This report was the cause of a thorough & scientific examination and restoration of W.U wires to their first capacity and highest potential condition.

Mr Varley was an English engineer connected with the Atlantic cable service. I copied his report for the use of the service.

REPORT

OF

Cromwell. F. Varley. Esq.

on the condition of the

LINES

of the

WESTERN UNION TELEGRAPH Company.

December 20. 1867.

Hon William Orton.

President. Western Union Telegraph Co.

Sir.

Herewith I have the pleasure of handing you the tests of some of your lines which I have endeavored to tabulate in a clear and simple manner. ________

I have had but one damp day since I began, and, therefore, the value of the tests is not so great as if there had been both wet and dry weather. ________

By inspecting sheets I. to VI. you will see how very inferior the City insulation was on only a semi-damp day. Also, that, after deducting the City escape, the more extended tests to Newhaven, Albany, Buffalo, Elisabeth, and Hartford, the insulating power of your lines was, on an average, but 20 to 25% of the minimum allowed in England in the very worst weather. ______

The next feature of importance is the conductivity of the wires. This is most irregular on all except the Southern wires, which, for some reason or other, are less obstructed by bad joints. On the other hand, the insulation is bad.

By comparing the resistance shown on different days by the same wire this will be found to vary, thus indicating that there are imperfect connections in your circuits, doubtless bad joints.

I have instructed two of your men how to tin, solder and bind over existing joints, and I would recommend that the joints in your most important wires be thus properly looked to. This trouble is one which will not grow less, but increase rapidly by age. Vide No. 10. and No. 25. wires sheets 15 and 16 &c &c.

The next feature is the existence of many large faults of special character big enough, when added to wet weather escape, to stop the line, and yet not large enough to attract notice by the ordinary relay tests. Vide Nos. 8. 9. 11. & 27 in sheet 14. Also 3 & 4 in same sheet. Also No 10. [cable] wire in 4th column, table 20, sheet 16. Also table 21 sheet 17 column 4.

1.

New York.

Tests made November 26. 1867. between 8.20 A.M. and Noon. State of weather dull, and somewhat damp after fog, viz. It was not foggy at 145 Broadway, but was reported thick at Harlem. There had been Scotch mist all the previous evening. During the tests the weather was clearing up, and by noon the sun began to shine. At 6. P.M. it was clear, cold, frosty weather.

EASTERN ROUTE.

Wires open. (disconnected) at the Harlem Cable House. Length 8½ m.

No. of WIRE.	Mean of + and − readings in B.A. units or Ohms.	Insulation resistance per mile viz. 2nd column multiplied by length. 8.5.	Comparative Insulation taking number 3 wire as Unity.	REMARKS.
1.	7750.	65,875.	1. 23.	—
2.	7750.	65,875.	1. 23.	The insulating
3.	6,300.	53, 550.	1. 00.	power of No 10. is
7.	20,200.	171, 700.	3. 20,	8¾ times as great
9.	49.700.	422, 450.	7. 92.	as No. 3.
10.	55,000.	467, 500.	8. 73.	—
18.	34,750.	295, 370.	5. 52.	
27.	20,000.	170. 000.	3.17	
28.	24,500.	208, 250.	3.90	—

II.

The minimum mileage insulation allowed by me in England where the atmosphere is very humid and full of smoke &c. is 1,000,000. ohms per mile in worst weather.

Thus then.	No 1. has but	6.6 %	of the	proper insulation.
	2. - -	6.6	---	---
	3. - -	5.4	---	---
	7. - -	17.2	---	---
	9. - -	42.2	---	---
	10. - -	46.7	---	---
	18. - -	29.5	---	---
	27. - -	17.0	---	---
	28. - -	20.8	---	---

III.

The same wires disconnected at Newhaven, Nos 3 & 9 excepted.

Distance 76 miles.

No. of Wire.	Mean of Readings	Computed Resistance.	Mileage Resistance	Relative Value. No 18 as Unit.	to No 3 in City.	to English Standard.
	Ohms.	Ohms.	Ohms.			
1.	3000.	4915.	282.000.	1.80.	5.26.	28.
2.	2400.	3486.	—	—	—	—
7.	3050.	3600.	231.000.	1.47.	4.30.	23.
10.	2850.	3022.	168.000.	1.07.	3.13.	17.
18.	2450.	2630.	157.000.	1.00.	2.93.	16.
27.	2550.	2930.	168.000.	1.07.	3.13.	17.
28.	2650.	2970.	173.000.	1.10.	3.23.	17.

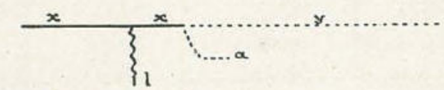
III.

TABLE No 4.

Wires open at Hartford. Distance 127. miles.

Wire			Mileage.		City wire No 3. as Unity.	English Standard.
3.	1950.	2720.	218.000.	1.39.	4.07.	22.
9.	2600.	2744.	206.000.	1.27.	3.84.	21.

Column No 3. was obtained by subtracting the resistance due to the City length, in the following manner.



$2x$ – resistance of City conductor.

y – insulation resistance at the point a.

l. – resistance of City escape.

Table No 1. gives x and l. where x is a known quantity = ½ conductor's resistance, and l is found by the test R. deducting x from it, $R - x = l$.

The second test gives $R_1 = x + \frac{l(x+y)}{l+x+y}$ from which the value of y is easily obtained: $y = \frac{(R-x)l}{R-R_1} - x$.

The fourth column is ascertained by obtaining the resistance of the line, and then computing what length of line has a thousand times the conducting power for its insulation resistance, and then deducing the miles resistance. Owing to the unequal resistance of different parts of the line, this column must be taken as an approximation to the truth.

The foregoing tests were begun at 8.20 and completed at 8.55 or 9. a.m and, therefore, there was not time for any considerable change in the weather.

TABLE. 5. Eastern Route.

via Manhattanville. Distance 9 miles. Wires disconnected at Manhattanville.

NO. OF WIRE.	MEAN of + & − TESTS.	MILEAGE INSULATION RESISTANCE.	COMPARED with No 3 as UNITY.	COMPARED WITH ENGLISH STANDARD.	Remarks.
29.	34.750	212,750.	5.51	21	These tests
30.	34.000.	306,000.	5.4	31.	were made betn
31.	35.500.	319,500.	5.63.	32.	9.40 & 9.50 a.m. and
32.	31.000.	279,000.	4.99.	28.	weather was decidedly dry

These wires were not nearly so much influenced by cross connection as the other wires and which is a far more serious cause of interruption than simple escape.

The sign ⫤ stands for "approximately equal to."

SOUTHERN WIRES. 9.15. A.M.

via 15th street to Jersey City. Length of pole line in circuit ⫤ 6 miles.

TABLE. 6 Wires disconnected at Jersey City.

No. of Wire.	Mean Reading	Mileage Insul:	No 3. as Unity.	Eng. standard 100.	Remarks.
13.	5,600.	33,600.	0.63.	3. 4.	There is a great
20.	15,000.	90,000.	1.68.	9.	escape on 13.

7 Wires open at Elizabeth. Jersey City to Elisabeth 14 miles.

The third column gives the mileage resistance between Jersey City & Elizabeth.

20.	2550.	34,500.	0.64.	3. 4.	

8 Open at 15th Street. 3. miles.

10.	21,000.	⫤ 63,000.	⫤ 1.18.	⫤ 6. 3.	Very severe cross connection with other wires.

9 Western Wires.

Open at Albany. 150. miles.

4.	2,925.	Computed mileage ⫤ 270,000.	5. 0.	27.	The english standard is for very wet weather (not fine) 100.

Erie Wire.

Open at Buffalo. 437. miles.

10

3.	3,180.	Computed. ⫤ 561,000.	14.6.	56.	

The same night. Nov 26. was clear. frosty. and starlight.

The following tests were made at Harlem. each side to ascertain the improvement due to the frost. as also the conducting power of the wire.

Number 8 wire in England gives 12½ ohms at 60° Faht. = 15.5°

Iron improves in conductivity by reduction of temperature. ⩦ 1 per cent for 5° Faht. American No 8 is rather lighter than English wire. I am informed. and. allowing it 13½ ohms at 60° Faht. its resistance at 32° will ⩦ 13. and at 0 ⩦ 12.2.

Table 11. Harlem to New York. 8½ miles.

No of Wire	MORNING Test Damp. OHMS.	EVENING Test Frosty. OHMS.	RATES of IMPROVEMENT	CONDUCTIBILITY Wire to ground at NEW YORK.	SHOULD not EXCEED.
	—	—	—	—	—
2.	7750.	290,000.	1 to 37.	194.	110.
5.		650,000.		260.	110.
7.	20,200.	600,000.	30.	720. *	
8		600,000.		730. *	
10.	55,000.	1,000,000.	18.	210.	110.
18.	34,750.	640,000.	18.4.	133.	110.
27.	20.000.	340.000.	17.	134.	110.
28.	24,500.	800.000.	32.	138.	110.
3.	6,300.	323,000.	51.	—	—
9.	49.700.	613,000.	12.3	—	—

Remarks.

It will be seen that each wire has far too much resistance.

* An instrument in each of these circuits.

Table 11. continued.

Harlem to New York.

Wire No.	Morning Test.	Evening.	Rate of improvement.	Conductivity.	Should not exceed.
3.	6,300.	500,000.	1 to 79.	146.	110.
9.	49,700.	1,100,000.	" " 22.	126.	110.

Harlem to New Rochelle.

Distance 11½ miles. Weather – hard frost.

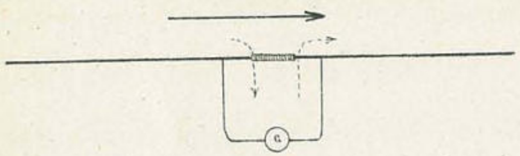
NO.	Evening Test Ins.	Mileage Insulation.	Conductivity in Ohms.	Should not exceed.
2.	900,000.	10,350,000.	210.	150.
5.	1,000,000.	12,650,000.	690.	150.
7.	800,000.	9,200,000.	170.	150.
8.	600,000.	6,900,000.	437.	150.
10.	500,000.	5,750,000.	200.	150.
18.	450,000.	5,175,000.	207.	150.
27.	650,000.	7,475,000.	173.	150.
28.	700,000.	8,050,000.	172.	150.

Table 13. Harlem to Williams Bridge. 5½ Miles.

3.	1,250,000.	6,875,000.	760.	72.
9.	1,300,000,	7,150,000.	500.	72.

I observed that the junction between the line and the cable wires was made in the Cable house by means of fine copper wire twisted, but *the joints were not soldered.*

I tested these to see whether they gave any material obstruction to the current. The test was made as follows.



the resistance of the galvanometer was as great as 140 miles of line.

If the joint, which was less than a foot long, offered no appreciable resistance, then no appreciable current would pass through the galvanometer.

Nearly every one of these joints gave an appreciable current. Therefore, they offer obstruction to the current.

Several of your wires are led into the Harlem Telegraph Office. There are several joints in each wire, none soldered. The wires are merely cotton covered and cross each other. In damp weather this would be very likely to cause escape from wire to wire, of serious amount.

From enquiries made on the spot the impression was given me that there was now no actual necessity for these wires being run into the station at all, and I would suggest that, if that necessity no longer exists, these wires be put straight over the office like the other wires.

The "leading in wires" are fruitful sources of interruption every where in England. We formerly used with great success wires first covered well with gutta percha, then wrapped with tape and then saturated with the following mixture nearly cold.

MIXTURE.

Boil together equal parts in bulk of wood tar, gas tar, and slacked lime. stir well when boiling, and continue the heat until the moisture is driven out which is seen by the frothing subsiding. When cool apply to the taped wire, and then cover the wire with dry sand. Hang the wire up to dry in the air, and in three or four days time it will be ready for use. This resists sun and moisture and protects the gutta percha effectually.

During the last few years we have used Hooper's wire, which is cheaper and better, and in some cases we have used the semi-hard vulcanite covered wire, which seems excellent.

All are good and effective.

TESTS.

December 1. 1867.

Table 14. Eastern Route. New York to Harlem north hut.

Tests include the cable.

N.B. Megohms are used here for the insulation test

One megohm = one million ohms.

No.	Megohms.	Test of Nov. 26.	Conductivity in ohms	Test of Nov 26.
1.	2.0		153½.	
2.	1.3	0.9	193.	194.
3.	3.4		142.	
4.	2.5		140.	
5.	7.5	1.1	163.	260.
6.	5.4		410.	
8.	4.7	0.6	150½	
10.	8.5	.5	183.	210.
18.	6.	.45	126.	133.
25.	5.5		127	
27.	10.5	.65	128½.	134
28.	5.	.7	130.	138.

Remarks.

The wires have, in most instances improved in conducting power viz. 5 × 10.

The insulation has greatly improved by the continued dry winds, and the cross connection was greatly reduced. —

There were instruments in circuit in No. 6. Its conductivity was sometimes 1300 ohms which indicates that one of the instruments has more than twice the resistance of the other.

SOUTH — WIRES.

Wires disconnected at 15th street Cable House. Distance 3. m.

Table 15. December 1. 1867.

Weather - hard frost. clear.

No. of Wire.	Insulation resistance. in megohms.	Conductivity in ohms.	Resistance should not exceed.
1.	6.1.	41.	
2.	2.65	44.	
3.	3.5	44.	
4.	5.4	41.5	
5.	3.	41.5	
6.	4.	41.5	
7.	3.4	45.	3×13 = 39
8.	4.	41.5	
9.	1.53	* 989.	
10.	1.55	43.5	
11.	5.	43.	
13.	2.4.	49.5	
14.	1.36	59	
16.	1.03	51.5	
17.	3.6	45.	
18.	1.35	52.	
22.	0.91	49.5	
23.	2.9	43.	
26.	2.31	44.	
27.	5.30	41.5	

Number 14 has over 50 per cent too much resistance.

13. 16. 18. 22 have from 26 to 33 per cent too much.

All the wires have too much.

* Two instruments in circuit.

South wires.

via 55th Street.

Wires disconnected at 55th St. Distance 7. miles

Table 16. Continued clear hard frosty weather.

No.	Insulation in Megohms.	Insulation per mile in Megohms.	Compared with 1 South as unity viz 18.3. Megohms	Compared with No 22 South as Unity viz. 2.73. megohms per mile.
29.	0.33	2.31	0.126.	0.846.
31.	1.20	8.4	0.46.	3.08
32.	10.00	70.	3.82.	25.64.
33.	1.34	9.38	0.51.	3.43
34.	5.55	38.5.	2.05.	14.10

Table 17. "United States" western wires.

	More than	More than
5.	> 11.	> 77.
6.	> 11.	> 77.

These two wires retained a sensible charge for 20 seconds after the battery was removed.

South Wires.

NEW-YORK to PHILADELPHIA.* 99 miles.

Dec 2. 1867. Weather. hard frosty. clear.

Table 18. Distance. 99 m.

No of wire.	Insulation in ohms.	Conductivity Resistance in Ohms.	Resistance should not exceed.
1.	175,000.	1292.	1276.
2.	160,000.	—	—
3.	155,000.	1288.	"
4.	170,000.	1529.	"
5.	272,000.	2355. Instruments in circuit.	
8.	27 to 87,000.	1214. Contains a bad escape.	
9.	10 to 160,000.	—	idem
11.	5,800.	1167.	"
16.	160,000.	1223.	1276.
17.	270,000.	1182.	"
18.	145,000.	1360.	"
23.	140,000.	1243.	"
26.	175,000.	1250.	"
27.	60,000.	1202.	" Bad escape.
28.	134,000.	—	"

When Nos 8. 9. 11. + 27. are excepted, the wires have a mileage insulation during this cold dry weather, from 13 to 27 megohms per mile. From No 17. the proper resistance for a mile of wire would be not more than 11.94 ohms.

CONDUCTIVITY.

No 4 wire has over 19 per cent too much resistance. The other wires approach very nearly to their proper resistance on this section. ——

The escapes on Nos. 8. 9. 11. + 27. are located

No 8. between Trenton and Philadelphia.
" 9. " Jersey City and Newark.
" 11. " New Brunswick + Trenton.
" 27. " idem. idem.

Nos 3 & 4 each offer too much resistance to conductivity between New York and New Brunswick. ——

No 3. gives 510 should give 442. = 12 p.c too much.
" 4. " 547 " " 442 = 24 " " "

The faults on 8 & 9 have the appearance of being in the river cables, or may be caused by touching a wet wall or tree. The latter would hardly be able to produce so large an escape. ——

When the conductivity resistance varies, as in several of the previous tests, it is not due to reduction of the wire by rust, but indicates the existence of bad conducting joints. ——

Eastern Wires.

Table 19. Dec 3. 1867. New York to New Haven. 76 miles. Weather very dry, hard frost. Wires open at New Haven and then to ground. ——

	No. of wire.	Insulation in ohms.	Insulation per mile in megohms.	Resistance in ohms.	Conductivity resistance should not exceed =
	1.	205,000.	15. 4.	1727.	980.
	4.	180,000.	13. 4.	5240.	"
x	5.	260,000.	19. 5.	2910.	"
x	7.	90,000.	6. 7.	1730.	970
	8.	420,000.	31. 8.	6825.	985.
	18.	270,000.	20. 2.	1264.	980.
x	25.	1100, to 140,000.		12880.	"
	27.	125,000.	9. 3.	1436.	975.
x	28.	215,000.	16. 1.	1245.	980.
	10.	81,000.	6.	1344.	965.

x There was considerable cross connection on these wires, especially on 5. 7. + 28. No 25 contains a most serious resistance. No 10. the cable wire, has 38 per cent too much resistance, and No 1. 75 %. The following tests of No 10 indicate its condition.

Tests of No 10. between New York and New Haven and intermediate stations.

