Rosebush.
Contact resistance.

49

CONTACT RESISTANCE.

T H E S I S

for

the Degree of

Bachelor of Science

in

E L E C T R I C A L   E N G I N E E R I N G.

UNIVERSITY OF MISSOURI

1906.

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G. F. Harris.

CONTENTS

CURVES

Contact Resistance.

Nearly every possible loss of power about a dynamo has been investigated more or less thoroughly and efforts made to eliminate such loss by careful design of the part in which the loss occurs.

The losses at the brushes due to friction, electrical resistance, etc. have been investigated several times but the results of these tests do not always agree with each other and in so far as they do agree are not generally known. It is usual, in finding the losses of a machine, either experimentally or by calculation, to include the brush losses with the load losses. The actual value of the losses at the brushes is seldom known.

Consideration of the lack of certain knowledge of this subject, led us to attempt this investigation. It was our original intention to investigate the voltage drop and contact resistance of several kinds of brushes at different current densities, different brush pressures,

different speeds of rotation of the commutator or collector rings, different frequencies of alternating current, etc.

(Since beginning to investigate this subject our attention has been called to tests made by a German Engineer, Doctor Kahn. He has made a thorough investigation covering all the details mentioned above.)

We spent a great deal of our time in preparing apparatus and getting ready for the test. We first arranged a commutator, short-circuiting all the bars and mounting it on a shaft which could be rotated at different speeds by means of a variable speed motor to which the shaft was connected by belt and pulley. The commutator brushes were arranged so that the pressure could be adjusted and provision was made for measuring this pressure. We also provided an auxiliary brush for taking the voltage drop from the main brushes to commutator, or from commutator to brush when a current was sent through the commutator from brush to brush.

Before this apparatus was completed we thought of a plan for trying the contact

resistance of different conducting materials by taking strips of these substances pressing them together and sending a current across the junction.

We arranged the apparatus as shown in Diagram on next page. The contact-peices were held together between two blocks. One of these blocks was fastened rigidly to the bench, one of the contact pieces placed against the block and the other contact piece placed in proper position against the first. The last block, a light wood piece, was then placed against this and held in position by the cord which passes thru the pulleys and up to the spring balance as shown. The movable block was not allowed to touch the bench so there was very little friction in the system. Correction was made for the weight of the pulleys. The force was reduced to pounds per square inch of contact surface and plotted in curves.

Electrical connections were made as shown in Fig. 2 . The source of supply was the 110 volts D. C. mains. The current taken was adjusted by means of the lamp bank in the circuit as shown in diagram; finer adjustment was ob-

Fig. 1.

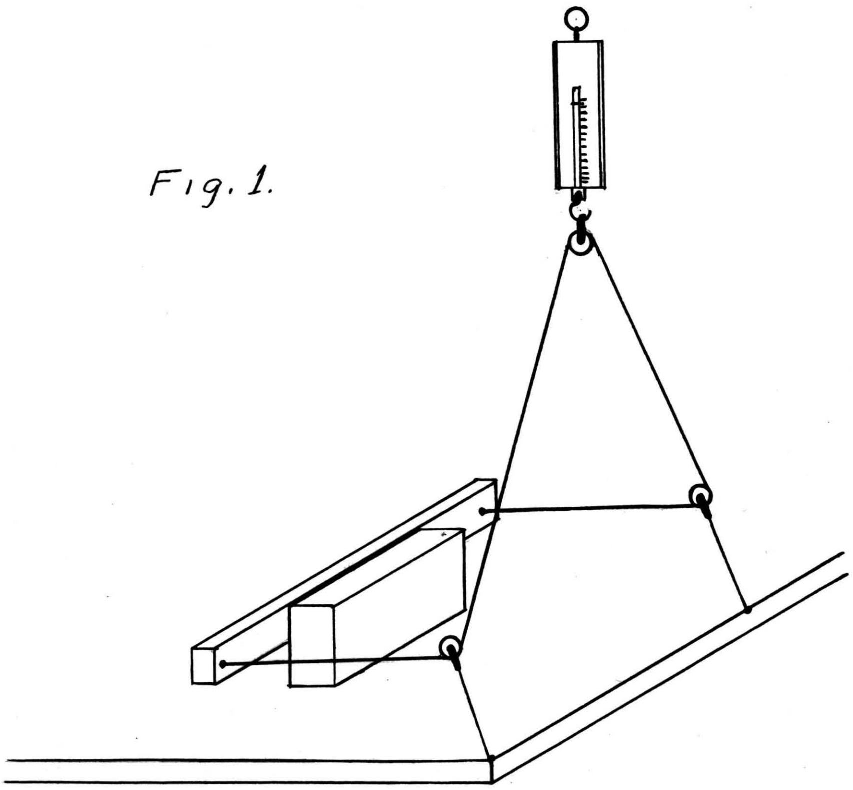


Diagram Showing the method of

measuring the pressure.

CONNECTIONS

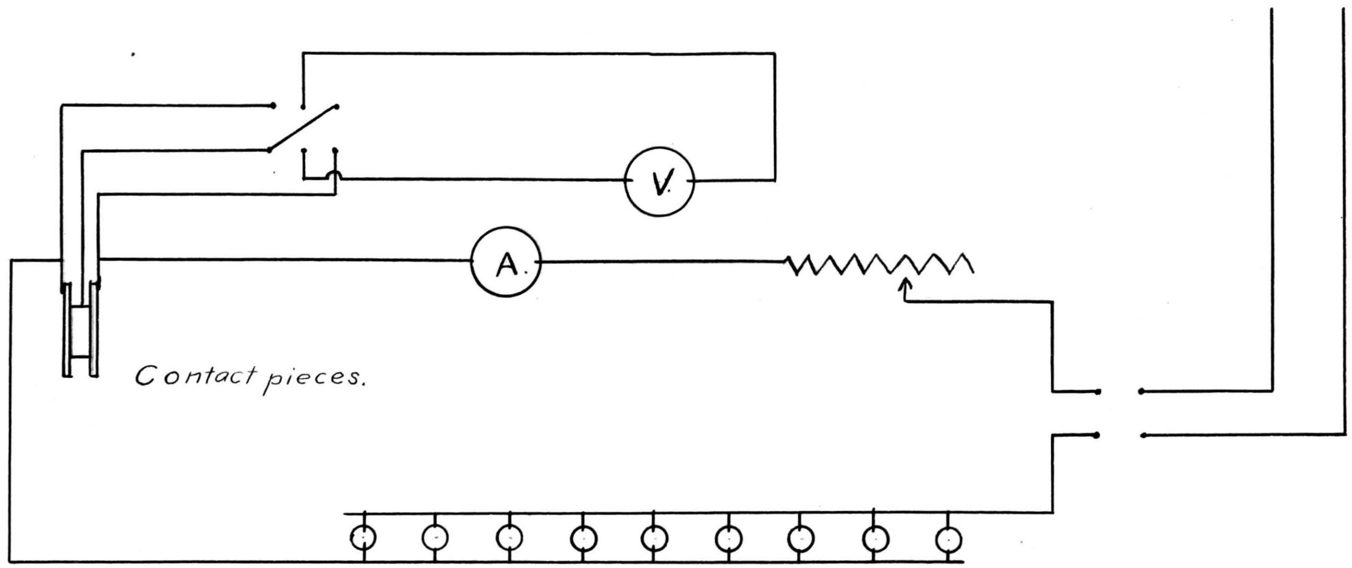


Fig. 2.

tained by means of the rheostat in series. The current was kept in the same direction thru the circuit. Two single pole double throw switches were put in the voltmeter circuit so that by simply throwing these switches in the right combenation the one voltmeter could be made to read the voltage drop from a to b, from b to c, or from a to c. We took several curves with this arrangement of connections with varying current and also several with varying pressure. We then noticed that even though the pressure was the same and the two junctions made as nearly alike as possible there was yet a difference in the resistance of the two joints. Since we wished to see whether the resistance was the same for current in different directions, we discarded this arrangement of connection and during the remainder of the test made use of the connections as shown in Fig.3. In this method the resistance of only one junction was measured.

Having obtained the resistance when the current was flowing in one direction, we reversed the current by means of the reversing switch (at the same time throwing the reversing switch in

CONNECTIONS

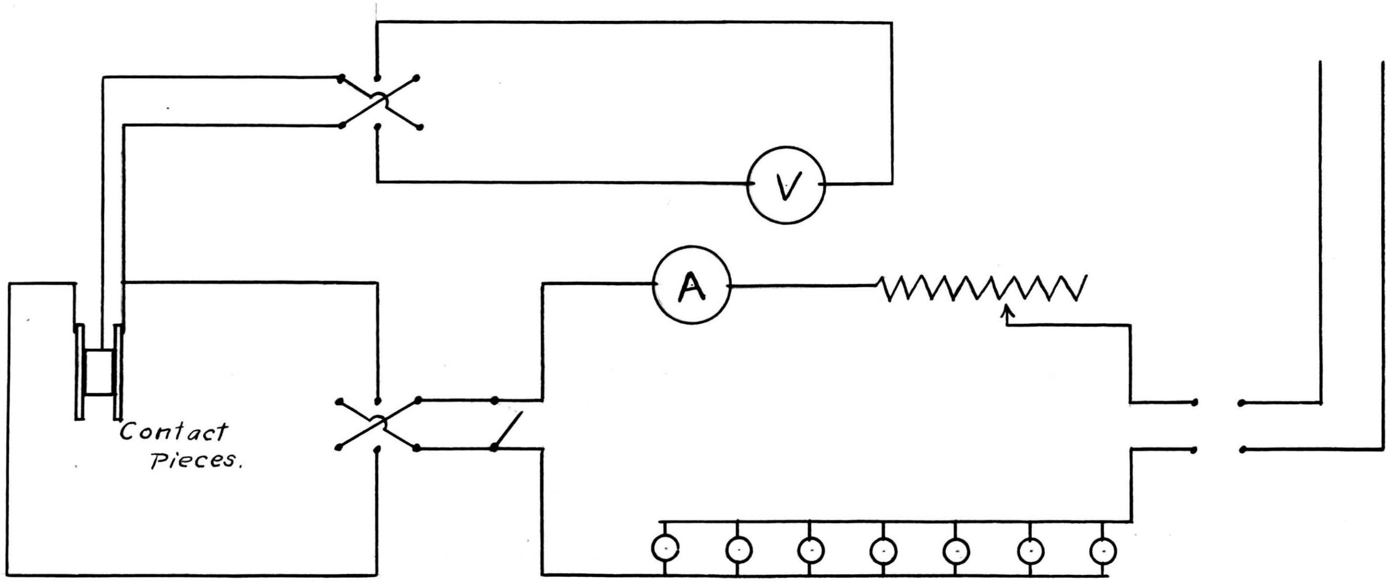


Fig. 3.

the voltmeter circuit) and measured the resistance with the current flowing in the opposite direction.

Carbon and copper were the first contact materials tested.

These materials were selected because they are the ones usually used for brush and commutator respectively.

In taking the readings with varying currents we found that the voltage across the junction was not the same when we were descending on the current curve as when ascending from the zero value. We attributed this difference to the difference of temperature on the two curves. On going up from zero the temperature at any point of curve was less than that on the descending curve at the same current density.

To determine the effect of temperature we drilled a hole in the carbon strip and inserted a thermometer bulb and took the temperature readings at the same time that we took the voltage and current values.

Tests were made with current densities of 5, 10, 15, 20, and 25 amperes per square inch and the resistance in each case was plotted

against the temperature.

We also took curves of resistance against pressure at constant current density and constant temperature.

In every case the resistance was greater when the current was flowing from carbon to copper than when it was flowing from copper to carbon. This difference of resistance increased with the temperature as shown by the curves.

This apparent difference of resistance of the junction of currents flowing in the different directions through the circuit was due to Thermo Electric effects. ?

The fact that an electro-motive force is produced when the two junctions of two different metals are unequally heated, has long been known, but, so far as we know, has never been considered in connection with dynamo brushes and commutators the value of the electro-motive force being considered too small to merit attention.

We were not able to find any data of experiments in thermo-electricity when carbon was one of the substances used.

The existence of thermal-electro-motive forces may be shown by sending a current around the circuit by means of a battery or other outside source. There will be a rise or fall of temperature at the junction depending upon the direction of the current. This shows that in one direction there is a force opposing the flow of the current in the other direction there is a force aiding the flow of current. This effect was noticed to a slight extent in our work. It was not very marked, however, probably because the thermometer we used was not sensitive enough.

The opposing effect of the thermal-electro-motive force acts in the same direction as the resistance drop and makes the apparent resistance of the junction greater than the real resistance. The aiding electro-motive force acts to overcome the resistance drop and makes the apparent resistance less than the real resistance.

