Experiments made

by

A. Graham Bell

(Vol. I.)

Illustrations to Experiments made October 1875.

Fig. I.

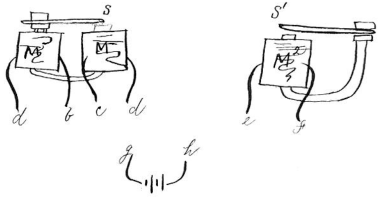


Fig. 2.

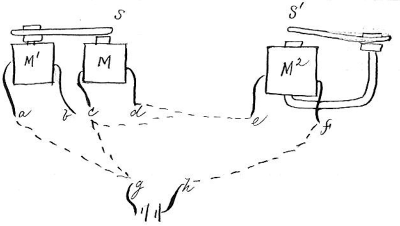


Fig. 3.

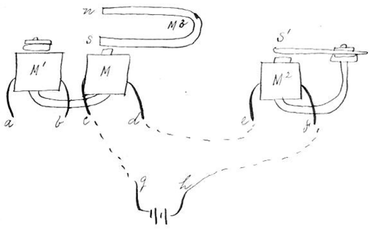


Fig. 4.

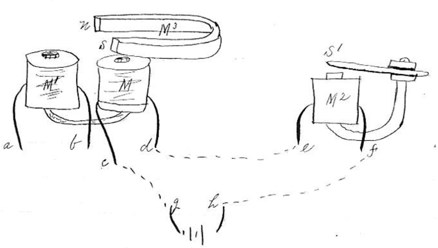
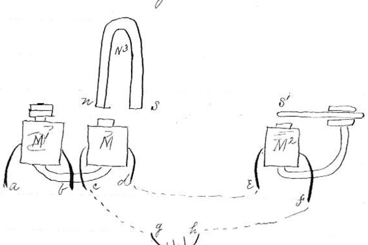


Fig. 5.



Experiments made by A. Graham Bell during the Autumn of 1875 — Not earlier than June nor later than October 1875.

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1. Circuit ($g - cMd - eM^2f - h$) Battery power two Grove cells.

Upon plucking S the other armature S' was thrown into vibration. Upon placing the ear against M^2 a loud musical note was perceived which was inaudible when the finger was placed upon the armature S'.

2. The armature S' was removed and the ear placed as before against M^2 Upon plucking S — no sound was audible from M^2.

3. Circuit ($cMd - eM^2f - c$). No battery employed. Upon plucking S — S' could be felt to tremble. Upon placing the ear against M^2 a faint musical tone could be perceived each time S was plucked.

4. Same arrangement as last but a & b crossed so as to make a closed circuit $aM'ba$ Sound audible at M^2 as before when S was plucked.

5. No sound audible from M^2 when S' was touched with the finger or when S' was removed.

6. Circuit $aM'b - eM^2f\ a$ No battery. Faint sound from M^2 weaker than that mentioned in experiment 3.

7. Same arrangement but c d crossed making closed circuit $cMdc$. No sound audible

from M^2 when S was plucked.

8. { Circuit $c\,M\,d - e\,M^2 f - c$ No battery.
 and
{ Circuit $g - d\,M'\,b - h$ two cells of [illegible] elements

Sound heard from M^2 similar to that mentioned in experiment 6.

9. Circuit $g - c\,M\,d - e\,M^2 f - h$ (as in experiment)

Loud sound from M^2. But upon changing the direction of the current by making circuit $g - d\,M\,c - f\,M^2 e - h$ – the sound at M^2 became very much weaker.

10. Wires a & c united to g; b & d united to e; & f to h. Sound at M^2 slightly fainter than in exp. 1 – but louder than in any of the other cases. (see Figs. 1 & 2.)

11. Wires a & d united to g; ~~[illegible]~~ b & c united to e; and f to h. Sound similar to last – may have been slightly fainter (See Fig. 1.)

12. Circuit $g - d\,M'\,b - c\,M\,d - e\,M^2 f - h$. The two coils $M\,M'$, being connected as in a Morse Sounder. Sound decided – similar to that mentioned in experiment 10.

13. Circuit $g - a\,M'\,b - d\,M\,c - e\,M^2 f - h$. The coils $M\,M'$ opposing each other's action.

Sound exceedingly faint – only half as loud as last.

14. Circuit $a\,M'\,b - c\,M\,d - e\,M^2 f - a$ No battery.

Sound faint – similar to that in exp. ~~6~~ 3.

15. Circuit $a\,M'\,b - c\,M\,d - e\,M^2 f - a$. No battery.

Sound very faint – similar to that in exp. 6.

16. Effect of battery power upon the sound.
Sound audible at S^1 when no battery was used call. equal to 10 in intensity. Upon introducing battery between f & c - the intensity of the sound was increased.
Circuit g - c M d - e M^2 f - h fig. 1

Results —

0 cell	= intensity about	10
1 cell	= " "	20
2 cells	= " "	22
3 cells	= " "	19
4 cells	= " "	18
5 cells	= " "	17

17. As the battery power was increased the pitch of S became lower. From the pitch when no battery was employed to that when 5 cells were used - the difference was a whole tone.

18. Effect of Intensity Battery & Quantity Battery. Circuit as in last experiment.

2 cells	arranged for intensity	= 22
2 cells	" " quantity	= 22
5 cells	" " intensity	= 17
5 cells	" " quantity	= 17

Estimate of the loudness of the resulting sound at M^2. The loudness of the sound when no battery was employed being called 10.

