2	"	"	2.4	65.7	31.9
3	"	"	2.5	64.8	32.7
4	"	"	3.3	66.0	30.7
5	"	"	3.0	65.1	31.9
6	"	"	2.9	65.5	31.6
Ave**	"	"	2.8	65.5	31.7

* This value is obviously too high. The sample probably became contaminated with dust.
** Sample #1 omitted from this average.

Since the VE 5900 blue has about 6% (of total weight) less plasticizer in it than the other VE 5900 colors analyzed and since all colors were supposed to have the same plasticizer content, it appears that the manufacturer made an error in the formulation.

14. Calibrations with known samples indicate that the real values of resin and plasticizer content will differ by about 1% from those given in Table I because the plasticizer is not completely separated from the resin. For instance, if the quantitative analysis indicates the resin content to be 66% and plasticizer 30%, the true values may be taken as resin 65% and plasticizer 31%. This method of separating the components of plasticized polyvinyl chloride is based on differences in solubility in organic solvents. The details of this method are given in NRL letter S62-2(9)(460) of 21 April, 1943 to the Bureau of Ships.

CONCLUSIONS AND RECOMMENDATIONS

(a) Facts Established

15. Although the dielectric strength of the black VE 5900 sample appears somewhat less than that of the other samples (column I of Table II), there are no significant differences in the dielectric strength shown by various colors. There are differences shown, however, in the insulation resistance of the various samples. The blue color is distinctly higher than the others for the VE 5900 formulation (chemical analysis showed this particular batch to be improperly compounded when compared to the other VE 5900 colors), and both the white and the blue are distinctly better for the VE 5901 formulations. The biggest difference between the colors is shown by the dissipation factor temperature curves for these materials at 60 cycles and at 10,000 cycles. The temperature at which the dip occurs in the 60 cycle dissipation curve is distinctly higher for the blue VE 5900 material than for any of the other 5900's. The same is true for both the blue and the white VE 5901. These same conditions hold true for the peak in the 10,000 cycle dissipation factor curves.

(b) Opinions

16. That the blue and white colors are superior to the other six for the VE 5901 is due to the probable presence of more, or a better, stabilizer in these colors. Chemical analysis shows each white specimen to contain over 6% filler. This is a larger percentage than was found in the other colors, and might be responsible for the better electrical properties shown by these specimens. It is probable that the white color is basic lead carbonate. This material is known to improve the heat stability and high temperature electrical properties of polyvinyl chloride formulations. It is not known what the blue color is, but it appears that this substance also has a stabilizing effect on the resin.

17. The black material (which contains carbon black) was not much different in electrical properties from the yellow, green, red, brown, or orange. This indicates that the percentage of carbon black is so small that it does not have an appreciable effect on the electrical properties of the formulations.

(c) Conclusions

18. No particular color appears to be distinctly worse than any other in the samples tested. Two of the colors (white and blue) in the VE 5901 showed superior electrical properties. The presence of carbon black in the samples did not appear to have any marked deleterious effect in this regard.

19. Since many different materials may be used by different concerns to give the same color, it cannot be concluded that the information gathered on the eight colors of this report will always be true for similar appearing colors used by various companies. For instance, Clark (see Paragraph 3 above) listed 25 different coloring materials that could be used to give a red color. It is not known what particular materials were used to color the specimens measured here. All that can be said is that none of the eight colors studied produced any marked lowering of the electrical properties of the VE 5900 or VE 5901 formulations.

SUMMARY

20. The electrical properties of eight colors of VE 5900 and of VE 5901 were measured and are tabulated in Table II and curves are shown on Plates 1 to 16. None of the colors appeared of itself to cause poor electrical properties. In two instances, VE 5901 - white and VE 5901 - blue, the electrical properties were distinctly improved because the coloring agent appeared to serve also as a stabilizer.

Table I

Distribution of Resin, Filler, and Plasticizer in Synthetic Resin Insulation of Various Colors

Type	Color	Filler* % wt	Resin	Plasticizer % difference
VE 5900	black	6.1	57.0	36.9
"	orange	1.6	59.2	39.2
"	blue (dark)	2.8	65.5	31.7
"	white	6.6	55.0	38.4
VE 5901	black	3.4	65.9	30.7
"	orange	4.9	66.1	29.0
"	blue	4.9	66.7	28.4
"	white	6.1	63.8	30.1

* Component insoluble in hot diisopropyl ketone.

Table II

Electrical Properties of VE 5901 and VE 5900 as a Function of Color

Type and plate number	Color	Dielectric strength 25°C, 40% R.H. volts/mil	Insulation resistance** Dry	Insulation resistance** Wet	Dip in 60 cycle dissipation factor curve Temp. °C	Dip in 60 cycle dissipation factor curve Height %	Peak in 10,000 cycle dissipation factor curve Temp. °C	Peak in 10,000 cycle dissipation factor curve Height %
VE 5901								
1	orange	720	800	17	57	4.1	41	20.4
2	green	715	180	10	59	3.4	38	20.1
3	brown	705	600	25	59	3.7	40	20.1
4	black	675	700	12	60	3.6	36	17.5
5	yellow	745	230	13	62	2.7	38	20.3
6	red	732	160	12	62	3.3	42	20.4
7	blue	745	1200*	200*	85	2.3	52	19.0
8	white	675	1500*	300*	86	2.4	52	18.3
VE 5900								
9	orange	702	580	11	59	3.5	42	20.5
10	green	780	125	13	58	3.3	38	20.2
11	brown	797	320	18	58	3.5	41	20.2
12	black	610	400	18	58	3.7	35	17.7
13	yellow	735	130	7	63	2.9	37	20.2
14	red	747	145	8	58	3.3	39	20.3
15	blue	722	800	50	66	4.0	51	20.7
16	white	780	170	11	62	3.0	40	20.6

* Approximation (electrodes started to peel off); dissipation factor data good.

** Multiply these figures by 10^9 ohms (1000 megohms) to obtain insulation resistance across a thickness of 35 mils and area of 4.9 square inches. Dry samples were conditioned 6 hours at 100°C (dry). Wet samples were conditioned 100 hours at 50°C, 95% relative humidity. All measurements were made at 25°C.