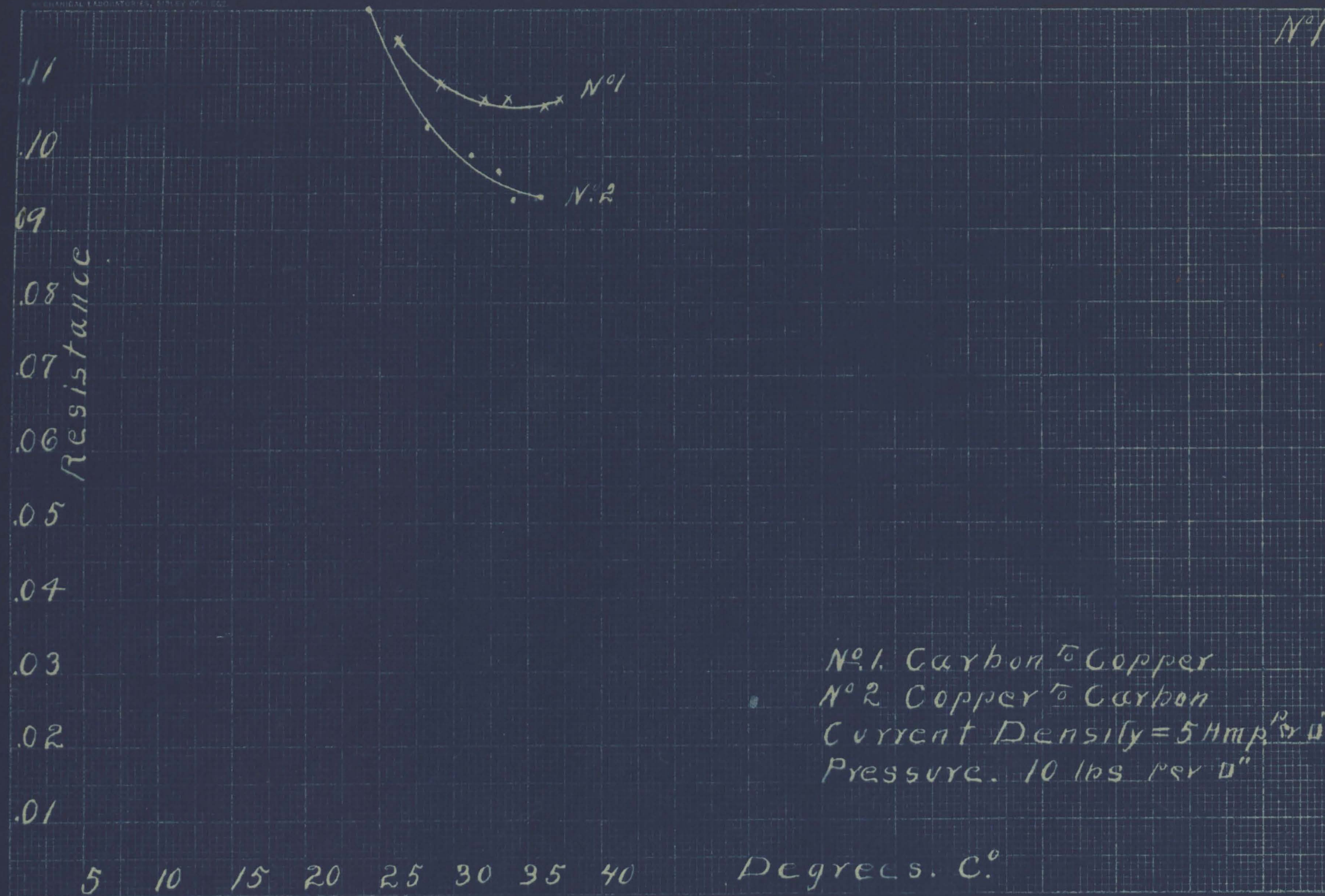
Curve number 1 in each case shows the variation of resistance when the current was flowing from the carbon to the copper; curve number 2 the variation of resistance when the

current was flowing from copper to carbon.

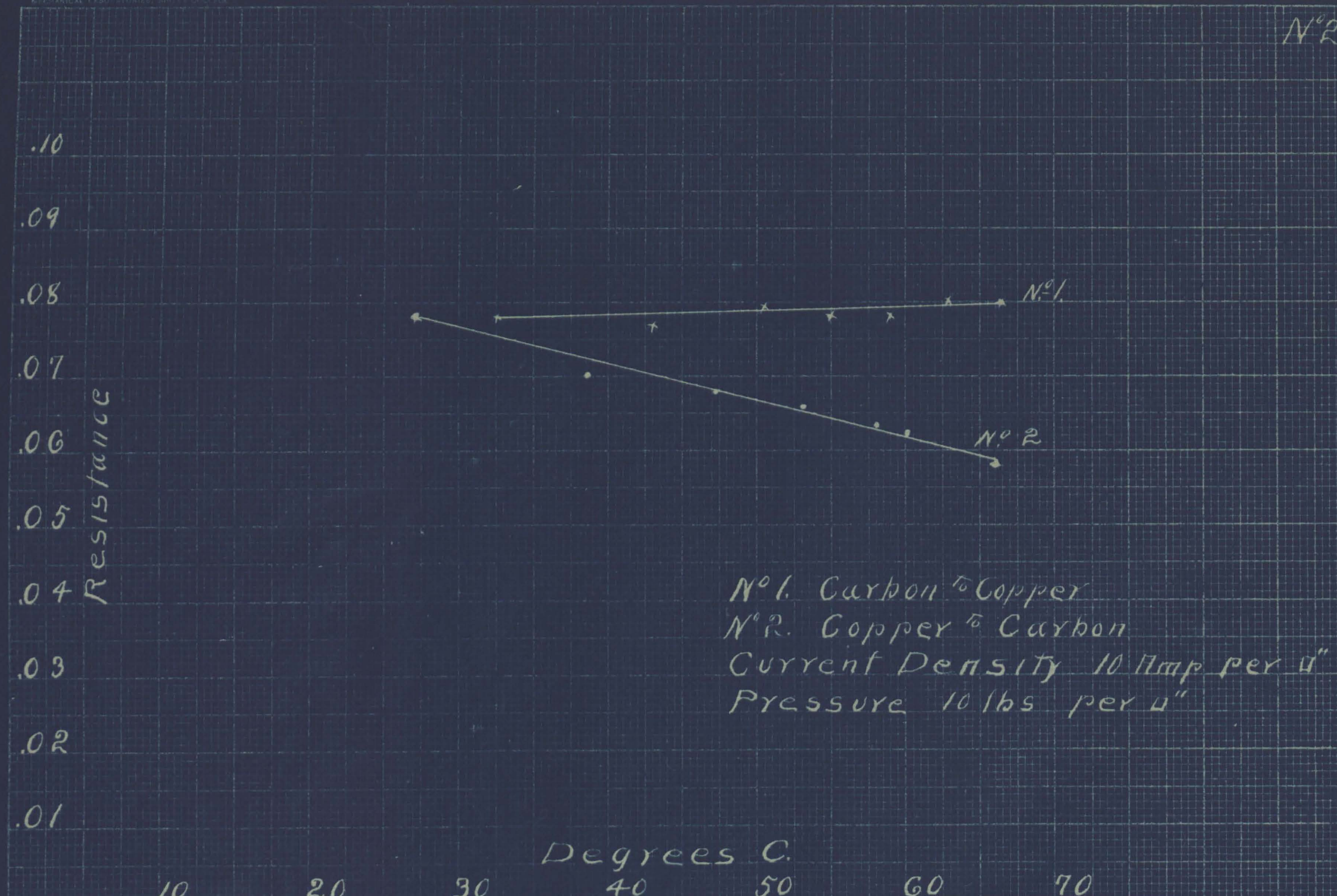
The true resistance curve would come midway between the two resistance curves as plotted.

Looking at the curves it is seen that the resistance decreases as the temperature increases. This is probably due to the negative temperature co-efficient of the carbon.

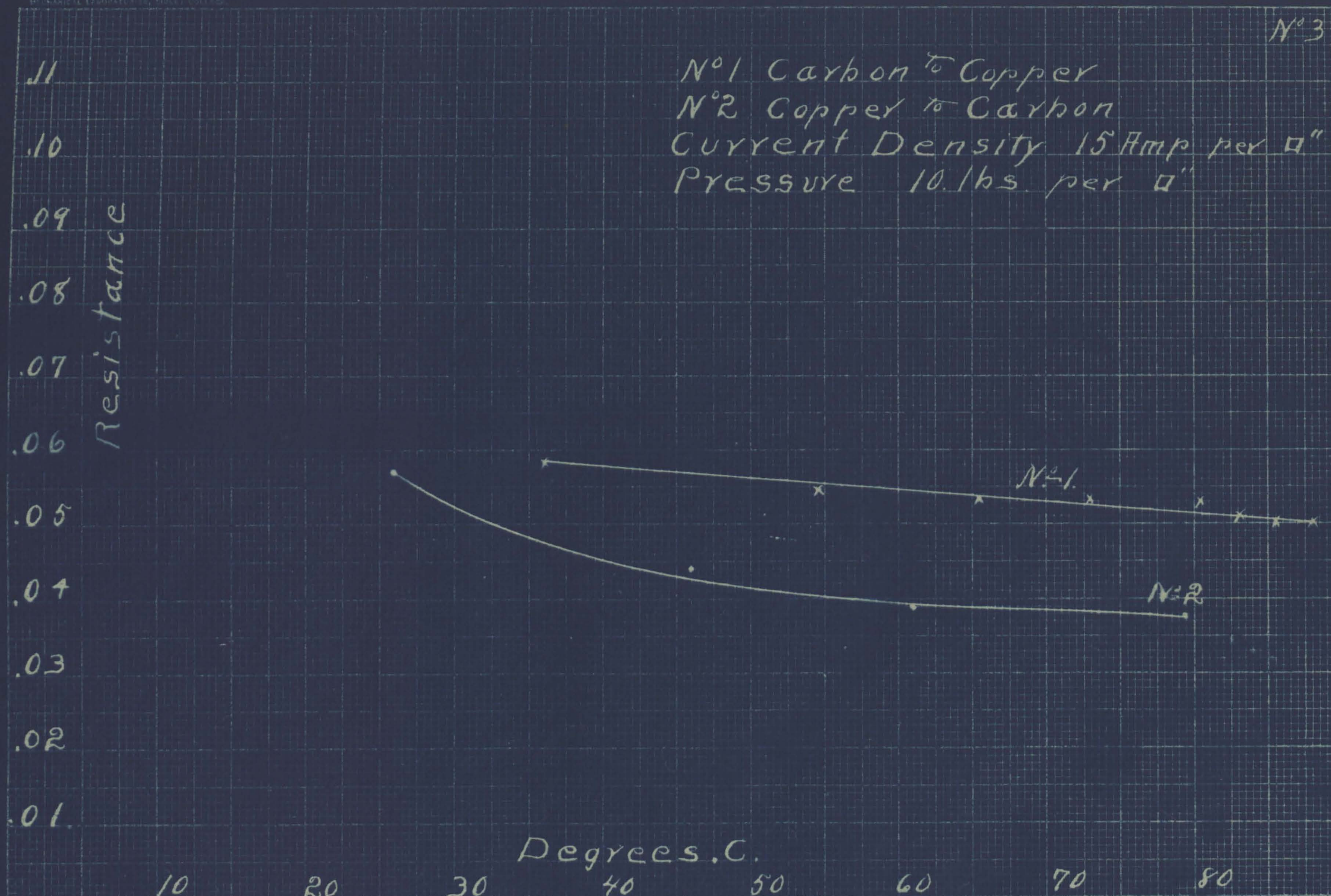
The Resistance-pressure curve shows that the resistance at first decreases quite rapidly as the pressure increases, becoming more and more nearly constant at the higher pressures.

