TESTS ON BREAKERS, FUSES, AND EXTENSION CORDS

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Approval Sheet

SUMMARY OF RESULTS

The purpose of the following tests was to determine whether fuses were necessary or whether thermally operated circuit breakers would efficiently protect certain types and sizes of drop cords.

The results obtained indicate that the fuses are faster, but that either of the breakers would protect any type of cord as tested under the conditions of these tests. However, this statement cannot be accepted as conclusive, since only one breaker of each make was tested.

INTRODUCTION

This series of tests was performed at the University for Mr. R. A. Hopkins head Electrical Engineer of the T. V. A. The items tested were: various makes of small lighting cabinet circuit breakers, one-time fuses, and various samples of extension cord.

REASON FOR INVESTIGATION

The present importance of breakers and fuses in domestic use cannot be overestimated. Many of the houses in use today were wired when lights were parctically the only domestic electrical load. Consequently the wiring was designed primarily for the small non-inductive loads offered by lamps. However, with the greatly increased use of modern household electrical appliances, such old style wiring is sometimes greatly overloaded. Therefore, the problem of adequate fuse or breaker protection on such old circuits is of great importance. Modern circuits also need efficient pretection.

The time necessary for a breaker or fuse to open a circuit should be considerably less than the time necessary for the smallest wire in the circuit to attain a dangerous temperature. This is especially true of any extension cord in the circuit which may be in contact with inflamable material such as paper and fabrics.

PURPOSE

These tests were made to determine the length of time necessary for various makes of small thermally operated circuit breakers and one-time fuses to open a circuit at various values of overload currents. Tests were also performed with various samples of extension cord to determine the length of time necessary for them to attain a dangerous temperature at various values of overload currents. These tests make possible the selection of a breaker or fuse which will safely protect a given type of cord.

DEVICES TESTED AND TESTS PERFORMED

The following devices were tested:

1. Square D, 125 V. 15 A. lighting cabinet circuit breaker.
2. Westinghouse, 125 V. 15 A. lighting cabinet circuit breaker.
3. Bull Dog, 125 V. 15 A. lighting cabinet circuit breaker.
4. G.E. A-6, Type AF-1, 125 V. 15 A. lighting cabinet circuit breaker.
5. G.E. A-8, Type AF-1, 125 V. 15 A. lighting cabinet circuit breaker.
6. One-Time Buss Fuse, 250 V. 15 A., Buss No. 25015.

The following tests were made on the devices lested above:

1. Resistance of each device when cold and when hot.
2. Time to trip on 200%, 400%, 600%, 800%, and 1000% rated current, non-inductive load starting cold.

3. Same as 2 except starting after attaining constant temperature on half rated current.

4. Same as 3 except on full rated current.

5. Same as 2 except on 50% power factor load.

6. Same as 3 except on 50% power factor load.

7. Same as 4 except on 50% power factor load.

Samples of the following types and sizes of cords were tested:

1. No. 12 Style S all rubber cord, Simplex-Tirex 600 V., 20 A.

2. No. 14 Deltabeston heater cord, Style A, stranded, 20 A.

3. No. 14 Style S all rubber cord, Simplex-Tirex, 600 V., 15 A.

4. No. 16 Style PO SJ all rubber cable, 7 A.

The current ratings on the above cords are those specified by the National Electrical Code for cords of corresponding sizes and types of insulation.

The following run was made on the types and sizes of cord listed above:

Run A. Time to fail on various values of current, non-inductive load, starting cold.

DESCRIPTION OF TESTS

The original purpose of the first run was to measure the impedance of each device. However due to the lack of an A. C. millivolt meter, the D. C. resistance was measured instead. As these breakers are entirely thermally operated, containing no coils, and therefore, having little or no inductance, it was assumed that the D. C. resistance would

not differ materially from the A. C. impedance. This resistance was measured at room temperature, and after attaining a constant temperature when carrying current. In measuring the resistance of the fuses, they were placed in a molded bakelite unit with 30 A. single pole switch and cartridge fuse holders connected in series. The resistance of the switch and holders is included as part of the fuse resistance. The resistance was measured in this way in order to obtain a better comparison with the breakers which contain built in switches.

The wiring diagram shown in Figure 1 was used for the other breaker and fuse tests. In Run 2, the inductance was adjusted to zero. The non-inductive load rheostats were adjusted to attain the desired current before the breaker or fuse was inserted into the circuit. The various breakers and fuses were then inserted one at a time, each device being at room temperature, and the time necessary for it to trip was recorded. This procedure was repeated for the other desired values of overload currents.

In order to determine the time necessary for a breaker to reach constant temperature at half rated current, one was opened and a thermometer taped to the thermal element. This breaker was then placed in the heating circuit carrying 7.5 A., and the time necessary for the thermometer to reach a maximum temperature noted. It was assumed that the other breakers would require the same amount of time to reach a constant temperature on the same current. By this method it

Circuit Diagram for Breaker & Fuse Tests

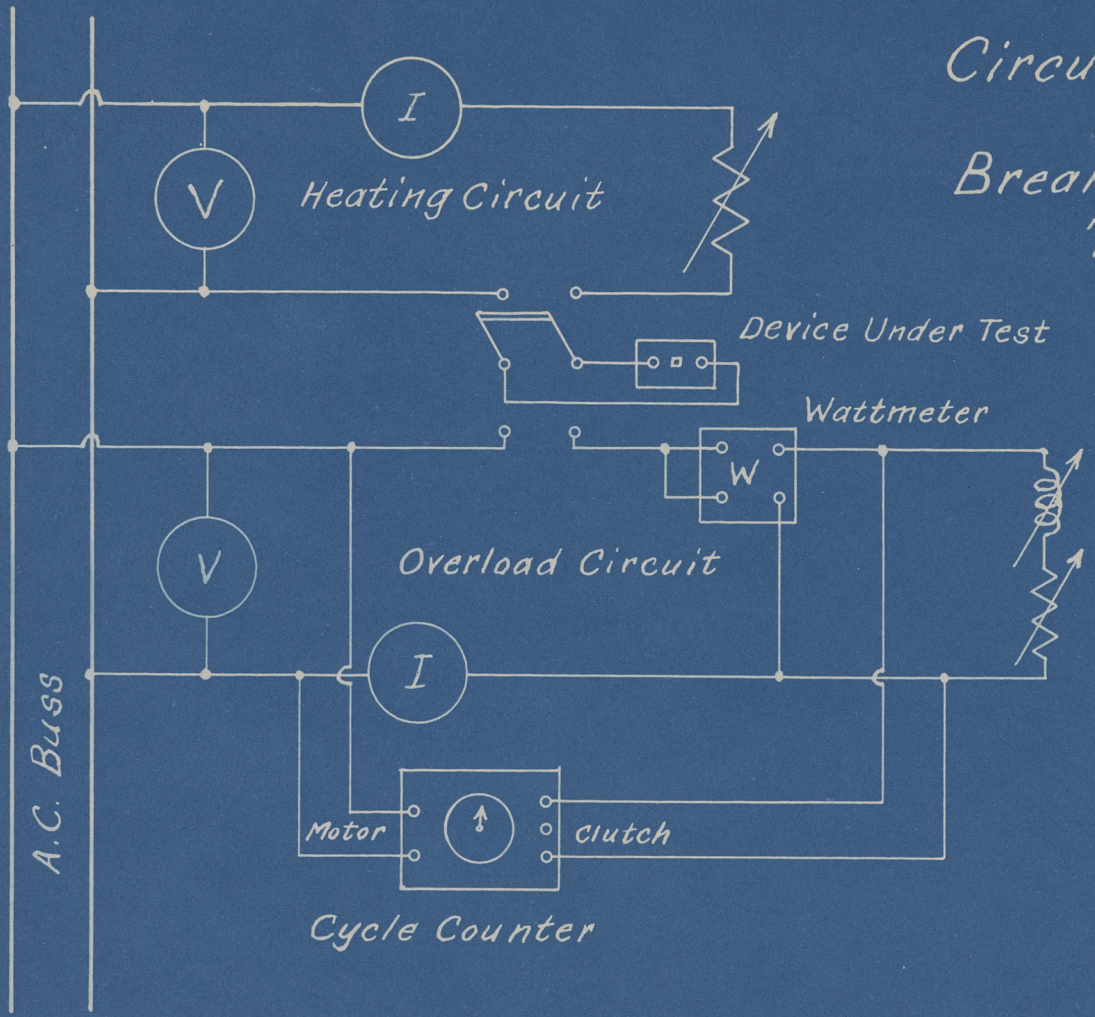


Figure I

was found that 30 minutes was necessary for the breaker to reach a constant temperature. In Run 3, each device was inserted in the heating circuit carrying half rated current and allowed to remain for 30 minutes. It was then shifted by means of the double throw switch to the overload circuit which had previously been adjusted to carry the desired overload current. The time for the device to trip was recorded. In this run, non-inductive load and the same values of overload current as in Run 2 were used.