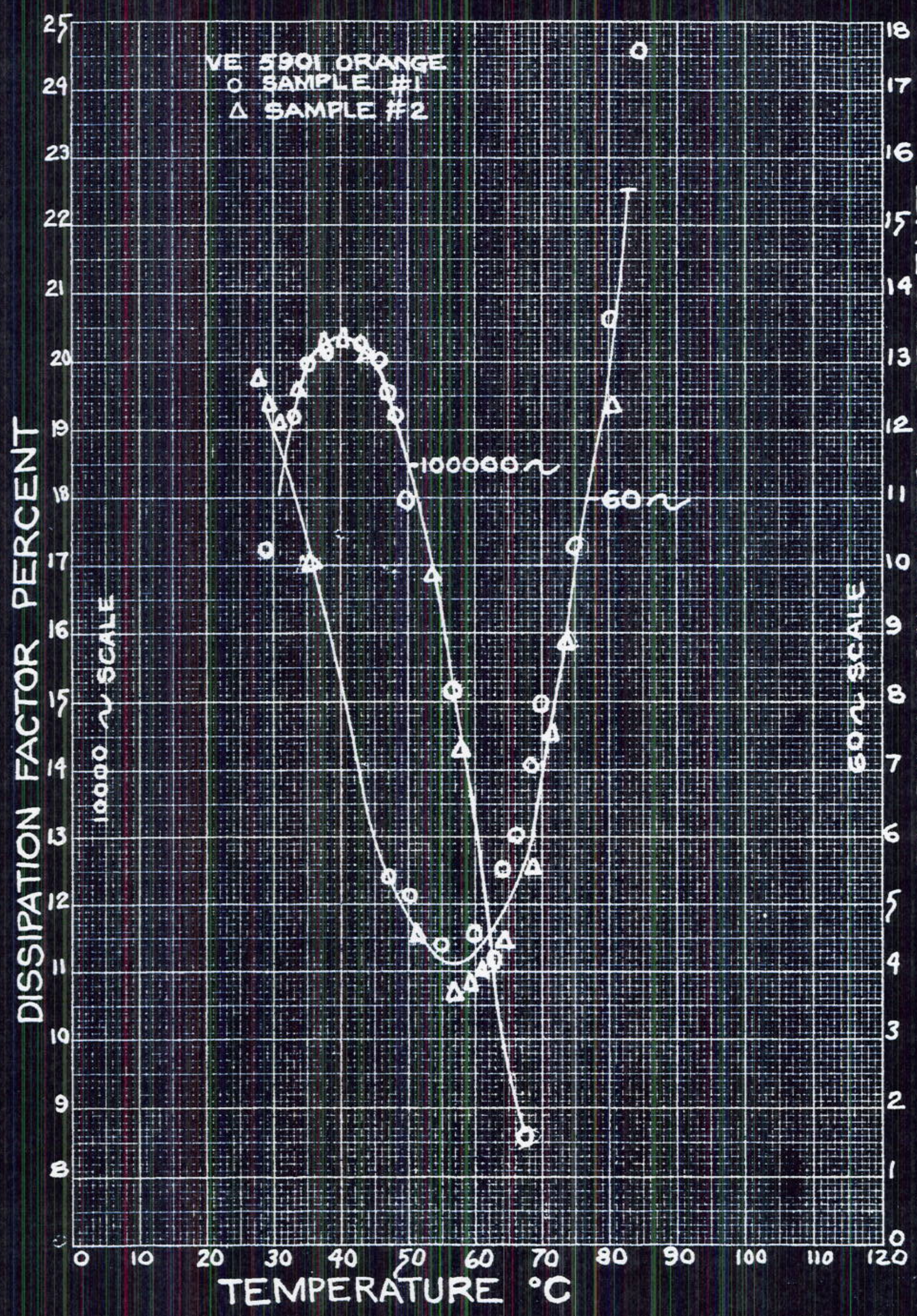
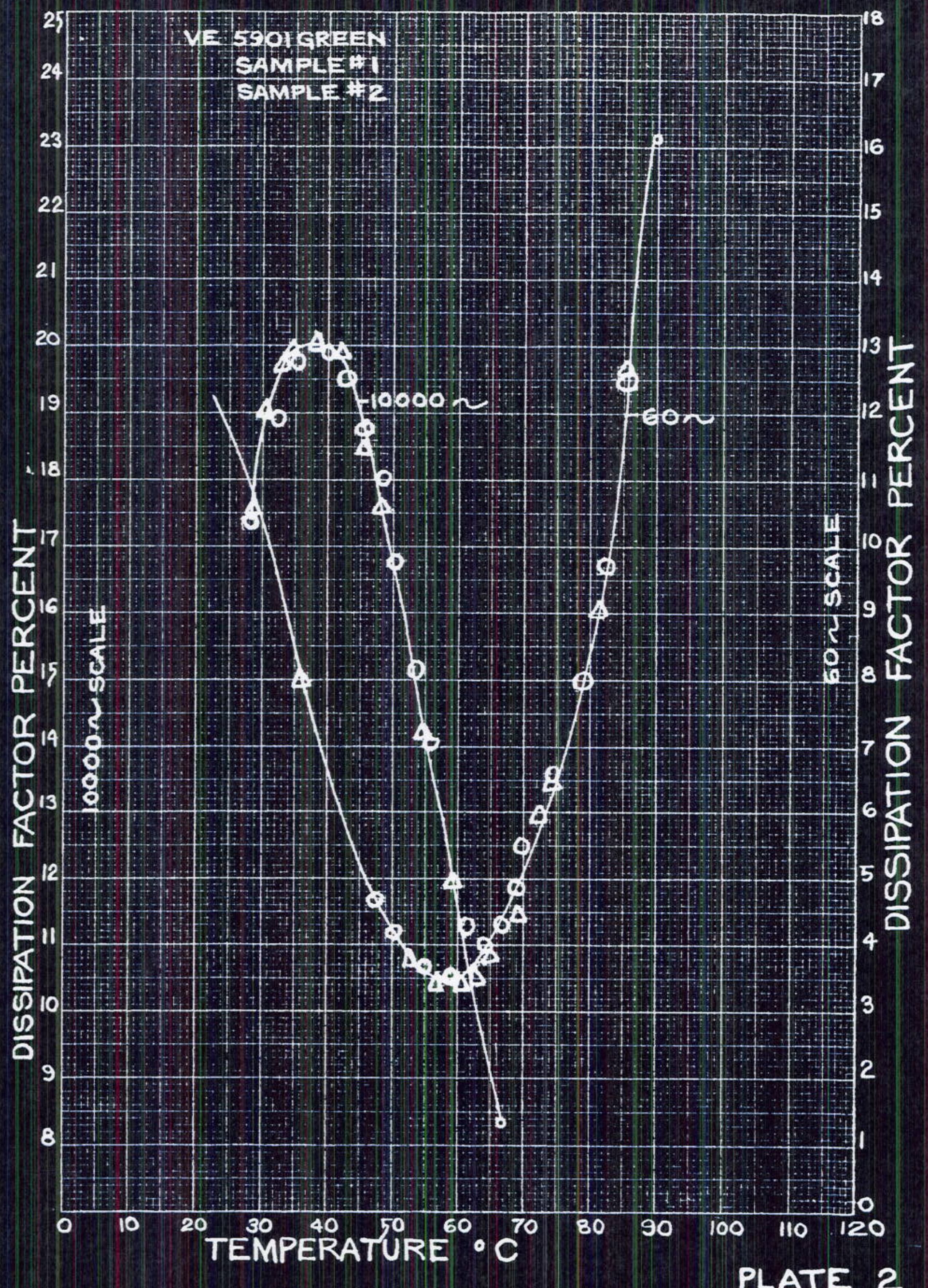

VE 5901 ORANGE
O SAMPLE #1
Δ SAMPLE #2
100000 ~
60 ~
DISSIPATION FACTOR PERCENT
10000 ~ SCALE
60 ~ SCALE
DISSIPATION FACTOR PERCENT
TEMPERATURE °C

PLATE I


VE 5901 GREEN
SAMPLE #1
SAMPLE #2
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60 ~
10000 ~ SCALE
60 ~ SCALE
DISSIPATION FACTOR PERCENT
DISSIPATION FACTOR PERCENT
TEMPERATURE °C

PLATE 2

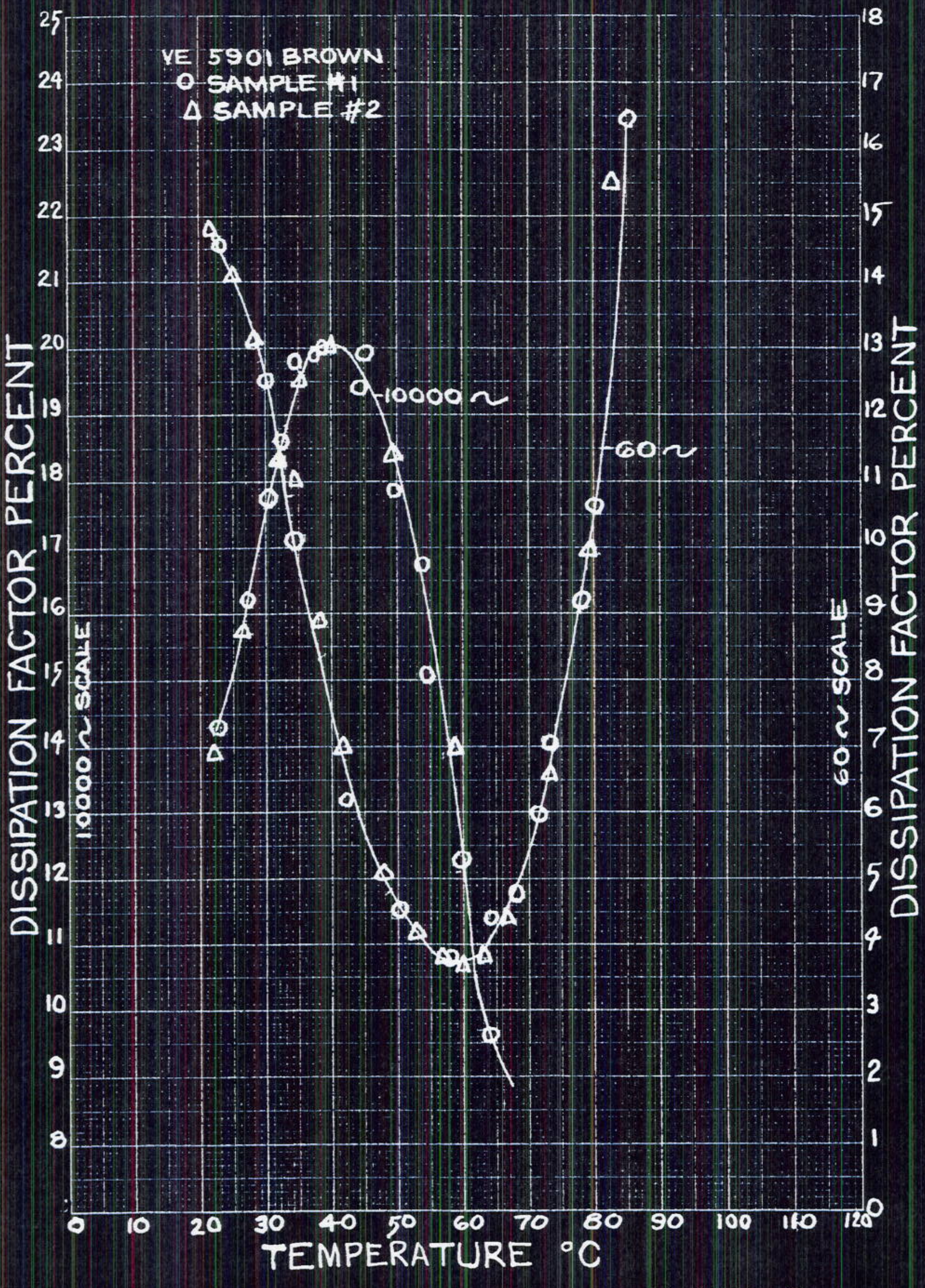

VE 5901 BROWN
O SAMPLE #1
Δ SAMPLE #2
-10000 ~
-60 ~
DISSIPATION FACTOR PERCENT
10000 ~ SCALE
60 ~ SCALE
DISSIPATION FACTOR PERCENT
TEMPERATURE °C
0 10 20 30 40 50 60 70 80 90 100 110 120
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