Table 20. Wires open	Ins. resistance in ohms. —	Miles between each station.	Computed mileage res. in megohms.	
at New Haven.	81 000.	17.	3. 5.	
" Bridgeport.	137. 000.	22	3. 6.	
" Stamford.	670. 000.	17.	24. 0	
" New Rochelle.	1. 275. 000.	20.	25. 5.	
To ground at	Conductivity		Mileage conductivity in ohms. —	Should not exceed
New Haven.	1344.	17.	27. 8.	13.
Bridgeport.	888.	22.	13. 2.	13.
Stamford.	597.	17.	12. 2.	13.
New Rochelle.	389.	20.	19. 5.	13.

From the above it will be seen that the insulation of Number 10. is 7 times worse between New Haven and Stamford than it is between Stamford and New York. viz coln 4. Its resistance is far too great over the two extreme sections. Between Bridgeport and New Haven it is 114 per cent greater than it should be, and 50 ℘ cent between New York + New Rochelle. As this resistance varies from day to day, it is doubtless due to imperfect connection, probably bad, rusty, unsoldered joints on the line.

N.B. The fourth column gives the value of the wire between each station tested to.

Table

21. This shows the condition of No 25 wire.

Open at	Insulation Resistance in ohms.	Miles between Stations.	Computed mileage resistance Megohms.	
New Haven.	140,000.	17.	3. 4.	
Bridgeport.	510,000.	22.	30. 9.	
Stamford.	800,000.	17.	30. 3.	
New Rochelle.	1,450,000.	20.	29.	
To ground at	Conductivity.	—	Resistance in ohms per mile	, Should not be more than. —
New Haven.	12,980.	17.	450.	13.
Bridgeport.	5320.	22.	146.	13.
Stamford.	2,843.	17	118.	13.
New Rochelle.	300.	20.	15.	13.

On this wire, as well as number 10. there is far too much resistance and far too much escape. Each wire is especially defective between New Haven and Bridgeport. ———

The annexed tests show the condition of Numbers 4. 5. 8. On number 4 there was one instrument in circuit at Bridgeport. On No 8. one instrument at Stamford. Number 5 clear through to New Haven. ———

Resistance to conduction of Nos 4. 5. & 8 between

Table 22 New York. New Haven & Intermediate Offices.

NO 4.

Wires to ground	Conductivity Resistance in ohms.	Computed resistance per mile	Should not exceed.	
at New Haven.	5240	44.	13.	
Bridgeport	4495.	136. x	13.	x after deducting 792 ohms for the relay at Bridgeport.
Stamford.	703.	22.6.	13.	
New Rochelle.	318.	15.9.	13.	

NO. 5.

New Haven	2910.	50.	13.
Bridgeport	2093.	47.	13.
Stamford.	1059.	19.	13.
New Rochelle	733.	36.5.	13.

NO. 8.

New Haven.	6825.	52.	13.	
Bridgeport.	5935.	241. ++	13.	
Stamford.	1835.	61.	13.	+ deducting 800 for relay.
New Rochelle.	454.	22.7.	13.	

The above shows how enormous is the resistance to which your electric currents are submitted. x 1000 per cent too much. xx 1750 per cent too much.

New York to Boston.

Table 23. Distance 236 miles. Weather. Hard frost.

No. of Wire.	Insulation in ohms. –	of Mileage in megohms.	Conductivity in ohms.	Con. resistance should not exceed in ohms.
1.	95000.	22.	4160.	3068 x
3.	170,000.	39.	4000.	3068. x
4.	68,500.	16.	9230	same.
7.	76,500.	17.5.	——	——
18.	33,000. xx	7.	3340	3068.
27.	66,500. xx	15.	4000.	3068.
28.	97,000. xx	22.	3330.	3068.
32.	14.900.	3.	——	——
31.	——	—	5240.	3068.

x 900 ohms added as the resistance of two relays. Without the relays, the resistance should not exceed 3068. Numbers 18 & 28 are near that amount.

Table 24. New York to Hartford. Distance 127 miles.

3.	540.000.	68.	1987.	1651.
9.	925.000.	117.	2341.	1651.

xx These wires were all very much affected by cross connection.

Western Wires.

Dec. 4. 1867. New York to Albany. Distances 145. 155. 160 Miles. Hard Frost.

Table 25.

No of wire.	Insulation ohms.	Mileage ohms.	Conductivity ohms.	Should not exceed.	Relays in circuit.	Miles of wire.
1.	75.500.	=| ×	2250.	1885.	0.	145.
3.	255.000.	37.	3290.	1885.	0.	145.
4.	77.000.	×	—	—	0.	145.
5.	300.000.	43.	2660.	1885.	0.	145.
6.	304.160.000.	×	—	—	2.	155.
7.	185.000.	28.	2600.	2015.	0	155.
10.	19.500.	×	—	—	17	160.
11.	1.000.000. **	155	3740. **	—	8.	155.
12.	24.000.	×	5800.	—	4	160.
13.	130.800.	21.	—	—	0	160.

× An election banner foul of the wires affecting Nos. 1. 4. 6. 10 + 12. on same side of pole I am informed.

Although there 8 relays in No 11. and only 4 in No 12. 12 has a very much larger resistance, by far too much. Deducting 2015 ohms for lines resistance leaves 1725 for the 8 relays or 216 ohms each – a small resistance. This would seem to indicate that the resistance of No 12. was 4940 ohms instead of 2015 or 150 p^r cent too much resistance.

Table 26. **Erie wires.**

Dec. 5. 1867. Open at Buffalo =| 440 miles. Weather frosty, clear.

No of wire.	Mileage =| Megohms.	Conductivity in ohms.	Should not exceed.	
3.	240.	7570.	5720.	Much cross
4	66.	13.870.	—	connection.

New York to Susquehanna. 197. m.

3.	1.250.000.	245.
4	189.000.	37.

New York to Harrisburgh. =| 182. m.

12.	75.500.	13.2.	2657.	2366.
20.	113.000.	20.	—	—

The number 3 Erie wire has a high insulation this dry weather, and its resistance to conduction is nearly as low as it should be. Not so number 4.

The tests of the Pittsburgh wires were stopped by contact coming on.

It rained a little during the night of December 6th but I was not fortunate enough to get any tests. ——————

December 7th 8. A.M. Frost and clear.
9. " " Ther. at 145 Broadway close to window. 38°
Philadelphia reports. ———— 37°

—— New York to Philadelphia. ——

Table 28.

No of wire.	Insulation ohms.	Tests of Dec. 2nd.	Remarks.
1.	84,000.	175,000	
16.	81,000.	160,000.	The little shower
17.	180,000.	270,000.	of the previous night
18.	106,500.	175,000.	has reduced the
26.	75,000.	145,000	insulation very much.
27.	52,000	60,000.	vide Table 18.

Table 29. Pittsburgh wires. 430 miles. Weather clear & dry after rain previous day.

No of wire.	Insulation in ohms.	= Resistance of a mile in megohms.	Tests of Dec. 5. ohms.	December 5. Mileage in megohms.
12.	26,500.	10.5.		
20.	35,500.	13.5		

Same wires open at Harrisburgh.

= 182 miles.

12.	42,000.	17.2	75,500.	7.2
20.	46,750.	20.	113,000.	8.0

The Harrisburgh wires are more affected by cross connection than any of the other wires tested. It was quite impossible to get accurate readings. A mean of 6 to 8 tests had to be taken.

—— Eastern Wires. ——

Table 30. Dec. 7. 1867. Clear after little rain previous evening followed by frost.

No of wire.	Insulation in ohms.	Mileage megohms.	Dec. 3 Insul.n	Table 19. mileage	Remarks.
1.	497,000.	37.5.	205,000.	15.4.	Nearly all of
2.	335,000.	24.3.	—	—	these wires vary
4.	420,000.	31.8.	180,000.	13.4	much by reversing
5.	500,000.	37.9	260,000.	19.5.	the current fre-
7.	166,000.	12.5	—	—	-quently. This is
8.	580,000.	44.	420,000	31.8.	one of the phen-
18.x	30,000.	2.2.	270,000.	20.2.	-omena indicating
27.	500,000.	37.9.	125,000	9.3.	broken insulators.
28.	650,000.	49.3.	215,000.	16.1.	——
29x	150,000.	11.3.	—	—	
30.	1,750,000.	132.9.	—	—	
31.	770,000.	58.4.	—	—	
32.	285,000.	21.6.	—	—	

x On No 18. there is a bad local fault which varied, under test, from 30,000 to 430,000. 29. varied very much.

Dec. 7. 1867.

New York to Albany.

No.	Insulation.	December 3.
1.	625,000.	205,000.
3.	155,000.	———
4.	85,000.	180,000.
6.	25,000.	260,000.

The little rain of the previous evening had not affected these or the Eastern wires. Probably the rain was local. The cross connection, however, was greatly increased, and this would be accounted for by local damp in the neighbourhood of New York. ———

The arms become wetted by rain and their conducting power increased thereby long before the poles feel moisture enough to increase their conducting power and so carry off the escaping electricity. ———

December 22. 1867.

Weather wet and lines working very badly all along the coast. Only able to work to Washington on a few wires at the same time, and this only by means of Repeater's at Philadelphia. Working with equal difficulty to Boston, two wires working with repeaters nearly midway, and two or three wires working direct, but very slowly and feebly.

After much delay, owing to the difficulty of getting the attention of the stations, the number 1 wire south was opened at Philadelphia.

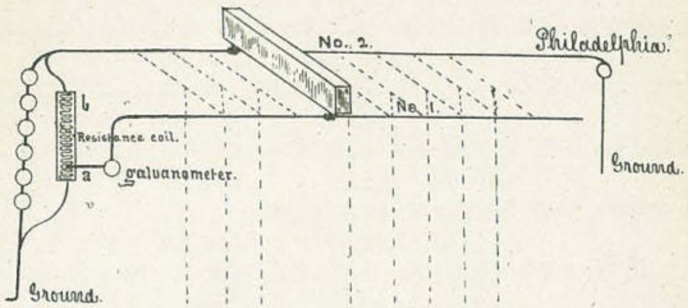
Its resistance, when open was No 1. = 1350 ohms. On Dec. 2. 175,000 ohms. and when to ground on Dec 2nd at Philadelphia 1292 ohms.

The computed mileage resistance of insulation was 48,000 ohms.

Experiments were now commenced to ascertain how much electricity escaped from the other wires into it: (Note. This mixing of the currents into each other, from wire to wire has been miscalled "Induction" and "sympathetic currents". The term "cross connection" is far better.)

The following experiment was tried. A Battery of 60 cups was applied to the No 2 wire, all the others being put to ground. and then the potential in number 1 was measured. That is to say, I determined how many cells of the same battery were necessary just to balance this current which had escaped from No 2 into No. 1.

This was done as follows.



When the Battery was on No 2. the galvanometer was connected to the resistance coils. and a. and b varied until the galvanometer was found to stand at zero.

When the potential in the wire No 1. was to that in No 2. &c. as $1 : \frac{a}{a+b}$; & $\frac{a}{a+b} \times 60$ = number of cups of Battery to balance the potential in No 1.

All wires being connected as usual at Philadelphia except No 1 open at that station. All were put to ground at New York except 1 & 2.

2 joined to 60 cups. a = 157. b = 1000. cups to balance. 8. 15

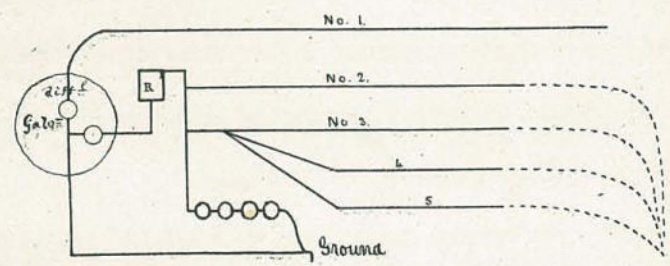
Two wires were then joined to the 60 cups and No 1. again tested.

Then 4 wires. ______

Table 32.

60 cups on	Values of a.	b.	Value $\frac{a}{a+b}$	Cups to balance No. 1.	Wires to ground at
No 2.	157.	1000.	0.136.	8. 15.	New York all except 1. 2. + 7.
2 & 3.	235.	1000.	.1903.	11. 42.	1. 2. 3 & 7. ____
2. 3. 4. 5.	348.	1000.	.258.	15. 49.	1. 2. 3. 4. 5 & 7. __
2.	167.	1000.	.143.	8. 59.	__ 1. 2. 7. ____
2. 3. 4. 5.	475.	1000.	.322.	19. 32.	1. 2. 3. 4. 5. 7. __
2.	186.	1000	.157.	9. 4.	__ 1. 2. 7. ____

Note. During the latter tests it was beginning to rain again which increased the conducting power of the horizontal arms in a greater ratio than the vertical poles. To test the strength of the current from No 1. the apparatus was arranged as follows.



One wire of the differential galvanometer was joined to No 1. and to ground. The other wire of the galv. was connected by the resistance coils to Nos 2 &c. its other end being to ground.

The resistance of each wire of the galvanometer is = 900 ohms. The computed resistance of No 2. wire at New York as presented to the New York battery would be about 600 ohms supposing Philadelphia's battery to be equal to that of New York.

Therefore, more than one eighth part of the current entering one of the wires 2.3.4 & 5. returned on No 1.

When all wires were to ground except 1 & 2. 2 being the only wire on the battery, the current on No 1 was balanced when R=7000. and more than one eleventh part of the current entering number 2 returned on No. 1.

This prodigious mixing of the currents on the different wires is by far the most serious difficulty you have to contend with in this country.

It therefore became necessary to ascertain the average resistance of the following.

1st The average resistance of the insulator and half the arm.

2. The average resistance of the pole.

Owing to an unfortunate mistake in the wedge used during the other tests made this day to determine these points, one half of my labor was lost. I give here the useful parts of that days work.

Table 31. Wires open at 15th street. Length 2 3/4 miles.

No of wire.	Insulation in ohms.	Mileage Ivan.	Eng. standard = 100.	
1.	27,800.	75,950.	7.6.	Lefferts. glass.
2.	28,200.	77,550	7.7	" "
3.	22,500.	61,875.	6.2.	" "
4.	25,100.	69,025.	6.9.	" "
6.	24,500.	68,125.	6.8.	" "
7.	20,600	56,650	5.7.	" "
8.	18,000.	49,500	4.9.	" "
9.	10,000.	27,500.	2.7.	" "
10	20,000.	55,000	5.5.	" "
12.	42,000.	115,500.	11.6.	Brooks.
13.	11,000	30,250.	3.2.	Lefferts glass.
14.	2,310.	6,352.	0.6. x	
26.	18,800.	51,700	5.2.	"
27.	21,000.	58,250.	5.8.	"

x contains evidently a special ground.

Tests to 55th Street. Dec. 22. 1867.

Wires open at 55th Street. Weather_ Raining at frequent intervals.

Table 33. Distance ≒ 7. miles.

No of wire.	Insulation in ohms.	Mileage Insn.	English Standard 100°	
28.	3000.	21.000.	2.1.	
29.	4720.	23.000.	3.3.	
30.	3950.	27.650.	2.8.	
31.	6100.	42.700.	4.3.	Pin and Glass.
32.	9400.	65.800.	6.6.	
33.	5600.	39.200.	3.9.	
34.	9600.	67.200.	6.7.	

On December 25. the weather became very wet and I endeavoured to get some tests. The lines were working very badly, and the staff on duty being a holiday minimum I found it impassible to get any thing done at out stations.

Late at night I got the following which are important as showing the amount of disturbance arising from a mixture of the currents in the different wires.

A galvanometer was first placed between Nos. 6 and the ground. b.

Second. Between general battery. No 2. and the wire No. 6. a

Third. Between "general battery" 3. and No 6. wire. c

The two wires on each side of No 6. were during each of the above three positions connected 1st to the ground.

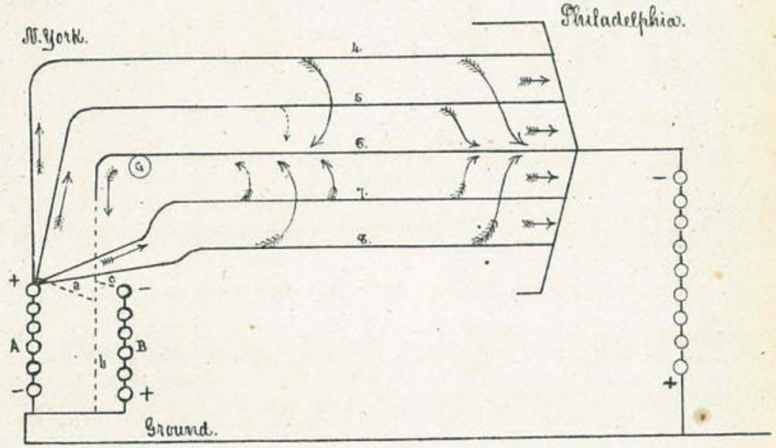
2nd open.

3d. connected to general battery. 3.

4. " " " " 2.

The same experiment was tried with No 32 wire in place of No 6. and with Nos 30. 31. and 33 + 34 in place of Nos 4. 5. + 7 + 8.

The distant end of lines were joined to their usual batteries.



When Nos 4. 5. 7. + 8. were to Battery at A. the current from 6 passing through g was measured, also when it was itself joined to A +c.+c. as above described. ______

Note. General Battery No 3. has the opposite pole to ground to that of G. B. No 2. ______

Table 34.

1.	2.	3.	4.
Nos 4-5 + 7-8 Connected to.	No 6 wire connected to ground through a galvanometer gave.	No 6. connected through galvanom. to Gen. Bat No 3.	No 6 wire to general Battery No 2.
1. Ground.	2° to the left.	26½ right.	21° left.
2. Open.	0°	27½ ..	19½° ..
3. Connected to Gen. Battery No 3.	10° to the left.	18° ..	26¼ ..
Gen. Battery. 2.	4½° to the right.	30° ..	15½ ..

Table. 35.

No 32 wire in place of No. 6.

Nos. 30. 31. 33. 34 in place of .... 4. 5. 7 + 8.