By the method described above, it was found that each device required 20 minutes to reach maximum temperature when carrying full rated current. Run 4 was performed in the same manner as Run 3 except that the heating circuit was adjusted to carry full rated current, and each device was allowed to remain in it for 20 minutes.

Run 5 was performed in the same manner as Run 2 except that the inductance and rheostats were adjusted to obtain 50% power factor load at 200%, 400%, 600% rated current. Due to the current limitation of the inductance it was impractical to obtain 800% and 1000% rated current at 50% power factor.

Run 6 was performed in the same manner as Run 3 except for 50% power factor load and only for 200%, 400% and 600% rated current.

Run 7 was performed in the same manner as Run 4 except for 50% power factor load and only for 200%, 400% and 600% rated current.

In performing Run A, a sample of cord about 12 inches

long was placed in the circuit between the buss and the load, the load being previously adjusted to draw the desired current. A non-inductive load was used in all cord tests. The cord was at room temperature when inserted into the circuit, and the time of failure was recorded. The time of failure was assumed to be the time necessary to completely melt the conductor so that the circuit was broken. This procedure was repeated with a sample of each of the cord listed above, and at various values of current for each.

Detailed tables of data taken during the above runs may be found in the appendix. All curves were drawn from the condensed data in Tables 1, 2, 3, 4, 5, 6 and 7.

Runs 2 and 3 were performed with 30 A. fuses on 200%, 300%, 400% and 500% rated current. As only ten fuses were available, more runs could not be made.

Table 1

BREAKERS and FUSES

Non-Inductive Load

Run 2

Cold
Temp. 26° C

Overload	195% 29.3 A	403% 60.5 A	600% 90.0 A	794% 119 A	995% 149 A
Square D	29.6	4.4	2.0	0.92	0.58
	30.6	4.2	1.75	0,92	0.61
Westinghouse	18.4	2.8	1.2	0.70	0.48
	20.2	3.2	1.32	0.70	0.46
Bull Dog	15.0	2.6	1.2	0.63	0.43
	15.9	2.6	1.15	0.62	0.40
G.E. A-6	46.2	6.8	3.2	1.38	1.02
	46.0	6.4	2.81	1.42	0.95
G.E. A-8				1.00	0.69
	26.7	4.6	1.67	1.04	0.67
One-Time Fuse 15 A	4.57	0.33	0.15	0.075	
	4.10	0.36		0.083	
One-Time Fuse 30 A		5.79	1.29	0.65	0.37
		5.48			0.39

Table 2

BREAKERS and FUSES

Non-Inductive Load

Run 3

Const. Temp.
7.6 A

Overload	196% 29.4 A	403% 60.5 A	598% 89.6 A	794% 119 A	995% 149 A
Square D	23.3	3.4	1.4	0.78	0.48
Westinghouse	14.6	2.6	1.0	0.56	0.37
Bull Dog	10.6	1.8	0.8	0.45	0.30
G.E. A-6	35.4	4.6	2.0	1.21	0.78
G.E. A-8	17.0	3.2	1.6	0.78	0.50
One-Time Fuse 15 A	1.85 3.25	0.33 0.317	0.13	0.067 0.083	

Table 3

BREAKERS and FUSES

Non-Inductive Load

Run 4

Const. Temp.
14.8 A

Overload	195% 29.4 A	403% 60.4 A	600% 90.0 A	795% 119 A	995% 149 A
Square D	12.4	1.6	0.68	0.37	0.27
Westinghouse	6.0	1.2	0.33	0.275	0.12
Bull Dog	3.2	0.8	0.10	0.13	0.05
G.E. A-6	12.5	1.2	0.82	0.31	0.30
G.E. A-8	2.4	0.8	0.23	0.10	0.08
One-Time Fuse 15 A	2.6 2.25	0.33 0.32		0.067 0.067	
One-Time Fuse 30 A		4.23	1.10	0.51	

Table 4

BREAKERS and FUSES

50% P.F. Load

Run 5

Cold
Temp. 24.5° C

Overload	189% 28.4 A	400% 60.0 A	586% 88.0 A
Square D	35.4	4.1	1.8
Westinghouse	22.4	3.0	1.4
Bull Dog	17.2	2.8	1.2
G.E. A-6	67.6	7.0	2.8
G.E. A-8	25.3	4.08 4.29	1.92
One-Time Fuse 15 A	1.79 1.81	0.25 0.27	0.12 0.13

Table 5

BREAKERS and FUSES

50% P.F. Load

Run 6

Const. Temp.
7.5 A

Overload	197% 29.6 A	404% 60.6 A	586% 88.0 A
Square D	24.1	3.28	1.42
Westinghouse	14.8	2.20	1.00
Bull Dog	10.7	1.67	0.80
G.E. A-6	41.0	4.17	2.02
G.E. A-8	18.7	3.06	1.41
One-Time Fuse	1.6	0.25	0.12
15 A	1.5	0.27	0.12

Table 6

BREAKERS and FUSES

50% P.F. Load

Run 7

Const. Temp.
14.8 A

Overload	197% 29.6 A	404% 60.6 A	586% 88.0 A
Square D	10.2	1.57	0.52
Westinghouse	4.6	0.55	0.32
Bull Dog	0.8	0.12	0.08
G.E. A-6	10.3	2.15	0.87
G.E. A-8	4.8	0.27	0.33
One-Time Fuse	1.4	0.22	0.108
15 A	1.0	0.20	0.108