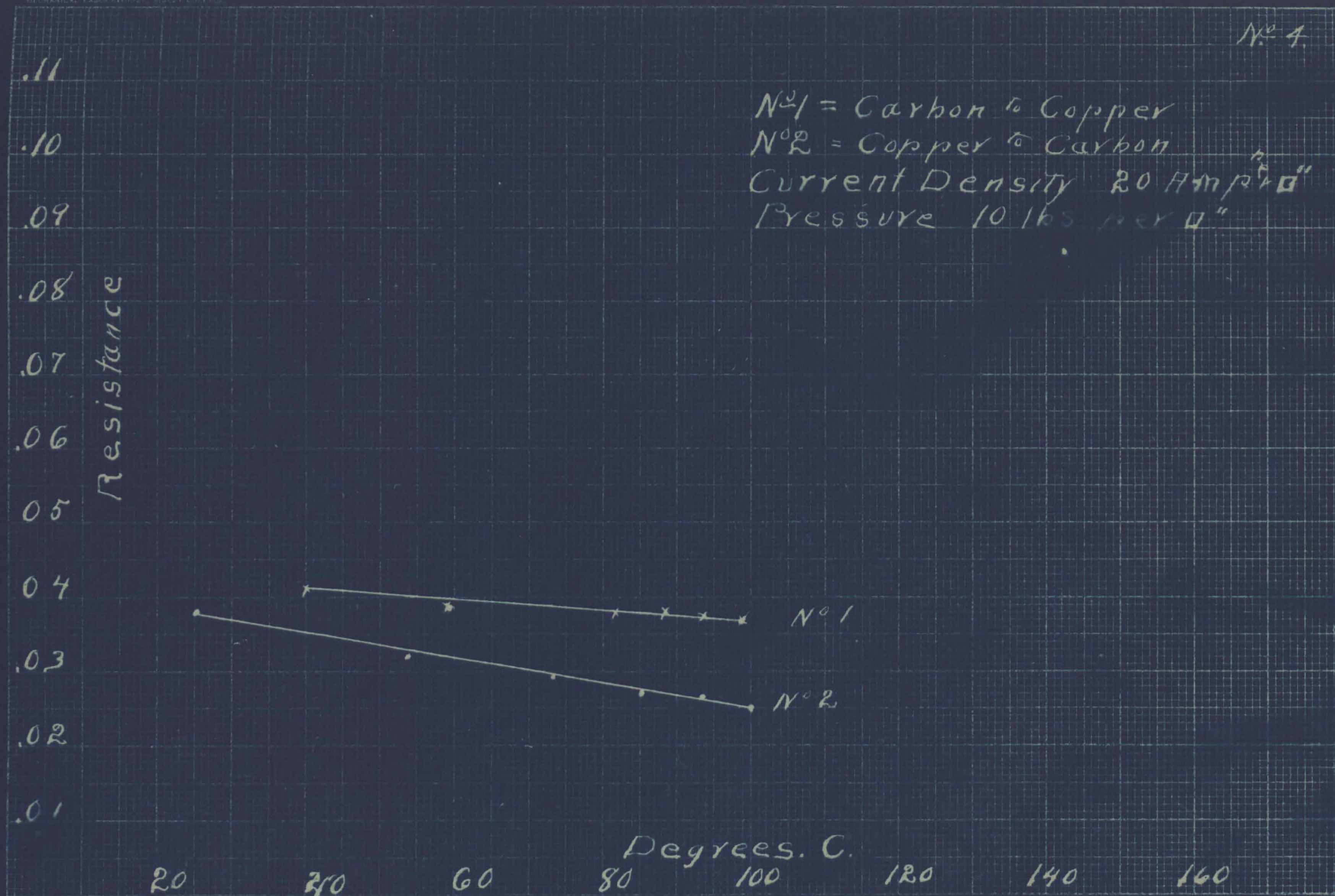


MECHANICAL LABORATORIES, SIBLEY COLLEGE
Nº1
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
Resistance
Nº1
Nº2
5 10 15 20 25 30 35 40
Degrees. C°
Nº1. Carbon to Copper
Nº2 Copper to Carbon
Current Density = 5 Amp per □"
Pressure. 10 lbs per □"
TAYLOR AND CARPENTER

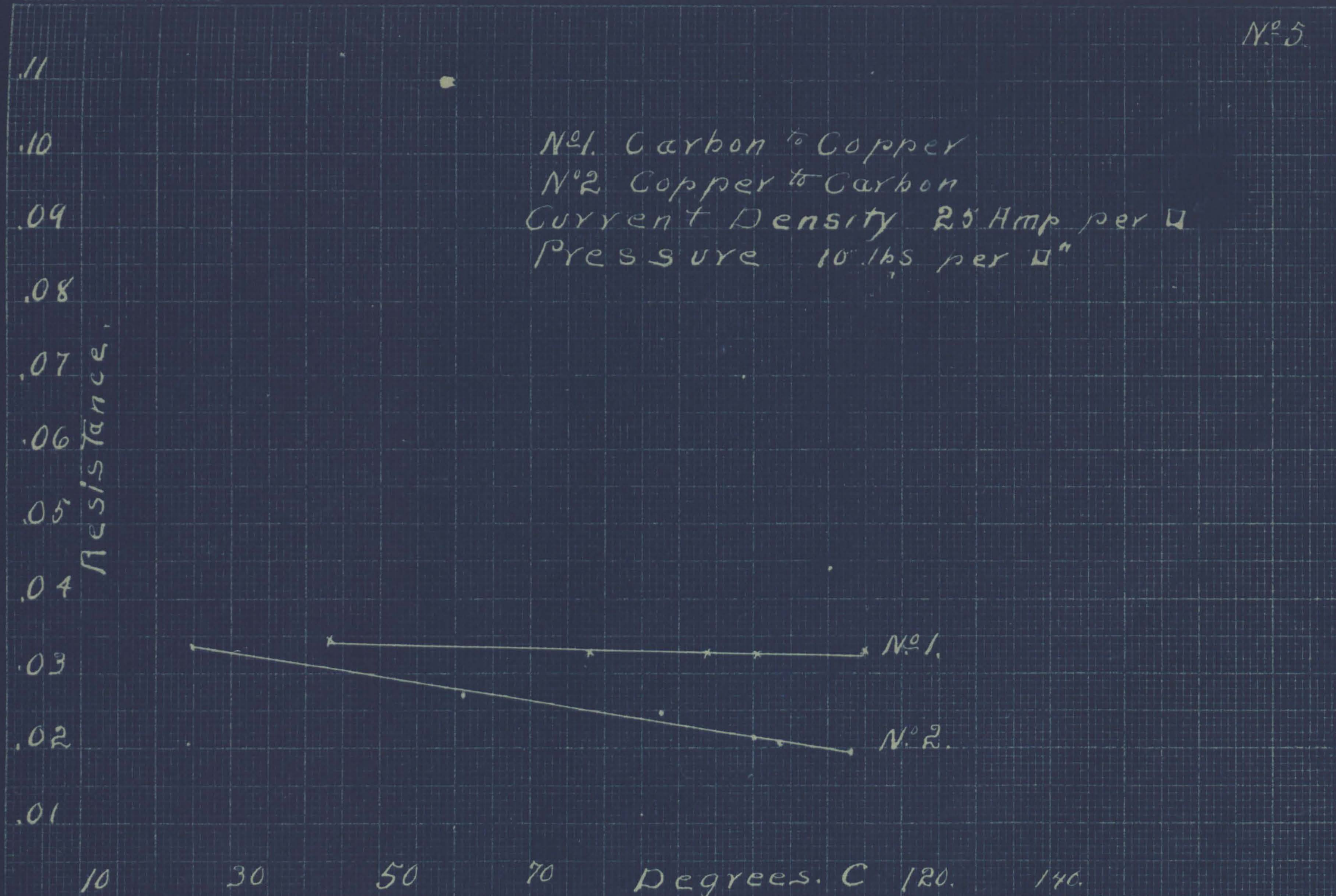


No 2
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
Resistance
No 1.
No 2
No 1. Carbon to Copper
No 2. Copper to Carbon
Current Density 10 Amp per □"
Pressure 10 lbs per □"
Degrees C.
10
20
30
40
50
60
70

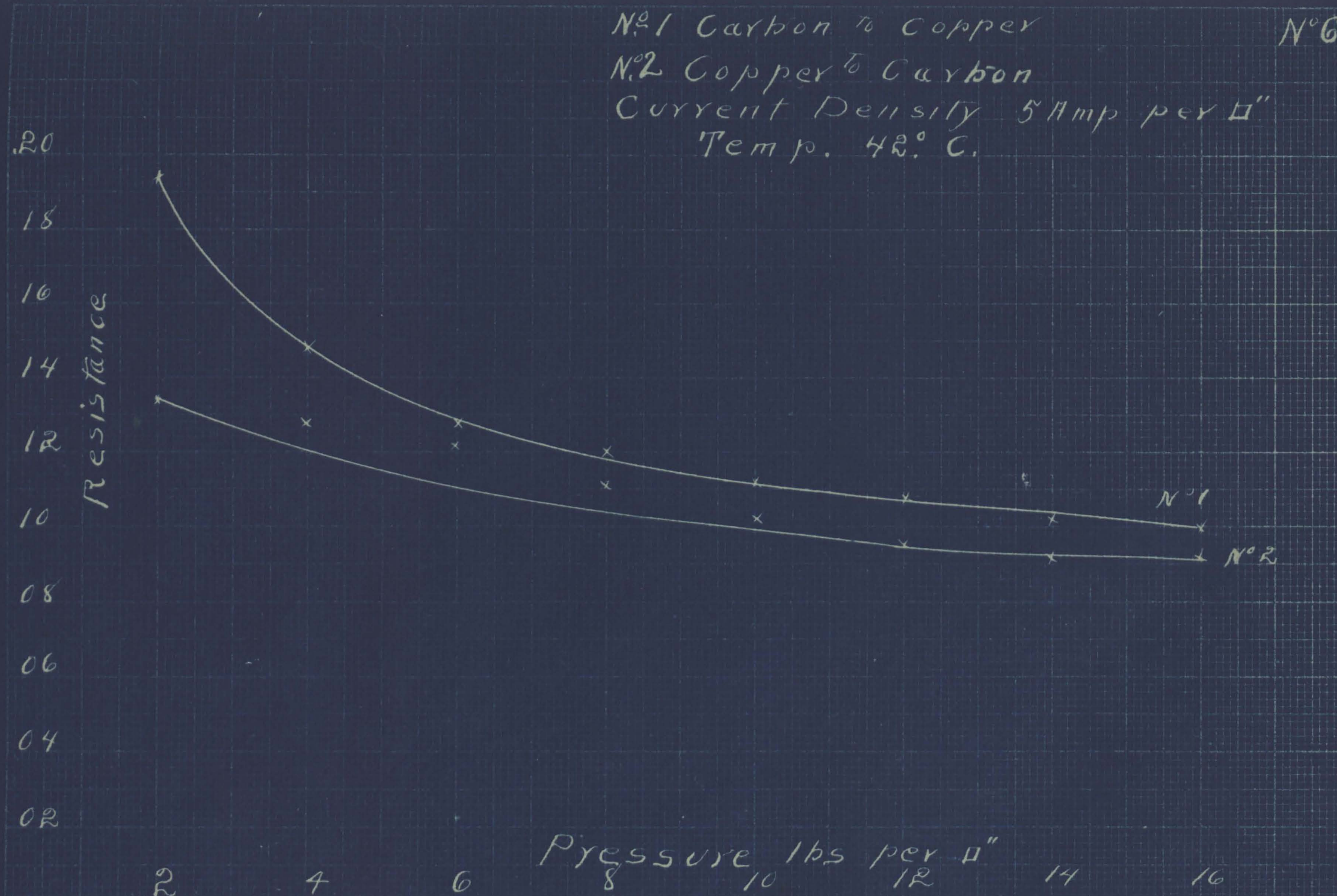

No 3
No 1 Carbon to Copper
No 2 Copper to Carbon
Current Density 15 Amp per □"
Pressure 10 lbs per □"
No 1.
No 2
Resistance
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
Degrees. C.
10
20
30
40
50
60
70
80