Nos 30.31.33.34	No 32.	No. 32 to general Battery No 3.	No 32 to general Battery No. 2.
to ground.	19° right.	42° right.	4° left.
Open.	18½ right.	43°. right.	2½ left.
On gen bat No 3.	16° right.	39° right.	7° left.
On gen bat No 2.	20° right.	32° right.	12° left.

Table 36.

The following table gives approximately the strength of current corresponding to the deflections of the galvanometer in tables 34 + 35.

Deflection in Degrees.	Relative strength of current.
1°	1
2°	2.
2½.	2. 5.
4.	4.
4½.	4. 5.
7.	7.
10.	10.
12.	12. 25.
15½.	16. 7.
16.	17. 3.
18.	19. 6.
18½.	20. 3.
19.	21. 0.
19½.	21. 7.
20.	22. 4.
21.	23. 7.
26¼.	31. 3.
26½.	31. 7.
27½.	33. 1.
30.	37. 5.
32.	41.
39.	60.
42.	66.
43.	68.

It will be seen from Tables 34 & 35 third column, second and third line of figures that when Nos 4. 5. 7. & 8 were first opened and then closed at New York, these acts alone at New York produced a variation in the strength of the current on the No 6 wire of from 18° to 27½°. By table 36 the variation of the strength of the current was from 19.6 to 33.1. :: 100 to 167.5.

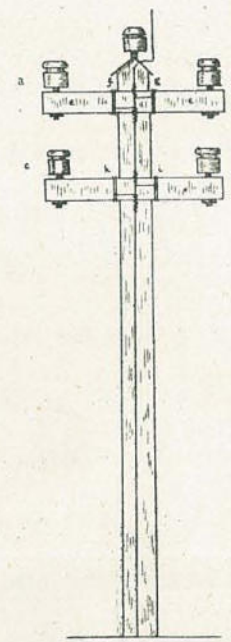
Of course it was utterly impossible to work No 6. wire.

On opening Nos 30. 31. 33. 34. and then closing them, the variation of current on No 32. was 39° to 43° as 60 to 68. or 100 to 113.

I was unable to get Philadelphia for reasons before stated to open these wires to see what variation that made in the strength of the current at New York.

But column No 1. Table 35 and Table 60 enables one to compute approximately that opening and closing at Philadelphia the No 32 wire would have produced a variation of current of about 30 per cent and when the opening and closing of the other lines at Phila is taken into consideration, that would make the percentage vary between 25 & 35. In other words the disturbing action of wire upon wire produced false signals

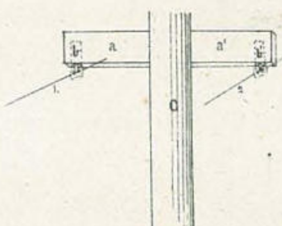
half as strong as the opening and closing of Philadelphia's Key. Without repeaters it was impossible to work at all beyond Philadelphia, and then only imperfectly. Were this disturbance between wire and wire, this mixing of the signals cut off, there would be no difficulty in working all these wires at the same time. It was therefore very desireable to ascertain what effect upon the signals would be produced if wires were attached to the poles to draw away to the ground the mixings from the other wires. Such wires are attached to the poles and arms on all our long lines in England, Ireland, Scotland and Holland. The sketch below shows how this is done.



Any current escaping from a along the wet arm c. on arriving at f finds a good easy channel down the wire w. to the ground. Any electricity which may pass f is arrested at g. h. or i. and taken away before disturbing the working of b. c. d. by getting into those circuits.

The question which is likely to be asked is if such wires be attached to the poles, seeing how bad the insulation is, will not nearly all the current escape to the ground?

To answer this question it becomes necessary to know the actual resistance of the following parts relatively to each other or rather the ratio of a + b to c. viz the resistance of half the arm — a. the average



resistance of your insulators b. in their present broken imperfect condition; and c. the resistance of the pole.

The following experiments give the value of (a + b) and c. Several wires on the same pole and some on the same arm were selected. The wires were all opened at the distant ends, and then the resistance of the circuit was tested. 1. By connecting the battery to ground and the galvanometer to No 1. wire.

2. The number 2 wire was used in place of the ground.

The first gave the resistance of a + b + c.

The second gave the resistance of a + a' + b + b'.

The first test I will call "ground"; the second "wet contact".

By adding together the ground tests of Nos 1 & 2. wires we get

a + a' + b + b' + 2c.

By the contact test we get a + a' + b + b'. so by subtracting the latter from the former and dividing the remainder by 2 we get the resistance of the pole c.

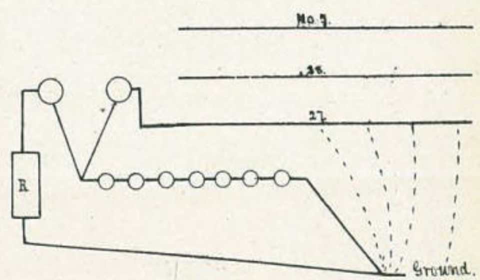
January 1. 1868.

Day wet. Holiday staff on duty but was much more successful in getting wires opened.

Eastern Route. Wires open at New Haven and New York.

Table 37. Ground or insulation Test.

No 7.	Ins. resistance. 2425.
10.	1300.
18.	2900.
27.	3050.
28.	3700.



"Wet contact" test. one wire used in the place of the ground.

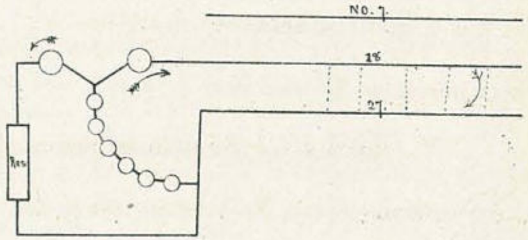
Nos. 7 & 10. 3050.

7 & 18. 4500.

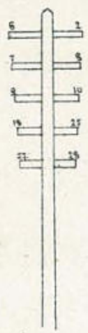
18 & 27. 5350.

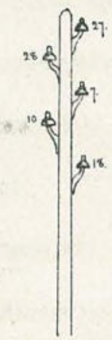
18 & 28. 5950.

27 & 28. 5850.



For the first 15 miles the wires ran thus. The remaining distance the wires ran thus.





therefore Nos. 27 & 28 are the best for getting the value of the pole considered as an insulator, compared with the half arm and insulator.

27 + 28 to ground give	3050.
	3700.
	6750.
"Contact"	5850.
	900.

$$C = \frac{900}{2} = 450 \text{ Ohms.}$$

while 7 & 10 give the value of C = 338.

The ratio for the two pair of wires $\frac{c}{a+b}$ is as under.

Nos 27 + 28 $\frac{c}{a+b} = \frac{900}{5850.} \doteq .15$

7 & 10. $\frac{c}{a+b} = \frac{675}{3050.} \doteq .22$ .19 mean.

It was difficult to find wires running all the way on the same arm, but Nos 16 & 17 South do. and Nos 26 & 27 run the greater part of the way on the same poles. Their tests are given as follows.

Table 38. South wires open at Philadelphia. Jan. 1'68. Raining.

Nos. 16. Insn. 1200. 1

" 17 650. 2

" 26 1270. 3

" 27. 866. 4

Wet ~~wire~~ contact test: one wire used for ground.

Nos. 16 & 17. 1650. 5

" 26 & 27. 1920. 6

Nos 16 & 17. 1200.
650. 1850.
1650. 1650.
200

Nos. 26 + 27. 1270.
866. 2136.
1920.
216

From 16 & 17. $\frac{c}{a+b} \doteq .12. \doteq \frac{1}{8}$

26 & 27. $\frac{c}{a+b} \doteq .11. \doteq \frac{1}{9}$

The mean of these* tests on pretty long lines give for $\frac{c}{a+b}$ .15. .22. .12. .11. $4\overline{)60}$ = 15 $\doteq \frac{1}{7}$

* four.

Maximum value of $\frac{c}{a+b}$ . . . . = 22 $\doteq \frac{1}{5}$

Minimum " " . . . . = 11 $\doteq \frac{1}{9}$

On January 4th the following tests were made in the City of N. York. which give the value of $\frac{c}{a+b}$ in the City alone and where the escape is much heavier owing to the air being charged with soot and ammoniacle salts.

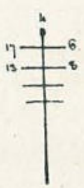
New York to Manhattanville

Table 39. Weather - foggy with light rain. Distance 8½ miles.

No.	Ins resistance. ohms.	Mileage in ohms.	Eng. Standard 100.	Hard rubber
4.	6700.	56,950.	5.7.	insulation.
6.	6600.	56,100.	5.6	"
17.	6200.	52,700.	5.3.	"
13.	6600	56,100.	5.6.	"

Wet contact tests.

6+17	9230.	$\frac{c}{a+b}$	$\frac{3570.}{9230.}$	= .38
4+17	10.800		$\frac{2100}{10800}$	= .2
17+13.	9.800.		$\frac{3000}{9800}$	= .3



Note. The arms on this line are not painted, and the surface insulating power of the old dirty hard rubber insulators being small, the resistance of the pole C compared with the half arm and rubber insulator is larger = 3. The tests of arms, farther on, prove this.

Table 40. Jan 4. 1868. Fog + rain. Tests to 15th St. 2¼ miles.

No.	Ins. ohms.	Mileage ohms.	Eng. Standard 100.	
1.	50,000.	112,500.	11.	
2.	53,100.	120,000.	12.	Insulation
3.	48,000.	108,000.	11.	Sefferts + arms
4.	50,000.	112,500.	11.	well painted.
5.	48,000.	108,000.	11.	
6.	45,500.	101,400.	10.	
26.	32,100.	80,200.	8.	
27.	31,800.	71,500.	7.	

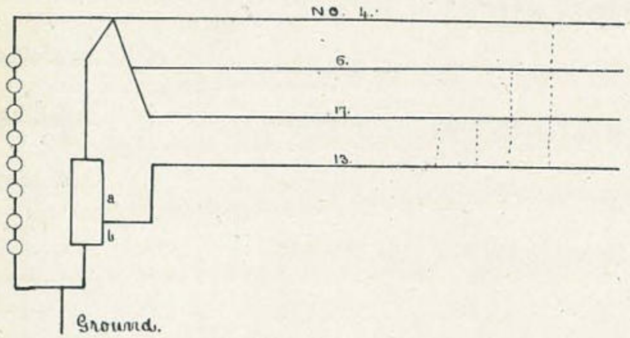
— Wet-contact Test —

		$\frac{c}{a+b}$	
1+2.	82,500.	.21	
3+4.	82,000	.20	Nos 26 + 27 were apparently
5+6.	80,500.	.16	crossed.
26+27.	41,500.	.54	

On the Manhattanville wires the following tests were made, the wires being clear at Manhattanville.

Nos 4. 6. 13 + 17 were connected, three of them to the battery, and the potential in the fourth wire measured as follows.

The resistance coils were inserted between the battery and the ground and the wire tested was moved along until the current was balanced thus.



a + b : b :: as the full power of the battery : the potential on No 13.

Attaching three wires to the Battery the fourth wire gave the following results.

Full power of Battery 100.

Table 41.	No. 4.	Potential.	42.
	" 6.	"	40.
	" 17.	"	43.
	" 13.	"	46.

Had there been wires attached to the poles and arms, all this would have been cut off.

From Tables 37 + 38 the insulating power of the pole added to that of the arm and insulation increases the insulation.

By tests to New Haven 15 to 22 per cent.
Philadelphia. 12. 11. Mean 15 per cent.
By tests to 15th Street 21. 20. 16. mean 19 per cent.

The mean of all the tests (excluding the hard rubber insulation, which, in the city of New York, has unpainted - chemically prepared arms) is as under.

To New Haven.	16.		
"	22.		
" Philadelphia.	12.		Table 41. a.
" "	11.		
" City of New York.	21.		
" "	20.		
" "	16.	117.	Grand mean. 16.7. per cent.

In other words were conductors attached to the poles and arms, the insulation would decrease as 116.7. to 100 or as 7 to 6. This would have weakened Phila's current on No 32 *vide Tables 34. 35. 36.* from 30 per cent to 27. a difference of 3 per cent, but would have removed "mixing" or "disturbing" currents from the other wires, amounting to 18 per cent. as will be seen by the following (vide Tables 34. 35. 36.)

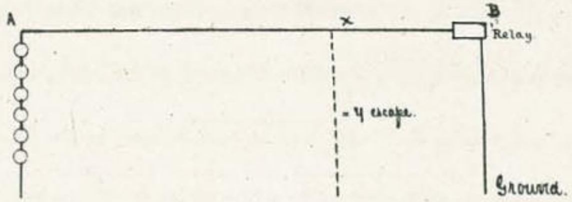
On opening and closing the adjacent wires at New York 30. 31. 33 + 34 the current on 32 was changed in strength from 100 to 113. The same operation at Philadelphia would have made a further variation of from 5 to 6 per cent viz. from 95 to 113. Total 18. per cent.

Now Philadelphia's signals when he was working No 32 only produced a variation of 30. Consequently when the mixing currents were adverse, the only power left for the signals was 30 - 18 = 12. while had this disturbance been cut off, there would have been steady signals of a strength of 27.

The foregoing, however, is under the truth, and not over, because the escape and wet contact are much greater in the City than in the clean country, and when an escape to ground is close to the end of a circuit, it is much less felt as a disturbing element than when in the middle, while the very reverse is the case with mixing currents from wire to wire "cross action".

For example.

Suppose a wire whose resistance is S has an escape whose resistance is Y located at x distance from the end



Let the resistance of the Battery and relay be included in S that is, be part of the line.

By ohms laws the current entering the line will be

$$\frac{E}{s - x + \frac{xy}{x+y}} = \frac{E}{s - \frac{x^2}{x+y}}$$

The current received at the distant end will be.

$$\frac{E}{S - \frac{x^2}{x+y}} \times \frac{y}{x+y} = \frac{E\,y}{S(x+y) - x^2}$$

It will be found by the differential calculus that this equation has two maximum values, and one minimum viz. a maximum when $sx - x^2 = 0$ which happens when $s = x$ or $x = 0$, that is, when the escape y is close to A or B – the ends of the circuit.

The minimum value occurs when $x = \frac{s}{2}$ that is when the escape is in the middle of the circuit.

The mixing current (escape from wire to wire) is the reverse, or rather, is felt most when close to the receiving station B. and least when close to A where its effect on B is nil (if, as assumed, the battery have no sensible resistance.

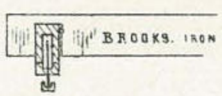
This report has already reached such a length, that I must at once go to the other important matter, but I think I have demonstrated all that has, thus far, been advanced.

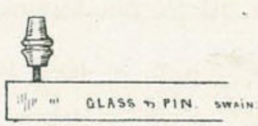
I have been minute in detail, for having, of necessity, to go through the work myself, I thought it better to give it so that others may be able to profit by it, either to check my work, or as a practical lesson to those working up the subject.

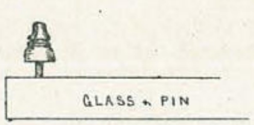
Examination of Arms & Insulators.

Taken down in New York.

There are five kinds of insulators largely in use on your lines.







Some of the arms have been chemically prepared, and not painted. These, as a rule, conducted largely when wet.

Some arms have wooden pins attached to their sides, and some have them inserted.

Some of the insulators are attached by wooden pin brackets direct to the poles.

I have examined and tested all the different parts both dry partially wet and well wetted all over in order to ascertain their value as insulators, because the wooden pin and arm have a slight insulating power of great service with your present imperfect insulators.

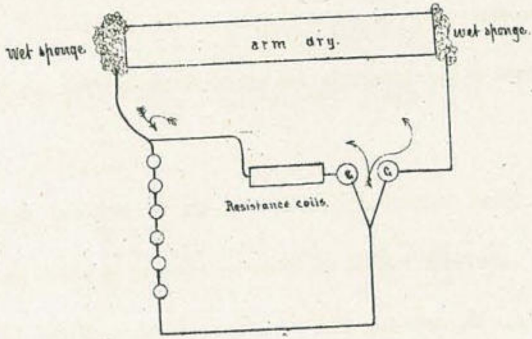
The pin and glass and hard rubber insulators when dry, showed no perceptible current with the galvanometer I had, and which, with 90 cups, and 50 Megohms (50 millions of ohms) gave only half a degree of deflection.

The Lefferts insulator when cracked would sometimes give a visible current <u>when dry.</u> ——

The Brooks iron insulators gave much more current when dry than any of the others.

I have tested the arms, wooden pins and (insulators sometimes) first dry and then wetted by a sponge dipped into a pail of water

When testing an arm or pin, the two extremities were wetted so as to connect the ends of the fibres together. Thus.



The wooden pins were dipped in water at each end thus and then tested like the arm.

The insulators were tested while in their arms by dipping them into a pail of water and then connecting one pole of a circuit to the wet arm and the other to the insulator pin or groove for receiving the line wire.

Washing the soot and salts off the insulators and arms especially the former, has a very great influence on their insulating power, especially the rubber insulator, which, in one case was improved by dipping 64 times in a pail of water from 1500

to 30° = as 50 to 1.

Examination of Insulators taken down in New York City.

Hard Rubber.

Total number tested.	38.	Per centage.	
Very bad.	6.	16.	
Slight defects.	2.	5.	
Sound.	30.	79.	100.

Lefferts Insulator. Total tested 135.

Broken & tested bad.	65.	48.	
Contain visible flaws. but not yet testing bad.	45.	35.	
Sound.	25.	17.	100.

Pin + Glass. dark + light green. Total 84.

Broken but held together by binding wire	10.	12.	
Contain visible flaws.	31.	37	
No flaws visible.	43.	51.	100.

New unused dark green glass Total	143.	82½	
Cracked and dont insulate.	25.	17½	100.

New light green in supply Department

Defective. ——— 7½ p cent.

Table 43.

Brooks Iron Insulators.

Total examined.		29.
Tested when dry. bad.	10.	35
Slight defect.	4.	14
No escape.	15.	51. 100.

But when they had been wetted and left to dry for one hour with their mouths downwards on a dry day in the warm battery room, they gave as follows.