PLATE 3

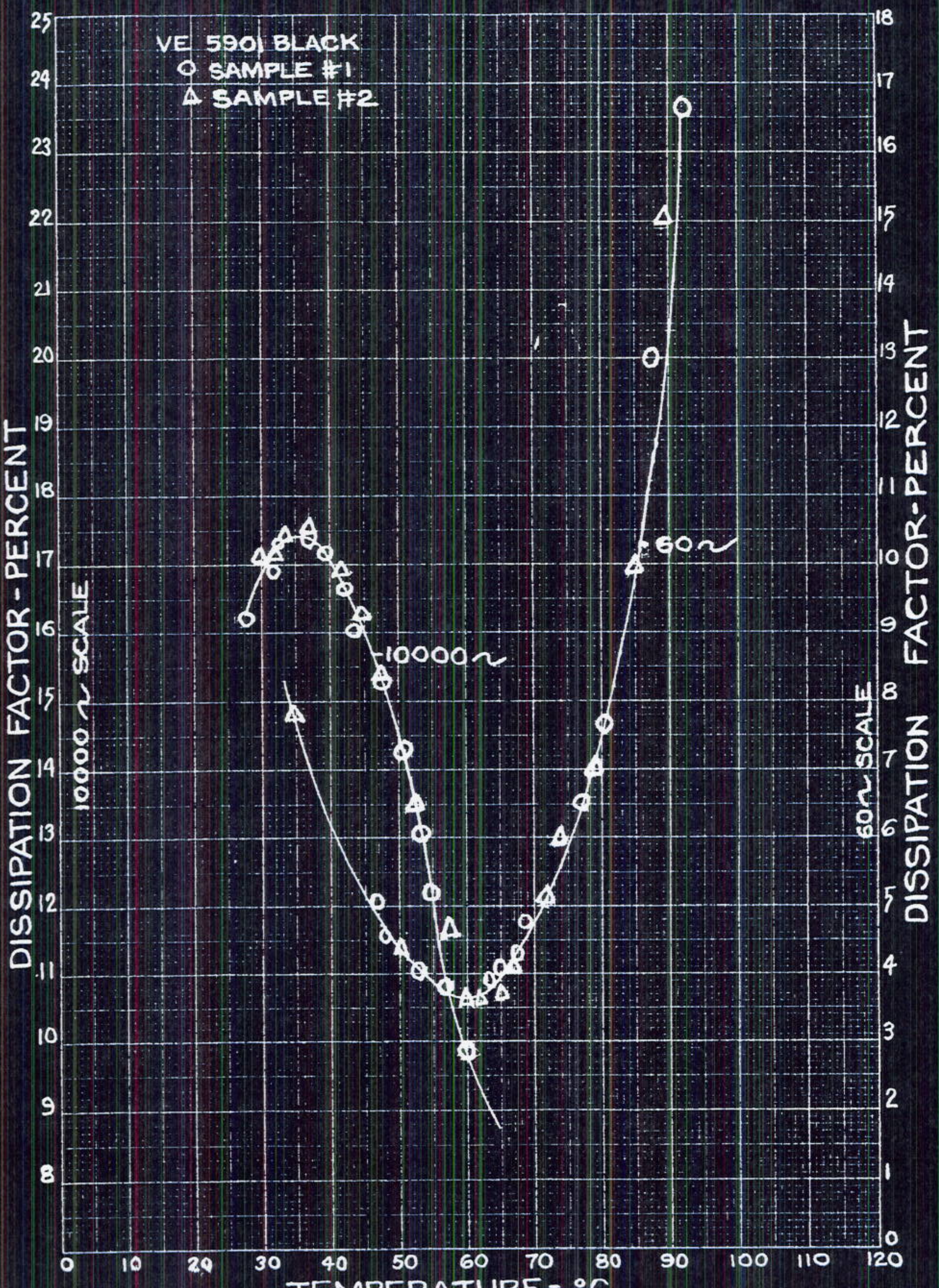

VE 5901 BLACK
O SAMPLE #1
Δ SAMPLE #2
DISSIPATION FACTOR - PERCENT
10000 ~ SCALE
DISSIPATION FACTOR - PERCENT
60 ~ SCALE
60 ~
10000 ~
TEMPERATURE - °C

PLATE 4

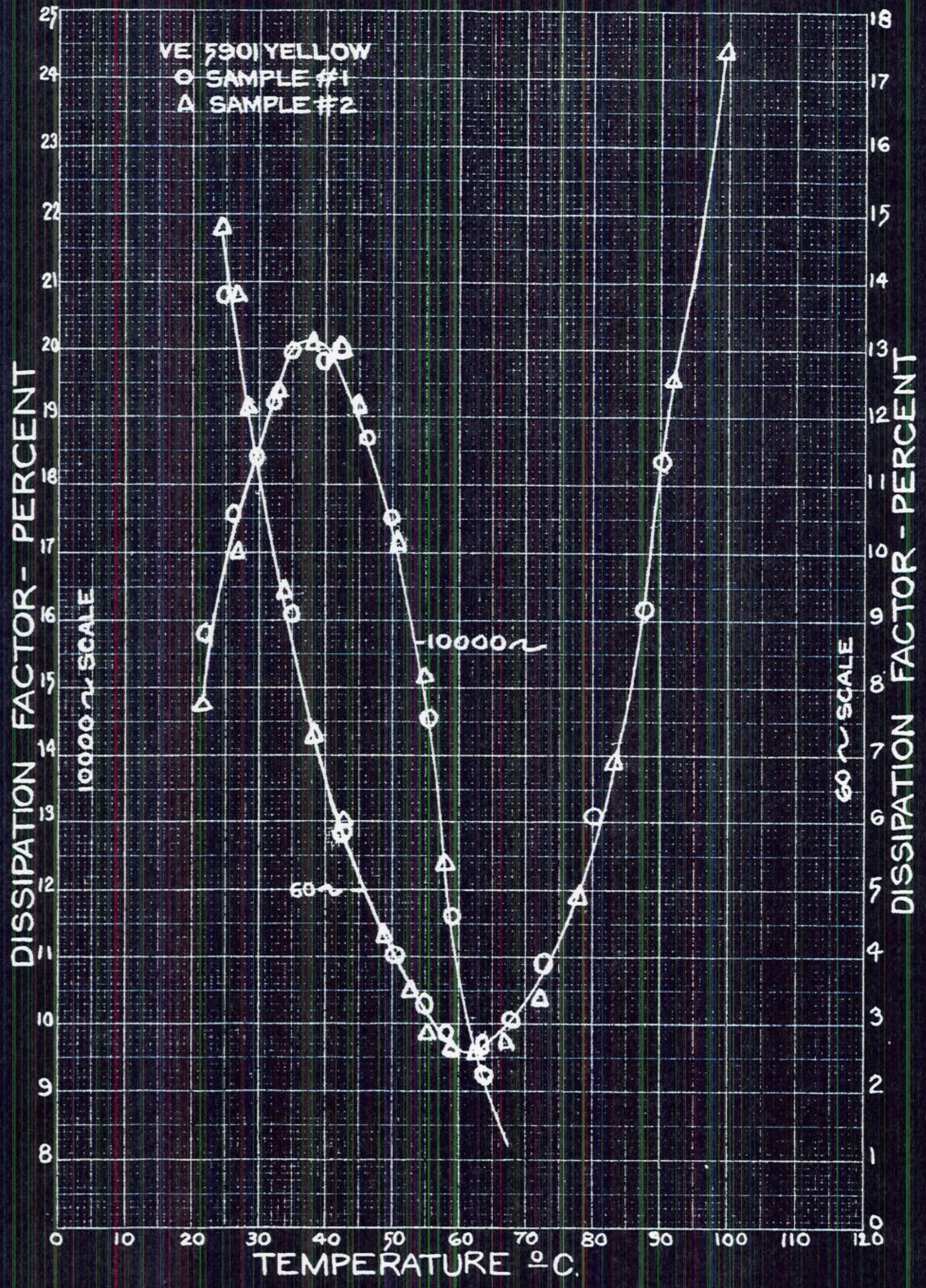
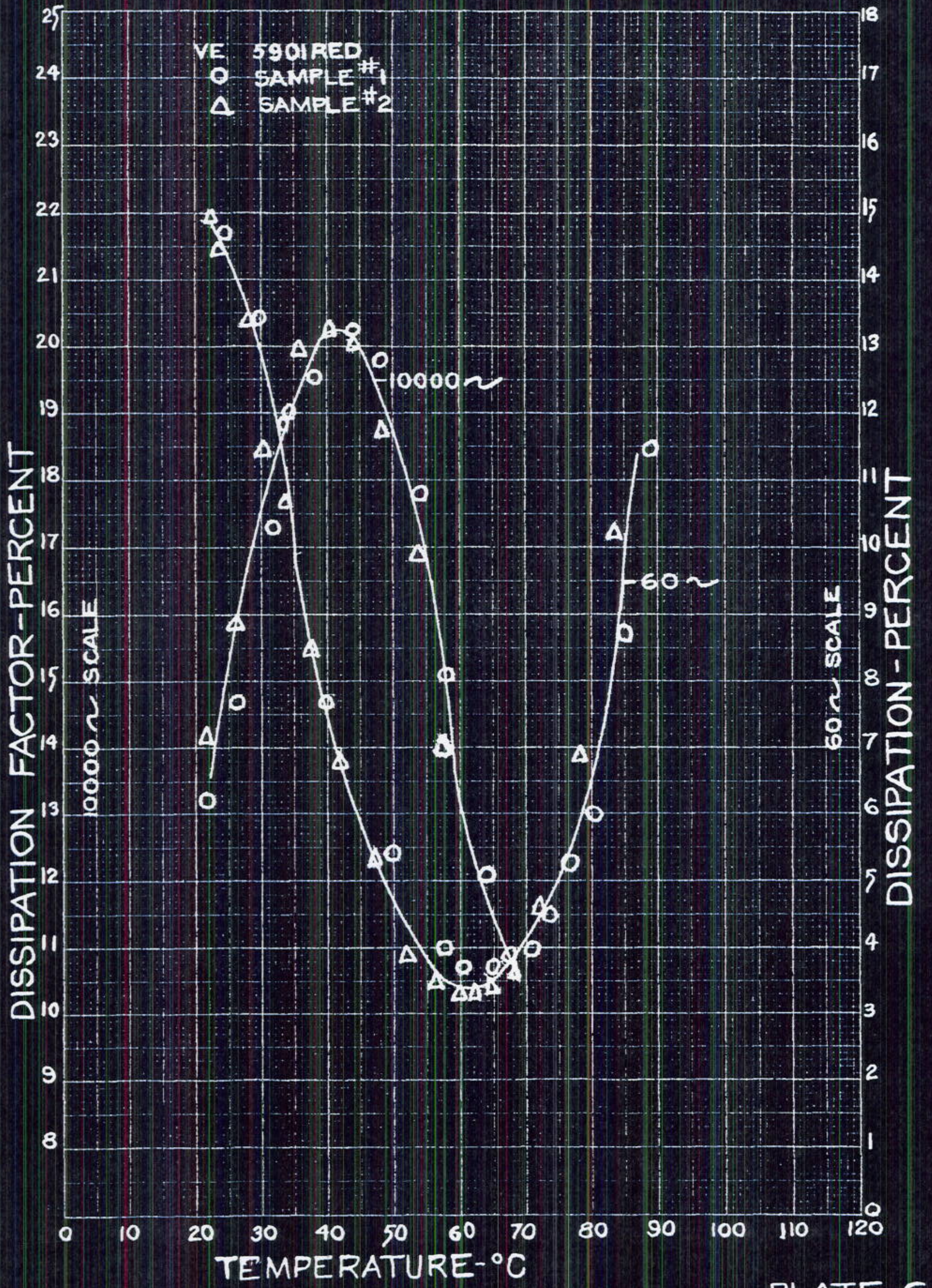