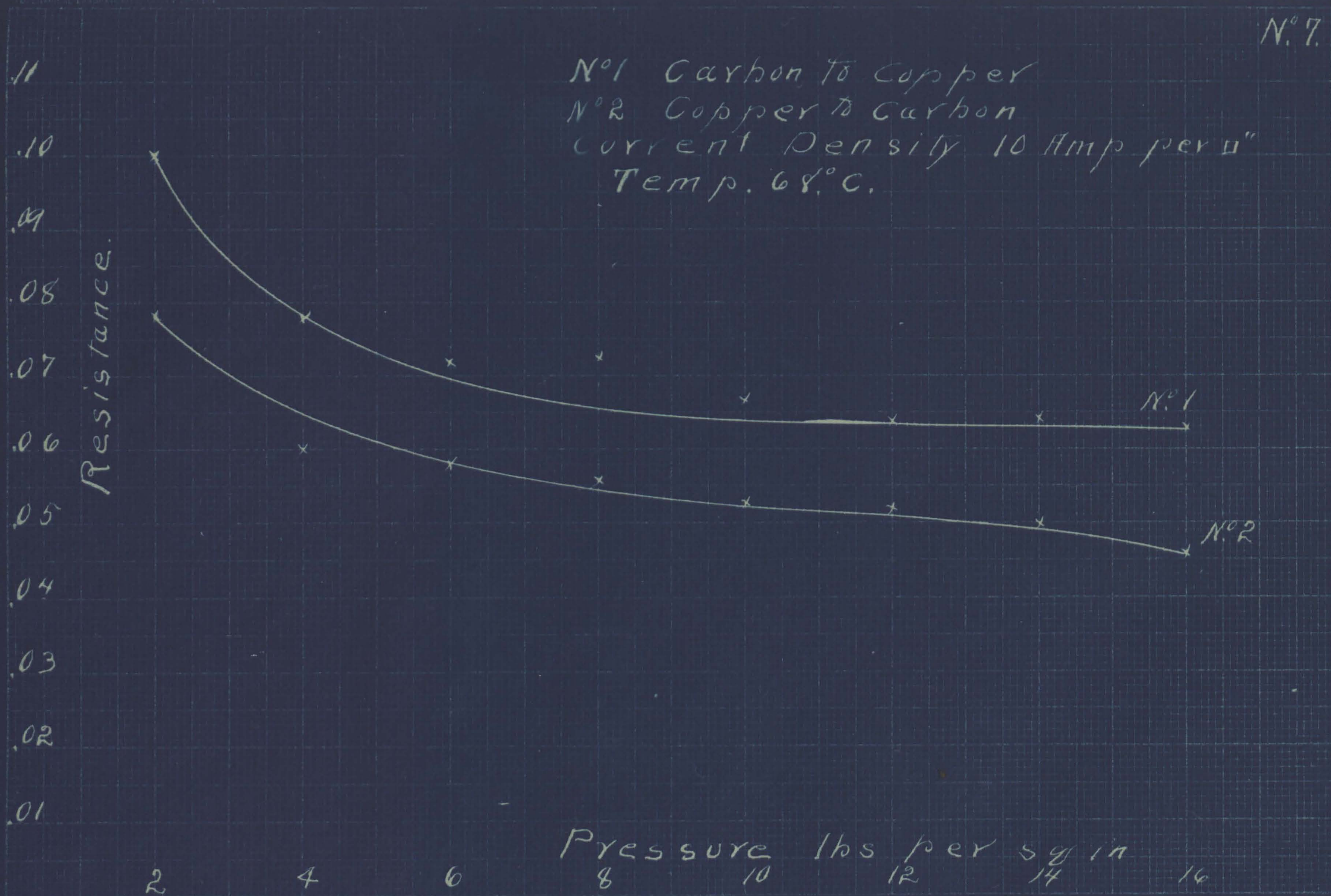
No. 4.
No. 1 = Carbon to Copper
No. 2 = Copper to Carbon
Current Density 20 Amp per □"
Pressure 10 lbs per □"
Resistance
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
No. 1
No. 2
Degrees. C.
20
40
60
80
100
120
140
160



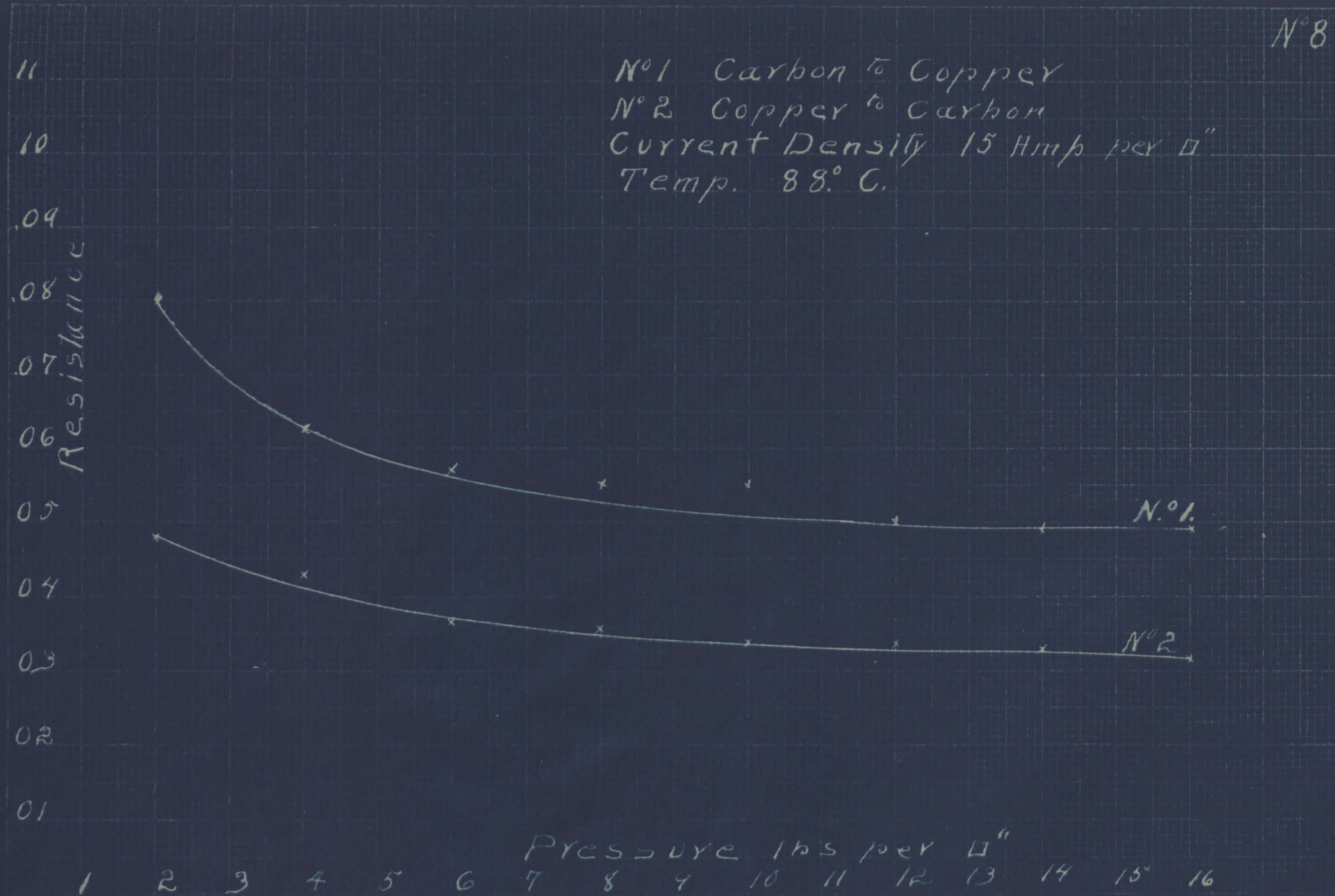
No 5
No 1. Carbon to Copper
No 2 Copper to Carbon
Current Density 25 Amp per □
Pressure 10 lbs per □"
Resistance.
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
10
30
50
70
Degrees. C
120.
140.
No 1.
No 2.



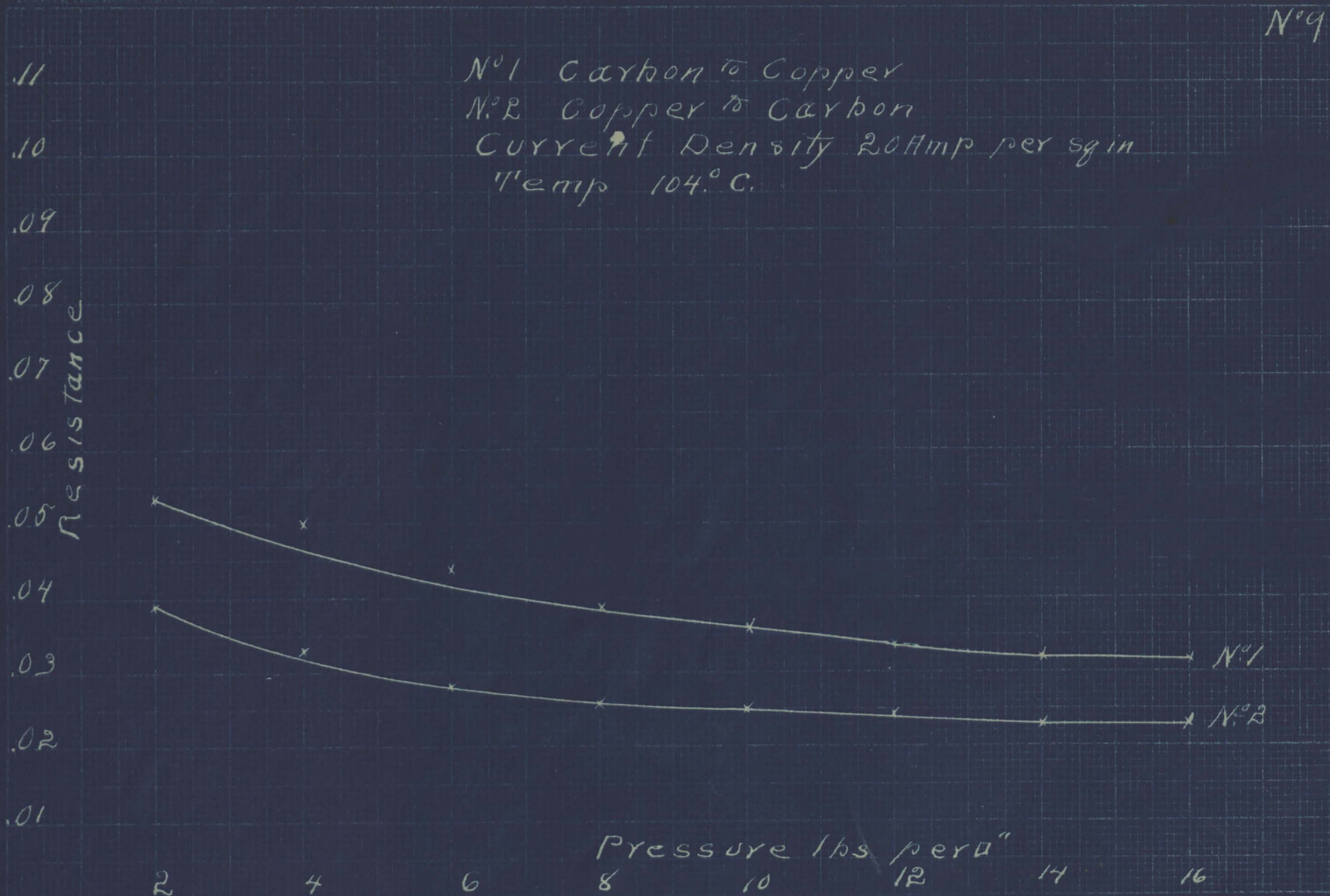
N° 6
N° 1 Carbon to Copper
N° 2 Copper to Carbon
Current Density 5 Amp per □"
Temp. 42° C.
Resistance
.20
18
16
14
12
10
08
06
04
02
N° 1
N° 2
Pressure lbs per □"
2
4
6
8
10
12
14
16

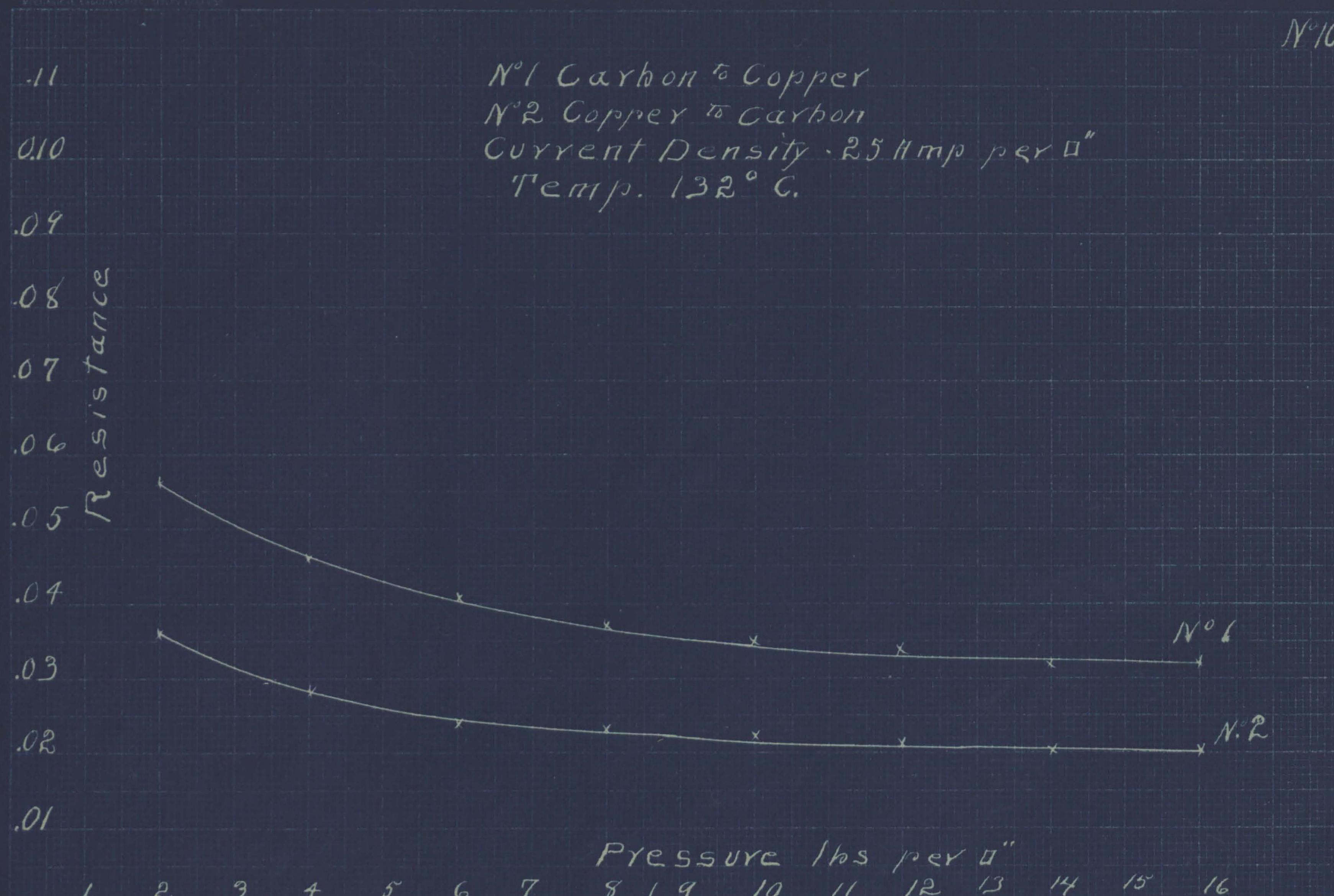


N.° 7.
N°1 Carbon to Copper
N°2 Copper to Carbon
Current Density 10 Amp per □"
Temp. 68°C.
Resistance.
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
N.°1
N.°2
Pressure lbs per sq in
2
4
6
8
10
12
14
16