19. The spring S (Fig. 1) was removed and a permanent magnet M^3 vibrated over M.

Circuit c M d – e M^2 f – c. No sound audible from M^2 whichever pole of the magnet was applied to M.
20. Battery introduced between c & W.
Circuit g – c M d – e M^2 f – h (See Fig. 3) M became a North pole – permanent magnet – M^3 held horizontally – vibrations vertical.
Upon vibrating the South pole of the magnet over M a loud sound was perceived at M^2 but the vibrations of the north pole over M produced no audible effect at M^2.
21. Battery reversed so as to make M a south pole (Fig. 3). Then the vibration of the north pole of the magnet over M occasioned a sound at M^2 – but the south pole of the magnet produced no audible effect at M^2.
22. Magnet M^3 held horizontally as in Fig. 4, so that the vibrations _across_ the pole of M instead of _to_ and _from_ it as in Fig. 3. A faint sound was audible at M^2 when the pole of the permanent magnet presented to M was of opposite polarity to M
23. Permanent magnet held vertically over electro-magnet as in Fig. 5. Results – No sound audible from M^2 however the poles were arranged.
24. Resumés of results obtained by the vibration of a permanent magnet in front of the pole of an electro-magnet which latter

was in circuit with a battery of two Grove elements.

N. S. represent the poles of the permanent magnet; N' S' the poles of the electro-magnet M. M'; and R. the receiving electro-magnet M^2 (Figs. 3, 4, 5.)

Magnet held horizontally vibrations vertical
(See Fig. 3)

(a) $\begin{smallmatrix} & N \\ S' & S \\ & N' \end{smallmatrix}$ Sound audible at R. (c) $\begin{smallmatrix} & S \\ & N \\ S' & N' \end{smallmatrix}$ Inaudible at R.

(c) $\begin{smallmatrix} & N \\ & S \\ N' & S' \end{smallmatrix}$ Inaudible at R. (d) $\begin{smallmatrix} & S \\ & N \\ N' & S' \end{smallmatrix}$ Audible at R.

Magnet held horizontally vibrations lateral
(See Fig. 4)

(e) $\begin{smallmatrix} NS \\ N'S' \end{smallmatrix}$ Faintly audible at R. (g) $\begin{smallmatrix} SN \\ N'S' \end{smallmatrix}$ Inaudible at R.

(f) $\begin{smallmatrix} NS \\ S'N' \end{smallmatrix}$ Inaudible at R (h) $\begin{smallmatrix} SN \\ S'N' \end{smallmatrix}$ Faintly audible at R.

(i) $\begin{smallmatrix} NS \\ S'N' \end{smallmatrix}$ Inaudible at R. (j) $\begin{smallmatrix} NS \\ N'S' \end{smallmatrix}$ Inaudible at R.

Magnet held vertically vibrations lateral
(See Fig. 5)

(K) $\begin{smallmatrix} NS \\ N'S' \end{smallmatrix}$ Inaudible (m) $\begin{smallmatrix} SN \\ N'S' \end{smallmatrix}$ Inaudible

(l) $\begin{smallmatrix} NS \\ S'N' \end{smallmatrix}$ Inaudible (n) $\begin{smallmatrix} SN \\ S'N' \end{smallmatrix}$ Inaudible

(o) $\begin{smallmatrix} NS \\ S'N' \end{smallmatrix}$ Inaudible (p) $\begin{smallmatrix} NS \\ N'S' \end{smallmatrix}$ Inaudible

25. All the above exp. were repeated but in

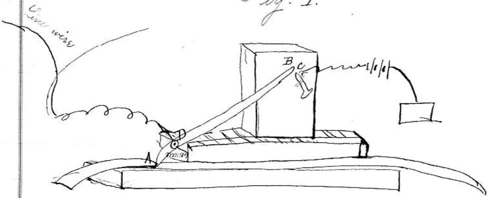
no case was any sound audible from M^2 when the finger was laid upon S^1 or when S^1 was removed (Figs. 1. 2. 3. 4. 5.)

Copied Feb 21st, 1876.

M. G. H.

February 18th. 1876.

Fig. I.



Yesterday Mr. Watson suggested a device for a new transmitting style for the Autograph Telegraph. We have tried it this afternoon and it promises complete success. The message is to be written upon ordinary paper with ordinary ink, or to be embossed like raised letters for the blind. The end A of the lever A. D. B. is raised when the ink surface passes underneath sufficiently to bring the point B in contact with C.

In the style tried this afternoon the arm D B. was 3 1/2 times as long as A D. I propose to make another lever in which D B will be 10 times as long as A D.

Thoughts.

pass undulatory current through empty helix. H place iron cylinder (C) in one end and listen at the other, d. Also try, whether Manometric Capsule arrangement as in Fig. 3 will show any curves.

Fig. 2

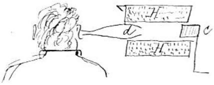
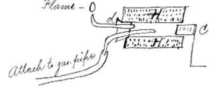


Fig. 3



Make Transmitting Instrument after the model of the human ear. Make armature (d) the shape of the 'ossicles. Follow out the analogy of nature.

Fig. 4

or

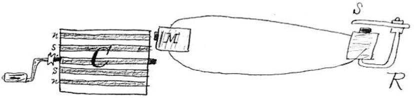
Fig. 5

(Helix & core, iron cylinder vibrated in helix.)

Copied Feb. 21st, 1876.
M. G. H.

February 19th, 1876.

Fig. I.



1. Cylinder C with bar-magnets revolved in front of electro-magnet M. Musical note heard to proceed from R. which changed its pitch with revolution of C. Armature S of R could be felt to tremble.

2. Cylinder C set spinning & allowed to come gradually to rest. Decending musical note heard from R which became momentarily loud when the unison of S was reached.

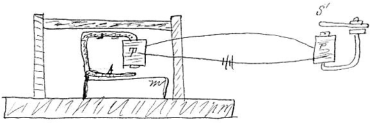
3. Same experiment repeated with 1, 2 + 3 cells of battery in the circuit — without increasing the effect. If anything the sounds from R were somewhat weaker than before.