Table 7

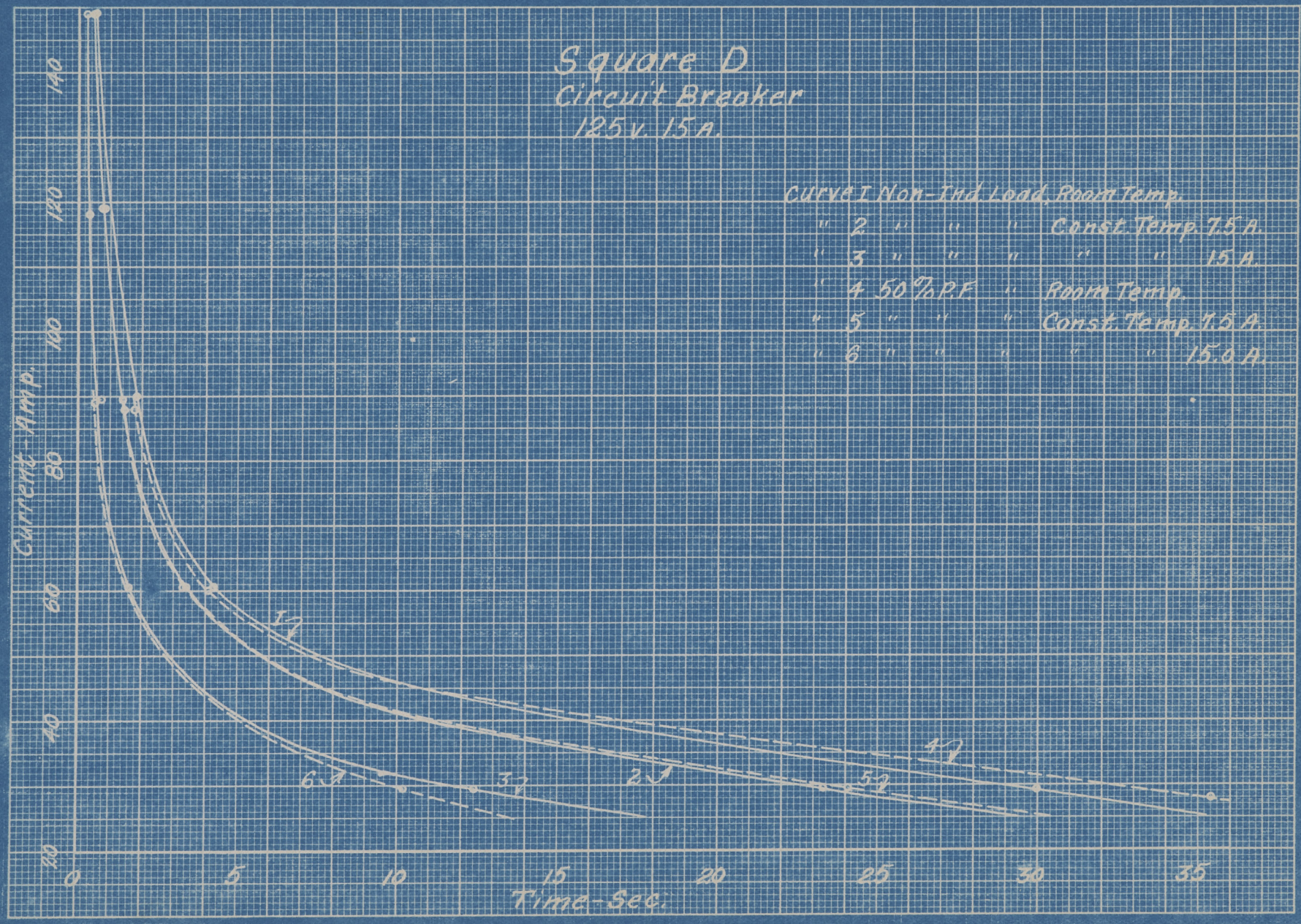
EXTENSION CORDS

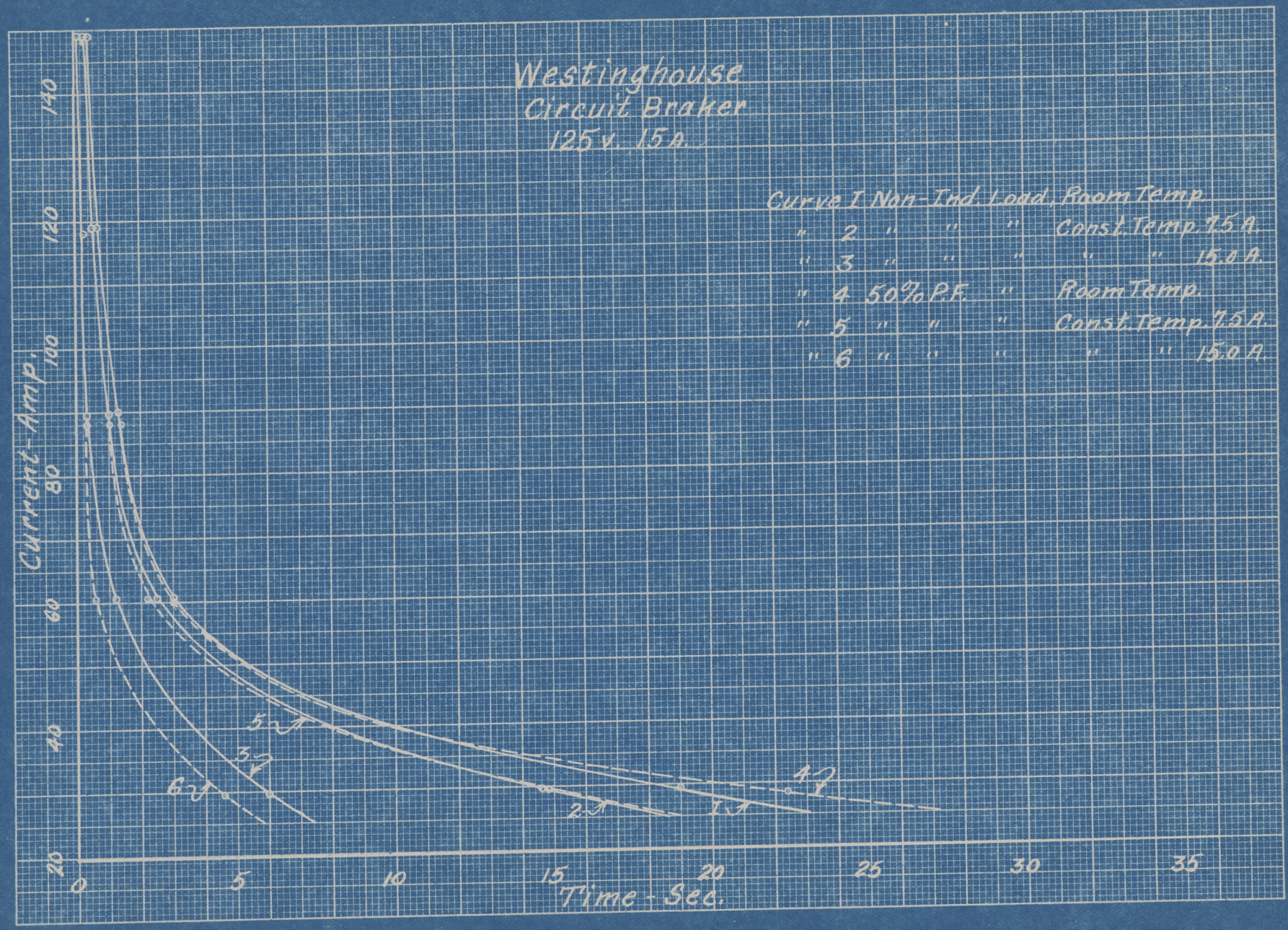
Non-Inductive Load

Run A

Cold
Temp. 27° C

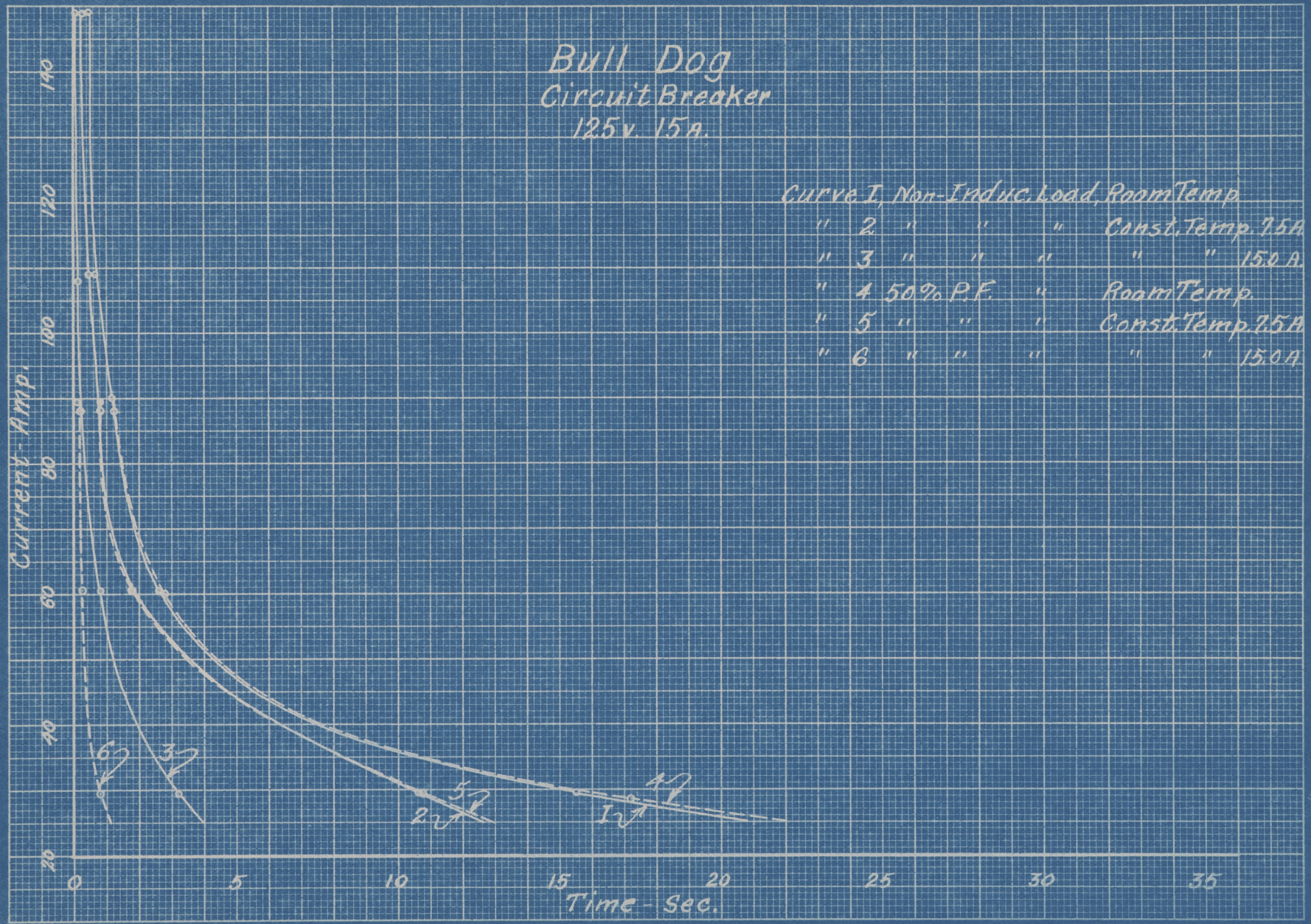
Overload	60.0 A	88.0 A	118.8 A	147.6 A	178.0 A	205.6 A
No. 12 Rubber (20 A)				9' 20"	4' 16"	1' 48"
No. 14 Rubber (15 A)			7' 3"	2' 26"	1' 2"	33"
No. 14 Deltabeston (20 A)			9' 9"	3' 17"	1' 47"	1' 21"
No. 16 Rubber (7 A)	2' 27"	27"	16"	10"	5"	3"