Bad escape.	25.	86 per cent.
No escape.	4.	14 " "
		100.

Table 44.

Value of deflections on the galvanometer, using 90 cups.

Degrees.	Resistance.	Degrees	Resistance.
1.0. =	20 megs.	26° =	64 0,000. ohms.
2°	10.	27.	61. 0,000.
3.	6.6.	28.	58 0,000.
4.	5.	29.	55 0,000.
5.	4.	30.	52 0,000.
6.	3.3.	31.	50 0,000.
7.	2.8.	32.	47 0,000.
8.	2.5.	33.	45 0,000.
9.	2.2.	34.	42 0,000.
10.	2.	35.	40 0,000.
11.	1.8.	36.	38 0,000.
12.	1.6.	37.	36 0,000.
13.	1.47.	38.	34. 0,000.
14.	1.35.	39.	32 0,000.
15.	1.25.	40.	31 0,000.
16.	1.17.	41.	29 0,000.
17.	1.08.	42.	28 0,000.
18.	1,000,000. ohms.	43.	27 0,000.
19.	940,000.	44.	26. 0,000.
20.	890,000.	45.	25 0,000.
21.	840,000.	46.	24 0,000.
22.	800,000.	47.	22 5000.
23.	760,000.	48.	21 0,000.
24.	720,000	49.	20 0,000.
25.	68 0,000.	50.	19 0,000.

Tests of arms for their resistance one half of which adds its insulation or resistance to that of the insulator.

As I find a very general idea in this country that wooden arms and pins add materially to the insulation, I have, in order to dispel the too great importance attached to this part of your system, tested a series of arms first quite dry, and then with their upper surface wet, and then with all four surfaces wet, to give the insulating power of an arm at the beginning of a shower of rain.

The average length of the arms tested may be stated as 3 feet 6 in.

Table 45. These arms had been painted well - years ago.

Arm dry. Deflection. with 90 cups.	Resistance divided by 80 to get mileage ins. in ohms.	Top of the arm wet.	All 4 surfaces wet.	Resistance ÷ 80 to give mileage insulation.
1½°	167,000.	17°	46. =	3000 ohms.
1½	167,000.	22°	46	3000
2°	125,000.	27°	48	2600
3½.	75,000.	20°	47.	2800.
2°	125,000.	17°	44	3250.
2°	125,000.	11°	35	5000.
3°	82,500.	20°	50.	2400.
6°	41,200.	27°	49	2500
4½	55,000.	17°	42	3500
			Mean resistance per mile.	3120. Ohms.

Tables 46 & 47.

Arms painted three years ago and not since repainted. These were soaked one day, left in warm battery room one day to dry and then tested.

Arm dry.	Resistance ÷ 80 for mileage insulation	Top of arm wet.	All 4 sides wet.	4th colm. by 80 for mileage.	Remarks.
10°	25000.	25°	48°	2500.	* This arm
9°	27500.	31°	44°	3250.	had 2 Brooks
8.	31200.	28°	49°	2500	insulations, and
37° *	4500.	41°	39 ×2.	2000	on being split open
5½	45.500.	27°	53	2100	the rust of the iron
4½	55000.	22°	42	3500	had run through the
10	25000.		45.	3120	grain of the wood.
4	62500.	27°	50	2400 mean 2680.	

The following were 5 days in dry room. Hard Rubber insulation, arms painted 3 years ago.

0½	500,000.	16°	31	6250	
1.	250,000.	14°	30	6500	N.B. The second & fifth
0½	500000.	12°	33	5600	column are obtained by
0½	500000.	16°			÷ 80. viz to get the value
1.	250000.	20°	31	6250	of 40 poles and half the
0½	500000.	16°	35	5000	arm on each.
2.	125000	16°	33	5600	
1.	250000	8	24	9000	
1½	167000	15	35	5000 mean 6150.	

The last 3 arms were afterwards well soaked and washed, but the removal of the dirt and salts more than compensated for the water absorbed, for they gave but 25°. 18½. 30° instead of 33. 24. 35

Table 48.

The 2 foregoing tables expressed in units. (ohms)

All four surfaces wiped with a wet sponge gave a resistance of

5600.
9000.
5000.

Mean 6533.

Arms well soaked & washed by repeated applications of the wet sponge

8500
12200
6.500

Mean 9166.

Four arms had their hard rubber insulators screwed out, the holes were then filled with water, and the poles inserted. The arms were otherwise dry.

Table 49. Deflection	Mileage in Ohms
0½	500,000
20.	11 100.
5½	45 500.
.¾	330 000.

This was an old painted pine arm but on being split, was found full of water.

Table 50. Rubber Insulators Tests of arms

	Degrees arm dry.	Insulation ÷ 80 for mileage.	Top wet.	All wet.	4th colm ÷ 80 for mileage.	
	.3/4.	330,000.	13.	28°	7,250.	
	.1/2.	500,000.	18.	32°	5,900.	
			20.	38°	4,250.	
	1¼	200,000	21.	37°	4,500.	
a.	12½	19,200	19.	35½°	4,870.	
b.	1.	250,000	5.	14°	16,900.	7278. mean.

a & b were of exactly the same kind of wood. but on being split open a was full of water and had an acid smell. The water seemed to have been shut in by the paint. b was the same wood but was quite dry.

Table 51.

Arms painted red within 2 months of date of test. On some of the arms the paint was not hard. The arms had been 3 or 4 days in the dry office

Arm dry Degrees.	Insulation ÷ 80 for mileage	Top of arm wetted.	All sides wetted.	4th column ÷ 80 for mileage.	Length of arm.
1/2.°	500000	11°	25°	8500	30 in
1.°	250000	7	19	11800	42. .
1½.	167000	7	20	11100	42. .
1	250000	7½	21	10500	48 .
½	500000	14	29	6900	. .
1.	250000.	10	24	9000	. .
½	500000	6	21	10500	. .
1.	250000	13	30	6500	. .
2½	100000	9	24	9000	. .
1.	250000	10	26	8000	. .
2	125000	10	26	8000	. .
2½	100.000	12½	27	7640	. .
½	500000	14	31	6250	42. .
½	500000	9	28	7250	. .
½	500000	7	40	3800	. .
4.	62.500	11	29	6900 mean 8228.	. .

Table 51 continued.

Dry.	Mileage	Top wet	All wet	Mileage	Length of arms.
1¼	200000	11	30	6500	42 in
2	125000	14	35	5000	"
7	35000	19	35	5000	"
4	62500	14	29	6900	"
4½	55000	19	32	5900	"
3	82500	25	47	2800	36 in
2½	100000	11½	28	7250	"
3½	75000	13	28	7250	"
4	62500	13	38	4250	30 in
2	125000	15	37	4500	"
5½	45500	17	30	6500	"
½.	500000	11	25	8500	"

Mean of the 28 (½) arms 7214 ohms per mile.

Arms painted white a long while ago, and not since painted. Paint nearly all washed off.

Table 52. These arms were not long in the Office before tested. The effect of well washing is given in the last two columns but one.

Dry	Mileage.	Top wet.	4 sides wet	4th col ÷ 80 per mileage.	Well soaked and washed	6th col ÷ 80 per mileage.	Length
1½	167000.	13.	32.	5900.	15.	15600.	42 in
6.	41300.	20.	32.	5900.	12.	20000.	"
5.	50000.	21.	29.	6900.	18.	12500.	"
6	41300.	33.	48.	2600.	30.	6500.	36 "
1½	167.000.	33.	52.	2200.	21.	10500.	"
1½	167000.	25.	43.	3380.	12.	20000.	30 "
4	62500.	26.	44.	3250.	21.	10500.	"
			mean	4300.		13.657.	

Oak pins bolted to the side of the arms thus.

These pins have never been painted, and have a remarkable amount of conducting power. Those which had been exposed to the rain without glass caps, and without red lead on them were found to be much poorer conductors or better insulators.

The top and bottom of the pin were wetted and a sponge applied to each so as to get contact with all the fibres.

N.B. Linseed oil and the acid sap of oak are much better conductors than water. The linseed oil generally contains much acid.

Many of the arms to which these pins had been applied had never been painted and were prepared (so I am informed) with a solution of zinc chloride - a most diffusive salt, and it would penetrate the whole of the pin and make it a conductor.

The high conducting power of these arms will be patent on the next sheet. I have not computed the individual resistance of them when wet, because the amount is far too small to be of any appreciable value.

Table 53.

1st pin Dry.	2d pin. Dry.	Arm. Dry.	1st pin wet.	2d pin wet	Arm wet	Mileage value in ohms of 1/2 arm & the 1st pin.	& the 2d pin.
2.	10 1/2	8°	30 × 10	24 × 10	20 × 10	—	—
2.	5 1/2	6.	30 × 10	10 × 10	16 × 10	—	—
1 1/4	2.	—	40 × 10	— —	14 × 10	2800.	—
2 1/2	7.	18	50 × 10	32 × 10	16 × 10.	2210	2920.
33.	1/2	6.	32 × 10	3.8 × 10	18 × 10	2710	5710.
35.	1 1/2	3.	52. × 10	14 × 10	18 × 10	1880	4960.
1/2.	1.	2.	—	36. × 10	19 × 10	—	2430.
1.	1.	9.	40.	30. × 10	12. × 10	3110	3560.
1 1/2	1 1/4	6.	30.	44 × 10	15. × 10	3120	2560
0 1/4	1 1/4	1 1/2	50.	20. × 10	14. × 10	2540.	4190.
3.	1	1.	50.	38. × 10	14 × 10	2540.	2870.
1.	1.	1 1/2	50	10. × 10	16. × 10	2210.	6460.
2.	3	1.	50.	44 × 10	14. × 10	2540.	2690.
1.	1	1 1/2	42	34 × 10	12 × 10	3050	3350
1	1 1/2	1	10	44 × 10	14 × 10	6690	2690
1 1/2	1.	1 1/2	50	44 × 10	16 × 10	2210	2460.
4 1/2	5 1/2	1/2	45	60 × 10	13 × 10	2840	2490
1/2	3/4	1/4	26	32 × 10	9.0 × 10	4590	4210
1/2	1.	1/4	30.	34 × 10	9. × 10	4310.	4100
1/2	3	1/2	30.	36. × 10	8. × 10	4680.	4370
1/4	1.	1.	32.	30. × 10	10 × 10	3650.	3960
1	1/2					3255.	3686.
1/2	2						
1/2	2 1/2						
mean 4°	mean 2.3°	mean 3.1°					

Same insulators that were tested dry but not taken in the same order owing to the pile of arms falling over.

It will be seen by the last three tables that the unpainted chemically prepared arms conduct 6 or 7 times as easily as the recently painted unprepared arms.

The insulators were now dipped into a pail of water to wet them all over, and were then left to drain in some cases a few minutes, in others only a few seconds.

Brooks Iron cap Insulators.

Dipped and left to drain 5 minutes.

Table 54.

Gave No 1.	900.
2.	750
3.	1050.
4	2250.
5.	1180.
6.	650
7.	784
8.	900
9.	1250
10.	1050
11.	764
12.	1100.
13.	1000
14.	2750.

Mean mileage insulation 1170 ohms

For mile of 40 insulators that is the resistance of each insulator has been divided 40 times as there are 40 poles to the mile.

The above figures show that when these insulators become soaked by driving rain and gusts of wind their insulating power is actually valueless being but = the 1/6 of that of the painted (half) arm.

The pin and glass insulators had a wire bound around the groove and two tests were made, sometimes three.

The whole having been dipped into water and allowed to drain a few seconds, (about 15) the two poles were applied, one to the bottom of the pin at a, the second to the wire around the insulator at b.

Secondly, the latter wire was removed from b and applied to the lip of the insulator at c because the inside of the insulators are all very dirty

Thirdly. The insulators were sometimes dipped several times in a pail of water and again tested.

Fourth. They were cleaned with the hand and a rag and again tested.

I give a few tests of sound insulators which show their value.

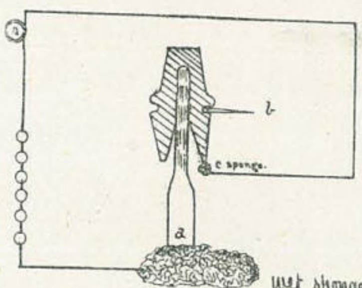


Table 55 Pin + Glass. Sound insulators.

Dirty			Dipped 4 times.			Cleaned.	
a to b.	a to c.	Value per mile of a to b. in ohms.	a to b	a to c.	a to b. per mile. ohms	a to b	a to c.
13°	23.	18400.	4.°	8.°	65,500	3.°	2.°
13°	20	18400.	3.°	9.°	82,500.	4.°	3.°
9°.	13.	27,500.	3.	1.5	82,500.	3.5.	1.
12.°	25	20,000.	5.5	12.	45,000.	3.5	3.5.
15.	20	15,600.	3.5.	6.	75,000	2.5.	1.5.
23.	40.	9,500.				7.	8.
3.	45	82,500.				2.	3.
12.	22	20,000.	6	14.	41,300	7.	7.5.
flaw × 35	48	5,000.	15.	26	15,600.	8	8
10	45.	25000	4.5	17.	55,000	7	6.
17.	42.	13,500.	5.5	7.5.	45,000.	× 7	1.5.
13°		23.220.	4.4.		56.400.	5	

These tests show how much benefit would be experienced if the insulators in the city were washed. The use of the fire hose on your pin + glass insulators in the City <u>would nearly quadruple their insulation</u>.

A number of new insulators from the Supply Department were tested the pins being covered with wet paint repelled the water in several cases.

Table 56

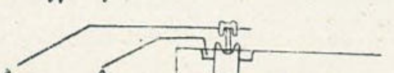
Tin & glass. New insulators from Supply Department.

a to b	b to c	a to c	a to b in ohms per mile.
3½	6°	2½	75000.
0	7°	0	∞
7	7	4	35000
3.	7.	2½	82500
4½	5.	2½	55000
0	2.	0.	∞
3	7½	2.	82500
3½	6.	2½	75000
6.	8.	5.	41300

Thus, then, even when quite new, they are poor insulators. They should give 1.000.000 to be up to the standard.

It is the favorable climate which permits such insulators to pay any dividend.

Lefferts insulators in newly painted arms - 1 coat two months ago. 2d coat 3 weeks ago. The insulator having been dipped into water the conductors were attached, one pole to the hook, the other first to the outside of the arm close second to the inside of the arm close to the glass lip. The insulators were then dipped four times to dissolve the salts and tested again. Thus.



The first dip was as short as possible and the test made from 15 to 30 seconds afterwards.

Table 57.

Lefferts insulators in newly painted arms.

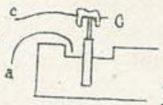
Dipped once.			Dipped 4 times more.			Cleaned.	
a to b. Degrees.	a to c Deg.	Mileage ohms a to b.	a to b	a to c.	a to b.	a	a to c.
× 30°	6×10		10°	30.°	250,000.		
12.	20	20,000.	15	45.	156,000.		
12.	23.	20,000.	5	12.	50,000		
17	28.	13,500.	6	17.	41,300		
× 45	15×10.	3,120.	12.	37.	20,000		
20	9×10.	11,100.	15	40.	15,600		
12.	37.	20,000.	5.	17.	50,000.		
20	48.	11,100.	8	30.	31,200		
20	50.	11,100.	11.	28.	22,500.		
22	40.°	10,000.	10	25.	25,000		30°
Mean. 15.6	50.°	14600.	9.4°	30.	31.400		30°
	45.°			50.			35.°
	45.°			20.			25.°

× These were badly broken.

As the paint had extended to the insulators it was not possible to get a test of the glass surface without taking the insulators out, and this is of no practical value.

The hard rubber insulation is the most curious of all. The action of the air upon its rough surface, and which is very short, not above an inch, combined with the accumulation of dirt, makes these insulators very inferior. They improve immensely by soaking in water.

Hard Rubber insulators tested by applying the poles at a + c thus



and dipped several times.

Table 58.

1 Dip. a to c.	4 Dips. a to c.	8 Dips. a to c	16 Dips. a to c.	32 dips. a to c.	64 Dips. a to c.	Rubber scraped clean.	Mileage of 1st column in ohms.
35 x 10.	12 x 10.						500.
40 x 10.	24 x 10	15 x 10					380
25 x 10.	18 x 10						850
13 x 10.	7 x 10						1840
14 x 100.	8 x 100						169
19 x 100	27 x 10						518
35 x 10	13 x 10	60	30	21.	22.	17.	500
15 x 100	23 x 10	9 x 10	37	32.	28	18.	156
25 x 10	19 x 10						850
Mean after 4 dips.	1410.					Mean say	600

The two last insulators but one were improved by mere ablution without friction from 500 ohms per mile to 10,000 per mile
156 " " " " 7,250. " "
and by scraping the surface to " " " 13500. " "
" " " 12500 " "

These are as regards their body, the soundest of all your insulators, but from being kept out of the rain, their surface insulation is the worst of any.

The resistance of the instruments in a circuit whose insulation is imperfect is a very important item. No care seems to have been taken either to procure good conducting copper or uniformity of resistance. "Keep down the resistance in every thing" is a golden rule in Telegraphy. I tested nearly all the relays in 145 Broadway on Jan 23. 1868. They vary from 69 ohms to 1205!!

The 69 ohm is where it should be on a long line No 2 Chicago. The Long Island circuit, about 100 miles, has a relay of 1182 ohms. viz as much as the resistance of 94 miles of No 8. wire.

Copper of high conducting power is a specialité in England. The conducting power of commercial copper varies from 14 to 85, and for a cost of about three dollars more per relay they could be furnished with this wire.

The values of the different Relays is given on the next sheet.

All your instruments should, at once, be tested, and should have marked on them their respective resistances

The resistance should not exceed* 130 ohms per relay and it will pay you well to have them all rewound.

* say 10 miles No 8 wire.