VE 5901 YELLOW
O SAMPLE #1
Δ SAMPLE #2
DISSIPATION FACTOR - PERCENT
10000 ~ SCALE
60 ~ SCALE
-10000~
60~
TEMPERATURE °C.
0 10 20 30 40 50 60 70 80 90 100 110 120
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

PLATE 5


VE 5901 RED
O SAMPLE #1
Δ SAMPLE #2
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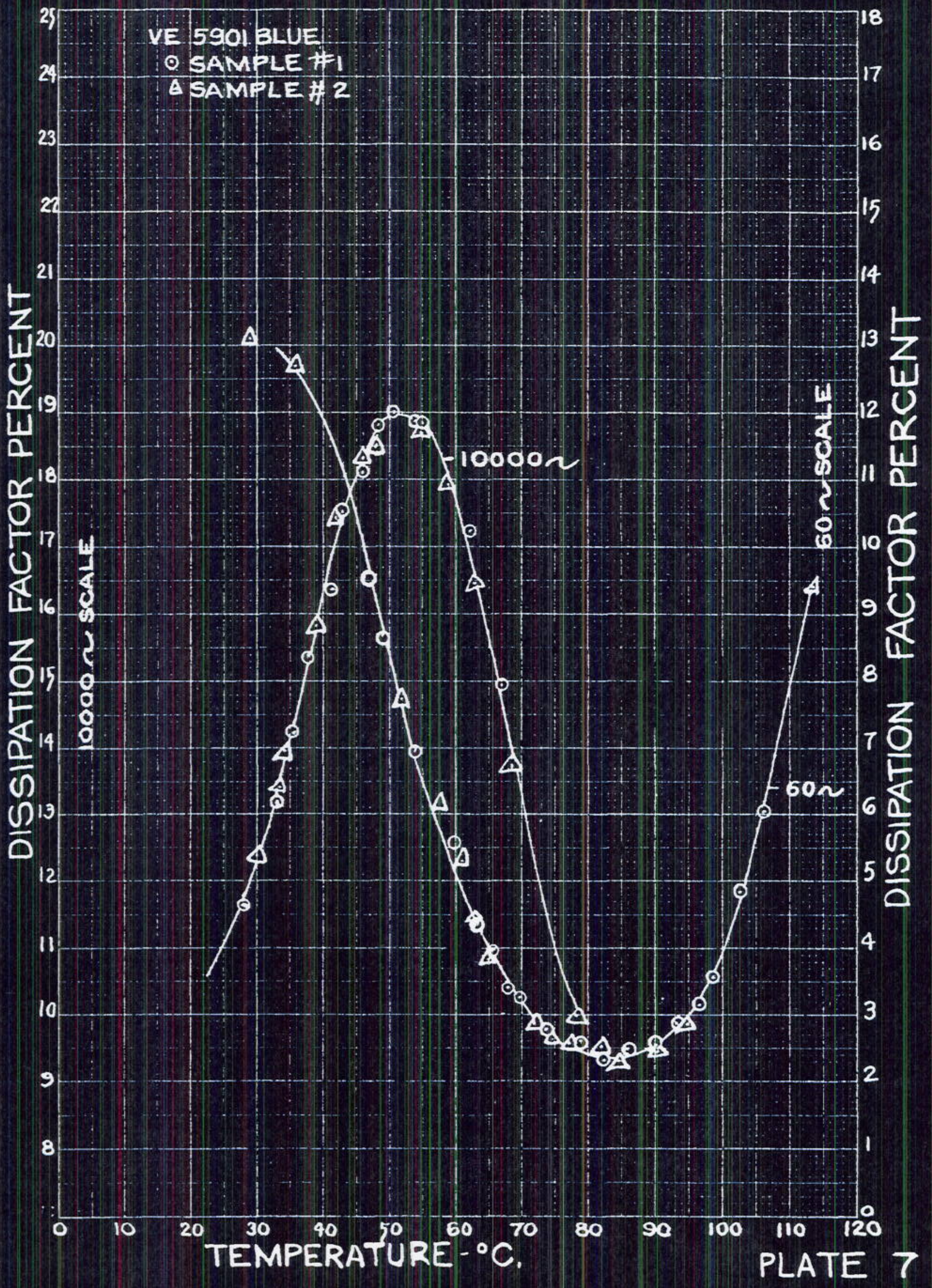
60~
DISSIPATION FACTOR-PERCENT
10000~ SCALE
60~ SCALE
DISSIPATION-PERCENT
TEMPERATURE-°C

PLATE 6


VE 5901 BLUE
⊙ SAMPLE #1
Δ SAMPLE # 2
DISSIPATION FACTOR PERCENT
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60 ~ SCALE
DISSIPATION FACTOR PERCENT
10000 ~
60 ~
TEMPERATURE - °C.
0 10 20 30 40 50 60 70 80 90 100 110 120