Square D
Circuit Breaker
125 v. 15 A.
Curve 1 Non-Ind Load, Room Temp.
" 2 " " " Const. Temp. 7.5 A.
" 3 " " " " " 15 A.
" 4 50% P.F. " Room Temp.
" 5 " " " Const. Temp. 7.5 A.
" 6 " " " " " 15.0 A.
Current-Amp.
Time-Sec.
0
5
10
15
20
25
30
35
40
60
80
100
120
140
1
2
3
4
5
6


Westinghouse
Circuit Breaker
125 v. 15 A.
Curve 1 Non-Ind. Load. Room Temp.
" 2 " " " Const. Temp. 7.5 A.
" 3 " " " " " 15.0 A.
" 4 50% P.F. " Room Temp.
" 5 " " " Const. Temp. 7.5 A.
" 6 " " " " " 15.0 A.
Current-Amp.
140
120
100
80
60
40
20
0
5
10
15
20
25
30
35
Time - Sec.
1
2
3
4
5
6

Bull Dog
Circuit Breaker
125 v. 15 a.

Curve 1, Non-Induc. Load, Room Temp.
" 2 " " " Const. Temp. 7.5 A
" 3 " " " " " 15.0 A.
" 4 50% P.F. " Room Temp.
" 5 " " " Const. Temp. 7.5 A
" 6 " " " " " 15.0 A.

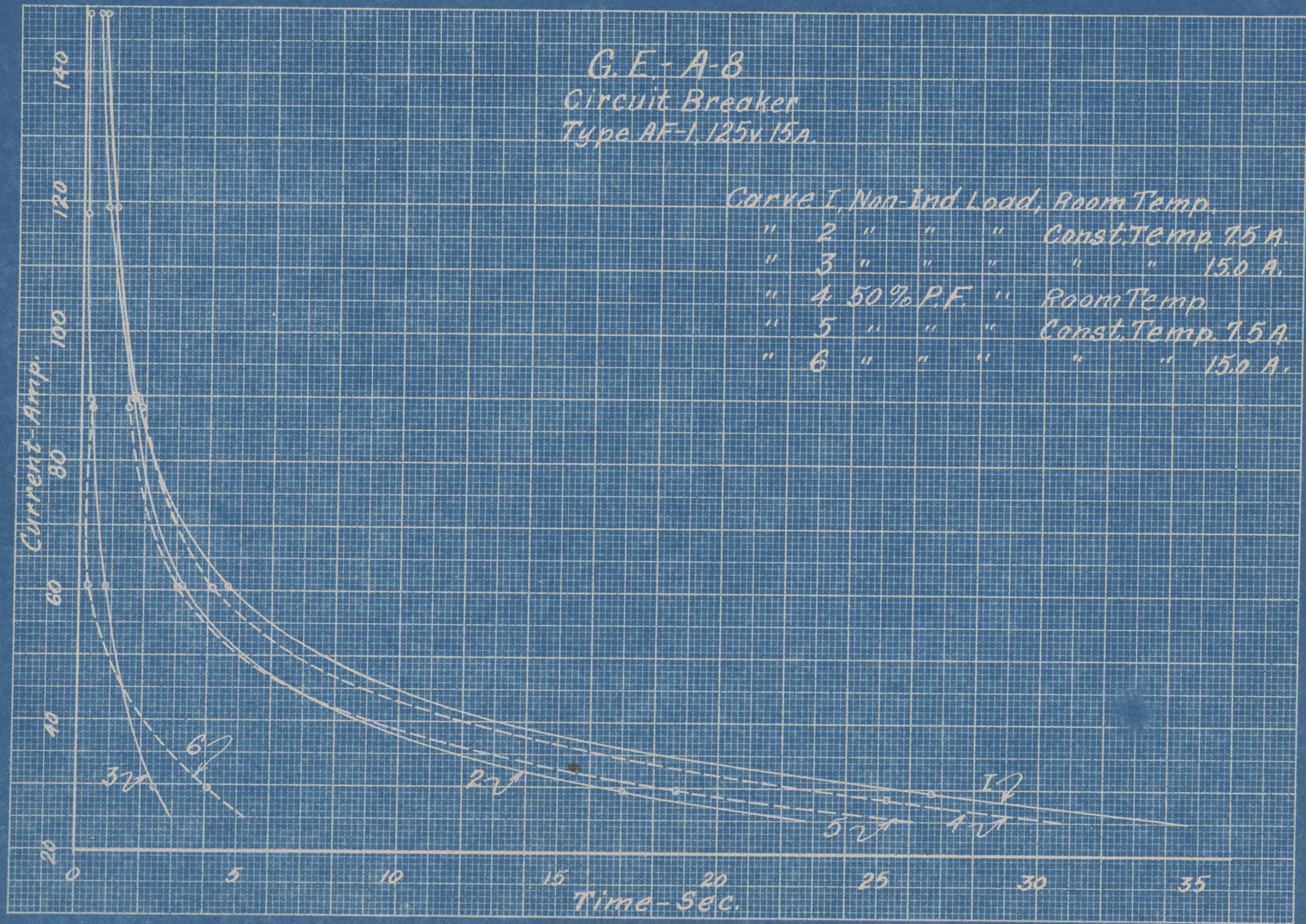


G.E. A-6
Circuit Breaker
Type AF-1 125 Amp.

Curve 1 Non-Ind Load, Room Temp.
" 2 " " " Const Temp. 75 A
" 3 " " " " 150 A
" 4 50% Ov. " Room Temp.
" 5 " " " Const. Temp. 75 A
" 6 " " " " 150 A