Name of Instrument	Resistance.
East side. Milliken	162 ohms
South side Repeater	139 "
East side. Hick's	247 "
South side Repeater	316 "
East side. Button	906 Bradley
South side Repeater	509

No 1 south wire	149	Washington Printing
2 " "	568	
4.	173	
5.	172	
6	147	
7	296	
8	158	
9	161.	
11.	200.	
13	836.	Bradley
14	225	
16.	124	
17.	197.	
17 ex	196	
18	180	
22	129	
26	168	
28	282	
28.	354	
8. W.U	201.	
33.	582.	

Table 59.

Resistance of Relays continued.

No 1. East	178 ohms.	
2. "	583. "	
3. "	150. "	
4. "	1038. "	
5. "	77	
6 "	182.	
7. "	117	
7. ex	166	
8 "	185	
9 ex	191	
25 "	786	
28 "	134	
29. "	179.	
31 "	411	
1. " Montreal	203.	
1. " ex	182	
2. "	124	
Harlem	362	
Long island	1182.	
1 West	174	Chicago No 1.
3. "	361.	
4. "	144	
5. "	98	
7 "	95	
8. "	972	
9 "	261	
10 "	138	
11. "	116.	
12. "	189.	
13 "	111.	
14 "	168	
15 "	203	
17 "	767	
18 "	109	
19. "	161.	

Resistance of relays continued.

20. West.		180	
22. "		186.	
23. "		719	
24. "		69	No 2 Chicago.
25. "		126.	
26. "		615	
27. "		758	
28. "		1205.	

Under	100 ohms.		4.
Over	100 under	150.	15.
"	150 "	200	23.
"	200 "	300	8
"	300 "	400	4
"	400 "	500	1.
"	500 "	600	4
"	600 "	700	1.
"	700 "	1000	7
"	1000 "	1205.	3

The effect of great resistance in the relays will be seen to be detrimental to good working by the following.

By ohm's laws the strength of a current is proportional to Electro-motive force divided by Resistance.

Let us take a line in wet weather whose insulation resistance per mile is 130,000 and, being of No 8 wire, its conductivity is 13. and therefore the ratio of conductivity to insulation is 1 to 10,000. The table on the next sheet shows the resistance of 10. 20. 30 &c up to 200 miles of such line.

The column r shows the resistance when the line is to the ground. The column R shows the resistance when the line is open. This Table is correct to about one per cent of the amount given.

The unit of length y in this table is that length of line whose insulation resistance is 10000 times its conductivity resistance.

This table enormously facilitates the solution of questions connected with leaky lines, such as what is the best place for batteries on a line worked upon the American plan of a continuous current.

Table 60 giving the resistance of various lengths of leaky line.

The Length of Line.	r. = R_g	R. = R_f	Strength of current e' in r
10 × y	9.96 × y	1003 × y	1.
20.	19.72	506	1.005
30.	29.1	343	1.02
40.	37.93	263.	1.044
50.	46.11.	216.	1.08
60.	53.56.	185.	1.13.
70.	60.25.	163.	1.18.
80.	66.2	148.	1.25
90.	71.2	138	1.33.
100.	76.	130.	1.42.
110.	79.8.	125.	1.53.
120.	83.	121.	1.64
130.	85.7.	118	1.78.
140	88.	115.	1.92.
150.	90.	113.	2.09.
160.	91.6.	111.	2.27.
170.	93.	109.	2.47
180.	94.2.	107.	2.7
190.	95.	106.	3.
200.	96.	105.	3.3.
210	96.7.	104.	3.6.
220.	97.4.	103.	3.9.
230.	97.9.	102.4.	4.3.
Infinite	100.	100	∞

The diagram shows the condition of the leaky line - open + closed as to the electric power in various parts.

Figure 1.

Line closed at A and B.

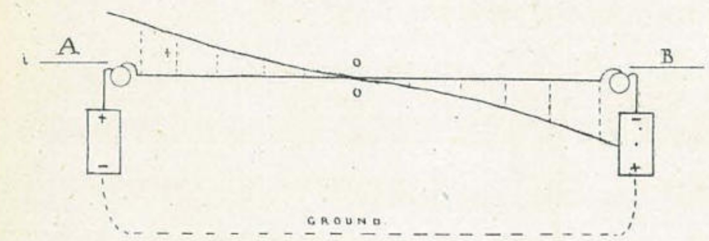
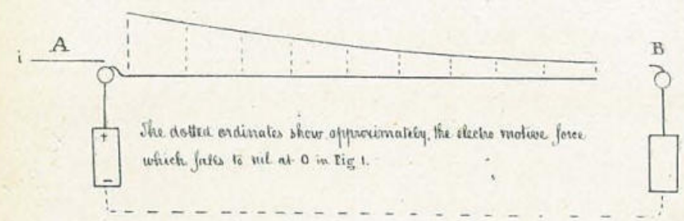


FIG. 2.

Line open at B.



i = instrument resistance in ohms.

$\frac{i}{y}$ = resistance of relay in units of the table in the case under discussion.

y = 13 ohms y = 1 mile of No 8 wire.

The length of the line from A to B is 200 miles = 200 y.

When the line is closed, the instruments at each end having equal resistances i. the batteries at each end having the same number of cups. and having no resistance of any importance. It will be found that the first half of the line between A and O is + (positive). The second half between O + B is negative so long as both keys are closed. When B is speaking to A the key is alternately open and shut

When open. the whole line is +.

When the line is closed. if an instrument were connected at O between the line and the ground no current would be found to traverse the instrument. because the electric potential at O is O

Therefore the strength of the current at A is the same as if a line of half the length were grounded at O. so long as B's key is closed. If E be the force of the Battery say 100 cups. then by Ohms law the strength of the current at A will be $\frac{100}{i + r_{100}}$.

When the line is open at B. it will be $\frac{100}{i + R_{200}}$.

r_{100} + R_{200} being the resistance of the leaky line. r_{100} = half the line to ground.

R_{200} = the whole line open at B.-

In the table $r_{100} = 76\,y$ $R_{200} = 105\,y$ as $y = 1$ it may be omitted

Now let i have the value = 10 miles.

and i' .. - .. = 100 .. i.e another relay of 100 miles resistance

we get the following strengths of current at A when the line is open and closed at B.

	CLOSED at B.	OPEN at B.
i = 10 miles.	$\frac{100}{76+10} = \frac{100}{86} = 1.163$	$\frac{100}{105+10} = \frac{100}{115} = .87$
i' = 100 miles	$\frac{100}{76+100} = \frac{100}{176} = .568$	$\frac{100}{105+100} = \frac{100}{205} = .488$

Thus, when the resistance of the instruments are each 10 miles, and are each 100 miles, the currents will be

	Open.	Closed.
i = 10 miles	.87	1.163.
i' = 100 ..	.568	.488.

$$\text{Now} \quad \frac{1.163}{.87} = 1337$$

and

$$\frac{.568}{.488} = 1.165.$$

In other words, if the resistance i be small, ie. 10 miles in the 200 mile circuit, and if we call the current at A 100 when the line is open at B it will be nearly 134 when the line is closed at B a difference of nearly 34 p. cent. If the resistance of the instrument be 100 miles, then if the current at A be called 100. when the line is open at B it will be only 116.5 when the wire is closed at B. or a difference of 16½ per cent only instead of 34 p cent. If the line had no escape, the change would be in each case from 0 to 100.

In other words, when there is escape on a line, keep down the resistance of the circuit to the lowest pitch compatible with power to move the relay, and the best result is then attained.

Your relays vary in resistance from 69 to 1205. ohms, and in the above case they would be. $\frac{i}{y} = \frac{69}{13} = 5\frac{1}{4}$ miles & $\frac{i'}{y} = \frac{1205}{13} = 93$ miles.

So that on such a line of 200 miles, the relays of small resistance would work over 100 per cent better than the relays of the largest resistance.

The next question is, what is the best position for the Batteries out of the following 1. Half the battery at each end.

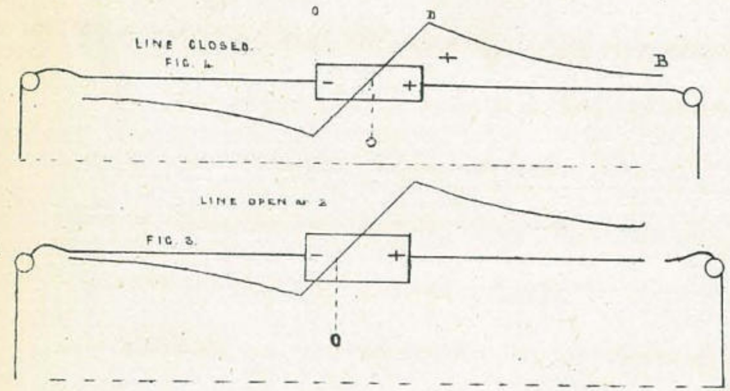
2. All the battery in the middle.

3. Half the battery in the middle, two quarters at each end.

This investigation is extremely difficult to translate into words. I have twice tried to make it clear, but failed. The diagrams following will explain the condition of the three lines when open and closed, and also the results.

The figures 1 and 2 show the first case. Page 73.

Figures 4 and 3 show the second case, viz. when all the Battery is in the middle.



Here we have the whole battery 200 cells in the middle, and when the line is closed at each end, the neutral point is in the midde of the battery and the current at C will be the same as the resistance between A and C allowing for leakage and for relay (say 10 miles) These by the table are found to be 80 so that the current will be at C $\frac{100}{80}$ 64 p cent only of which will reach A. so the strength at A will be. $\frac{64}{80} = \frac{80}{100}$

When the line is open at B the resistance on B side will be

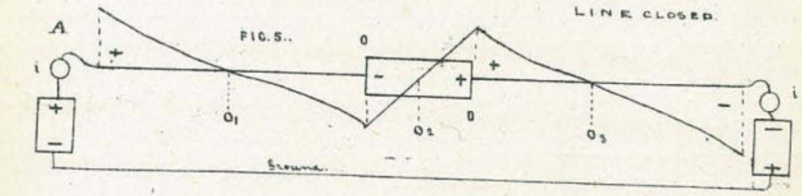
$R_{100} = 130$

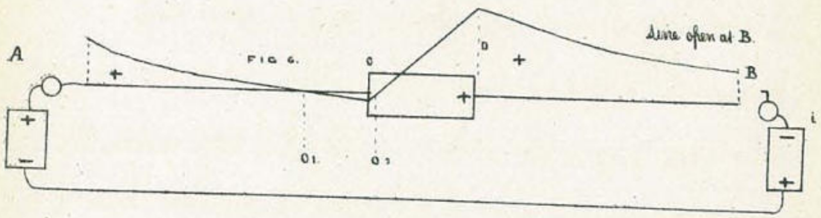
on A side including relay $r_{101} = \frac{80}{\underline{\underline{210.}}}$ (and $\frac{200}{210}$ cells 4 resistance will be / be the current at C, D.

* 64 per cent will reach A so $\frac{64}{105} = \frac{60}{100}$ & $\frac{\frac{80}{100}}{\frac{60}{100}} = \frac{4}{3} = 1.333$ or as 133.3 to 100.

* for this consult (c') last column in Table 60.

Third case - viz. half the Battery in the middle, one quarter at each end.





In figure 5. it will be seen that there are three neutral points, when the line is closed viz. O_1 O_2 O_3. O_1 is nearer to A than to C because of the resistance of the relay i. and O_3 nearer to B than to D.

As the distance from A to C is 100 y. and i = 10 y we shall find by the table r and calculation that O is about nearly 45 (y or) miles from A. and when open at B the neutral point is about 67½ miles from A. the resistance of the leaky line in the two cases. plus the resistance of the relay i is ⫤ closed at B 51.7 open at B 68.6 or as 132.8 to 100.

Thus then it will be seen that when the Battery is located in either of the three following positions. the results are nearly the same

and if the tables were quite correct. would probably be quite the same.

First position. Battery in two halves and half at each end.

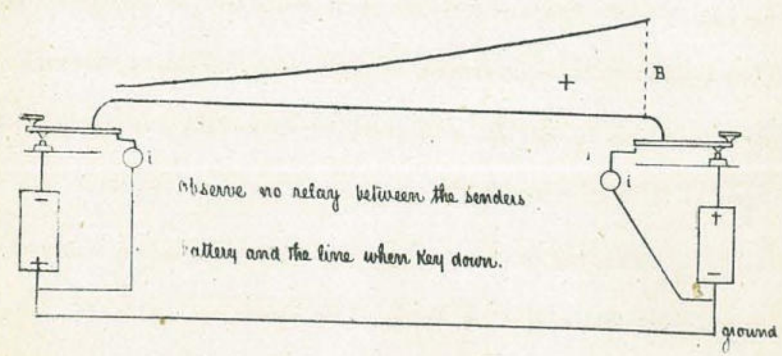
Second position. Battery all in the middle.

Third Position. Half the battery in the middle, and quarter at each end give the following ratio of strength of signals.

Table G1.		Open at B.	:	Closed at B.
Positions	1.	100	:	133⅓
	2.	100	:	133⅓
	3.	100	:	132¾.

The table does not profess to be nearer to the truth than 1 per cent, and therefore it is probable that all three positions would give 100 to 133⅓.

The next plan to be considered is the German plan of working with the Battery at one end of the line the other being to ground when receiving



The fifth plan is my plan, by which twice the power is obtained from the same Battery. and the system is *self adjusting.*

The relay, like as in the German plan is to ground, but the key reverses the Battery instead of intermitting, or simply opening and closing the line; and further, the resistance of the relay i at the senders station, is cut out of the circuit while sending. This is the system used by the Electric and International Telegraph Co over Great Britain, Ireland and Holland.

To compare these systems, I have drawn up the table beneath.

Table 62. Actual strength of the current at A.	Key down at B.	Key up at B.	Difference, or available power for signals.
American plan.	116.3.	87.	29.3
German plan. *	30.	0	30.
My plan of reverse currents.			
Self adjusting.	30 +	30 −	60

A variation of insulation makes the following variation in strength of the currents at A. Let the insulation be increased four times

Note. * I have called this the german plan because it is used all over Germany. It is also used in Russia. This plan was used by Alexander Bain in 1847 for the Electric and International Telegraph Co. Mine has supplanted it since 1853-54.

and then the actual strength of	Key down at B.	Key up at B.	available difference.
Current at A on the American plan.	98.	37.	61.
German plan.	71.	0.	71.
Varley's self adjusting.	71 +	71 −	142.

In my system the negative current is used instead of the spring and consequently the power to move back the relay is always the same as the power that moves it forward, only the one acting at one time. The adjustment is, therefore, produced in the currents themselves.

Working several lines from one battery.

I have tested your platina Groves Battery and also your carbon Groves, the former charged with nitric acid, the latter with the bichromate of potash &c.

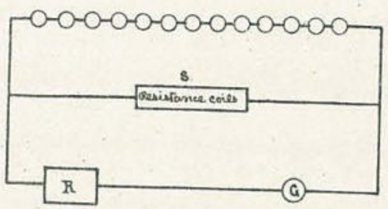
The former has less resistance and will carry 50 per cent more wires than the latter, but the latter is much cheaper and free from fumes.

These batteries, however, are all worked a great deal too hard, and, in wet weather, when you want the most uniform and steady currents, you have the very reverse.

In order to see how much mischief arises from this source, the following experiment was made.

Carbon Grove charged with sulphuric acid and the bichromate of potash.

Battery of 60 cups.



S = shunt or coil that could be varied at pleasure. It was the box of resistance coils.

G the galvanometer. R a resistance of 2000 ohms. The latter was about the same resistance as that of one wire of 200 miles in wet weather.

The amount S was varied until it reduced the strength of the current in G from 100 to 90. 300 ohms did this.

Now in wet weather (Dec. 22.) the No 1 Philadelphia wire, gave 1350 ohms when clear, or open, at the latter station and therefore, when connected to the Philadelphia Battery including a relay of 200 ohms at each station, the resistance presented to New York's battery would be about 594 + 200 ohms = 800. Three such wires attached to the Battery by closing their keys, would cause a variation in the current in the fourth wire of 12 per cent.

Eight wires attached, or rather, their value in resistance,

brought down the current about 24 per cent.

At 145 Broadway there are two batteries of 75 cups each carrying 10 wires and 11 wires.

4 batteries of 60 cups carrying each		8	and	9 wires.	
2. "	" 45 "	"	" 4	and	10 wires.

There are other smaller batteries of 30 & 15 cups.

1	of 30 cups	negative to line, carrying	.	5 wires
1	" 30 "	" " " "		6 wires.
2	" 15 "	" " " "	each	2 wires.
1	" 15 "	" " " "		1. wire.

Here the greater the number of cells the more the number of wires thrust on to the overloaded battery. When the number of cups is increased the internal resistance increases also in like proportion, and to avoid the above mentioned fluctuation of current the number of wires attached to a battery must <u>decrease</u> *in proportion to the* <u>increased</u> number of cups, that is, assuming that the wires have each the same resistance.

The above wholesale cause of bad working has hitherto escaped the attention of your Officers because it appears like bad insulation, and, indirectly, it is bad insulation which causes this variation to be so large and to be of consequence, because the signals from the distant station are weakened by the bad insulation.

This system of working several wires out of one battery instead of being an economy is the cause of a prodigious loss to the Company every wet day.

There is another great evil attending it. Whenever one wire is "grounded" near to the working station, every time that wire is used, all the other wires attached to the same battery are momentarily interrupted every time the key on the bad wire is depressed. Here is a fruitful source of errors, of slow working, and no working at all.

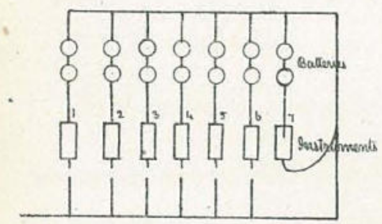
One half the trouble you experience in bad weather from bad insulation would disappear had you a seperate battery to each wire.

In England, many years ago, I convinced the Board of the Electric and International Telegraph Co of the great loss they sustained by this system, and they passed a law forbidding the use of one battery for more than one line wire.