4. The experiments 1 & 2 were first made unsuccessfully in November 1874 — The cause of the failure lay in using the Receiving Magnet R without any vibratory armature S. When an intermittent current is used sounds proceed from the core of the receiving magnet — but as yet I have been unable to detect any audible effects from the core

when an undulating current is used. Indeed in the above experiment the sounds became inaudible when the finger was merely laid upon the armature S.

5.

(Fig. 2.)



5. Armature vibrated in front of electro-magnet produces undulating current. Experiment to try vice versa.
Electro-magnet T fastened to a support as in Fig. 2 placed upon the sounding board S. of a parlor organ. The armature A. placed upon a membrane M, which had been damped. When a note of the organ was sounded the magnet T was forced to vibrate to and from A. The result unsatisfactory. It seemed as if the unison of the note played on the organ came from the Receiver R - but how much was really fancy cannot say. This experiment must be repeated with organ in one room and R in another.
6. When S' was pressed against the pole p of its magnet it remained attracted.

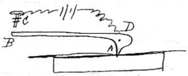
When p and S' were forced apart a sudden click was heard. This click seemed to have quite a metallic ring about it - and appeared to be the unison of whatever note was played on the organ.

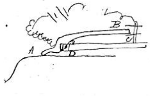
However experiment indecisive on account of the great noise made by the organ.

Copied Feb. 22nd, 1876.
Mabel G. Hubbard.

Monday February 21st, 1876.

Experimented with a new style for the Autograph (see p. 8.) Arm DB about six times as long as DA. Supported by a spring attached to DB instead of to DA. Cannot get satisfactory results with ordinary ink - but with embossed writing apparatus works satisfactorily. The style and support must be made more carefully before reliable results can be obtained. The following are a few forms to have made.

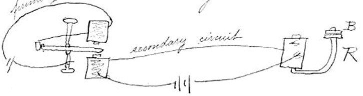




Noted Feb. 22, 1876,
by A. G. B.

Tuesday, Feb. 22, 1876.

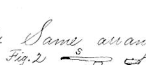
1. Fig. 1.



No sound audible at R.

2. Same arrangement as (1) but a steel spring (S)

Fig. 2



held closely against R. A sound audible similar to that heard from the core of an electro-magnet when an intermittent current of voltaic electricity is passed through the coils of the magnet. When the steel spring was held close against but not absolutely touching the core of the electro-magnet the curious crackling noise became a pure musical note.

Fig. 3.

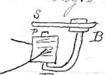
3. Same arrangement as (1) but an ordinary Morse sounder armature was laid upon R. Results similar to those stated in (2) save that the sounds were not so loud.

Fig. 4.

4. Same arrangement as in (3) save that the armature A was clamped firmly to B and touched R. No sound audible.

Fig. 5

5.



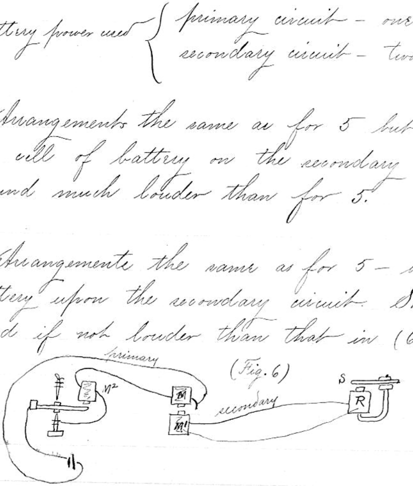
Arrangement as in (1) save that a steel spring S, was clamped to the pole B (Fig. 5). Upon pressing S into contact with P – crackling noise was heard. Allowing S almost to touch P quite a loud musical note was audible (the unison of the Transmitting Instrument) accompanied by other very high and shrill notes. Upon gradually shortening the vibrating length SB it was found that the loud fundamental ~~note~~ tone remained the same but the upper tones became more and more shrill until one of the octaves of the fundamental was reached – when the spring SB vibrated as a whole producing the unison of the Transmitting Instrument loudly enough to be heard (with attention) all over the room. The vibration was visible.

Battery power used { primary circuit – one cell / secondary circuit – two cells.

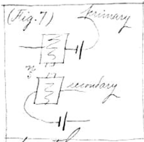
6. Arrangements the same as for 5 but only one cell of battery on the secondary circuit. Sound much louder than for 5.

7. Arrangements the same as for 5 – but no battery upon the secondary circuit. Sound as loud if not louder than that in (6).

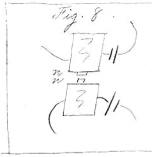
(Fig. 6)



8. One cell upon primary circuit — no battery upon secondary circuit. S vibrated visibly producing a musical note as loud as in Exp. 5.



9. One cell upon each circuit. Arrangement otherwise as in (Fig. 6). Poles of electro-magnets opposed to one another. Sound at S about the same loudness as that mentioned in Exp. 5.



10. Arrangement as in Exp. 9 save that like poles are presented to one another. Sound at S. (Fig. 6) same as in Exp. 9.

11. Arrangement similar to that in Fig. 6. save that two cells of battery were placed upon the secondary circuit. The poles of M M' were opposed as in Fig. 7. Sound about the same as in Exp. 10 — perhaps weaker.

12. Three cells upon the secondary circuit (Fig. 6) and one cell on the primary. Poles of M M' opposed. Sound much weaker than in Exp. 11 — about the same intensity as that heard in Exp. 5 — perhaps weaker.

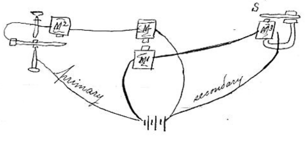
13. Three cells upon the primary circuit (Fig. 6) and one upon the secondary. Poles M M'

opposed. Loud sound. Louder than in any of the preceding experiments.