Time-Sec.
0 5 10 15 20 25 30 35

Current-Amp
20 40 60 80 100 120 140

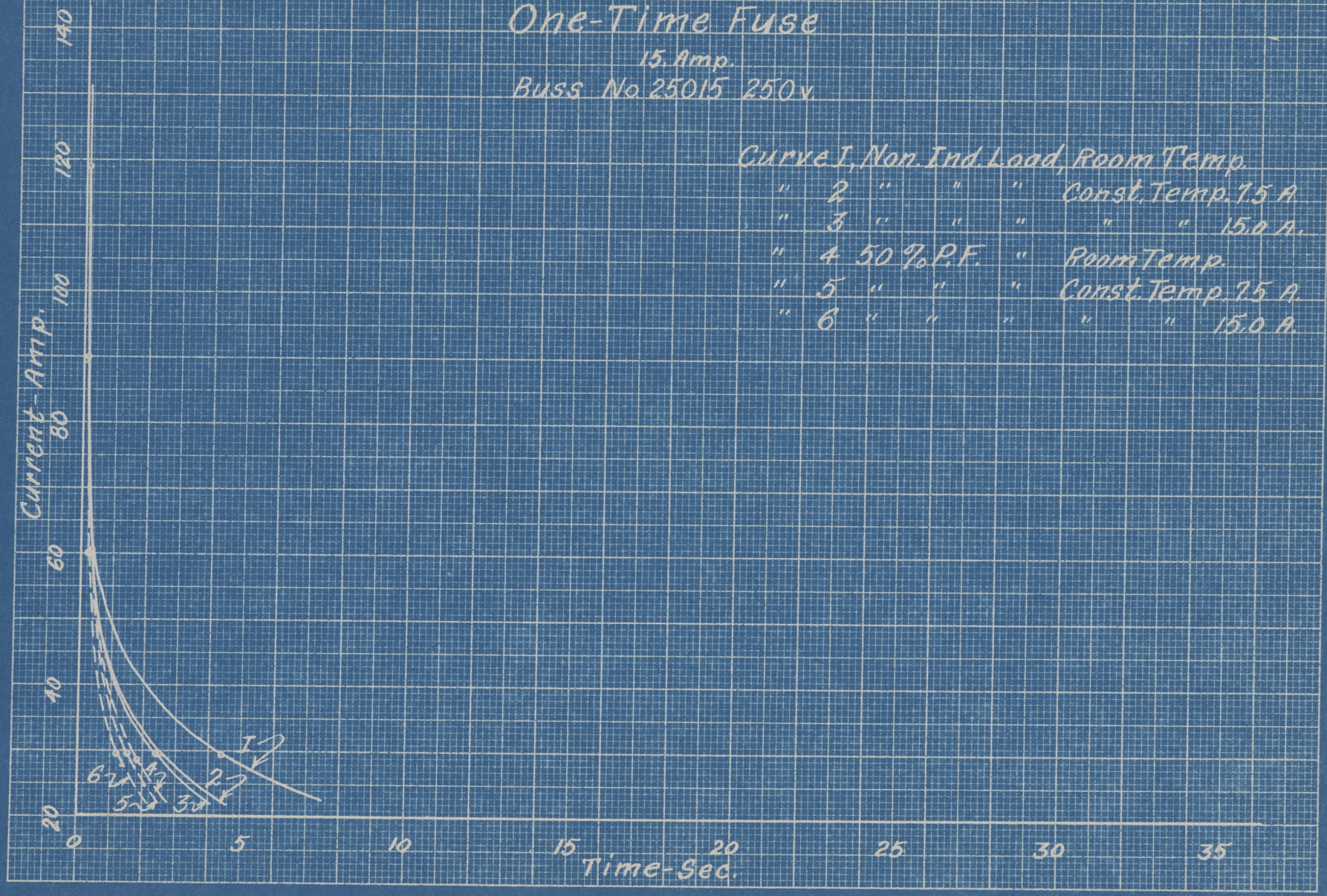

G.E.-A-8
Circuit Breaker
Type AF-1, 125v 15A.
Curve 1, Non-Ind Load, Room Temp.
" 2 " " " " Const. Temp. 7.5 A.
" 3 " " " " " " 15.0 A.
" 4 50% P.F. " Room Temp.
" 5 " " " Const. Temp. 7.5 A.
" 6 " " " " " " 15.0 A.
Current-Amp.
Time-Sec.
140
120
100
80
60
40
20
0
5
10
15
20
25
30
35
1
2
3
4
5
6

One-Time Fuse

15. Amp.

Buss No. 25015 250 v.

Curve 1, Non Ind. Load, Room Temp.
" 2 " " " Const. Temp. 7.5 A.
" 3 " " " " " 15.0 A.
" 4 50 % P.F. " Room Temp.
" 5 " " " Const. Temp. 7.5 A.
" 6 " " " " " 15.0 A.



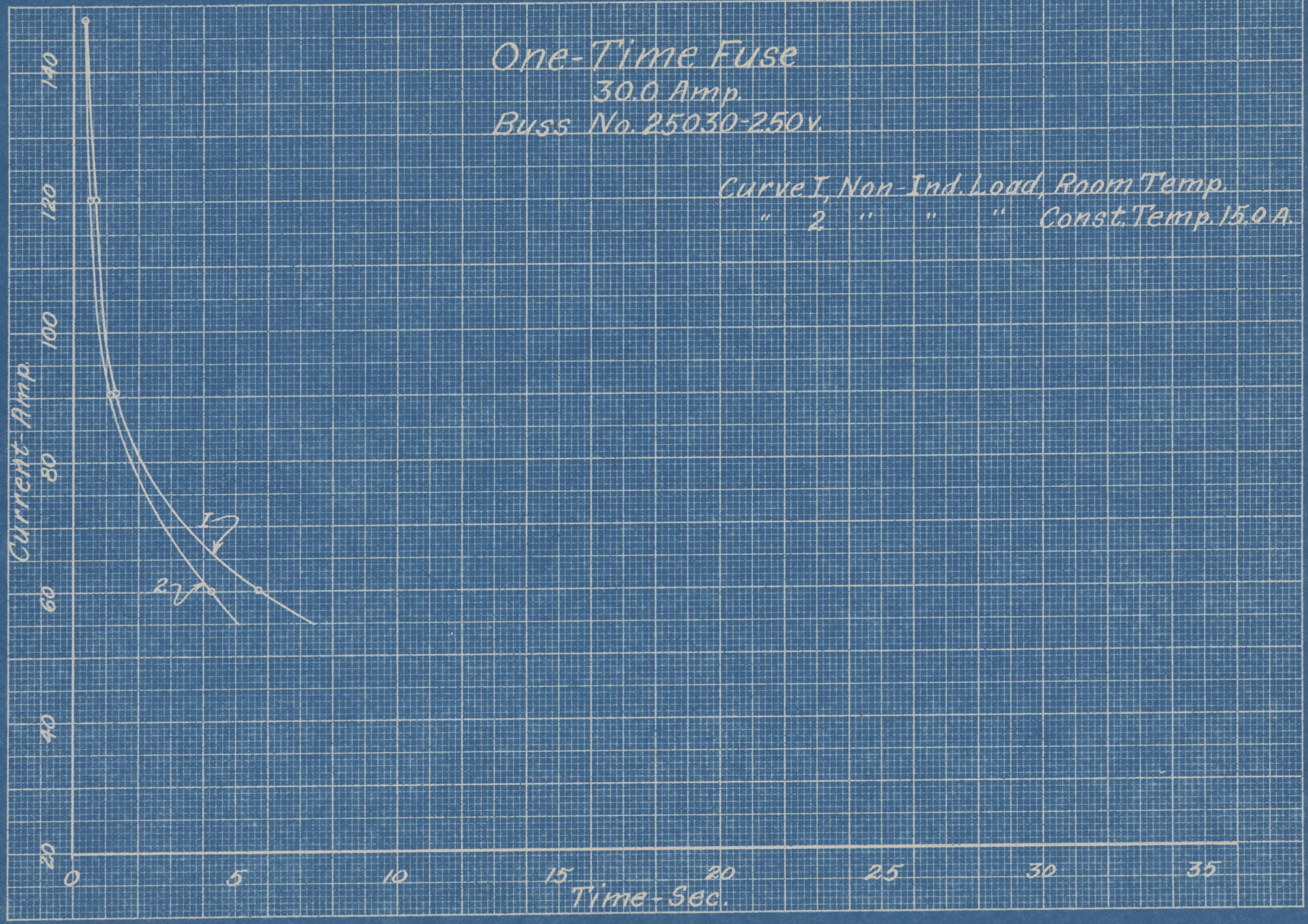
One-Time Fuse

30.0 Amp.

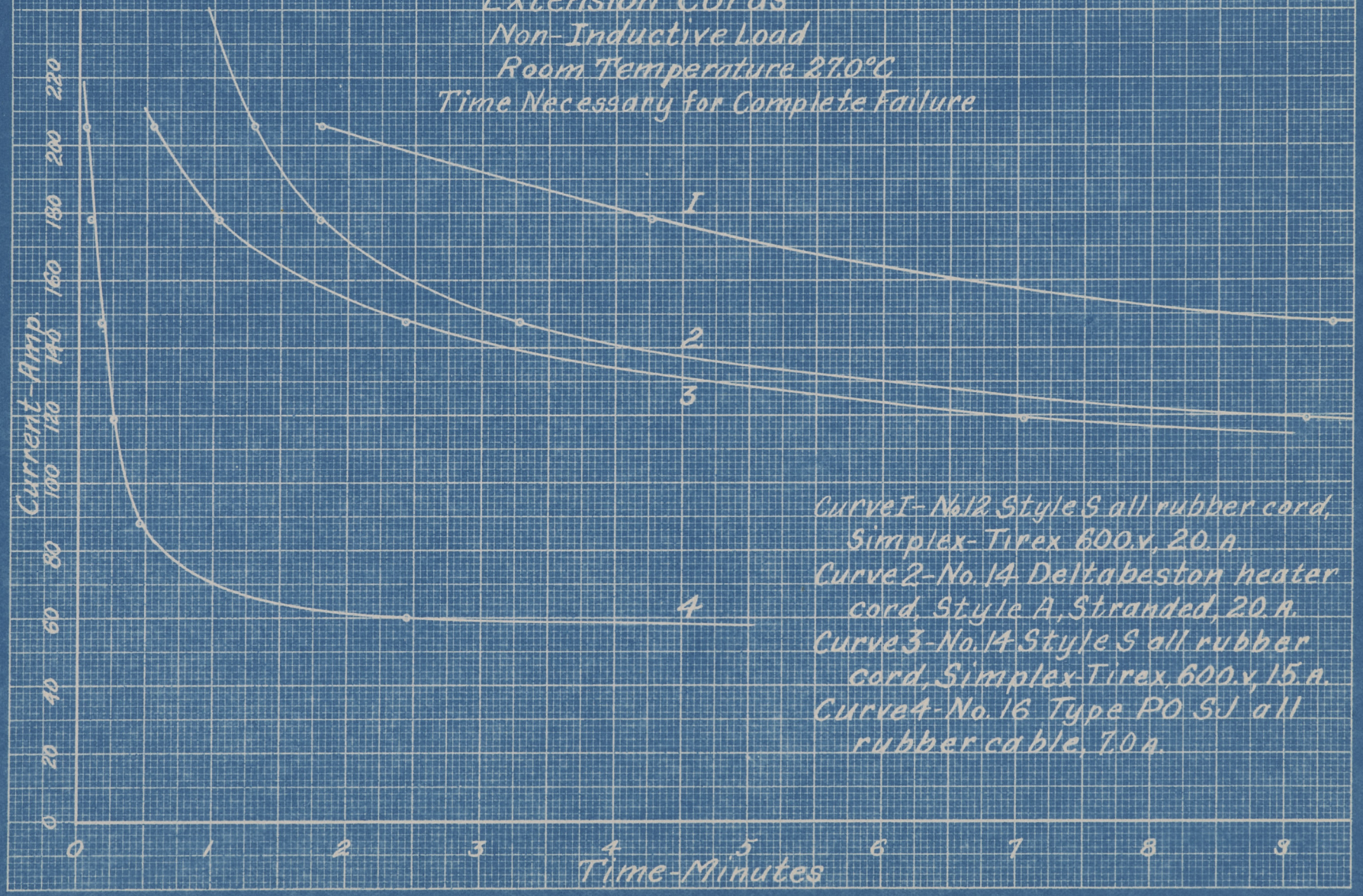
Buss No. 25030-250v.