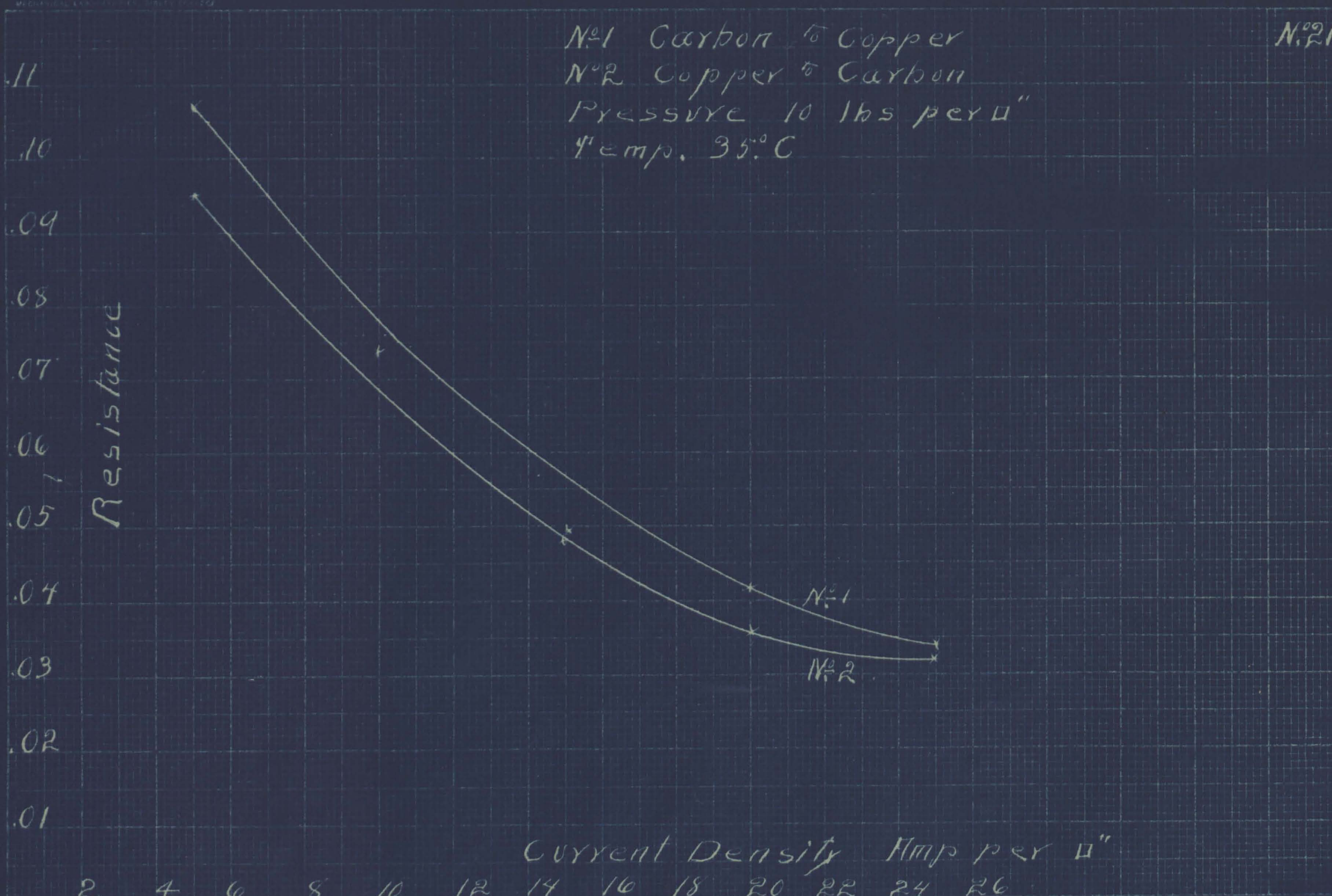


N°8
N°1 Carbon to Copper
N°2 Copper to Carbon
Current Density 15 Amp per □"
Temp. 88° C.
11
10
.09
.08
.07
06
05
04
03
02
01
Resistance
N°1.
N°2
Pressure lbs per □"
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16


No. 9
No. 1 Carbon to Copper
No. 2 Copper to Carbon
Current Density 20 Amp per sq in
Temp 104° C.
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
Resistance
No. 1
No. 2
Pressure lbs per □"
2
4
6
8
10
12
14
16



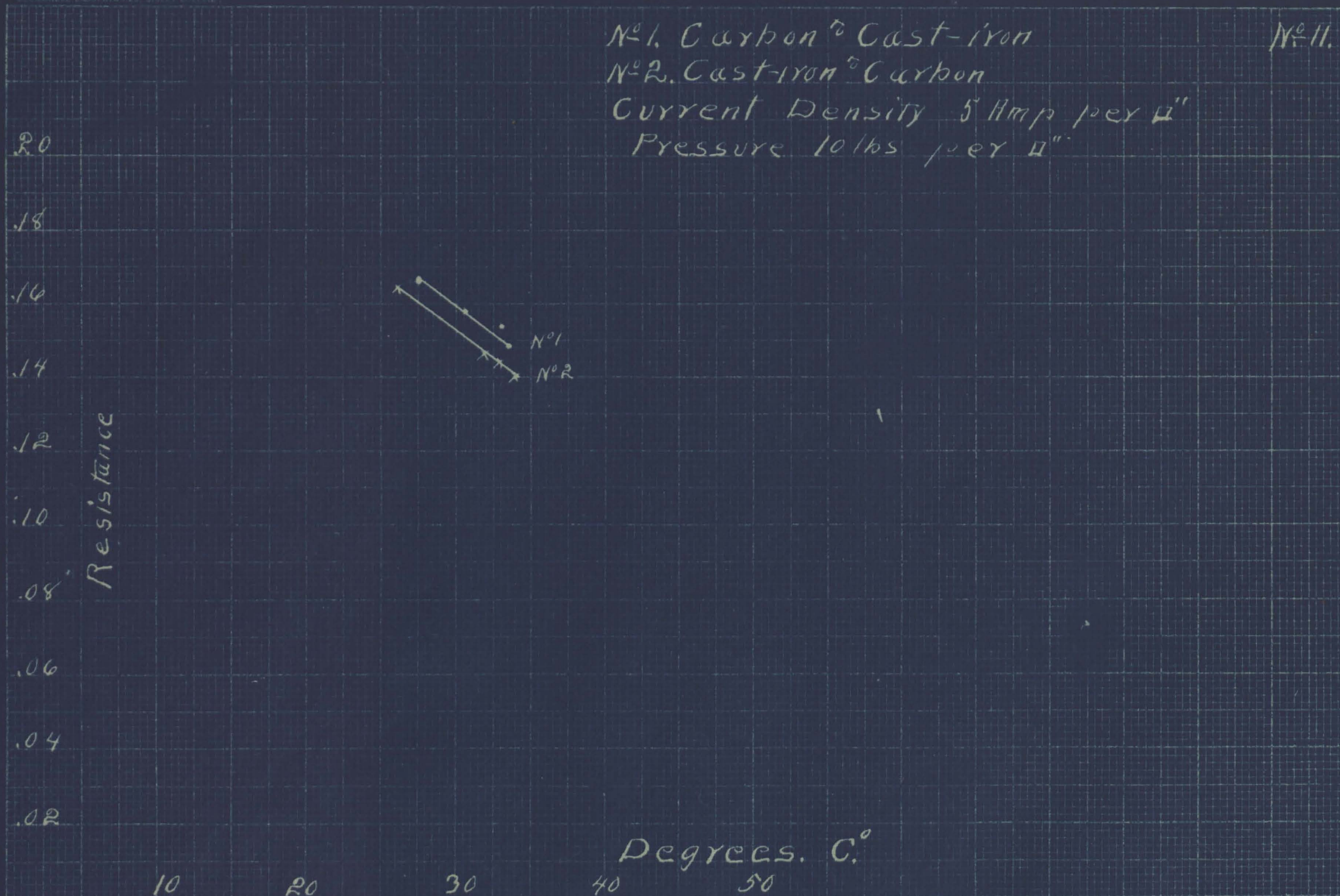
No 10
No 1 Carbon to Copper
No 2 Copper to Carbon
Current Density .25 Amp per □"
Temp. 132° C.
Resistance
.11
0.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
No 1
No 2
Pressure lbs per □"
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

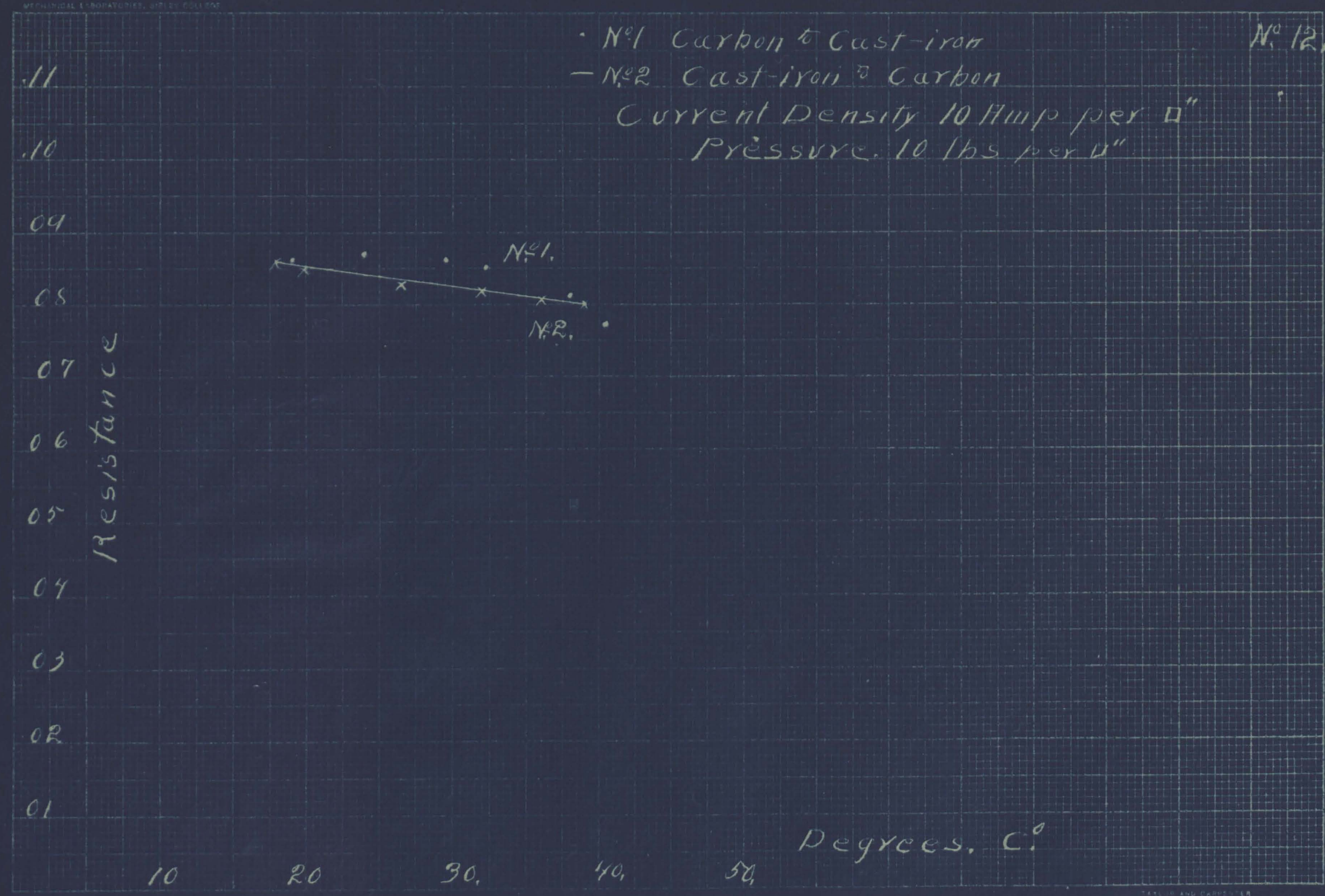

No. 21
No. 1 Carbon to Copper
No. 2 Copper to Carbon
Pressure 10 lbs per □"
Temp. 35° C
Resistance
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
No. 1
No. 2
Current Density Amp per □"
2 4 6 8 10 12 14 16 18 20 22 24 26

Similar tests were made using cast iron and carbon as the contact pieces. Comparison of the results obtained when we used copper and carbon with those obtained when we used cast iron and carbon shows that the resistance under ordinary working conditions is slightly higher between cast iron and carbon, than between copper and carbon. The resistance variation with temperature is nearly the same in the two cases.