14. Three cells upon the primary circuit - no battery upon the secondary circuit. Sounds at R or S (Fig. 6) louder than in Exp. 13.

15. Electro-magnet M' had at least six times the resistance of M. M = ½ ohm. M' = 3 ohms. (approx.) M' was placed in primary circuit, and M in the secondary circuit. Arrangement otherwise as in Exp. 14. Sound at S (Fig. 6) as loud as in (14) if not louder.

(Fig. 9.)



16. Three cells divided between the two circuits as in (Fig. 9). Sound from S about same loudness as that mentioned in Exp. 5.

17. Arrangement as in (Fig. 10). Three cells upon primary circuit. No battery upon secondary circuit. Resistance of M' = ½ ohm; M = 150 or 200 ohms; M² = ½ ohm; M³ = ½ ohm. Sound audible when the ear was placed near S.

18. Arrangement same as Exp. 17. save that M was placed upon the secondary circuit and M' upon the primary (Fig. 11). Sound at Q about the same as in Exp. 17. Could not determine which was the louder.

19. Arrangement as in (Fig. 12). Sound about the same as in Exp. 17 and 18. Like poles approximated (M M').

Fig. 10.

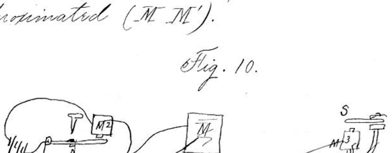


Fig. 11.

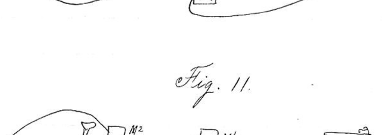
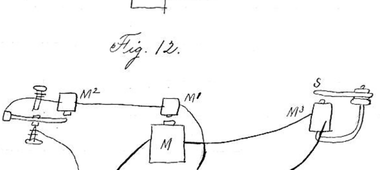


Fig. 12.



20. Arrangement as in Fig. 12. Poles of M M' opposed. Sound about same as in Exp. 19.

21. Experiment to test the influence of the battery in affecting the pitch of S (Fig 6).

The spring S (Fig. 13) was plucked by the finger, and the pitch observed was called <u>do</u> (Fig. 15). The circuit was then completed as in (Fig. 13) and the spring plucked again — the difference of pitch being noted. Battery power was then introduced into the circuit and the pitch noted.

Results. (See Fig. 15).

(a) no circuit ——— sound = do.

(b) circuit but no battery — sound = do ($\frac{1}{4}$ b?)

(c) one cell of battery — sound = do b (half way between d & t.)

(d) two cells — — sound = te.

(e) three cells — — sound = te ($\frac{1}{2}$ b?)

22. Double circuit as in Fig. 14.

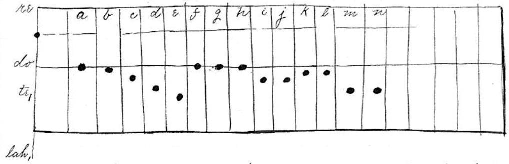
Results. (see Fig. 15)

	Primary circ.	Secondary circ.	Poles	Pitch of sound
(f)	one cell	no battery	—	d
(g)	two cells	no battery	—	d
(h)	three cells	no battery	—	d
(i)	one cell	one cell	nn	d (b)
(j)	one cell	one cell	ns	d (b)

Fig. 13.

(Fig. 14)

(Fig. 15)

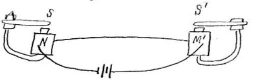


	primary circuit		secondary circuit		poles		pitch
(k)	two cells	"	one cell	"	n n	"	d(½b)
(l)	two cells	"	one cell	"	n s	"	d(½b)
(m)	one cell	"	two cells	"	n n	"	t
(n)	one cell	"	two cells	"	n s	"	t

(Thoughts)

23. Try whether armatures on the same circuit are similarly affected in pitch by the passage of a current.

(Fig. 16)



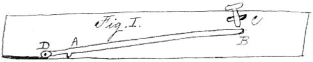
For instance if S and S' (Fig. 16) are in unison when no battery is employed — will they still remain in unison when a battery is put in circuit with them?

24. Why should not vibratory armatures be attached to the bent axles of wheels so as to form regulators of the speed of revolution or to give motion to the wheels.

Noted Feb. 22d. 1876
by
A. G. B.

Wednesday, Feb. 23d 1876.

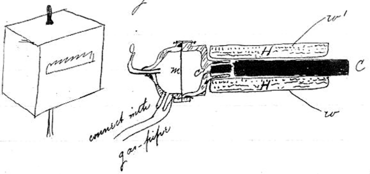
1. The following improved form of Autograph Style has been made today but has not yet been tried.



Compare Fig. I. page 12 [8 of this MS.] and Figs. 1, 2 & 3 page 17 [12 of this MS.].

2. Following out the idea shown in Fig. 3 page 13 [9 of this MS.] I have had a Manometric Capsule constructed and arranged as in Fig. 2 — but have been unable to try it yet.

Fig. 2



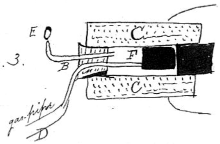
It seems to me that this instrument may prove as useful in the examination of undulatory currents of electricity as a galvanometer has proved for ordinary continuous currents.

An undulatory current (however powerful) scarcely affects a galvanometer needle — because the alternate positive and negative impulses oppose each other's action. They succeed each other so rapidly that the needle has not time to swing to one side before the next impulse comes to stop the motion. The Capsule seems to promise to be a valuable galvanometer for the Undulatory current. Still simpler forms may be made. I like that shown page 13 [9 of this MS.] (Fig. 3) if the cylindrical iron core can be fitted tightly but this would impede its motion.