PLATE 7

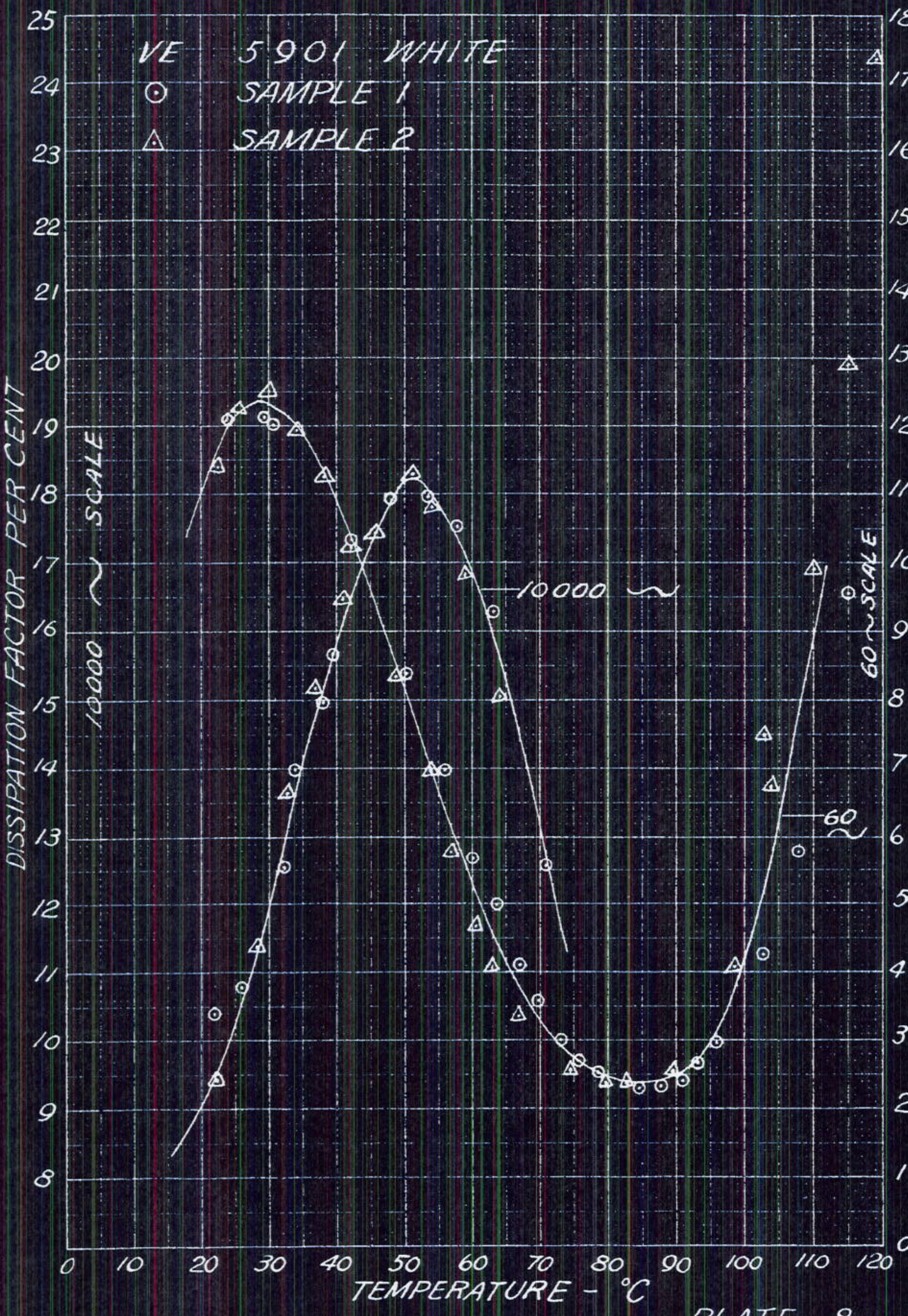

VE 5901 WHITE
SAMPLE 1
SAMPLE 2
DISSIPATION FACTOR PER CENT
10000 ~ SCALE
10000 ~
60 ~
60 ~ SCALE
DISSIPATION FACTOR - PER CENT
TEMPERATURE - °C