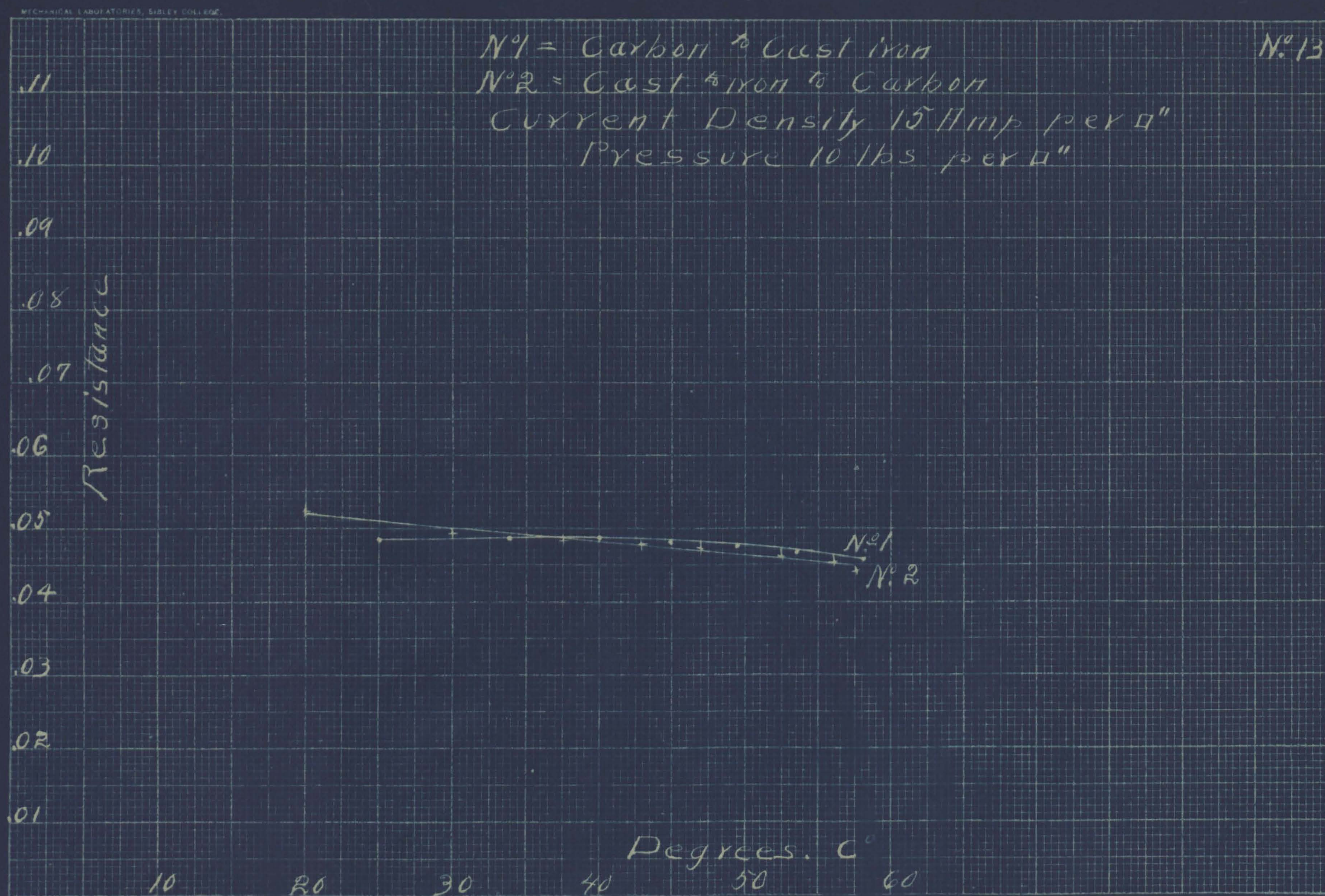
The thermo-electro-motive force produced is not so great with cast iron and carbon as with copper and carbon.

The difference of resistance to currents flowing in the different directions is therefore very small.

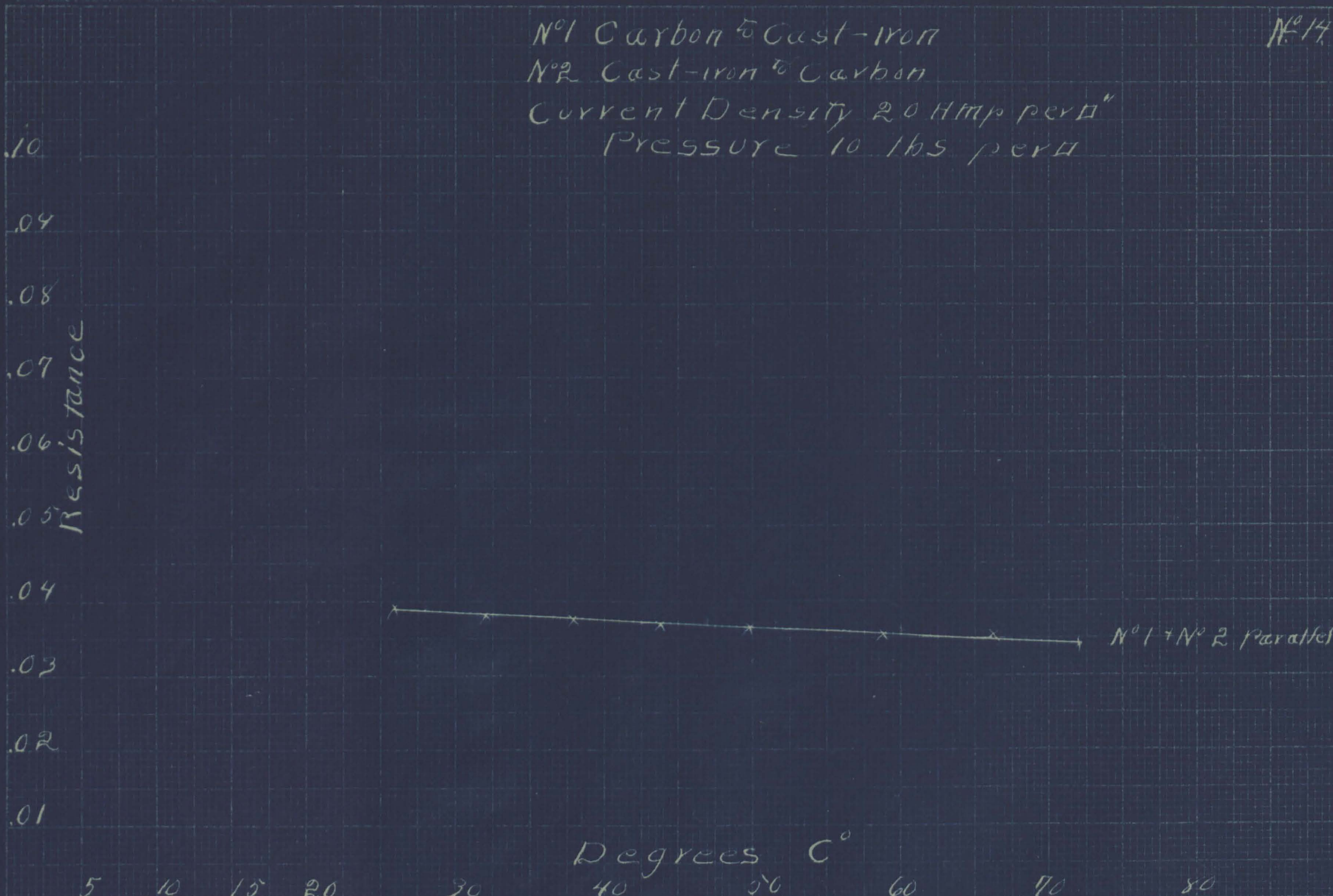

No. 11.
No. 1. Carbon to Cast-iron
No. 2. Cast-iron to Carbon
Current Density 5 Amp per □"
Pressure 10 lbs per □"
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
Resistance
No. 1
No. 2
Degrees. C.°
10
20
30
40
50

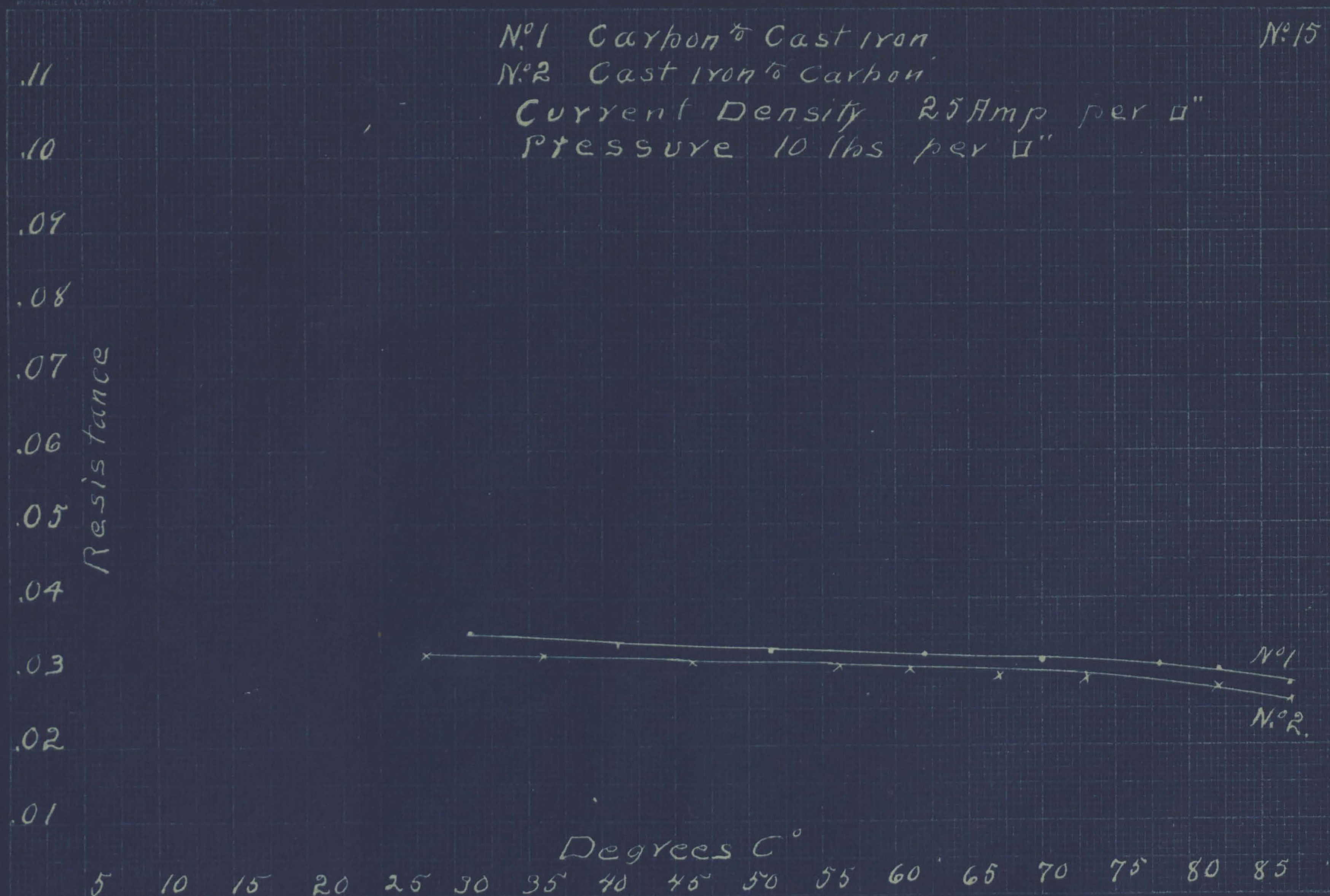


MECHANICAL LABORATORIES, SIBLEY COLLEGE
No. 12
· No. 1 Carbon to Cast-iron
— No. 2 Cast-iron to Carbon
Current Density 10 Amp per □"
Pressure. 10 lbs per □"
.11
.10
09
08
07
06
05
04
03
02
01
Resistance
No. 1.
No. 2.
10
20
30.
40.
50.
Degrees. C°
TAYLOR AND CARPENTER