Thoughts.

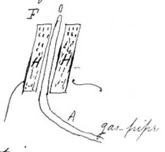
Improved forms of "Flame-Galvanometers".

Fig. 3.



Compare Fig. 3 with that on page 13 [9 of this MS.]. Both ends of the coil (C) are plugged up. One end A with iron. The other end B with a piece of wood containing two pipes communicating respectively with D the gas-pipe and E the burner. The loose-fitting iron-cylinder F is free to vibrate against A. Would not an iron gas-pipe A (Fig. 4) placed within a helix (H) through which a discontinuous (or undulatory?) current is passing be thrown into molecular vibration and never cause vibrations in the gas and in the flame F.

Fig. 4



De la Rive states that flames change their shapes when brought near the poles of an electro-magnet. If this is so a vibratory current of electricity should impart a vibratory motion to the flame placed near the poles of an electro-magnet on circuit.

Fig. 5 shows one form of Flame-Galvanometer for the undulatory current. The flame F is merely placed between the poles S, N of an electro-magnet on circuit.

Fig. 5

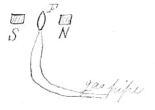
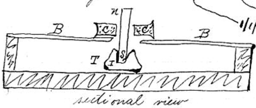
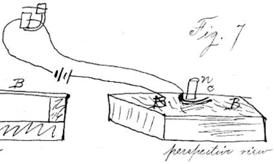


Fig. 6



sectional view

Fig. 7



perspective view

Figs. 6 and 7 show new experimental transmitter consisting of a sounding-board upon which is the coil (C). A permanent magnet N S is supported in a block of india-rubber (I). It is presumed that a sound made near the sounding board will set it in vibration—that the coil I will occasion electrical undulations in the coil.

Noted February 23^{d} 1876
by
A. Graham Bell.

Thursday Feb. 24th 1876.

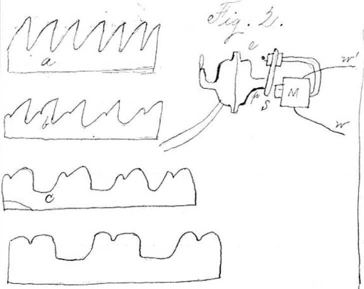
1. The capsule arranged as in Fig. 2. page 27 [21 of this MS.] was tried this morning. An intermittent current from one of the Transmitters was passed through the helix (H) by means of the wires w, w'. The little cylinder C' vibrated against the end of the large cylinder C reproducing the note due to the Transmitting Instrument. The reflection of the flame was watched in a mirror swung backwards and forwards as in Fig. I.

Fig. I.

M'M' being the initial position of the mirror it was swung so as to assume successively the positions M M; M² M²; M M; M'M'; M M; M² M² &c. The imaginary axis a was vertical. No trace of vibration was perceptible in the reflected flame.

2. The capsule was disconnected from the helix H. (Fig. 2. p. 27) [21 of this MS.] and held in front of the spring armature S (Fig. 2. p. 31) [25 of this MS.] of one of the new Receivers. When the intermittent current was passed through w m w' the spring S vibrated and immediately the flame reflection was resolved into waves of light of the form and appearance of those shown in (a) (Fig. 2). Upon pressing S against the end of the pipe, p, the flame waves presented the appearance shown in b.

Fig. 2.



Continuing the pressure until the spring S was pinned between p and M the waves became successively c and d.

3. The capsule was opened and a steel spring SS (Figs. 3 & 4) held across the membrane M. Intermittent current passed through H. Cylinder C allowed to touch spring SS. Flame curves like those shown in d (Fig. 2) made their appearance. Similar curves were seen when a small piece of steel spring S (Fig. 5) was glued to the centre of the membrane M and subjected to the action of the cylinder C (Fig. 3). The instrument was finally arranged for experiment as in Fig. 6.

Fig. 3.

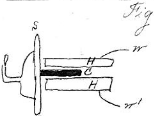
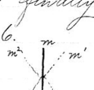


Fig. 4.

Fig. 5.



(Fig. 6.)

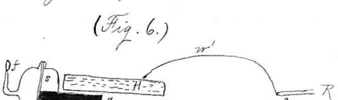


Fig. 7.

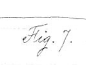
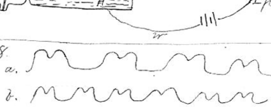
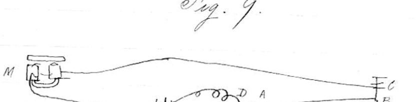


Fig. 8.



4. The spring S S (Figs 6 and 7) is glued to the membrane and is acted upon by the arm of the cylinder C. I tried it with notes of different pitches - and found that the curves produced were always of the two - headed pattern (See a b c Fig. 8).
The Transmitting Instrument was a small parlor organ with the reeds R (Fig. 6) arranged so as to make and break contact with a platinum point p when vibrating.
5. I think that probably the most sensitive kind of flame galvanometer would be a Receiving Instrument like R (Fig. 5 - p. 19) [13 of this MS.] enclosed in a box which should be filled with gas. The flame at the burner should vibrate when the spring vibrates.
6. Autograph style (p. 27 - Fig. 1) [p. 21 of this MS.] tried this morning. The axis upon which it turns and all the parts want nice adjusting - Results unsatisfactory. While I was experimenting with this instrument I was struck by hearing a very remarkable sound proceed from the Morse sounder M (Fig. 9) placed in circuit.

Fig. 9.