Curve 1, Non-Ind. Load, Room Temp.

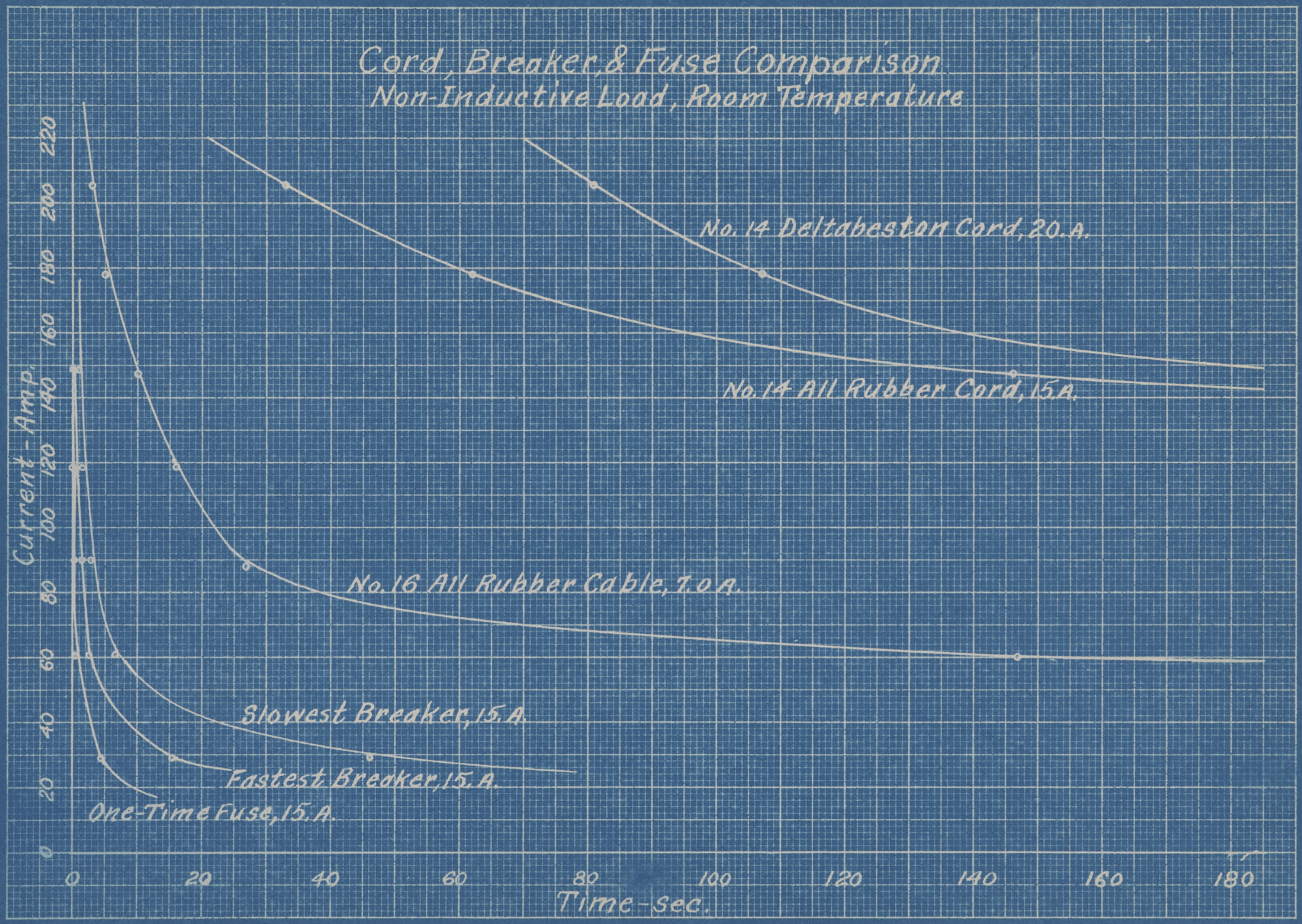
" 2 " " " Const. Temp. 15.0 A.



Extension Cords
Non-Inductive Load
Room Temperature 27.0°C
Time Necessary for Complete Failure



Curve 1 - No. 12 Style S all rubber cord, Simplex-Tirex 600 v, 20 A.
Curve 2 - No. 14 Deltabeston heater cord, Style A, Stranded, 20 A.
Curve 3 - No. 14 Style S all rubber cord, Simplex-Tirex 600 v, 15 A.
Curve 4 - No. 16 Type PO SJ all rubber cable, 7.0 A.


Cord, Breaker & Fuse Comparison
Non-Inductive Load, Room Temperature
No. 14 Deltabeston Cord, 20. A.
No. 14 All Rubber Cord, 15 A.
No. 16 All Rubber Cable, 7.0 A.
Slowest Breaker, 15. A.
Fastest Breaker, 15. A.
One-Time Fuse, 15. A.
Current - Amp.
0
20
40
60
80
100
120
140
160
180
200
220
0
20
40
60
80
100
120
140
160
180
Time - sec.

CONCLUSIONS

Because all of the breakers tested were thermally operated, the slowest time measured was in Run 2 when starting with room temperature. When tested after the device had attained a constant temperature at a given load, a decrease in the time necessary to trip was noted in all breakers. The higher the starting temperature the shorter the time necessary to trip. The same effect was also noted in the case of the fuses. This increase in speed with an increase in starting temperature is true on both non-inductive and 50% power factor loads. From the results obtained, it is uncertain what change in the speed of operation of a breaker may be expected due to a change from non-inductive load to 50% power factor load when starting at the same temperature and same per cent overload current except that the change will be very small.

However, in the case of the fuses there seems to be a definite increase in the speed of operation due to a change from non-inductive load to 50% power factor load at all starting temperatures tested. As the per cent overload increases less affect is noticed due to either the starting temperature or nature of the load, and the curves become almost vertical between 600% and 1000% rated current. In the case of the fuses, little change is noted due to either the nature of the load or original temperature above 400% rated current. Curves No. 3 and 6 for the Bull Dog breaker are of doubtful value since this breaker would not carry

rated current for more than 15 minutes without tripping. It is believed that this was due to wear on the breaker since it had been in service before these tests were made.

In general, the relative speed of operation of the breakers used in these tests was as follows, listed in order of their speed of operation: Bull Dog, Westinghouse, G.E. A-8, Square D, and G.E. A-6. However, these results should not be excepted as comclusive since only one breaker of each make was tested. In all cases, except as noted below, the fuse operation was faster than any breaker under the same conditions. An exception was noted in the case of curve 6 for the Bull Dog. However, this curve is unreliable as explained above. Another exception is the 30 A. point on curve 3 for the G.E. A-8. However, all curves for this breaker may be questioned since it was inoperative when received. In order to make it work it was necessary to open it and oil the mechanism. This may have speeded it up, and probably accounts for its being faster than the other G.E. breaker.