We use the Daniels battery which is free from fumes and, when properly constructed, will work for months without cleaning. We work 70 main lines from rather less than 400 Daniels batteries, each containing 10 flat cells. These batteries we make ourselves, and they cost about $7.50 gold all complete.

These batteries take up more room. That is their only disadvantage. They are incomparably more constant in their action, there is no acid or mercury used in them, so that there are no fumes, and two men keep in order the 6000 cups used at the head, or central station in Telegraph Street.

Another very easily remediable defect in 145 Broadway consists of connecting all your local batteries to one return wire,- Thus.



If the iron core of number 1 relay be in connection with the silk covered wire by a small bare place or by moisture, and say number 5 is so likewise. Now if these two relays be connected each with batteries whose opposite poles are to ground, then whenever the two armatures happen to touch the poles of the magnet, the whole force of the two batteries are connected together by the general return wire and the relay may be burned. This however is a very small evil to the numbers of errors produced at that moment on each of the wires (20?) connected to these two batteries. And further, these two batteries run down (and no one knows the reason why) producing still more bad working.

I found eight relays thus united to their cores. $800 would supply seperate return wires and sweep this disgrace from your station. On one relay more than two feet of the wire had had all its silk burnt off.

While on the topic of batteries I have omitted to mention that 29 wires are being worked out of one Grove's battery.

By what I have above said it will be apparent that if only 13 wires were attached to this battery, then whenever the 12 wires were simultaneously open, the current on the 13th wire would increase in strength from 76 to 100 on a wet day, the wires in question being 100 miles in length and similar to your Philadelphia wires on December 22. 1867.

Of course when the weather is dry, this is not felt to anything like the same extent. Your batteries give a brilliant flame. Hence, whenever it is thought adviseable to ascertain their condition, the flame is tried. This lasts but a few seconds, but during this time, all the 10 or 11 wires attached to that battery are either stopped altogether, or else they are making errors compelling the operators to guess at what was intended to have been sent.

With a seperate Daniels battery on each wire, but one line would be affected instead of 10. the pretty flame would be wanting, and would not invite the curious, and, as this form of battery works without

attention for weeks it would seldom have to be looked after.

While the present system remains in force, a considerable improvement, in bad weather would be experienced if the batteries at each end of each line were divided into a larger number of seperate batteries, each battery having fewer lines upon it.

Example. Batteries Numbers 5. 6. 7. 8. 9. 10. 11. & 12. in all eight batteries and total cups 480. work 69 wires. The two 75 cup batteries work 21 wires or 10½ each. Now if the 480 cups were divided into

2 of 60 cups each carrying 4 long wires.
6 - 40 " " " 6. " "
4 - 30. " " " 8. " "

there would still be more power than necessary, and the variation in wet weather, due to working so many lines from one common source, would be reduced more than one half.

Increasing the power on any one line, gives it an advantage over all the others on the same poles, <u>but at their expense</u>; and, contradictory as it may seem, the working in bad weather would be greatly improved by reducing the number of cups and making more batteries with fewer circuits upon each. Remember that on the American plan of continuous current, the <u>latter increases</u> in strength in wet weather; the <u>variation</u>

decreases.

Example.

Take the 200 mile circuit before referred to with a mileage insulation of 10 000 miles = 130000 ohms, and with relay of 10 miles = 130 ohms. The currents at New York A will be as under.

When the line is opened and closed by B.

	B closed.	B open.
Wet weather as above	116. 3.	87.
Perfect insulation	90. 9.	0.

The differences which constitute the strength of the signal are

In wet weather as above 116.3 - 87 = 29.3.

In hard dry frost 90 9. 0 = 90 9.

The strength of the current in the wet weather has increased from 91 to 116½, or nearly 30%.

Your relays would work much better if enclosed in a case with glass sides so as to keep the pivots and the oil in them clean and yet permit the operators to see that the armatures and other parts are in proper adjustment. This alone would contribute a large amount towards overcoming present difficulties.

Return of work done upon the circuits running into New York being the daily average for the week January 4th to 10th 1868. Sunday has not been considered as the messages were very few on that day.

Column No 1. gives the daily average to and from 145 Broadway. N.Y.

" 2 . . . work between other stations.

" 3 . . . total for day.

Table 64.

Wire No.	Circuit	1.	2.	3.	Remarks
1 West	N.Y. to Chicago. Brokers.	393.	0	393.	Works day + night.
4 .	N.Y. to Chicago for San Francisco.	91.	0	91.	No Press work.
1. East.	Printing to Boston.	313.	0.	313.	2½ hours Press work.
1. South	Washington Printing.	311.	0.	311.	2½. " " "
8 South.	Philadelphia Printing.	291.	0.	291	h 3 Press work.
10 East.	Boston Printing.	286½	0.	287	1 17m Press work.
7 South	Philadelphia "	273.	0.	273	0 0. "
5. West.	Albany Printing.	218.	0.	218.	0 - 5. "
18 South	New Orleans direct.	243.	?		0 33. "
3. West.	Detroit, Cleveland, Buffalo.	203.	25.	228	0 - 4. "
5 South	Philadelphia Brokers.	209.	0.	209.	0 - 34 "
3 Erie.	Buffalo + Buffalo Docks.	190.	12	202.	5 - 40 "

Wire No	Circuit	1.	2.	3.	Remarks
25 East	Newhaven way wire.	188.	10.	198.	
11th Street	Washington Broker	175.	0.	175.	
7. West	Syracuse + Oswego	175.	15	190.	h. m. 0.- 40 Press work.
29 South	Pittsburgh + Philadelphia	164.	25.	189.	0- 7. " "
30 "	Cincinnati + Philadelphia	156.	0.	156.	2. 21. " "
28. "	Philadelphia way wire.	161.	50.	211.	0- 0. " "
33. "	same.	6½.	15.	21.	0- 0. " "
9 East.	Boston. Providence	154½	30	184½	0- 0. " "
2. Montreal	Montreal way wire.	144.	33.	177.	2. 6. " "
4. Erie	Way wire.	142.	150	292.	0- 0. " "
4. South.	Baltimore.	140.	0	140.	2. 0. " "
17. "	Richmond. Balt. Philadelphia	123.	62.	185.	0- 45. " "
27 "	Washington Printing.	125.	0.	125.	2. 40. " "
20. Nat.	Louisville + Pittsburgh.	126.	100.	226.	0. 25. " "
18 East.	Boston.	111.	0.	111.	27. " "
6 West.	Albany. Buffalo way wire.	110.	75.	185.	6. 30. " "
12. Nat.	Pittsburgh + St Louis.	104.	84.	188	0- 10. " "
5. East.	Way wire.	93.	100.	193.	0- 0. " "
7 East	Boston Exchange.	84.	75.	159.	6. 20. "

Wire No	Circuit	1.	2.	3.	Remarks.
31 East.	Boston Brokers.	83.	3.	86.	0. 13. Press work.
6 South.	Wilmington + Washington.	96.	25.	121.	1. 15. "
14. "	Easton way wire.	90.	50.	140.	0. 0. "
28 East.	Boston Brokers.	76.	0.	76.	0. 27. "
32. "	same.	73.	0	73.	0. 32. "
3 South	Philadelphia Brokers.	77.	0	77.	0- 0. "
22 "	Easton + R.R. Offices.	75.	100.	175.	0- 0. "
4 West.	Chicago + West.	91.	0.	91.	0- 0. "
8 "	Way wire.	52.	100.	152.	0. 0. "
29. East.	Boston City Offices.	57.	25.	82	4. 45. "
	Long Island way wire.	51.	23.	74	0- 0. "
10 West	Albany way wire.	48.	?		0- 0. "
27 East	Broker's wire.	38.	0.	38.	1- 11. "
13 South.	Way wire.	42.	40.	82.	0- 0. "
	Harlem way wire.	33.	100.	133.	0- 0. "
9 South.	Philadelphia way	31.	75.	106.	
5 Erie.	Honesdale way.	22.	80	102.	
34 South.	Scranton way.	15.	20.	35.	4- 35 "
33 "	Philadelphia.	6½	15	21½	0- 0. "
23. "	same.	6.	25	31.	0- 0. "
26. "	Washington.	5.	0.	5.	3. 0. "
13. West.	Albany + 2 way stations.	4.	23.	27.	0- 5. "

The above data speak for themselves. The last column in the Appendix

A is I regret, of no use, because it was made up as follows. The number of the messages has been multiplied by 31 words, and the time for the transmission of news by 18¾ words per minute – 1121 per hour. The average length of your messages paid for by the public from statistics supplied to me some time since, was over 10 and under 11 words. If 31 words be the true length, but which is hard to believe, then the address date and signature are 20 words which is out of all proportion. But in the Journal of the Telegraph for February 1. 1868 Page 4 the time for transmitting 2500 words is 1 hour while in the return, the time for transmitting 1121 words is one hour as 2¼ to 1. In page 5 column 1. the rate is 2518 words in one hour instead of 1121. In page 4 column 2 same Journal, the length of 94 messages is given as 20 words each, and this is probably more near the truth than 31 words. These 94 messages were sent 1400 miles direct, in one hour.

Your most active circuit, in the above return, does but little more than 4 times this number of messages in 24 hours, it being a circuit that works day and night. You have then but 6 wires which do more than 3 hours of such work per day; 10 wires doing over 2 hours and under 3 hours of such work per day.

If the published statement be true, then you are not getting more than one third of the work out of your wires that is possible with

good operators. This is worthy of very careful observation, for operator's salaries are the greatest tax upon the earnings of the Telegraph, far greater than any other, excepting, perhaps, the cost of renewing the poles, insulators, wires and apparatus.

Appendix **B** gives the way your Batteries are used at 145 Broadway.

Number of Poles to the Mile.

In England and Scotland I have reduced the number of poles to the mile from 32 to 20. 16. 12. 10 & 8. 20 where we have many wires and the lines run on curved roads. By using iron wire that will elongate 25% without breaking – wire in 100 lengths without welds or joins, and all the kinks and brittle places removed by passing it through the "Killing machine", I have erected wires that will not break, but only stretch, that if twisted together untwist of themselves because they contain no joints and no kinks. N.B. The three joints to the mile are made near a pole.

Although this wire costs £23. ($115 gold) per ton, the fewer poles and insulators give a cheaper and vastly better line, one that keeps itself in much better order, because the wires do not get together.

Sleet, we only have in Scotland. Your 40 poles do not save you, because the weight of ice is enormous. I reduced the poles in Scotland from 16 to 8 to the mile, using the excellent wire above alluded to, or then the sleet brought the wires to the ground, but did not break them, and so long as it froze hard, the wires worked. Immediately the ice thawed, the wires lifted off the ground and the lines worked again.

It is better to have more sets of independent poles carrying fewer wires than to crowd all on to one set. Remember half the number of poles doubles the insulation and halves the "cross connecting" points. viz the arms, and halves the cost of insulation.

Cromwell Fleetwood Varley.

RESUME.

With recommendations for putting your telegraphs into good condition.

On a foggy day, but clearing up viz Nov. 22. 1867. your wires gave the following insulation, the standard 100. being the minimum allowed by the Electric and International Telegraph Co. the minimum per mile being 1.000.000 ohms.

This, in the following remarks, has been reduced to 100. so as to give a percentage of insulating power.

November 22. 1867.

New York to Harlem.	Maximum.	Minimum.	Mean.
	47.	5½	21.
Harlem to Newhaven.	28.	16.	21.
N.Y. to Manhattanville.	32.	21.	28.
N.Y to Jersey City.	9.	3½.	6¼.

December 2. Very wet.

To Philadelphia.			5.
To 15th Street.	7¾.	0½.	5¾.
To 55th Street.	6¾.	2.	4½.

The following will give you a fair idea of your insulation in wet weather as compared with the English maximum here taken as 100.

Dec. 22. Very wet. N.Y. to 15th street.	Maxm. 7 3/4	Min 0 1/2.	Mean 5 3/4.	Insn	Lefferts.
To Philadelphia.	"		5.	"	Mixed.
To 55th Street.	6 3/4	2.	4 1/4.	"	Pin + glass.
Jan. 1.'68 Very wet. To New Haven.	4 1/4	1.	3	"	Lefferts.
" 4. Fog + rain. To Manhattanville	5 3/4	5 1/4	5 1/2	"	Hard Rubber.
To 15th Street.	12.	7.	10.	"	Lefferts.

For the above see pages 25 to 43.

Examination of insulators taken down in New York City.

Percentage of defective insulators.	Dec.	Lefferts.	83 p cent.
	"	Pin + glass.	49. p cent.
See pages 50. 51. 52.	"	same, unused.	17 1/2 p cent.
	"	Brooks.	49. p cent.
	"	Hard Rubber.	21. p cent.

The cracked pin and glass, though less in number than Lefferts are much more felt than the latter because fully exposed to the rain.

From page 45 the value of the pole considered as an insulator is compared with the standard 100. only 0.92 per cent.

This latter is of very far greater mischief than good because it causes cross

connection between the wires. In truth it really it is of no good. The insulating power of the arm is valuable with your present very defective insulators by reducing cross connections.

In pages 37 + 38 will be seen how the experience of many years has taught me the best way of cutting off this disturbance. More good would be experienced from this and at less cost than any other thing you can do for the money. Do this, and work fewer wires on your batteries and an improvement of 100 per cent in wet weather will be the result. ———

Pages 54 to 66. give the insulating value of arms and pins considered as insulators. Their insulating power when wetted gave the following means - Eng. Standard 100.

0 1/2. 0 1/4. 0 1/4 0 1/4 0 1/4 0 1/2. Grand mean. = 0 1/2 per cent. ———

When well worked they increased in insulating power from 0 1/2 to 1 1/4 per cent.

In tables 53 + 49 pages 60 + 56. it will be seen that the dry arms have a mileage insulation of only 3 to 8 per cent. The following summary in ohms will be useful. ———

	Page.	Table	ohms per mile of 40 arms
Taken down in New York. arms 4 surfaces wetted with a sponge.	54.	45	.3120.
soaked one day and left in warm room, one day to dry + then wetted.	55.	46	.2680.
Arms not painted for 3 years.	55.	47.	.6150.
3 arms as in last	56.	48.	.6533.
3 arms washed.	56.	48.	.9166.
This shows that dry arms vary from 1 to 22 as insulators	56.	49.	11.100. to 330.000.
Recently painted	57	51.	.7214.
Arms not painted many years.	58.	52	.4300.
same arms well washed.			1.3657.
Dry arms	60.	53.	8.0000.
Dry pins.			8.0000.
Arms and pins together wet	60.	53.	.3255. .3686.
Brooks insulators dipped in water + drained 5 minutes.	61.	51.	— .1170.

The . at the fourth figure to the left is to permit of comparison with the English standard 100.0000. viz 1.000.000 ohms.

Pin and glass insulators dipped in water	once.	1.8400	ohms per mile.
	4 times.	3.1400.	" "
	Cleaned.	5.0000.	" "
Lefferts insulators.	Dipped once.	1.4600.	" "
	4 times.	3.1400.	" "
Hard Rubber.	Dipped once.	0.600.	" "
	4 times.	1400.	" "
	64. "	8620.	" "
	Cleaned.	1.3000.	" "

Thus mere ablution improves these insulators much. vide pages 65.66.

Resistance of Instruments.

Your relays vary from 69 to 1205. and it is demonstrated that the latter on a wet day reduced signals on a line with even three times as good insulators as you have between here and Philadelphia such line being 200 miles in length, from 33.7. to 16½.

Pages 71. 81. show that working on the American constant current it matters not whether the Battery be in the middle, at each end, or divided between them. The result is the same so far as escape to ground is concerned.

Pages 82-88. show the great disadvantages arising from your present system of Batteries. Great improvement can be effected here at once by decreasing the number of cells in each battery and increasing the number of sets.

Recommendation.

Lines which work with difficulty work slowly and require a most efficient but highly expensive staff. Lines which do not get out of order and do not vary, work faster and better, and fewer wires and fewer operators do more work.

I advise you to apply earth wires (lightning conductors) to your poles, especially for the first 40 miles out of each terminus. The work is not costly, but it must be well done, and no pole missed. These will produce immediate and permanent benefit, and, besides, saving poles from lightning.

Secondly. Your insulation is horrible in wet weather, and is getting worse. Take in hand those lines which earn most of your money, the Boston and Washington wires for example. Re-insulate one half or one third of these wires and I expect you will find them sufficient for your present traffic.

Third. Bind over with two separate wires all your joints on the line after first tinning the wire, then solder them, and cover the soldered joint with pitch and rosin mixed in equal parts (wood pitch) to prevent rust. This will prove of enormous benefit.

Fourth. Bring your batteries into a rational system as recommended in the report, and, at once, put return wires to the local batteries.

Fifth. Inaugurate a system of testing your lines in definite measure. Without this, all your efforts are based on the merest conjecture.

In Electricity <u>believe nothing until it is absolutely proved</u>, and then <u>doubt it</u>, because faults come on suddenly.

The insulation of all your main lines should be obtained at each end of a section every morning, such section not exceeding 200 miles. 100 miles or even less is better.

The resistance of conductivity should be taken not less than once a week, and then on a fine day. In England, when I introduced this system several years ago, I found from careful statistics, that 75 per cent of our defects were discovered by these tests before the defects were of sufficient magnitude to interfere with the working.

Besides this, the operators soon learn how to test for the locality of these faults and thus expedite their removal.

The tests should be made early in the morning – 10 to 15 minutes suffice – and they should be telegraphed to the head office for daily examination. You would then know, beyond any manner of doubt what was the condition of your lines from day to day, and whether bad working was due to the line or other causes.

Sixth. Have all your instruments, from time to time, thoroughly tested. Rewind with "high conducting" copper all your magnets.

Seventh. Do not pass by trifles, but let all be on the alert, for the bad working of a line is generally due to the neglect of trifles (in themselves)

Eighth. You have an unnecessary number of "leading in" wires. Most of these are defective. Cut out all you can.

Ninth. Your office connections should all be soldered where possible.

River Cables.