The point B was apparently in contact with C.
The sound persisted when the sounder was
removed from the circuit and the sound ap-
peared to come from the lever D A B. Upon
examining closely I found that a very minute
red or crimson spark passed between B and C

It is difficult to describe the noise heard
as it is unlike any sound I have heard from
magnets before. It partakes much of the
character of a kiss.

It resembles somewhat the sound caused by
effervescence - but still more I think the
noise made in sharpening the edge of a knife.
The sound was reproduced by the sounder M
whenever it was placed upon the circuit.

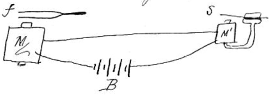
Noted Feb. 24th 1876,
by A. G. B.

Returned from Washington March 7th, 1876.

March 8th. 1876.

Experiments with an ordinary "C" tuning fork.

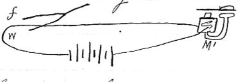
(Fig. 1.)

1. 

Resistance of M = $\frac{1}{2}$ ohm — M' = $\frac{1}{2}$ ohm.
Battery B — four cells almost run down.
Tuning-fork f vibrated — sound clearly audible from S although it was placed in a different room from f. The sound was perfectly audible when the armature S was in contact with M' and was pressed closely against the ear.

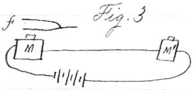
2. The magnet M was removed and another magnet having a very high resistance substituted. Very faint sound heard from M' when f was vibrated.

Fig. 2

3. 

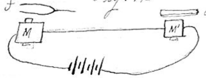
The tuning-fork f was vibrated in the neighborhood of the wire W. No audible effect from M'.

Fig. 3

4. 

Resistance of M = $\frac{1}{2}$ ohm; M' = $\frac{1}{2}$ ohm.
No sound audible from M' (Fig. 3) without armature.

5. Fig. 4



An armature (a) of steel or soft iron placed upon M' Sound audible from a (Fig. 4)

Fig. 5

6.

No sound audible from M'.

Fig. 6

7.

Some water W was placed in a dish. Conducting wire (C) was placed in the water. The vibrating tuning-fork f was held so that one leg vibrated in the water near the wire (C.)

A faint sound audible from M'.

Fig. 7

8. The water W (Fig. 7 was slightly acidulated.

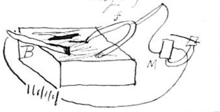
The sound audible from M was much louder than that mentioned in Experiment 7.

9. The Distance of f from the conductor wire (c) did not seem to affect the result.

Fig. 8.

In Fig. 8, f was about four inches from C. and yet the sound from M was as loud as in experiment 8 (Fig. 7) when the tuning-fork, f, was only about one tenth of an inch from C.

Fig. 9

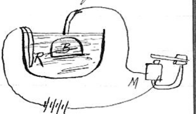


10. A ribbon of brass (B) was dipped into the water in place of the wire C (Fig. 8). Sound much louder.

Fig. 10

11. When the ribbon of brass (B) Fig. 10 was wholly immersed in the water the sound from M was very loud.

Fig. 11



12. A brass bell (B. Fig. 11) was substituted for the tuning-fork. The ribbon R was inserted also.
No sound from M.

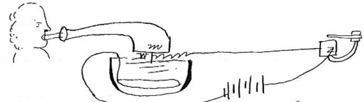
13. To test whether the difference of metals used in the last experiments had anything to do with the result – a piece of steel was substituted for the brass ribbon R and the bell B was then rung.
No sound from M.

14. Piece of steel substituted for B. (Fig. 9).
Sound as in Experiment 10.

(Thoughts.)

It seems as if the sound from M (Figs. 7, 8, 9, 10, 11) is loudest when the metallic surface B. Fig. 10 is largest and the vibrating surface in contact with the water smallest.

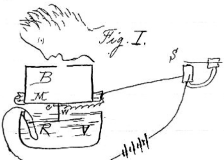
Try the following arrangement. Fasten wire W to stretched membrane M.



Noted March 8th.
by A. G. B.

March 9th. 1876.

Fig. I.



1. The apparatus suggested yesterday was made and tried this afternoon.

A membrane (M) Fig. 1 was stretched across the bottom of the box (B.) A piece of cork (C) was attached to the centre of the membrane (M) forming a support for the wire W, which projected into the water in the glass vessel V.

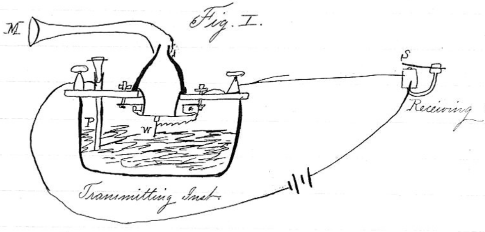
The brass ribbon R was immersed in the water also. Connections were made as in the diagram (Fig. 1). Upon singing into the box B. the pitch of the voice was clearly audible from S— which latter was placed in another room.

When Mr. Watson talked into the box - an indistinct mumbling was heard at S. I could hear a confused muttering sound like speech but could not make out the sense. When Mr. Watson counted - I fancied I could perceive the articulations "one, two, three, four, five" - but this may have been fancy - as I knew beforehand what to expect. However that may be I am certain that the inflection of the voice was represented 1 2 3 4 5

Noted March 9th.
by A. G. B.

March 10th. 1876.

Fig. I.



1. The improved instrument shown in Fig. I. was constructed this morning and tried this evening. P is a brass pipe and W the platinum wire - M the mouth piece - and S the armature of the Receiving Instrument.

Mr. Watson was stationed in one room with the Receiving Instrument. He pressed one ear closely against S and closed his other ear with his hand. The Transmitting Instrument was placed in another room and the doors of both rooms were closed.