The results from the cord tests indicate that any cord tested would be protected by the slowest breaker tested. It was observed that smoke was given off from the cord at some time before failure, but due to human error in deciding exactly at what time the smoke started it was decided not to try to plot this condition. Due to the large volume of smoke given off from some of the samples just before failure it was necessary to test them on the outside of the building. This may have caused some increase in the time necessary for

failure due to the heat being carried away faster by convection currents of air.

Based upon the above mentioned conditions, it is the belief of the writers that the breakers would not be sufficient protection for the No. 16 all rubber cable. Since this No. 16 all rubber cable is probably very representative of the common cords used in homes, it would not be advisable to try to protect such homes with breakers. The speed of operation of the fuse indicates that the fuse would be sufficient protection for any cord tested.

The conclusions given above are based upon tests which are very limited; therefore the conclusions are necessarily limited in scope. In order to verify these conclusions other tests should be made. It is suggested that tests be made on the breakers and fuses at higher values of currents, and also on the cords at higher values of currents including more types and sizes of cords.

APPENDIX

I

Direct Current Resistance

Cold, Room Temperature 27.0° C.

Item	Voltage	Current	Resistance
Square D	0.147 volts	10.62 amp.	9.91382 ohms.
Westinghouse	0.1456 "	10.63 "	0.01369 "
Bull Dog	0.187 "	10.62 "	0.0176 "
G. E. A-6	0.1156 "	10.64 "	0.01084 "
G. E. A-8	0.129 "	14.9 "	0.00866 "
15 A. Fuse	0.144 "	14.8 "	0.00973 "
30 A. Fuse	0.189 "	29.2 "	0.00648 "

D. C. Resistance, Hot

Square D	0.1478 "	10.64 "	0.01388 "
Westinghouse	0.148 "	10.62 "	0.01393 "
Bull Dog	0.1972 "	10.60 "	0.0186 "
G. E. A-6	0.1188 "	10.62 "	0.01118 "
G. E. A-8	0.1344 "	15.00 "	0.00896 "
15 A. Fuse	0.162 "	15.00 "	0.0108 "
30 A. Fuse	0.1914 "	29.6 "	0.00647 "

Non-Inductive Load

200% Rated Current

Item	Voltage	Current	%Overload	Temp.	Time
Square D	113.5	29.5 A.	197	27.0°C	29.6 sec.
"	112.0	29.6 "	197	25.5 "	30.6 "
Westinghouse	113.5	29.3 "	195	27.0	18.4 "
"	112.0	29.6 "	197	25.5	20.2 "
Bull Dog	113.5	29.0 "	193	27.0	15.0 "
"	112.0	29.6 "	197	25.5	15.9 "
G. E. A-6	113.5	29.3 "	195	27.0	46.2 "
"	112.0	29.6 "	197	25.5	46.0 "
G. E. A-8	112.0	29.6 "	197	25.5	26.7 "
15 A. Fuse	112.0	30.0 "	200	24.5	4.56 "
"	112.0	30.0 "	200	24.5	4.10 "

400% Rated Current

Square D	110.0	60.6 "	404	26.0	4.4 "
"	108.0	60.4 "	403	26.3	4.2 "
Westinghouse	110.0	60.6 "	404	26.0	2.8 "
"	109.0	60.4 "	403	26.3	3.2 "
Bull Dog	110.0	60.4 "	403	26.0	2.6 "
"	109.0	60.4 "	403	26.3	2.6 "
G. E. A-6	110.0	60.6 "	404	26.0	6.8 "
"	109.0	60.4 "	403	26.3	6.4 "
G. E. A-8	109.0	60.4 "	403	26.3	4.6 "
15 A. Fuse	109.0	60.4 "	403	22.5	0.33 "
"	109.0	60.4 "	403	22.5	0.36 "
30 A. Fuse	110.0	60.0 "	200	25.5	5.79 "
"	110.0	60.0 "	200	25.5	5.48 "

600% Rated Current

Item	Voltage	Current	%Overload	Temp.	Time
Square D	106.5	90.0 A.	600	26.0°C	2.0 sec.
"	105.0	90.0 "	"	24.5	1.75 "
Westinghouse	106.5	90.0 "	600	26.0	1.2 "
"	105.0	90.0 "	600	24.5	1.32 "
Bull Dog	106.5	90.0 "	600	26.0	1.2 "
"	105.0	90.0 "	600	24.5	1.15 "
G. E. A-6	106.5	90.0 "	600	26.0	3.2 "
"	105.0	90.0 "	600	24.5	2.82 "
G. E. A-8	105.0	90.0 "	600	24.5	1.95 "
15 A. Fuse	106.0	90.4	602	25.5	0.15 "
30 A. Fuse	106.0	90.4	301	25.5	1.29 "

800% Rated Current

Square D	102.5	118.8 "	792	26.0	0.92 "
"	"	"	"	"	0.92 "
Westinghouse	"	"	"	"	0.70 "
"	"	"	"	"	0.70 "
Bull Dog	"	"	"	"	0.63 "
"	"	"	"	"	0.62 "
G. E. A-6	"	"	"	"	1.38 "
"	"	"	"	"	1.42 "
G. E. A-8	"	"	"	"	1.00 "
"	"	"	"	"	1.04 "
15 A. Fuse	101.0	119.2 "	795	23.5	0.075 "
"	"	"	"	"	0.083 "
"	"	"	"	"	0.083 "
30 A. Fuse	102.5	120.4 "	401	25.5	0.65 "

1000% Rated Current

Item	Voltage	Current	%Overload	Temp.	Time
Square D	100.0	149.0A.	994.0	24.3°C	0.58 sec.
"	"	"	"	"	0.61 "
Westinghouse	"	"	"	"	0.48 "
"	"	"	"	"	0.46 "
Bull Dog	"	"	"	"	0.43 "
"	"	"	"	"	0.40 "
G. E. A-6	"	"	"	"	1.02 "
"	"	"	"	"	0.95 "
G. E. A-8	"	"	"	"	0.69 "
"	"	"	"	"	0.67 "
30 A. Fuse	99.0	148.0	494.0	25.5	0.37 "
"	"	"	"	"	0.39 "

III

Non-Inductive Load
200% Rated Current

Item	Voltage	Current	%Overload	Heating Current	Time
Square D	112.5	29.6 A.	196.0	7.6 A.	23.3 sec.
Westinghouse	"	"	"	"	14.6 "
Bull Dog	"	"	"	"	10.6 "
G. E. A-6	"	"	"	"	35.4 "
G. E. A-8	"	"	"	"	17.0 "
15 A. Fuse	113.0	30.0	200.0	7.5	1.85 "
"	"	"	"	"	3.25 "

400% Rated Current

Item	Voltage	Current	%Overload	Heating Current	Time
Square D	109.5	60.6 A.	403.0	7.6 A.	3.4 sec.
"	"	"	"	"	3.4 "
Westinghouse	"	"	"	"	2.6 "
"	"	"	"	"	2.4 "
Bull Dog	"	"	"	"	1.8 "
G. E. A-6	"	"	"	"	4.6 "
G. E. A-8	"	"	"	"	3.2 "
15 A. Fuse	109.0	60.4	403.0	7.5	0.33 "
"	"	"	"	"	0.317 "
"	"	"	"	"	0.317 "

600% Rated Current

Square D	105.5	89.6 A.	598.0	7.6 A.	1.4 Sec.
Westinghouse	"	"	"	"	1.0 "
Bull Dog	"	"	"	"	0.8 "
G. E. A-6	"	"	"	"	2.0 "
G. E. A-8	"	"	"	"	1.6 "
15 A. Fuse	106.0	90.4	603.0	7.5	0.13 "

800% Rated Current

Square D	103.0	119.0 A.	795.0	7.5 A.	0.78 sec.
Westinghouse	"	"	"	"	0.56 "
Bull Dog	"	"	"	"	0.45 "
G. E. A-6	"	"	"	"	1.21 "
G. E. A-8	"	"	"	"	0.78 "
15 A. Fuse	102.0	120.4	803.0	"	0.067 "
"	"	"	"	"	0.083 "

1000% Rated Current

Item	Voltage	Current	%Overload	Heating Current	Time	
Square D	100.0	149.0A.	995.0	7.5 A.	0.48	sec.
Westinghouse	"	"	"	"	0.37	"
Bull Dog	"	"	"	"	0.30	"
G. E. A-6	"	"	"	"	0.78	"
G. E. A-8	"	"	"	"	0.50	"