If these were all made into one cable of 30 tons, no ship could hurt them or get them up. Hence a very considerable saving in repairs and reduction of interruptions. A strong flexible cable, covered with a strand like the shore end of the Atlantic Cable, will resist injury. The anchor cannot break the strand, and the inner solid wires protect the gutta percha.

I first desired this form for our Dutch cables at Lowestoft channel, the great high road for coasting vessels. We laid it in 1863 and it has never failed. We found it a match for the sailors. I laid two other similar cables between England and Ireland and they have proved equally successful. These weigh from 17 to 20 tons per mile. You have larger ships to deal with and would require 30 tons or more to the mile. Such cables are very flexible and easily go round six foot wheel.

The great battery power you use at New York has burnt and produced so much heat when escaping from a defect in one wire, that the other good wires in the same cable have been injured by the heat and so "grounded". This is a strong argument against such great power.

Insulation for the City.

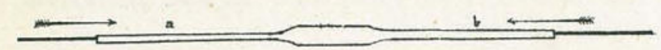
The best and cheapest way of getting rid of your City troubles is to lay down iron pipes from 145 Broadway to 15th or 55th street and carry all your wires underground to that point. The insulating covering which answers best is Hooper's wire which is a tremendously high insulator and is not affected by dark temperature even up to 212° Fahrenheit (100° cent.)

Next to this comes Gutta Percha covered with tape and the tar mixture alluded to in the report. The Electric and International Telegraph Co, the original English Telegraph Co, has no overground wires in London, Liverpool, Manchester, Glasgow, Edinburgh, Newcastle &c. We have, in Dublin City and find the cost of keeping them in any sort of order greater than that of the underground wires which give almost no trouble. However, I am afraid you will not adopt this course. The next best thing is to insulate your wires in the following manner so that the rain itself shall keep them in order.

An insulator is a misnomer. It should be considered as <u>a bad conductor</u>. As you vary the diameter of an "insulator" you vary its conducting power. Therefore, reduce the diameter as much as you can. Next increase its length, and a similar result will follow.

On the east coast of England and North coast of Wales our wires are close to the sea. The salt defied our ordinary insulators, but the one I recommend you for the City answered admirably.

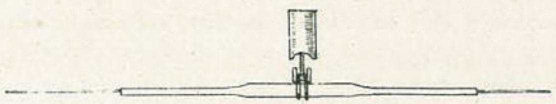
Cover a piece of No 8. wire which has been galvanized and then tinned, with hard rubber in the following form



Insert one of these at each arm and solder the joints. The length of these should be 7 feet: covered portion 5 feet.

I have shown that in page   your hard rubber insulators, which are one inch long in insulating surface, and nearly one inch in diameter, give a mileage insulation of 5½ %. vide page 95.

The above may be considered a double conductor a and b the electricity running over the surface from each end towards the middle where it is supported. But, as it is only three eighths of an inch in diameter, an inch of this will be a better insulator than your present "Hard Rubber hooks" as each arm of it is over two feet in length we shall have 5½ × 25 inches = 137 per cent of insulating power. The rain washes this insulator every time it falls and improves it by washing, because this insulator is constructed to work while saturated with water. These can be attached to your present insulators and so get their assistance also. I have used these since 1861. and they insulate better than all other forms. If I were reconstructing a line I would use them all the length of the line as nothing comes to them and they do not easily get out of order.



England. Russia. Holland. Prussia. Hanover. Belgium. France and Austria have all tried glass both blown and pressed. and every one of them have abandoned it.

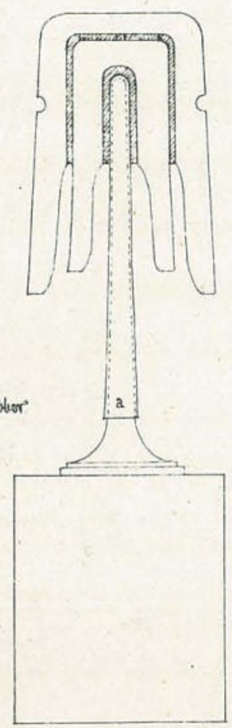
For several years I continued a careful series of experiments in my own garden which revealed the fact that soot will destroy the surface insulation of the best insulators unless they wash themselves in the rain, and that nothing can be relied upon as an insulator. It is therefore necessary to duplicate and triplicate the insulator so that the defects or accidents of the one part may be covered by the other.

I like one part of the insulator to be hard rubber because it is not so brittle as vitreous ware, and is good in resisting fog.

The stone-ware made in Derbyshire is the best material I have yet found. The brown ware is best as to its body but not as to its surface insulatory

power. The white stone ware is best as to its surface insulation.

The Electric and International Telegraph Co have used these insulators since 1862 and their high insulation is due to the triplicate form. The brownstone ware is used in the country, the white ware in places where there is smoke. Each part of the insulator is rigorously tested in acid and water. and every imperfect one smashed on the spot. Below is a rough sketch of a section of the insulator.



The pin is prepared so as not to rust. It is first galvanized and then tinned

The Prussian Government are using this insulator. but only double,-the inner cap being of Hard Rubber inside white stone ware (often miscalled porcelain) which latter is often a conductor.

France last year has reported, after a long series of experiments in favor of mine by an amount so high in their favor that I hardly like to allude to it. It is about 11 to 1.

If the annual income of the Electric Telegraph be consulted, it will be found that from the year 1846 to 1862. the annual increase of receipts or income only once exceeded £6000.

In 1863 when I had my insulators on the main lines, the increase over the preceding year was

1863.	£34.000 instead of £6000.
1864.	20.000. more.
1865.	30.000. more.
1866.	32.000 more.

The improved workings of our lines secured us the great bulk of our work. The greater despatch created more business.

C. F. Varley.

Method of making the Tests.

The tests are made to refer to the Royal Society and British Association standard of resistance. viz the Ohm. and the megohm, the latter equal to 1.000.000 ohms.

Advantages of these Standards.

No battery is constant in its power. No magnet is uniform in its strength. The earth, considered as a magnet, varies considerably. None of these three can be used as a basis of accurate reference or comparison.

Coils of wire of certain alloys, carefully prepared, are found to contain the same resistance or power of impeding the passage of an electric current, and certain metals have been found not to have varied $\frac{1}{1.000.000}$ th in 8 years. Consequently all tests made in terms of such coils can be referred to from time to time with an amount of accuracy far greater than is ever practically necessary. The only source of variation in such coils is that due to temperature— viz. their resistance increases 1 per cent for 40° Faht. or 22½° Centigrade.

The galvanometer is wound with two wires carefully insulated from each other (by unusual precautions. These are woven into a braid, and consequently the magnet is surrounded by an equal number of convolutions all equi-distant from the magnet they encircle. The inside end of one wire is joined to the outside end of the other wire, and is attached at this junction to a key which connects it with a battery when testing. The other two ends of the coils are attached to terminals (binders) for easy attachment to the lines to be tested.

The accompanying diagram Fig. 1. will explain how this galvanometer is used. The arrows show the directions of the currents. When these two currents are of exactly the same strength they exactly balance each other and therefore the magnet remains undeflected. The strength of an electric current has been ascertained (by Ohm) to be inversely proportional to the resistance of the circuit multiplied by the electro motive force - electric potential. The two wires on the galvanometer have exactly the same resistance. When the key is pressed down the battery finds two circuits, the one through the outer wire and Telegraph line to the ground at B say Harlem. Fig. I the other through the inner wire of the galvanometer to the Resistance coils and thence to ground.

If the resistance of the line wire be — r.

" " " Galvanometer wire be = g

Resistance coils in circuit = c

Potential of the Battery = E

Then the currents in each of the circuits be $\dfrac{E}{r+g}$ & $\dfrac{E}{c+g}$

If now c (the resistance coils) be varied until c = r the two currents will be exactly equal - the magnet of the galvanometer will be unaffected. because the one current exactly balances the other. It circulates around the magnet the same number of times but in the opposite direction to the other and therefore the needle will point to zero. C then is the resistance which the line opposes to the passage of the electric current.

N.B. The earth from its great dimensions offers no sensible resistance to the passage of the current and is therefore omitted in the formulas.

It will be evident that a variation of the Battery E will in noway affect the equality of the equation. $\dfrac{E}{c+g} = \dfrac{E}{r+g}$. And further. If the magnetism vary it will not affect the result, because, when the two circuits have equal resistances, the magnet is unaffected. A variation in the strength of the magnet only varies the rate of motion of the needle, but in no way interferes with the equality of the two circuits $c+g = r+g$

$\therefore\ c = r$.

Lastly, as the resistance coils c do not vary - are constant, tests made in this way can be referred to from time to time with more accuracy than it is possible to weigh any ponderable object.

Resistance Coils.

The box of coils usually supplied with the above described differential galvanometer contains coils of 1.2.3.4. 10.20.30.40. 100.200.300.400. and 1000.2000.3000.4000. ohms. which can be combined in any proportion by the insertion or withdrawal of small metal plugs so as to give from 1. to 11111 ohms.

One of the coils of the galvanometer is provided with three "shunts" which shunt off when inserted

$$\left.\begin{array}{ccc}\frac{9}{10} & \text{leaving} & \frac{1}{10}\\[4pt] \frac{99}{100} & & \frac{1}{100}\\[4pt] \frac{999}{1000} & & \frac{1}{1000}\end{array}\right\}$$

of the current to pass around the magnet, and in this way the instrument will measure any resistance from 0.001. to 1111000 ohms. The latter number is required in clear frosty weather. The method of using the shunts is shown in Fig. 2. the three small coils a. b. c. have a resistance of

$$a = \frac{g}{9} \qquad b = \frac{g}{99} \qquad c = \frac{g}{999}.$$

If the plug be inserted opposite 100. the current will find two channels between the battery and the resistance coils - the one $= g'$ the other b as $b = \frac{1}{99} \times g$. Ninety nine parts of the current that passes towards and through the resistance coils pass by the shunt b leaving but $\frac{1}{100}$ part to go through the galvanometer, and therefore, when the resistance in the left hand circuit is $\frac{1}{100}$ part that of the line and wire g, the action upon the magnet will be nil. Thus by inserting these plugs

the instrument is made to multiply or divide 10 100 + 1000 times.

The resistance of any two circuits b & g will be less than either of them taken singly. Their combined resistance is as their product by their sum viz. $\frac{bg}{b+g}$ and, in the above case $b = \frac{1}{99} \times g$. If the above be correct then

$$C + \frac{bg}{b+g} : g + r :: 1 : 100.$$

$$\therefore \frac{g+r}{100} = C + \frac{bg}{b+g} = C + \frac{\frac{1}{99}g^2}{\frac{100}{99}g} = C + \frac{g}{100}$$

$$\because 100\,c = r$$

Q.E.D.

FIG. I.

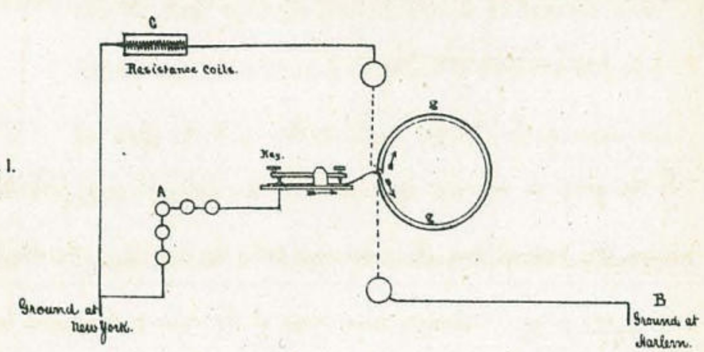
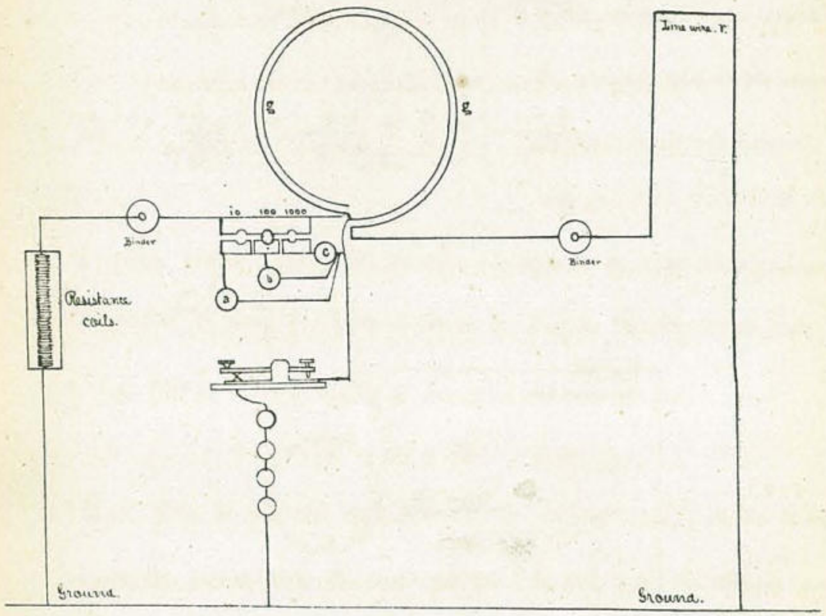


FIG. 2.



APPENDIX.

A. B. C.

WEST.

No 1. West. Through circuit to Chicago, used for sending business to Chicago direct from our Broker offices during the day and for receiving business at this office from Chicago. At night, all Chicago business is done on this wire.

No 3. West. Through circuit to Detroit Cleveland and Buffalo. On this wire the "Dock" office in Buffalo exchanges business with Detroit and Cleveland to the extent of about 25 messages per day which is not included in the accompanying statement. —

No 4 West. Through circuit to Chicago for sending Chicago & San Francisco business.

No. 5 West. Albany printing through circuit exclusively for Albany business.

No 6 West. Way wire and Press Reports. In addition to the business done from this Office as shown in statement, this wire is used for business between Buffalo Albany and other way offices to the extent of 75 or more messages per day.

No 7. West. Through circuit to Syracuse and Oswego. This wire is also used for local business between Syracuse and Oswego and for business from "C.N.D" office to Oswego to the extent of about 15 messages per day.

No 8. West. Way wire. About 35 offices exchange business on this wire to the extent of about 100 messages which do not appear in statement.

No. 9 West. Hudson River R.R wire. 300 or 400 messages exchanged between R.R. offices on this wire. Nothing done from this (N.Y.) office.

No 10 West. Albany and 15 way offices exchange business on this wire in addition to what appears in statement.

No. 11 West. Way wire. Albany and 13 way offices exchange business on this wire, not included in statement.

No. 12. West. This wire used for cattle yards at N.York and Buffalo and 5 way offices. It is not usually worked from this office. Way offices send 60 to 75 messages on it per day.

No. 13. West. Albany and 2 way offices exchange perhaps 20 or 25 messages per day, not included in statement.

No. 2. Erie. Erie R.R wire. Not worked from this office.

No 3. Erie. Through circuit to Buffalo and Buffalo Dock office. About 12 messages per day exchanged between the 2 offices.

No. 4. Erie. Way wire. 25 offices exchange about 150 messages per day in addition to those shown in statement.

No. 5 Erie. Way wire. Honesdale and others exchange about 80 messages per day.

No. 12. National. Through circuit to St Louis. This wire is used for local business between Pittsburgh and St Louis to the extent of about 75 messages per day, and by "C.N.D" office about 9 per day in addition to statement.

No 20. National. Through circuit to Louisville. Pittsburgh uses this for Lville business to extent of about 100 messages exclusive of statement.

No 29. South. Through circuit to Pittsburgh. Philadelphia uses this for his Pittsburgh business to extent of 25 messages per day.

No 30 South. Through circuit to Cincinnati. Philadelphia and Cincinnati use this for Press reports about 20 minutes daily.

EAST.

No 1 East. Through circuit. Printing, to Boston. No way or Broker offices on this wire.

No 3 East. Atlantic Cable business. Through circuit to Plaister Cove.

No 4 East. Press reports way wire. Boston and 9 Way offices exchange business with each other. average 100 messages per day in addition to statement.

No 6 East. Way and Railroad wire. Does about 100 messages per day between way offices.

No 7. East. Boston and way wire. Exchange 75 messages per day.

No 8. East. Way wire. Springfield. Hartford, and other way offices exchange about 45 messages per day.

No 9. East. Way wire Providence Boston & others exchange about 38 daily.

No 10. East. Through circuit (Printing) to Boston.

No 18 East. Broker's wire to Boston. Not generally used from this office.

No 25 East. Way wire. New Haven and 3 other offices average about 10 messages per day.

No 27. East. Broker's through circuit. 21 Wall St. to Boston. Not used at 145 Broadway.

No 28. East. Through circuit. Bankers and Brokers wire to Boston. Not used from 145 Broadway

No 29. East. City offices in Boston and three way offices exchange business on this wire about 25 daily. in addition to statement.

No 30. East. Spare wire. not used when others are in order.

" 31. " Through Broker circuit. "C.N.B." sends 3 messages per day over this wire in addition to statement.

No. 32. East. Through Broker circuit.

S O U T H.

No. 1. Through Printing circuit to Washington.

" 2. South way wire. Philadelphia and way offices exchange about 130 messages per day.

" 3. Brokers wire to Philadelphia. Exclusive.

" 4. Through circuit to Baltimore. Exclusive.

" 5. Philadelphia Brokers through circuit. Exclusive.

" 6. Through circuit. Wilmington Del. and Willard's Hotel Washington. Four up town (N.Y.) Offices on this wire send about 25 messages per day on this wire, not included in statement.

" 7. Through Printing circuit to Philadelphia.

" 8. Through Printing circuit to Philadelphia.

" 9. Way wire Phila + C.R.R. offices average 75 messages per day.

No. 11 Through circuit Baltimore and Washington. Used exclusively by N York Broker's offices.

13. Way. News room and other offices exchange about forty messages per day, not included in statement.

" 14. Easton and 10 way offices exchange about 50 messages per day on this wire.

" 16 Through wire. Cable room, exchanges about messages per day on this wire.