I then shouted into M the following sentence: "Mr. Watson — Come here — I want to see you." To my delight he came and declared that he had heard and understood what I said. I asked him to repeat the words. He answered "You said — 'Mr. Watson — come here — I want to see you.'" We then changed places and I listened at S while Mr. Watson read a few passages from a book into the mouth piece M. It was certainly the case that articulate sounds proceeded from S. The effect was loud but indistinct and muffled. If I had read beforehand the passage given by Mr. Watson I should have recognized every word. As it was I could not make out the sense — but an occasional word here and there was quite distinct. I made out "to" and "out" and "further"; and finally the sentence "Mr. Bell do you understand what I say? Do — you — un-der-stand — what — I — say" came quite clearly and intelligibly. No sound was audible when the armature S was removed.

2. The effect was not increased by increasing

the power of the battery. The maximum loudness was obtained with two cells.

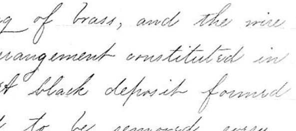
3. When more than two cells of battery were employed the escape of gas at the wire, W, was so violent as to cause the wire to vibrate. Upon listening at M the noise of the effervescence was perfectly deafening. The sound was audible from S also but in a lesser degree. No sound was audible from the Receiving Instrument when the spring S was removed.

When sounds were uttered into M by Mr. Watson – they were audible at S in addition to the hissing sound due the escape of gas at W.

4. The pipe P being of brass, and the wire W of platinum the arrangement constituted in reality a battery. A black deposit formed upon W which had to be removed every minute or two.

5. The acidulated water was caused to splash up against the membrane by the vibration of W – and the membrane soon ceased to respond to the voice until tightened.

Fig. 2.

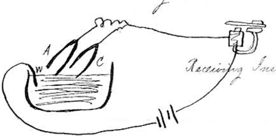


6. The more deeply the point P of the tuning-fork f (Fig. 2)

was immersed in the water the feebler the sound from S.

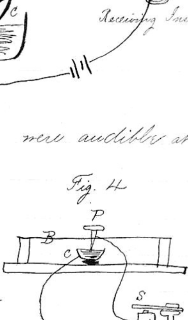
7. A larger number of experiments made to test the effect of varying the surface of W, exposed to the liquid have convinced me that the amount of surface exposed at W has little or nothing to do with the effect. The sound proceeding from S was sensibly as loud when the mere point of W troubled the water as when a large mass of metal (connected with W) was immersed in the water

Fig. 3



8. Two tuning-forks A and C pitched respectively to A and C were simultaneously sounded and presented to the water. Both sounds were audible at S.

Fig. 4



9. The sounding-board B (Fig. 6) was placed on a parlor organ. It was presumed that the vibration of the sounding-board, B, would cause the platinum point P to vibrate in the water contained in the metal cup (C) and thus the sound be reproduced by S.

No audible effect was obtained at S.

I am convinced however that a reconstruction of the apparatus will yield the desired result.

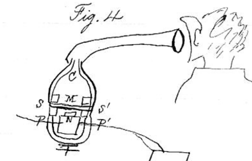
(Thoughts)

10. The metals P and W (Fig. I.) must be the same to avoid converting the arrangement into a battery.

11. The indistinct and muffled effect of the articulation is probably due to the imperfection of the Receiving Instrument. The spring S' was pressed so closely between the ear and the pole of the magnet that it had no room for vibration. Fig. 4 shows new form of receiver to be constructed.

C is a capsule.
M. Membrane.
SS', steel spring fastened to the membrane.

Fig. 4



The electro-magnet is arranged so as to have one negative pole N and two positive poles PP. The spring S'S' is in metallic contact with the positive poles PP', and the negative pole N can be adjusted nearer or further from the spring.

G. G. H.

Noted by A. G. B.

M. G. H. March 12th. 76.

March 12 th. 1876.

Sunday March 12th. 1876.

1. The instrument shown on the preceding page was tried again this morning - with the same results observed yesterday. The spring S S' was then fastened to a stretched membrane, as suggested on page 45 [36 of this MS.] Fig. 4.

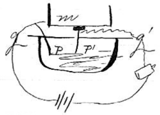
The electro-magnet E (page 46) [37 of this MS.] was then replaced as in Fig. I.

Result. The sound due to the vibration of the tuning-fork (arranged as in Fig. 2. page 43) [34 of this MS.] was so loud as to be clearly audible from A (page 46) [37 of this MS.] even when the ear was distant two feet from A.

Thoughts.

2. New Transmitting Instrument to be constructed and tested.

Fig. I.

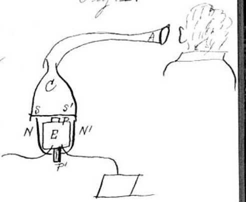


P and P' two platinum points, g g' wooden guard to prevent the acidulated water from reaching the membrane M.

3. If the audible effect is due to variations in the resistance of the circuit - then the sound should be increased by increasing the

Saturday March 11th. 1876.

Fig. I.



1. Mr. Watson completed the Receiving Instrument shown in Fig. I. this afternoon.
C is a wooden capsule. S S' a steel spring armature.
E electro-magnet.
N N' a hollow iron cylinder within which the electro-magnet E is placed. P P' the core. The pole P is positively magnetized - the circular rim N N' is negatively charged.

The instrument was tried this afternoon and no audible effect was heard at A.

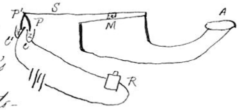
2. The capsule C was removed and the ear applied directly to the spring S S', a clear sound was perceptible. These experiments were made with a tuning fork as shown in Fig. 2 page 43 [p. 34 of <u>this</u> MS.]. The above instrument taking the place of the Receiver S (Fig. 2 page 43) [34].

Noted by A. G. B.
March 12th. 1876.