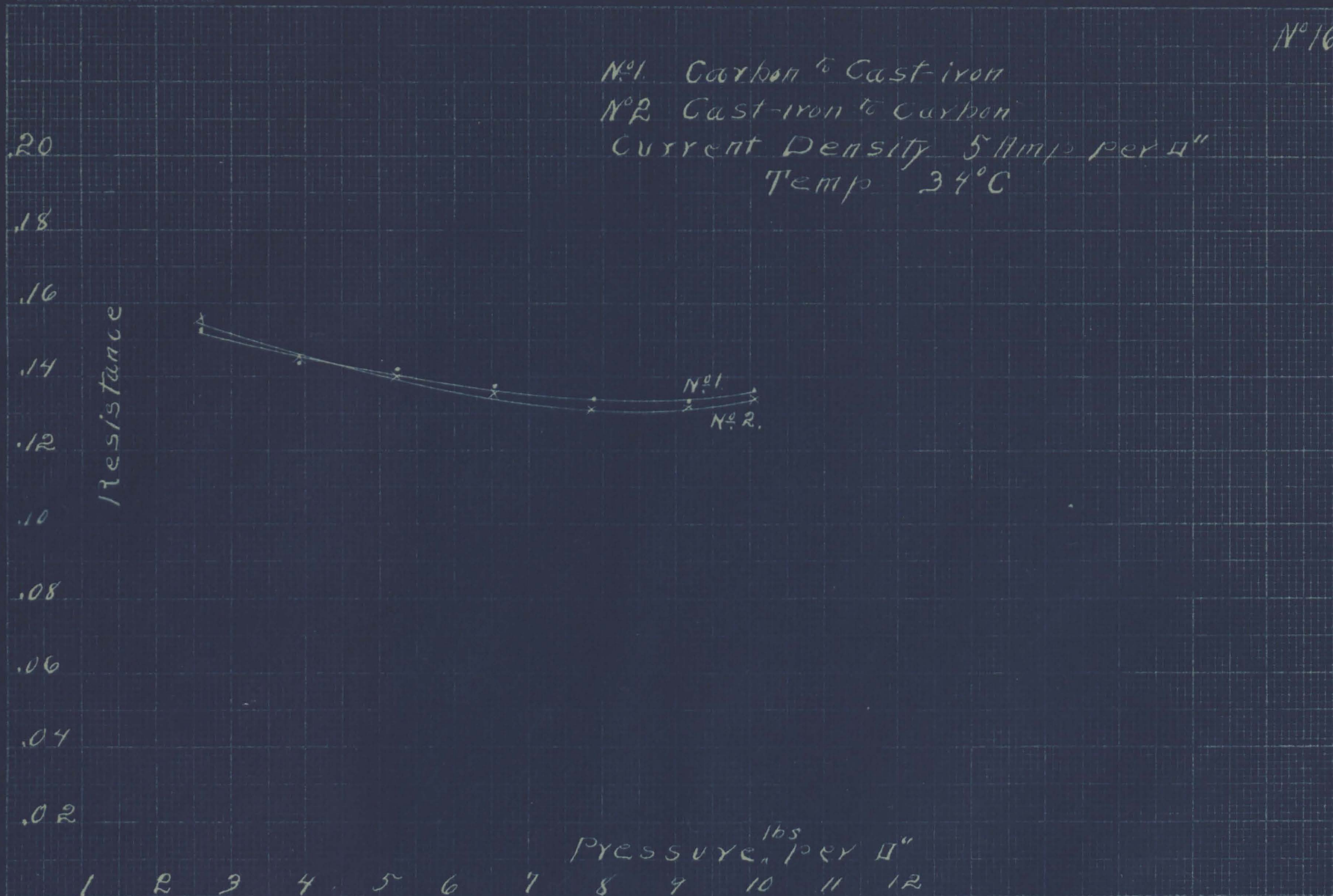


MECHANICAL LABORATORIES, SIBLEY COLLEGE.
No. 13
No 1 = Carbon to Cast iron
No 2 = Cast iron to Carbon
Current Density 15 Amp per □"
Pressure 10 lbs per □"
Resistance
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
No 1
No 2
Degrees. C°
10
20
30
40
50
60
TAYLOR AND CARPENTER

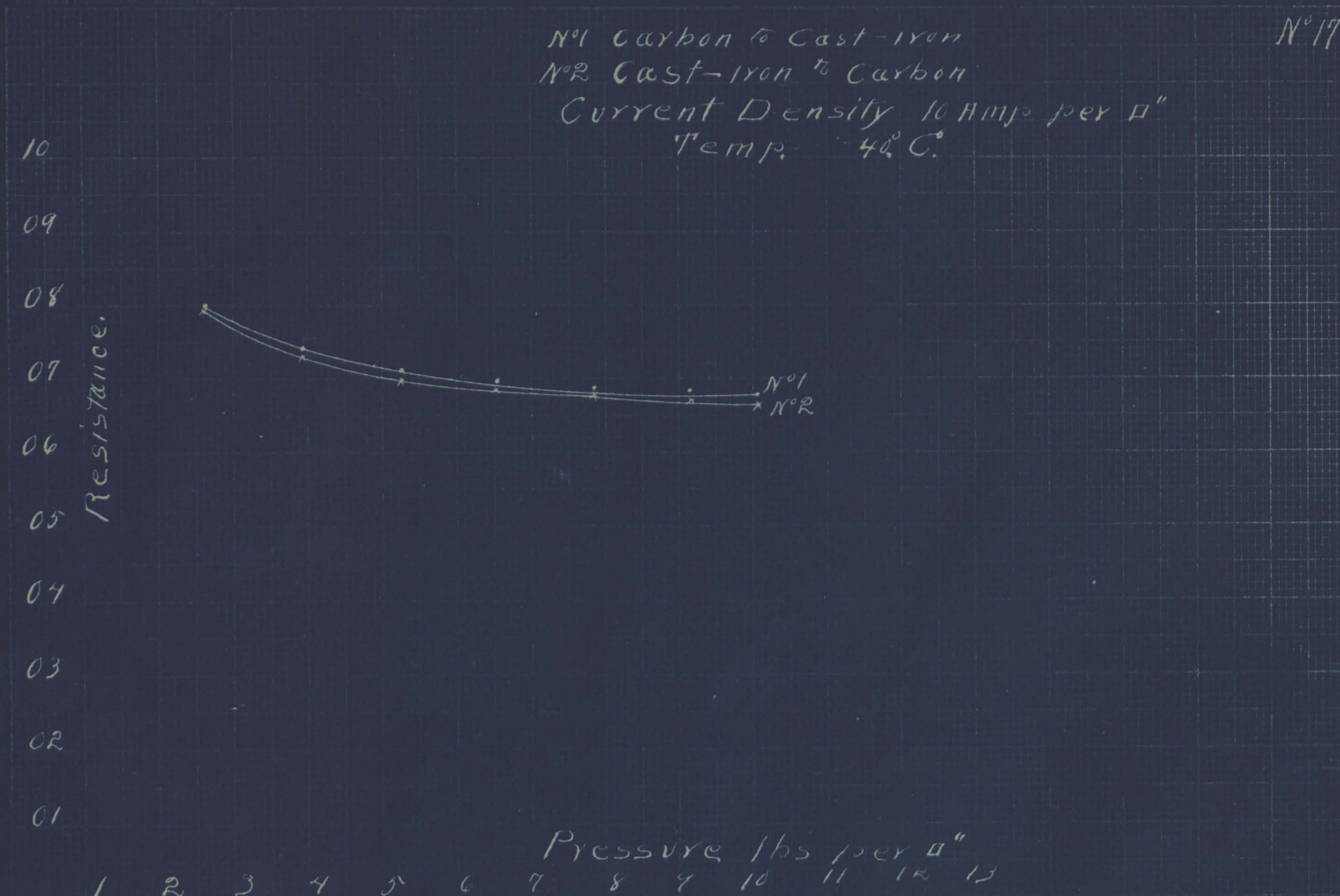

No 14
No 1 Carbon to Cast-iron
No 2 Cast-iron to Carbon
Current Density 20 Amp per □"
Pressure 10 lbs per □
Resistance
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
No 1 + No 2 Parallel
Degrees C°
5
10
15
20
30
40
50
60
70
80