" 17. Through wire. (Richmond, Baltimore, and Philadelphia, exchange about 50 per day, and "C.N.B." office about 12.

" 18. New Orleans direct circuit. This wire is used by Washington for southern business to a considerable extent, dependent on the state of wires south of Washington.

" 22. Way wire. Easton and Morris and Essex R.R. Offices exchange about 100 messages per day on this wire.

" 23. Way wire. Fulton and Washington market offices exchange business with Philadelphia on this wire to the extent of about 25 messages per day in addition to business included in statement.

" 26. Through circuit to Washington used for Congregational reports.

" 27. Through Printing circuit to Washington.

No. 28 So. Philadelphia Way. Exchanges business with 5 way offices. averaging 50 messages per day. not in statement.

" 33. Philadelphia and two way offices exchange business on this wire, averaging 15 per day.

" 34. Way wire. Scranton and way offices exchange about 20 per day.

" 2. Montreal. Way wire. Five offices exchange business on this wire and "C.N.B." offices send about 3 messages per day. total. 33.

Long Island way wire. 10 way offices exchange 20 to 25 mess per day.

Harlem way wire. 15 offices exchange between themselves about 100 messages daily.

A. S. Brown.
Manager

To J. Hinchman Esq
Supt N. Y.

New York. January 15. 1868.

Statement showing the number of messages sent and received each day on each wire from and to New York main Office and down town Broker Offices Jan 4th to Jan. 10. 1868. Also number of hours occupied on Press reports, and total number of messages and words sent and received from and to above Offices during same time.

No of wire	Jan 4. Mess.	Press	Jan 5. Mess.	Press	Jan 6. Mess.	Press	Jan 7. Mess.	Press	Jan. 8. Mess.	Press	Jan. 9. Mess.	Press	Jan. 10. Mess.	Press	Total Messages	Total Number of Words.
1. West	267	00	8	00.	486	00	412	00	358	00	283	^{15}	282	00.	2088.	64.728.
3.	230	07	19.	00.	176	00	2^{40}	^{15}	218	00	169	–	215	–	1267.	39.654.
4.	–	–	–	–	40	–	107	–	49	–	167	–	–	–	363.	11.253.
5.	238	–	–	–	219	–	196	–	228	–	194	^{30}	233	–	1308.	41.108.
6.	96	3^{40}	22.	3^{36}	97	7^{16}	114	7^{25}	100	7^{32}	120	6^{30}	111.	6^{33}	660.	68.107.
7.	169	^{35}	–	–	238	3^{00}	162	–	173	^{15}	162	^{05}	144	^{05}	1048	36.972.
8.	26	–	4	–	51	–	65	–	57	–	40	–	74	–	317	9.827.
10	54	–	4	–	56.	–	43	–	53	–	35	–	44	–	289.	8.969.
11	164	–	20	–	148	1^{15}	173.	1^{25}	131.	^{30}	144.	–	142	–	922.	28.582.
13	–	–	2	–	5	–	2	^{30}	5	–	3.	–	8	–	25.	2.175.
3 Erie.	207	2^{45}	4.	1^{25}	240	57	175	7^{15}	153.	7^{05}	115.	5^{53}	252	8^{05}	1146.	73.750.
4.	161.	–	5.	–	132.	–	131	–	148	–	126	–	132	–	855.	26.505.
5.	21	–	–	–	44.	–	21.	–	21.	–	16	–	11.	–	134.	4.154.
12 National	102	–	–	–	40.	–	–	–	137	1-	60	–	183	–	522.	18.303.
20.	167.	–	9	–	38	–	138	–	122	1^{55}	146	^{30}	136	^{15}	756.	27.359.
29. South	131.	^{15}	–	–	298	–	161.	–	119.	–	143.	–	131.	^{25}	983.	31.227.
30.	208	1-	1.	1^{55}	110	1^{42}	99	1^{30}	188	4^{30}	159	2^{45}	174	1^{36}	939.	44.803.
1. East	129.	1^{10}	61	1^{35}	349.	1^{45}	349	^{10}	346	5^{10}	365	4^{00}	349.	3^{45}	1948.	79.638.
4.	38	3-	77	2^{30}	34.	8^{25}	35	5^{42}	26.	11^{36}	57.	6^{00}	27.	6^{37}	294.	53.114.
5.	66.	–	1.	–	87.	–	101.	–	117.	–	96	–	91.	–	559.	17.329.
6.	56.	–	–	–	32	–	47	–	54	–	39	–	40	–	268.	8.308.
7.	83.	1^{51}	6.	2^{30}	103.	6^{25}	81.	4^{35}	78.	11^{36}	78	6^{00}	79.	6^{37}	508.	55.948.
8.	222	–	19	–	235	–	170	–	187	–	217	–	185	–	1235.	38.285.
9.	151.	–		2^{30}	172.	^{30}	175	–	118	–	163	–	148	–	927.	31.733.

No of wire	Jan 4.		Jan 5.		Jan 6.		Jan 7.		Jan 8.		Jan 9.		Jan 10.		Total No Messages	Total No Words.
10. East	306				328		284	2^{15}	274.	2^{30}	268	3^{00}	262		1719.	61.979.
18.	98	^{10}			119	2^{53}	114.		124.		113.		101		669.	23.823.
25.	190				226.		182		195		150		187		1130.	35.030
27.	51.				58	^{05}	48	1^{15}	30.	5^{44}	23		25		227.	14.937.
28.	107.			1^{50}	60		69	2^{45}	35.		66		119		456	18.900.
29.	29.	^{43}			58	4^{15}	53	2^{27}	65.	3^{56}	68	5^{53}	68	7^{15}	341.	27.563.
31.	71				71		90.		97.		87		85.	1^{20}	501.	17.029.
32.	39				63		95.	2^{25}	89.	^{50}	84.		70.		440.	17.283.
1. South	202.	^{30}		2^{30}	491.	2^{16}	271.	2^{45}	224.	3^{05}	418.	2^{15}	260.	3^{04}	1866.	76.342
2.	60.		4		53		82.		73.		76		69.		417.	12.927.
3.	80.				94		77		69.		88		55.		463	14.353.
4.	102.	^{10}		1^{30}	163		113.	2^{35}	155	2^{30}	144	3^{30}	162	3^{10}	839.	40.534.
5.	157.			1^{40}	188	2^{05}	214	1^{30}	201		288.		215.		1258	44.573.
6.	62.				78	^{35}	99.		129	3^{40}	113.	2^{40}	94.	^{35}	575	26.232.
7.	408				280	^{20}	202		228		262.	^{35}	259	^{35}	1639.	52.509
8.	418		7	^{15}	243.		291	^{10}	252.		311.	^{10}	232		1754	55.174
9.	33		1.		34.		20.		38		25.		36		187.	5.797
11.	133.				229.		179		158.		182.		173.	1	1051.	33.682.
13.	46		4.		41.		34		51		32.		54.		252	7.812.
14.	72		2		118		93		75		90.		90		540.	16.740.
16.	113	1^{30}	55		132	3^{05}	65	4^{45}	33.	5^{05}	43	1^{45}	72.	^{43}	513.	34.910.
17.	60.	^{30}	27	^{30}	131.	^{33}	133	^{35}	127.	1.	138.	^{50}	120.	^{40}	736	27.860
18.	184	^{15}	14.	^{32}	203	3^{00}	183.		287.		291.		311.		1473.	49.788.
22.	59		1.		101.		62.		93		57		80		453.	14.043.
23.	4				10		5.		8		4.		7.		38.	1.178.
26.					2.	2^{15}	4.	2^{00}	8	5^{45}	4.	2^{00}	8.	2^{55}	26.	23.806.
27.	236	2^{30}			25.	^{05}	216.	^{40}	125	1^{55}		6^{35}	149.	2^{40}	751.	39.254.
28.	140		1		155		152.		156.		199.		163.		966.	29.946.
31.															Spare wire	
32															same.	
33.					3.		8.		2.		10.		13		39.	1209.
34.	9.	1^{45}		1^{30}	26	5^{15}	16.	5^{30}	15.	5^{30}	23.	5.	5.	4^{30}	94	35376.
2. Montreal	116			1^{05}	111.	2^{50}	144.	2^{05}	156.	2^{40}	153.	2^{40}	187	2^{15}	867	40.377.
L Island	56				66.		38		65.		31.	-	49.		305.	9455.
Harlem.	36				34		35		34.		32.		28.		199.	6.169.
																1.735.631.

Coke Battery.

Battery No. 1. Special Batteries of 30 cups each, used in
" 2. through circuits between Washington and
" 3. Boston, or for increasing any of the general
" 4. batteries. Total No of cups 120.

No. 5. Zinc to Line. 75 cups.
Works No 1. West. Buffalo & Chicago.
" 3. " " & Detroit.
" 6. " " & Way.
" 2. Erie " "
" 3. " " " "
" 4. " " " "
" 12. West. Pittsburgh & Cincinnati. O.
" 20 " " Louisville Ky
" 32 South " Chicago.
" 33. " " St Louis.

No. 6. Zinc to Line. 75. Cups.
Works No 4 West. Albany Printing
" 6. " "
" 7. " " and Oswego.
" 8. " " and Way.
" 9. " " " "
" 10. " " " "
" 11. " " " "
" 12. " " " "
" 5. Erie. Port Jervis & Railroad
" 5. N.S. Scranton & Binghampton.
" 34. South. Pittsburgh.

No 7. Coke to Line. 45. Cups.
Works. 2. East. New Haven.
6 " " and R.R.
8 " Springfield & way.
25 " New Haven & Way

Forward. — 315 cups.

Forward. 315.

Battery No 8. Coke to Line. 60 cups.
Works No. 1. East. Boston.
" 3. " "
" 4. " "
" 5. " Providence & N. Bedford.
" 7. " Boston & Way
" 10. " " " Cable
" 18 " "
" 27 " "
" 28. " "

Battery No 9. Coke to Line. 60 cups.
Works. No. 9 East Boston & Way
29. " " " "
30 " " " "
31 " " " "
32. " " " "
1 Montreal
1. Long Island R.R.
17 South. Richmond. Va.

Battery No 10. Zinc to Line. 60 cups
Works No 1. South to Washington.
" 4 " " "
" 5. " " "
" 6. " " "
" 11. " " "
" 16. " " "
" 18. " " "
" 26. " " "
" 27. " " "

Battery. No 11. Zinc to Line. 60 cups.
Works. No. 2. South. Phila & way.
9. " " " "
13. " Sandy Hook.
14. " Reading & way
22. " Easton & Way
28. " Phila & way
2. Montreal.
1. Harlem & Albany R.R.

Forward. — 555 cups.

Brot Forward.		555 cups.
Battery No. 12. Works.	Zinc to Line	45. "
	No. 3. South. Philadelphia.	
	7. " "	
	8. " "	
	10. " "	
	23. " "	
	29. " "	
	30. " "	
	31. " "	
	13. West. Albany.	
	6. United States. Scranton.	
Total Main Battery.		600. cups.
Main Lines.		69.

About six weeks ago a Grove Battery of 60 cups was put up to work all the southern wires as an experiment. Therefore Batteries Nos 10 + 11 are not in use at the present time.

Wires Nos 1. 4. 5. 6. 11. 12. 14. 16. 18. 20. 22. 26. 27. 33. 32. + 34. South are worked from 60 cups of Grove Battery. Wires Nos 2. 3. 7. 8. 9. 10. 23 28. 29. 30 + 31. South and No 1. Harlem. + 2. Montreal are worked from 45 cups of the same (Grove) Battery.

	As above.	600.
Battery No 13.	Zinc to Line.	30 cups.
	Works. No. 3. City. Harlem.	
	" " 4. " 42d Street.	
	" " 6. " "	
	" " 12. Brooklyn.	
	" " 13. Harlem.	
		630. cups.

Brot Forward.		630. cups.
Battery. No 14.	Zinc to Line.	15. "
	Works. No. 1. American short wire.	
	" 2. " " "	
No. 15.	Zinc to Line.	15. "
	Works. No. 3. Amer. short City wire.	
	" 4. " " " "	
No. 16.	Zinc to Line.	30. "
	Works No 1. City Brooklyn + Fort Hamilton.	
No. 17.	Zinc to Line.	30. "
	Works No. 2. City. 5th ave Hotel.	
	" " 5. " 42d Street.	
	" " 7. " 5th ave Hotel.	
	" " 8. " Canal St. + St Nicholas Hotel.	
	" " 9. " 40th Street.	
	" " 10. " Madison Square.	
No. 18.	Zinc to Line.	15.
	Works 11. City to Astor House + Stewarts.	
No. 19.	Zinc to Line. French Battery.	15.
	Works Pacific Mail Steamship Company's City wire between their two Offices.	
Total Main Battery.		750 cups.

106 Local batteries of 2 cups each worked in 4 different combinations. ______ 212. cups.

Total cups. ______ 962.

Respectfully

W. F. Marks.

J. Hinchman Esq.

Supt. "

Metropolitan District New York
December 27. 1867.

Mr A. S. Brown
Manager &c.

You will please obtain for me the following information for Mr Varley Electrician, the request having been made through the Presidents Office and referred to me by the Genl. Supt.

1. The state of the circuit out of New York on Sunday December 22nd during evening and night.
2. Could more than one half or one third of the circuit between New York and Boston be worked at same time.
3. Same information as second question as relates to Washington wires.
4. Was it necessary to increase the Battery power on the wire worked to give it an advantage over the others.
5. How many repeaters in each of the long circuits and where.
6. How was message carrying capacity affected by the rain.

Very Respectfully.
J. C. Hinchman.
Supt.

New York. December 28th 1867.

J. C. Hinchman Esq
Supt. &c.

I enclose statement from Mr Marks in answer to enquiries as to state of wires on the night of December 22nd.

The information called for in your second series of questions as to the number of messages sent and received on each wire for one week, the number of words &c. will be furnished at the expiration of the week. An accurate record is now being kept on each wire for the purpose.

Respectfully.
A. S. Brown.

New York December 27. 1867.

A. S. Brown Esq.
Manager.

I herewith enclose a statement of the condition of wires on Sunday evening December 22nd which answers all questions asked by Mr Hinchman excepting his fourth and sixth.

In reply to his fourth I will say that we did not find it necessary to increase the battery. About 8. P.M. our southern battery (Grove) gave out entirely and I substituted 90 cups of coke in its place by doubling the 45 cup batteries east and south making one general battery of 90 cups.

Sixth. The message carrying capacity of our wires south was all that they required and fully up to the standard of the same number (4) of wires in any ordinary weather. The Repeaters at Philadelphia were our salvation, for, without them, we could not have had the working capacity of one good wire to Washington.

On the east the capacity of the three wires which we could work with Boston, without Repeaters, was not equal to one fair wire for half the time. We could just hear each other and that was about all. The two wires on which Springfield and New Haven had a Repeater were of greater service to us and of greater capacity than all our eastern wires together although we were frequently detained for want of attention to the Repeater at New Haven.

The greatest difficulty we have to contend with at night on the eastern wires is the want of Repeating facilities at some central office between New York and Boston. New Haven, Hartford and Springfield are all supplied with one or two setts of Repeaters, but it is very difficult to secure the use of them at night. We never get any at Hartford, and but one at Springfield and New Haven, and none are supplied with force to attend them. If we had proper repeating facilities at some one office between New York and Springfield, say at Hartford where all wires both via Springfield and Providence centre, I think our business would be done in a much more satisfactory manner. As at present arranged I fear we will some night be unable to do the amount of business handed to us for transmission.

Respectfully. D. F. Marks.
Night Manager.

Eastern Wires.
Sunday evening. Dec. 22. 1867.

Nos. 1. 2. 6. 18 + 25. very bad escape between New York + New Haven. All unfit for use on through circuits.
Nos 4. 7. 29. 30. 31. 32. entirely gone between New York + New Haven.
No. 9. Open between Waterbury and Hartford, and very strong wet cross with number 3.
Nos. 5. 8. 10. 27 + 28 work fairly to New Haven with battery both at New York and New Haven.
No 3. Bad escape and strong wet cross with No 9. but with battery both at New York and Springfield worked it fairly.
The only wires we could work to Boston without Repeaters were.
8 to New Haven with 32 to Boston.
27. New Haven with 18 to Boston.
10 Straight to Boston.
all of which worked extremely hard and very unreliably.
28 straight to Boston with Repeater at New Haven worked well, but was occasionally delayed by want of attention to Repeater. No 3 to Springfield with 4 to Boston, with Repeater at Springfield, worked fairly.

Southern Wires.
Sunday evening. December 22. 67.

Nos. 1. 5. 7. 8. 16. 17. 18. 23. 26. 27. 28. 31. + 32 all had considerable escape, but worked well to Philadelphia.
Nos 2. 6. 11. 30. 33 + 34 all work very hard to Philadelphia.
No 4 grounded between New York and Philadelphia.
Nos 3. 9. 13 + 29 were used to patch up the Sandy Hook and Camden and Amboy Railroad wire.
Nos 4. 5. 6. + 7. not working south of Philadelphia.
Nos. 1. 11. 16. 17. 18. 26 + 27. work fairly between Philadelphia + Washington but not good enough to work through without Repeaters.
Worked 4 through wires to Washington all with Repeaters at Philadelphia.

Western Wires.
Sunday evening. Dec. 22 1867.

No 1 Bad escape but works fairly to Chicago, with Repeaters at Albany, Buffalo, and Detroit.

No 4. to Albany. 3 to Buffalo and Cleveland works fairly. Repeaters at Albany and Buffalo.

No 6. to Albany and Buffalo with Repeater at Albany works fairly

No 31. to Philadelphia and Pittsburgh works well. Repeater at Philadelphia.

No 32. to Philadelphia Pittsburgh + Cleveland. works well. Repeaters at Philadelphia + Pittsburgh

All other wires to Albany have bad escape but all could be worked if necessary.
Nos 2. 3. 4 + 5 Erie gave out entirely. Could get no one to test.

No 12. west. heavily grounded.

No 20. west. Open between New York and Harrisburgh.

M. F. Marks.