PLATE 8

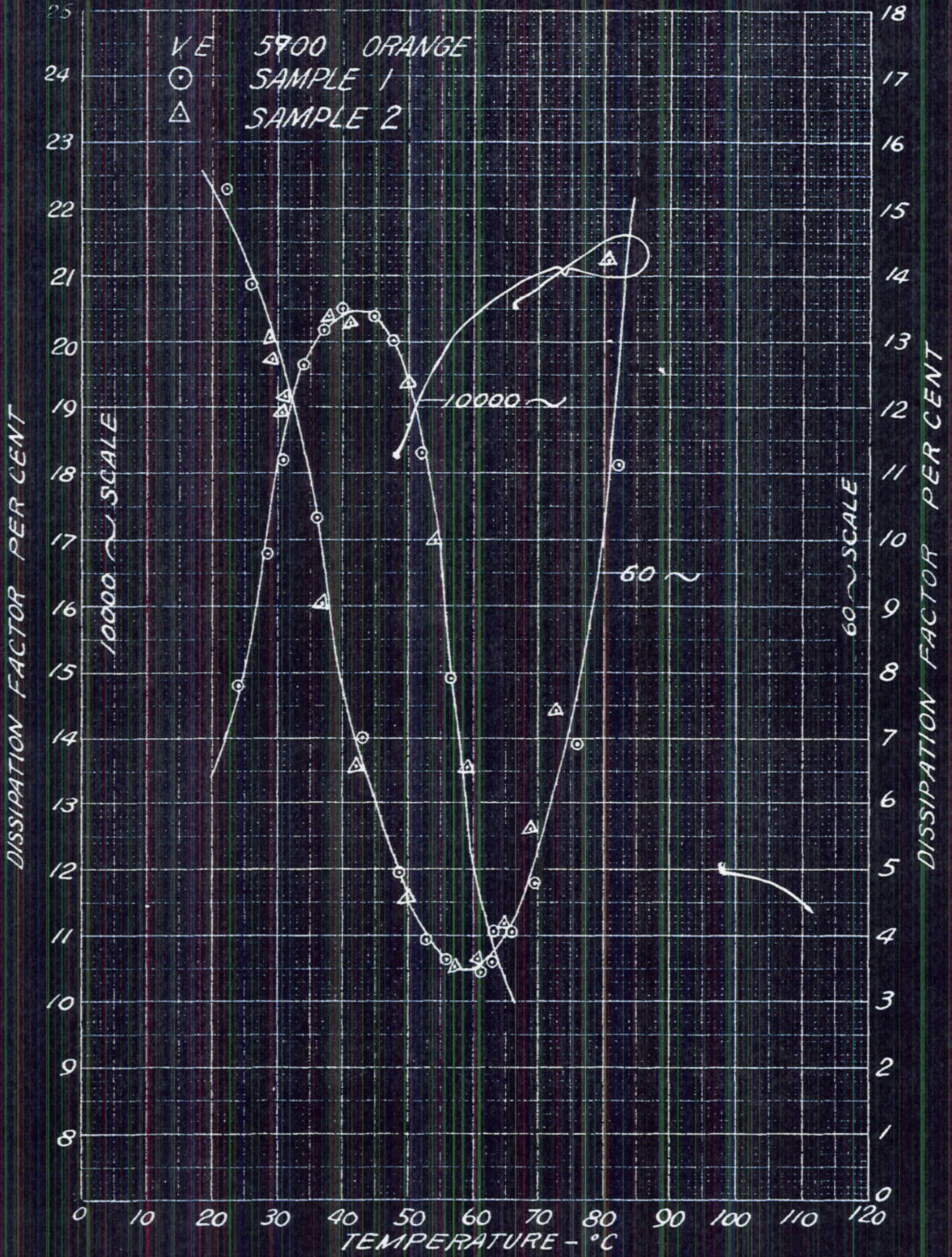

V.E. 5700 ORANGE
SAMPLE 1
SAMPLE 2
10000 ~
60 ~
DISSIPATION FACTOR PER CENT
10000 ~ SCALE
60 ~ SCALE
TEMPERATURE - °C

PLATE 9

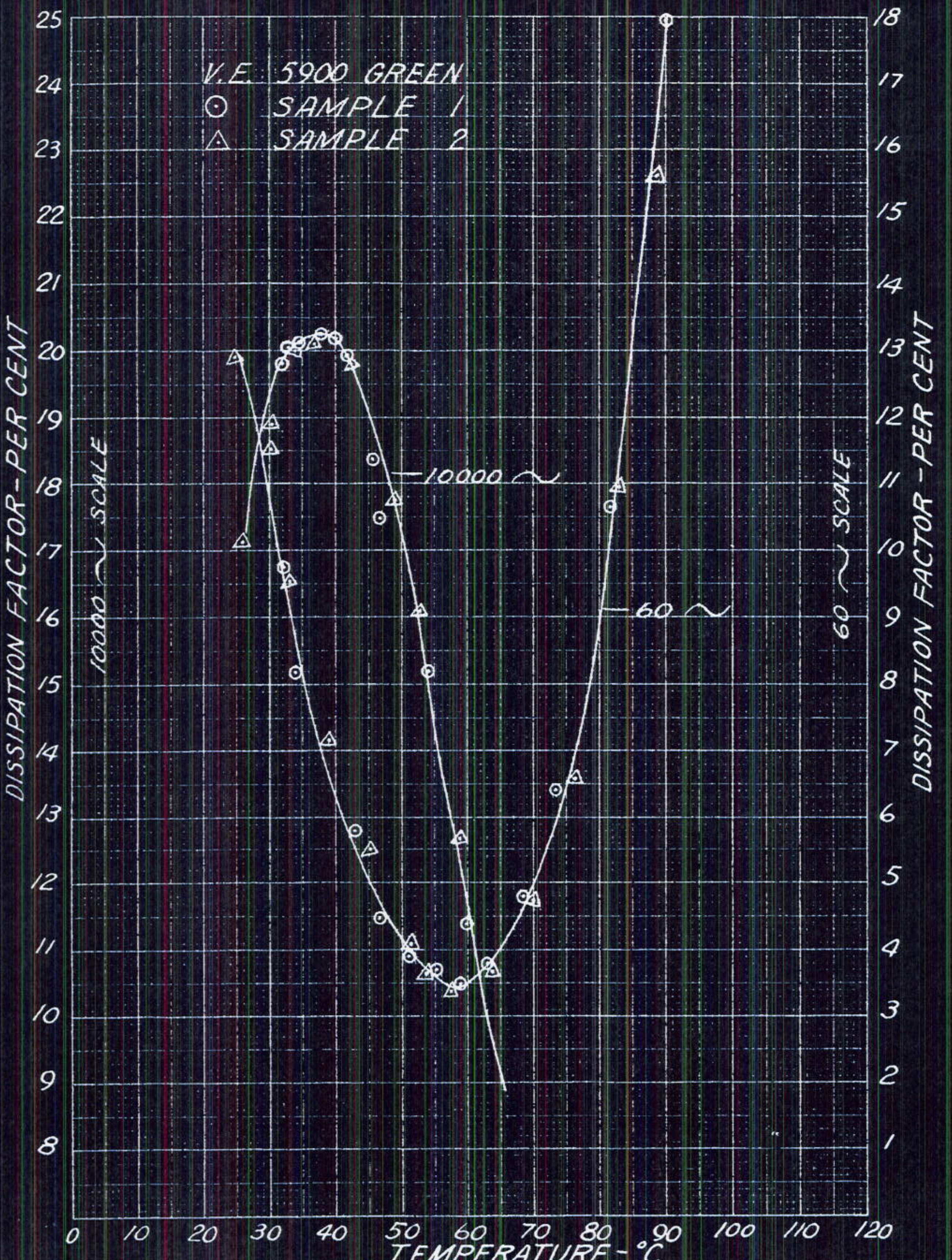
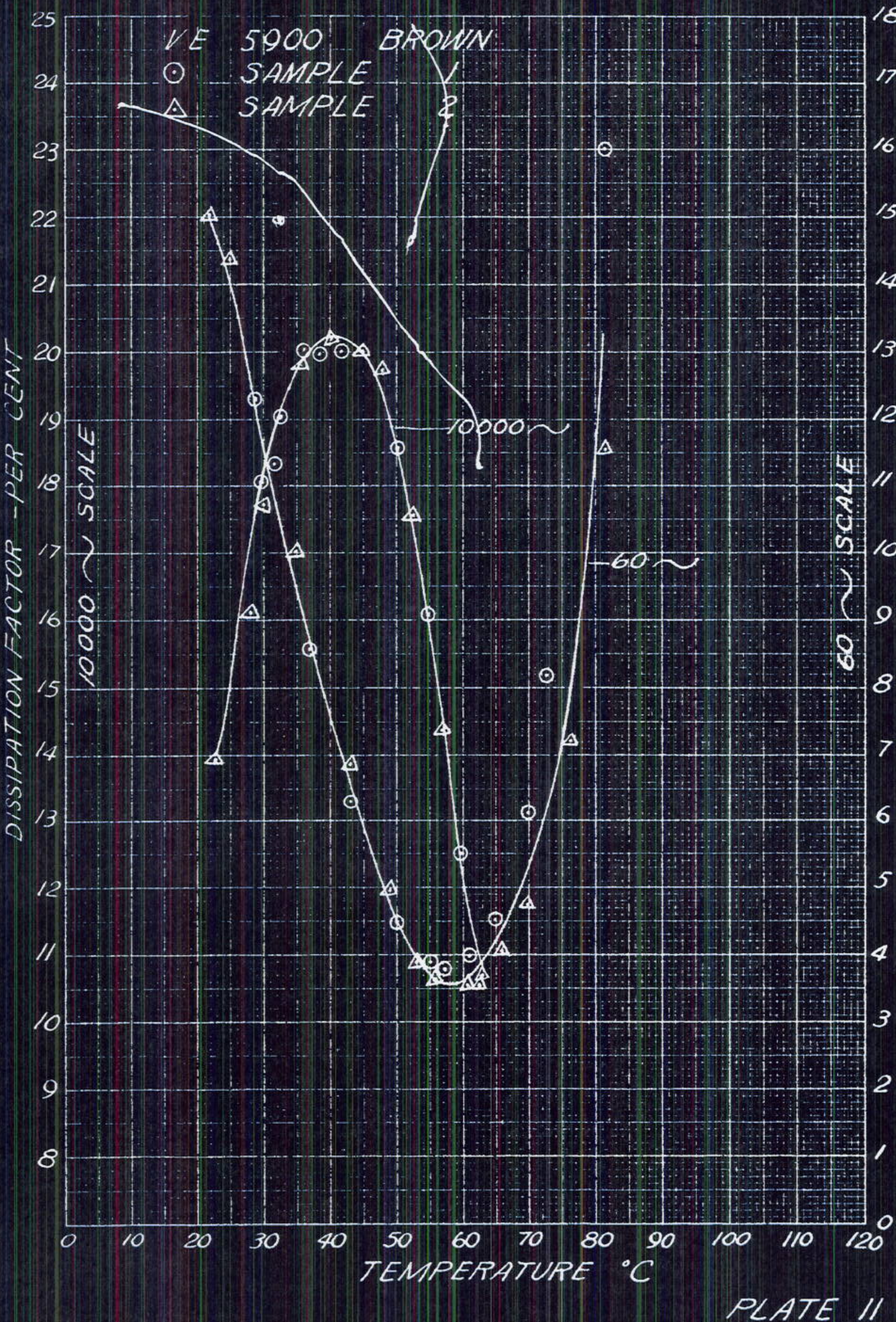
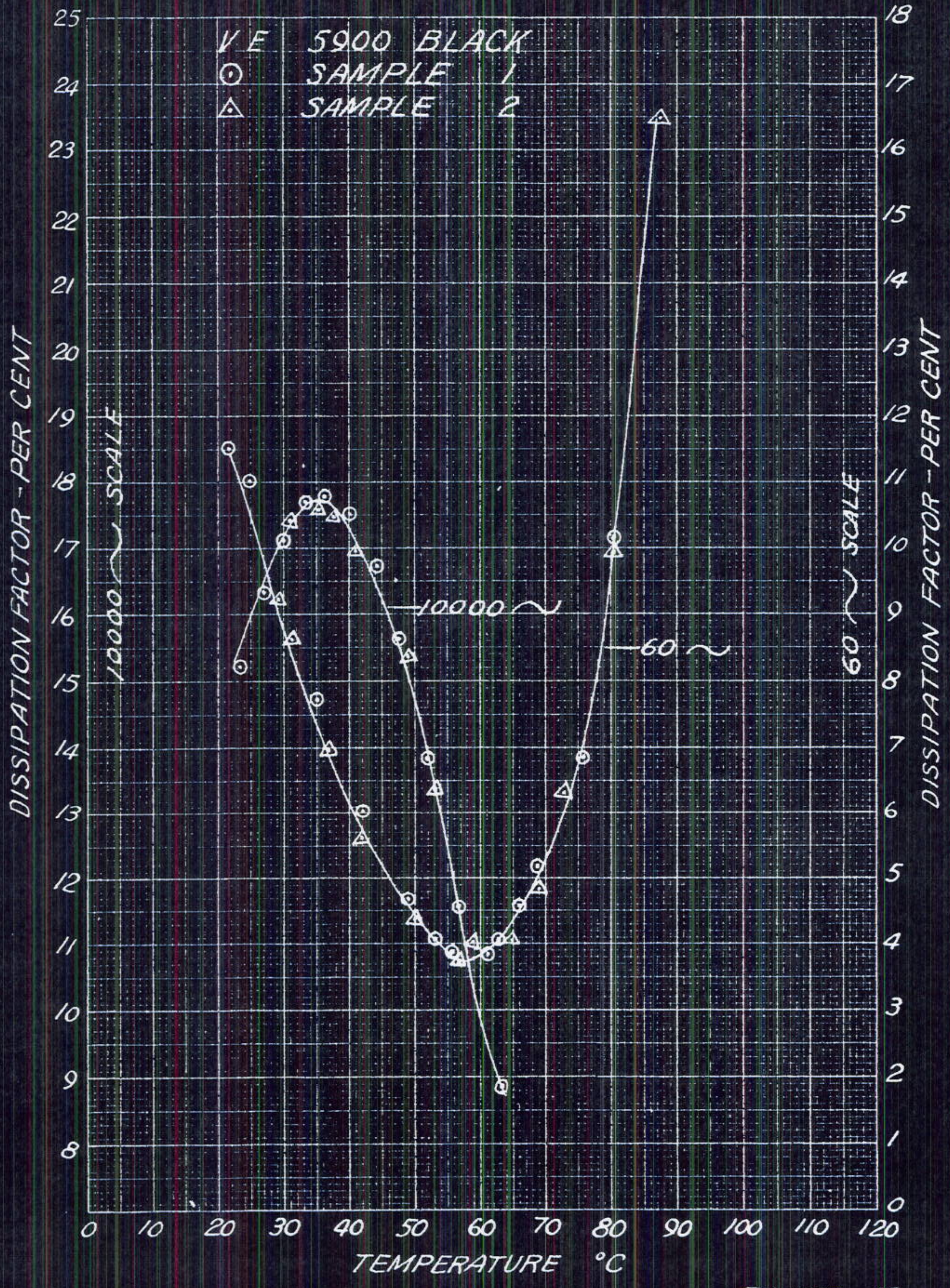