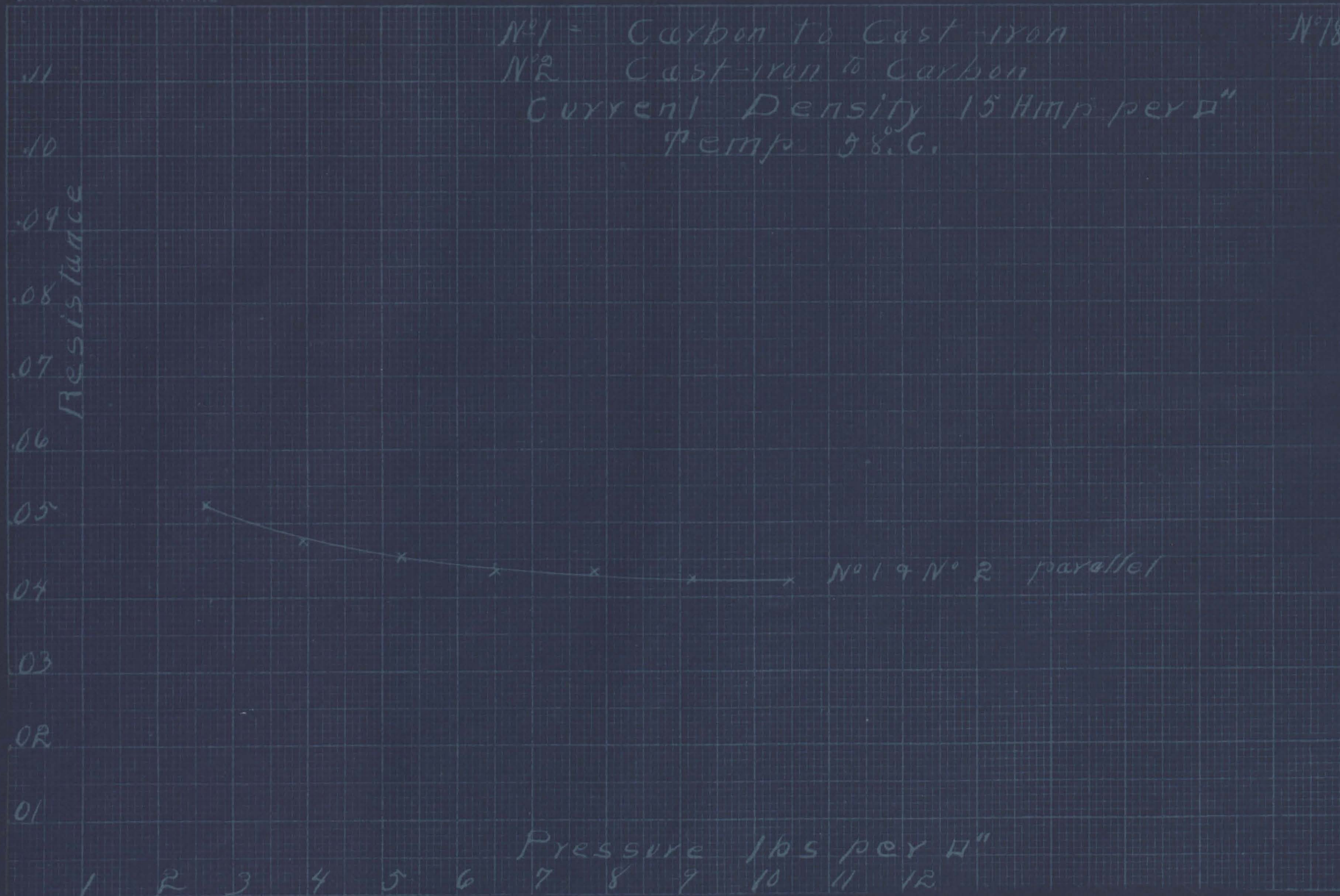


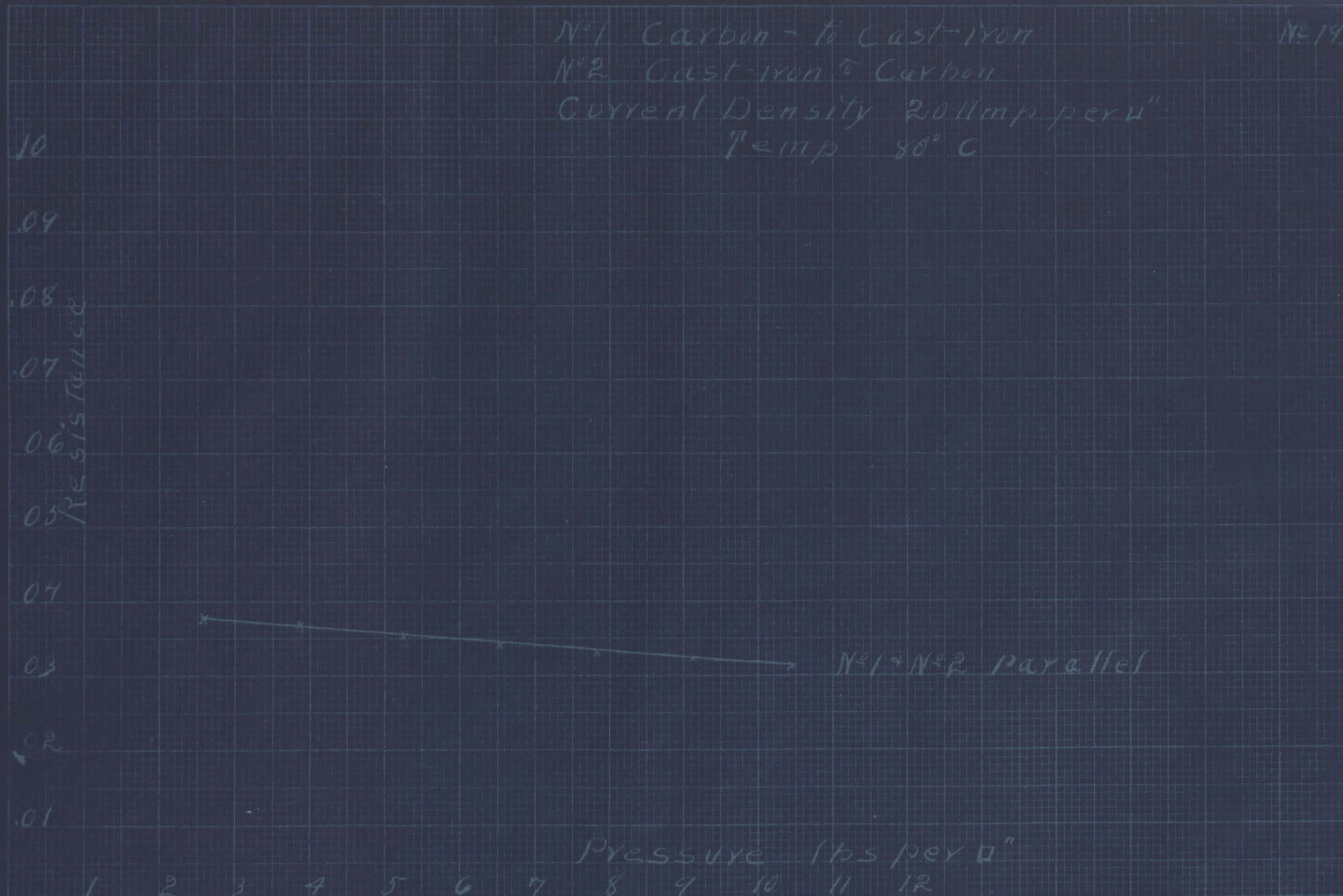
No 15
No 1 Carbon to Cast Iron
No 2 Cast Iron to Carbon
Current Density 25 Amp per □"
Pressure 10 lbs per □"
Resistance
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
Degrees C°
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
No 1
No 2.



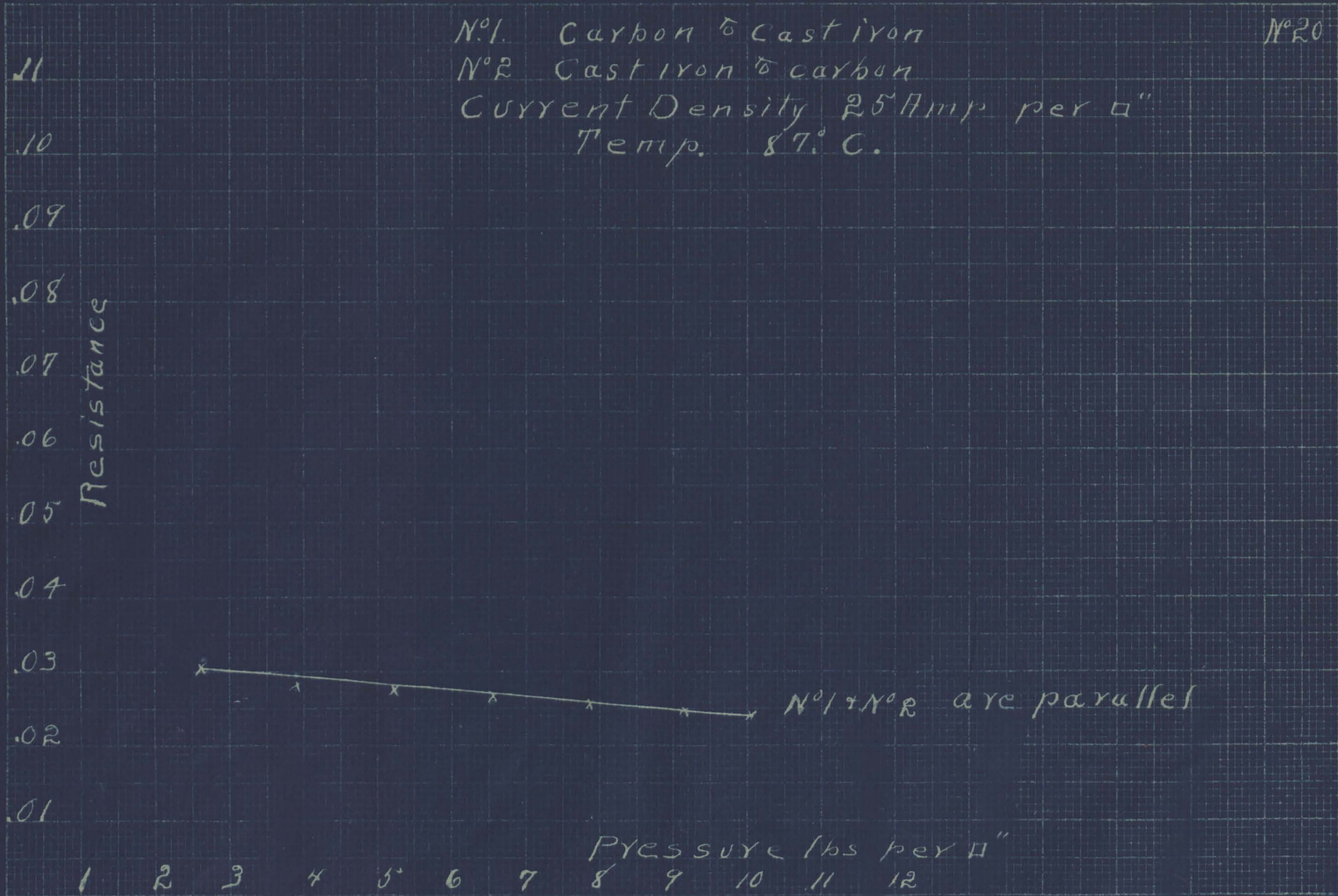
No. 16
No. 1 Carbon to Cast-iron
No. 2 Cast-iron to Carbon
Current Density 5 Amp per □"
Temp 34°C
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
Resistance
No. 1
No. 2.
Pressure, lbs per □"
1 2 3 4 5 6 7 8 9 10 11 12


№ 17
№1 Carbon to Cast-iron
№2 Cast-iron to Carbon
Current Density 10 Amp per □"
Temp. 40° C.
Resistance.
10
09
08
07
06
05
04
03
02
01
№1
№2
Pressure lbs per □"
1 2 3 4 5 6 7 8 9 10 11 12 13

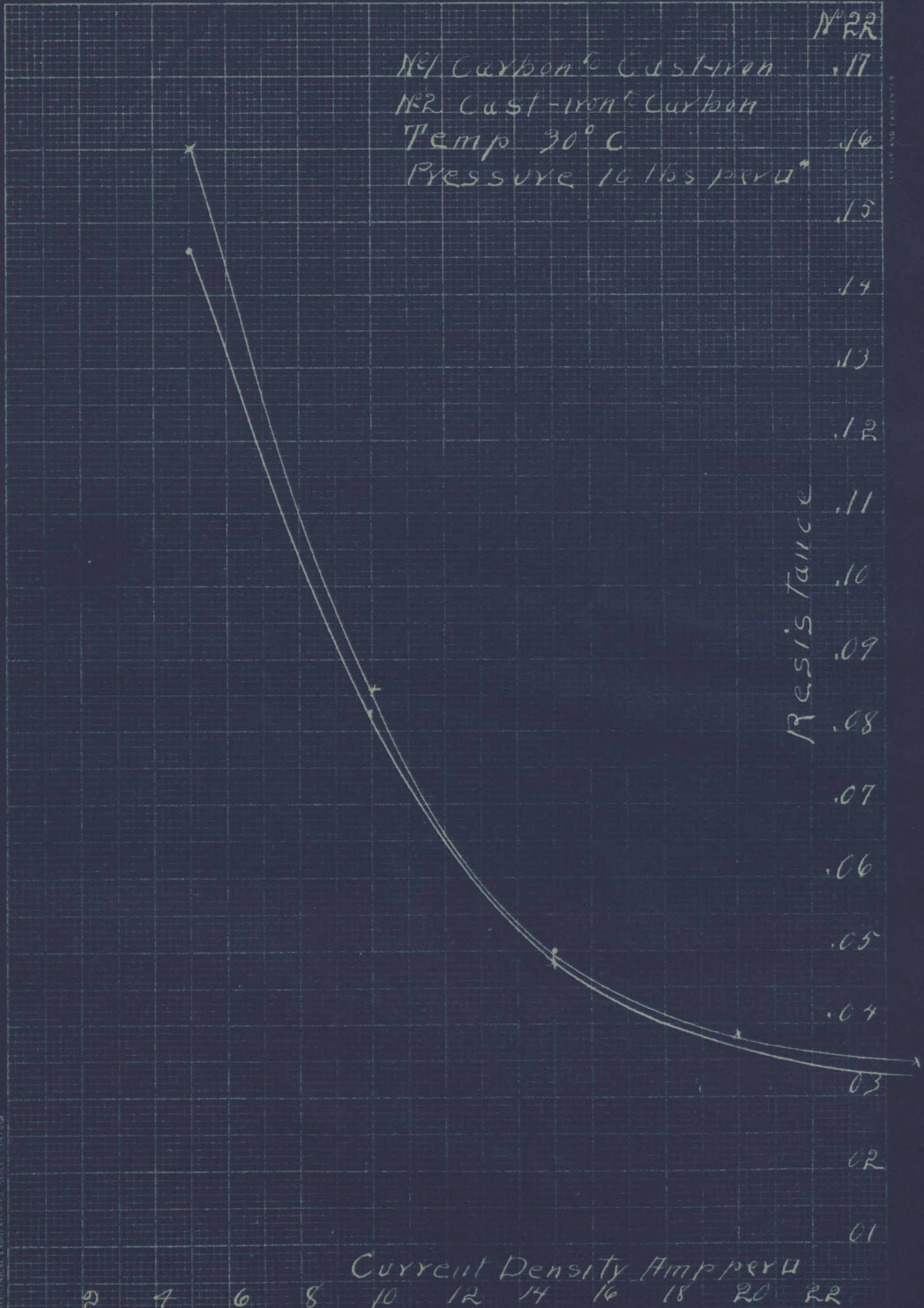

MECHANICAL LABORATORIES, SIBLEY COLLEGE
No 1 = Carbon to Cast iron
No 2 Cast iron to Carbon
Current Density 15 Amp per □"
Temp 38° C.
No 18
Resistance
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
No 1 & No 2 parallel
Pressure lbs per □"
1
2
3
4
5
6
7
8
9
10
11
12



No 1 Carbon - to Cast-iron
No 2 Cast-iron to Carbon
Current Density 20 Amp per □"
Temp 80° C
No 14
No 1 + No 2 parallel
Resistance
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
Pressure lbs per □"
1
2
3
4
5
6
7
8
9
10
11
12



No 20
No 1. Carbon to Cast iron
No 2 Cast iron to carbon
Current Density 25 Amp per □"
Temp. 87° C.
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
Resistance
No 1 & No 2 are parallel
Pressure lbs per □"
1 2 3 4 5 6 7 8 9 10 11 12


No 22
No 1 Carbon to Cast-iron
No 2 Cast-iron to Carbon
Temp 30° C
Pressure 16 lbs per □"
Resistance
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
Current Density Amp per □
2
4
6
8
10
12
14
16
18
20
22

Our time was all taken up with this work so that we did not get to the tests with commutator and brushes as was our original intention.

The apparatus which we prepared for this work is left in the laboratory for the use of any one who desires to investigate the subject.