IV

Non-Inductive Load

200% Rated Current

Square D	112.0	29.4A.	196.0	14.8 A.	12.4	"
Westinghouse	"	"	"	"	6.0	"
Bull Dog	"	"	"	"	3.2	"
G. E. A-6	"	"	"	"	12.5	"
G. E. A-8	"	"	"	"	2.4	"
15 A. Fuse	"	30.0	200.0	"	2.6	"
"	"	"	"	"	2.25	"

400% Rated Current

Square D	110.0	60.4A.	402.0	14.8 A.	1.6	"
Westinghouse	"	"	"	"	1.2	"
Bull Dog	"	"	"	"	0.8	"
G. E. A-6	"	"	"	"	1.2	"
G. E. A-8	"	"	"	"	0.8	"
15 A. Fuse	109.0	60.0	400.0	14.7	0.33	"
"	"	"	"	"	0.32	"
30 A. Fuse	110.0	"	200.0	15.0	4.23	"

600% Rated Current

Item	Voltage	Current	%Overload	Heating Current	Time
Square D	107.0	90.0A.	600.0	14.9 A.	0.68 sec.
Westinghouse	"	"	"	"	0.33 "
Bull Dog	"	"	"	"	0.10 "
G. E. A-6	"	"	"	"	0.82 "
G. E. A-8	"	"	"	"	0.23 "
30 A. Fuse	106.0	90.4	301.0	15.0	1.10 "

800% Rated Current

Square D	103.0	119.0A.	795.0	14.9 A.	0.37 sec.
Westinghouse	"	"	"	"	0.275 "
Bull Dog	"	"	"	"	0.13 "
G. E. A-6	"	"	"	"	0.31 "
G. E. A-8	"	"	"	"	0.10 "
15 A. Fuse	101.0	119.0	795.0	14.8	0.067 "
"	"	"	"	"	0.067 "
30 A. Fuse	102.5	120.4	401.0	15.0	0.51 "

1000% Rated Current

Square D	100.0	149.0A.	995.0	14.9 A.	0.27 sec.
Westinghouse	"	"	"	"	0.12 "
Bull Dog	"	"	"	"	0.05 "
G. E. A-6	"	"	"	"	0.30 "
G. A. A-8	"	"	"	"	0.08 "

50% Power Factor Load

200% Rated Current

Average Power Factor--49.6%

Average Room Temperature--24.6°C.

Item	Voltage	Current	%Overload	Power	Time
Square D	115.0	28.4A.	189.0	1600W.	35.4 sec.
Westinghouse	"	"	"	"	22.4 "
Bull Dog	"	"	"	"	17.2 "
G. E. A-6	"	"	"	"	67.6 "
G. E. A-8	114.0	29.4	196.0	1680	25.32 "
15 A. Fuse	"	"	"	"	1.79 "
"	"	"	"	"	1.81 "

400% Rated Current

Average Power Factor--49.7%

Average Room Temperature--24.8°C.

Square D	112.0	60.0A.	400.0	3320W.	4.1 sec.
Westinghouse	"	"	"	"	3.0 "
Bull Dog	"	"	"	"	2.8 "
G. E. A-6	"	"	"	"	7.0 "
G. E. A-8	111.0	60.6	404.0	3360	4.08 "
"	"	"	"	"	4.29 "
15 A. Fuse	"	"	"	"	0.25 "
"	"	"	"	"	0.27 "

600% Rated Current

Average Power Factor--50.3%

Average Room Temperature--25.1°C.

Item	Voltage	Current	%Overload	Power	Time
Square D	108.0	88.0A.	586.0	4720W.	1.8 sec.
Westinghouse	"	"	"	"	1.4 "
Bull Dog	"	"	"	"	1.2 "
G. E. A-6	"	"	"	"	2.8 "
G. E. A-8	108.5	"	"	4780	1.92 "
15 A. Fuse	"	"	"	"	0.12 "
"	"	"	"	"	0.13 "

VI

50% Power Factor Load

200% Rated Current

Average Power Factor--50.4%

Average Heating Current--7.5 Amperes

Item	Voltage	Current	%Overload	Power	Time
Square D	115.0	29.6A.	197.0	1720W.	24.09 sec.
Westinghouse	"	"	"	"	14.78 "
Bull Dog	"	"	"	"	10.71 "
G. E. A-6	"	"	"	"	41.00 "
G. E. A-8	"	"	"	"	18.73 "
15 A. Fuse	114.0	29.4	196.0	1680	1.62 "
"	"	"	"	"	1.50 "

400% Rated Current

Average Power Factor--49.9%

Average Heating Current--7.5 Amperes

Item	Voltage	Current	%Overload	Power	Time
Square D	111.0	60.6A.	404.0	3360W.	3.28 sec.
Westinghouse	"	"	"	"	2.20 "
Bull Dog	"	"	"	"	1.67 "
G. E. A-6	"	"	"	"	4.17 "
G. E. A-8	"	"	"	"	3.06 "
15 A. Fuse	"	"	"	"	0.25 "
"	"	"	"	"	0.27 "

600% Rated Current

Average Power Factor--50.2%

Average Heating Current--7.5 Amperes

Square D	108.5	88.0A.	586.0	4800W	1.42 sec.
Westinghouse	"	"	"	"	1.00 "
Bull Dog	"	"	"	"	0.80 "
G. E. A-6	"	"	"	"	2.017 "
G. E. A-8	"	"	"	4780	1.41 "
15 A. Fuse	"	"	"	"	0.12 "
"	"	"	"	"	0.12

VII

50% Power Factor Load

200% Rated Current

Average Power Factor--50.1%

Average Heating Current--14.8 Amperes

Item	Voltage	Current	%Overload	Power	Time
Square D	114.5	29.6A.	197.0	1700W.	10.18 sec.
Westinghouse	"	"	"	"	4.57 "
Bull Dog	"	"	"	"	0.77 "
G. E. A-6	"	"	"	"	10.33 "
G. E. A-8	"	"	"	"	4.84 "
15 A. Fuse	"	"	"	"	1.38 "
"	"	"	"	"	0.99 "

400% Rated Current

Average Power Factor--49.9%

Average Heating Current--14.7 Amperes

Square D	111.0	60.6A.	404.0	3360W.	1.57	sec.
Westinghouse	"	"	"	"	0.55	"
Bull Dog	"	"	"	"	0.116	"
G. E. A-6	"	"	"	"	2.15	"
G. E. A-8	"	"	"	"	0.267	"
15 A. Fuse	"	"	"	"	0.217	"
"	"	"	"	"	0.200	"

600% Rated Current

Average Power Factor--50.0"

Average Heating Current--14.8 Amperes

Item	Voltage	Current	%Overload	Power	Time
Square D	109.0	88.0A.	586.0	4800W.	0.52 sec.
Westinghouse	"	"	"	"	0.32 "
Bull Dog	"	"	"	"	0.083 "
G. E. A-6	"	"	"	"	0.87 "
G. E. A-8	"	"	"	"	0.33 "
15 A. Fuse	"	"	"	"	0.108 "
"	"	"	"	"	0.108 "

Run A

Non-Inductive Load

No. 12 Style S All Rubber Simplex-Tirex

600V. Cord

20 A. Current Rating

Voltage	Current	%Overload	Temperature	Time
209.0	205.6A.	1030.0	27°	1 Min. 48 sec.
100.0	177.0	885.0	27°	4 " 16 sec.
105.0	147.0	735.0	27°	9 " 20 "
104.5	119.0	595.0	27.3°	No Failure- 30 "

No. 14 Deltabestion Heater Cord

Style A, Stranded

20 A. Current Rating

209.0	205.6A.	1030.0	27°	1 Min. 21 sec.
100.0	178.0	890.0	27°	1 " 47 "
105.0	146.0	730.0	27.3°	3 " 17 "
107.0	119.0	595.0	27.3°	9 " 9 "

No. 14 Style S All Rubber Simplex-Tirex

600V. Cord

15 A. Current Rating

Voltage	Current	%Overload	Temperature	Time	
209.0	205.6A.	1370.0	27°		33 sec.
100.0	178.0	1187.0	27°	1 min.	2 "
105.0	147.0	980.0	27.3°	9 "	20 "
104.0	117.6	784.0	27°	7 "	3 "

No. 16 Type P.O.S.J. All Rubber Cable

7.0 A. Current Rating

209.0	205.6A.	2940.0	27°		3 sec.
100.0	172.0	2460.0	27°		5 "
104.0	150.0	2140.0	27.3°		10 "
107.0	120.0	1720.0	27.3°		16 "
106.0	88.0	1260.0	27°		27 "
108.0	60.0	858.0	27°	2 min.	27 "
110.0	30.0	428.0	27°	No Failure-20 min.	

APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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