V.E. 5900 GREEN
SAMPLE 1
SAMPLE 2
DISSIPATION FACTOR-PER CENT
10000 ~ SCALE
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
60 ~ SCALE
DISSIPATION FACTOR - PER CENT
—10000 ~
—60 ~
0
10
20
30
40
50
60
70
80
90
100
110
120
TEMPERATURE - °C

PLATE 10



VE 5900 BROWN
SAMPLE 1
SAMPLE 2
10000 ~
60 ~
DISSIPATION FACTOR - PER CENT
10000 ~ SCALE
60 ~ SCALE
DISSIPATION FACTOR - PER CENT
TEMPERATURE °C

PLATE 11



V E 5900 BLACK
SAMPLE 1
SAMPLE 2
10000 ~
60 ~
DISSIPATION FACTOR - PER CENT
10000 ~ SCALE
60 ~ SCALE
DISSIPATION FACTOR - PER CENT
TEMPERATURE °C
0 10 20 30 40 50 60 70 80 90 100 110 120
25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8
18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

PLATE 12

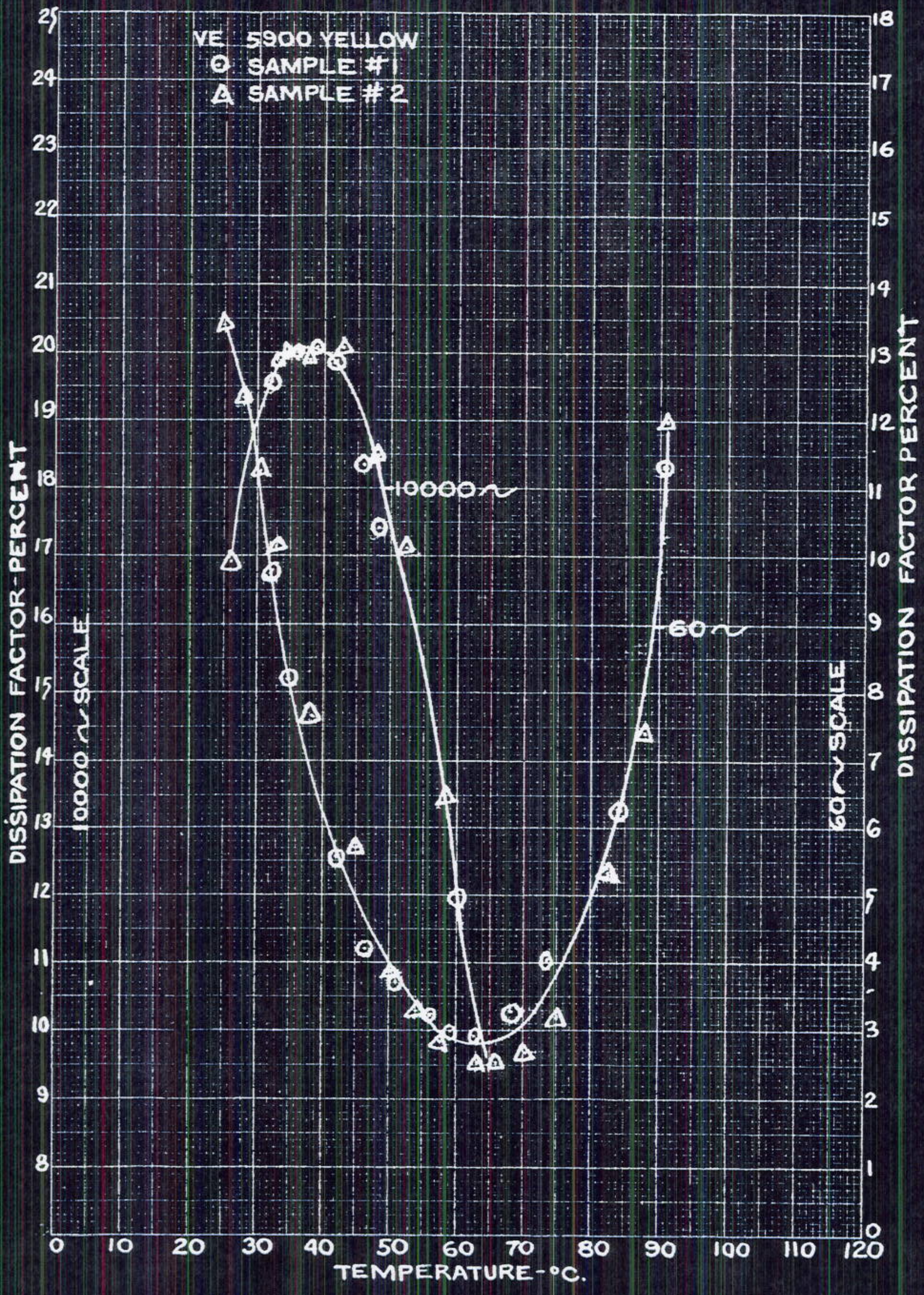
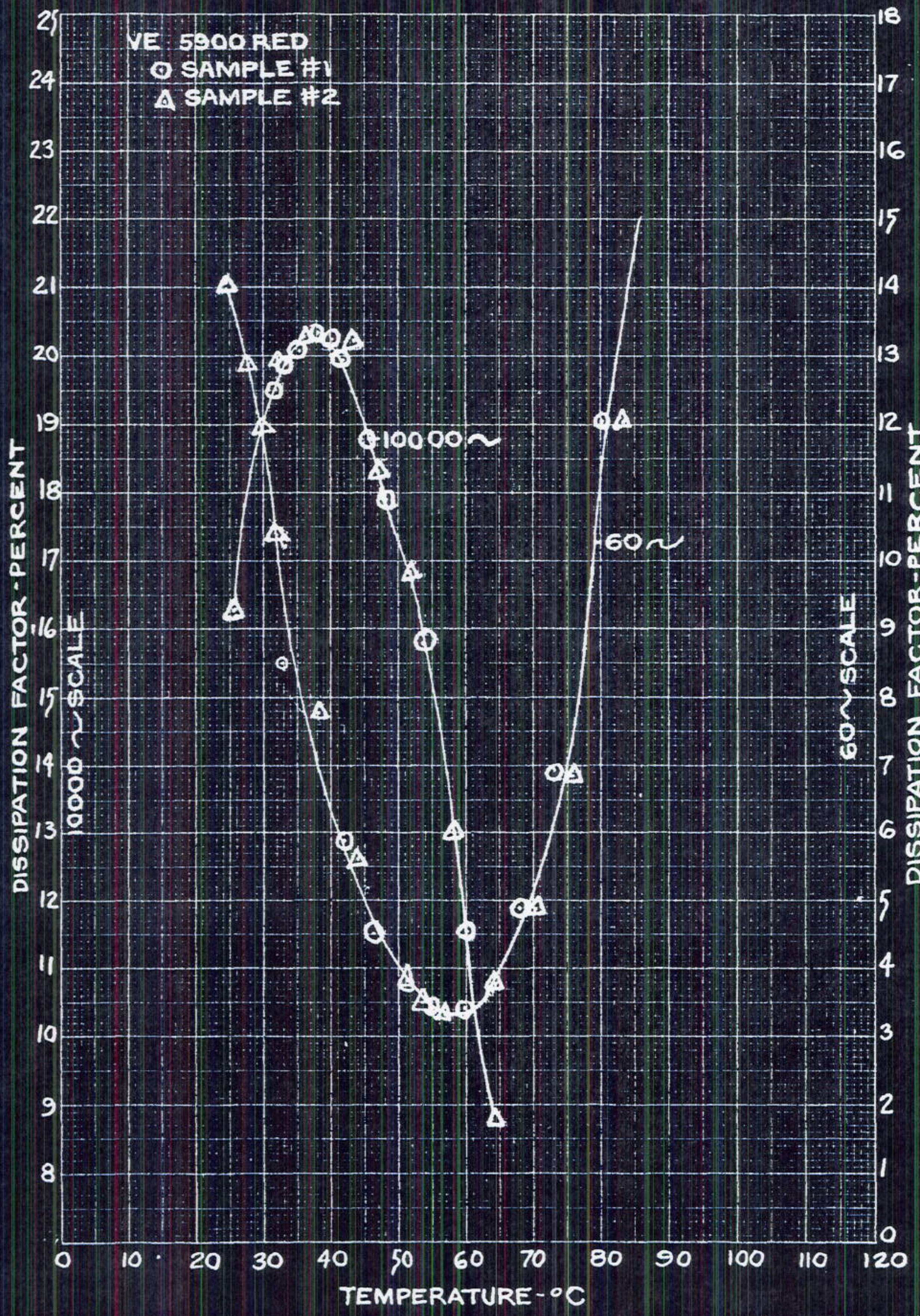
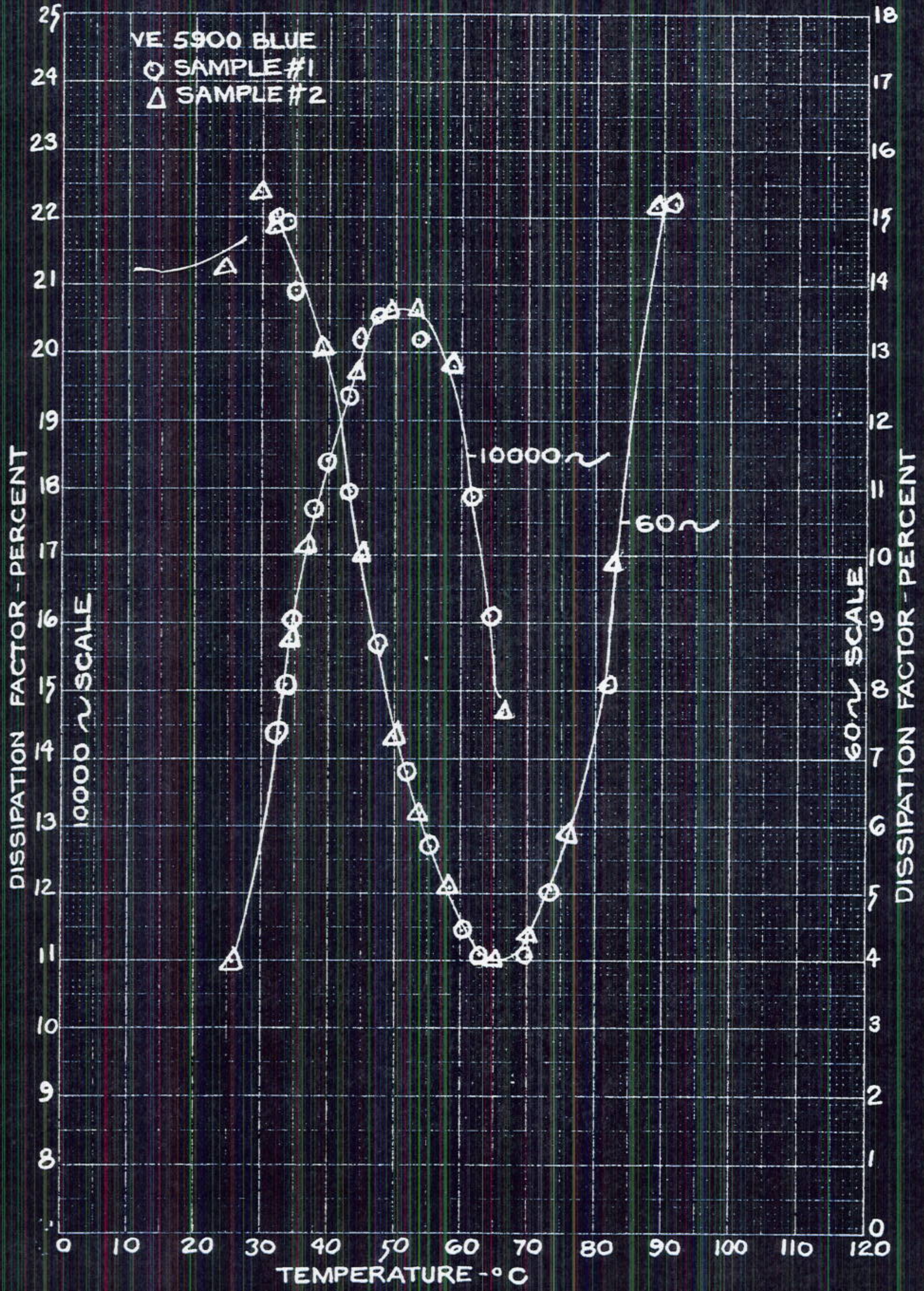

VE 5900 YELLOW
SAMPLE #1
SAMPLE #2
10000~
60~
DISSIPATION FACTOR-PERCENT
10000 ~ SCALE
DISSIPATION FACTOR PERCENT
60~ SCALE
TEMPERATURE-°C.

PLATE 13



VE 5900 RED
O SAMPLE #1
△ SAMPLE #2
10000~
60~
DISSIPATION FACTOR - PERCENT
10000 ~ SCALE
60~ SCALE
DISSIPATION FACTOR - PERCENT
TEMPERATURE - °C
0 10 20 30 40 50 60 70 80 90 100 110 120
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

PLATE 14



VE 5900 BLUE
○ SAMPLE #1
△ SAMPLE #2
10000~
60~
DISSIPATION FACTOR - PERCENT
10000 ~ SCALE
60 ~ SCALE
DISSIPATION FACTOR - PERCENT
TEMPERATURE - °C

PLATE 15

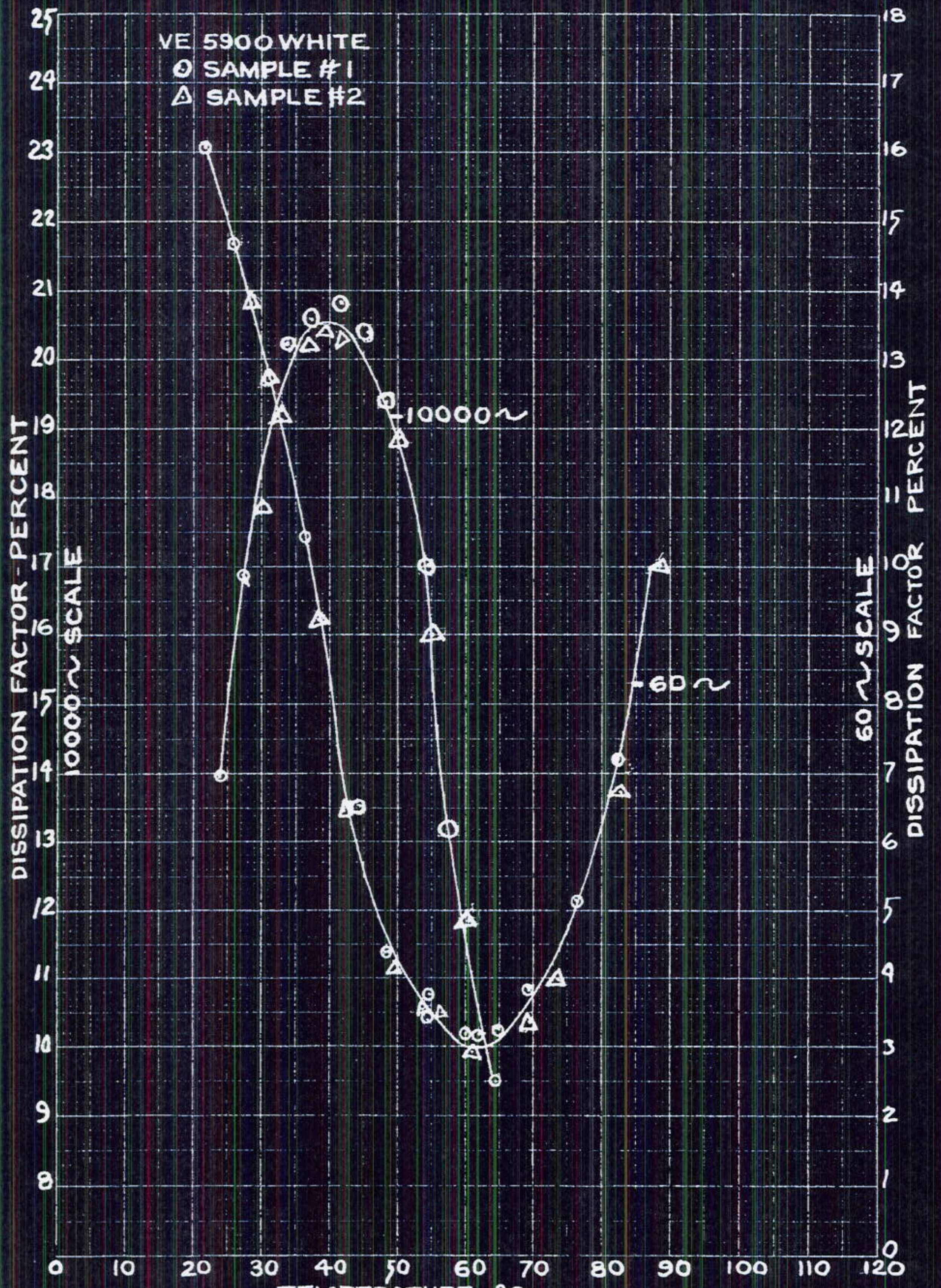

VE 5900 WHITE
SAMPLE #1
SAMPLE #2
10000~
60~
DISSIPATION FACTOR - PERCENT
10000~ SCALE
60~ SCALE
DISSIPATION FACTOR PERCENT
TEMPERATURE - °C.
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0 10 20 30 40 50 60 70 80 90 100 110 120

PLATE 16