M. G. H. March 12, 1876.

amplitude of the vibration
M is a membrane. A is the
mouth-piece. S a wooden
style arranged as in Morey's
improvement of the Phonautograph.

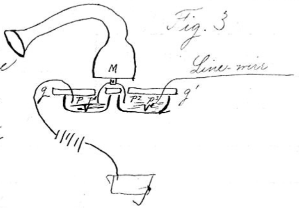
Fig. 2



PP' a bridge of platinum wire. CC' two metal cups containing water. R Receiving Instrument

Fig. 3 shows another
form of Transmitter
M membrane. PP^2 bridge
of platinum wire. The
ends pass through two
holes in the wooden
guard gg'. PP^3 two
fixed platinum points.

Fig. 3



It seems to me that the double resistance due to the water in the two glass vessels V V' and the synchronous vibrations of the two points $P' P^2$ in the two vessels - must produce a greater effect than when only one point is vibrated.

Noted by A. G. B.
March 12th. 1876.

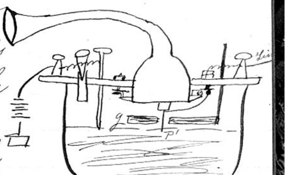
G. G. H.
M. G. H. March 12th. 1876.

Monday March 13th. 1876.

1. Mr. Hubbard and Prof. Monroe came to test the instrument for transmitting vocal sounds.

Improved instrument shown Fig. I. P and P' are two platinum points and g is a guard to prevent the acidulated water from splashing up against the membrane. Otherwise the apparatus is the same as that shown on page 40 [p. 32 of this MS.]. It was some time before either Mr. Hubbard or Prof. Monroe could hear anything at the Receiving Instrument, although both Mr. Watson and I could distinguish the sounds. Indeed both seemed at first rather sceptical, and I presume thought that the imagination had a good deal to do with the sounds. Prof. Monroe said he would like to test the reality of the phenomenon by articulating a sentence into the Transmitting Instrument while I listened at the other end. He did so but I heard quite distinctly the words "one, two, three, four, five, six" come from the armature of the Receiving Instrument, and could recognize the full rich tones of Prof. Monroe's voice — quite different in timbre from

Fig. I.



Mr. Watson's voice. Prof. Monroe said he would test me again. Mr. Watson and I wrote on a piece of paper ~~what~~ what we had heard so that Prof. Monroe might have the independent judgment of each of us. Several sentences were dictated and appreciated correctly. In one or two sentences I failed to understand what words were used but in every case Mr. Watson was successful.

A few of the sentences dictated were "A horse a horse my kingdom for a horse"— "It is time for me to go home"— "It is a very gloomy day"— "Songs were very readily heard." I distinguished at once "Home sweet home" sung with great effect by Prof. Monroe. Mr. Hubbard then discovered that he had held the Receiving Instrument so firmly against his ear that the armature had no chance of vibrating. When he held it more gently to his ear he distinguished the sounds, and declared that he was convinced that articulate sounds were transmitted along the wire although the articulation was so muffled as to be to him unintelligible unless when he was informed beforehand of the sense.

Prof. Monroe was also able after a while to make out the sounds. He did not feel perfectly sure however that consonant sounds were audible — nor indeed that anything was audible save the pitch and rythm. He thought the rythm of some well-known sentences would suggest the words even if the articulations had not been actually transmitted. In order to test whether the timbre was really transmitted he sang four vowels with equal force and with the same pitch. ee ah o i

I appreciated these as

Mr. Watson heard them as ā ah ō ī

and Prof. Monroe said he had uttered ee ah o i

Prof. Monroe then tried whether consonants could be distinguished. He sang several syllables like pee vee me de &c. — but we were unable to distinguish between them at the Receiving end — although there were differences audible.

The experiments were upon the whole satisfactory as demonstrating the fact that the timbre as well as the pitch of vocal sounds had been transmitted telegraphically.

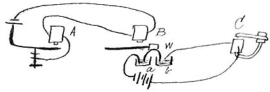
Noted by A. G. B.

March 15th. 1876.

Tuesday March 14th. 1876.

1. An Automatic Transmitter was arranged as in Fig. I. so as to enable me to carry on experiments without the necessity of employing Mr. Watson every moment of the time.

Fig. I.

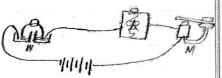


The armatures of A and B were kept in continuous vibration by the action of a local battery (L). To the end of B's armature an arch of copper wire (W) was fastened the ends of which dipped into two water cups or cells a b.

The Receiving Instrument C was in another room. The armature of C was tuned to be in unison with A and B.
The armature of C vibrated with a visible amplitude of about one eighth of an inch and the sound resulting from its vibration was audible all over the room.

Fig. 2.

2. A coil of high resistance (R) was placed in the circuit as shown in Fig. 2. The



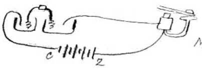
resistance of R was probably about 250 ohms while the resistance of M was only ½ ohm.
Battery four cells.

The sound was perfectly audible from M

although the motion of the armature was not ~~audible~~. visible.

3. Spiral points to the wire bridge. Sound at M rather feebler than in Exp. 1. (See Fig. 3).

Fig. 3.

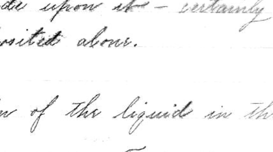


4. Arrangement as in Fig. 3. Sound audible from M when current was passed through high resistance as in Fig. 2.

5. Spiral connected with C pole speedily dissolved. Wire connected with Z pole increased in size. Reddish or brownish appearance. Looks like red oxide upon it — certainly not metallic copper deposited alone.

6. A curious motion of the liquid in the two water-cups or cells see Fig. 4
W, W' - vibrating wires
C, Z, the ends of wires connected with the C and Z poles of the battery.

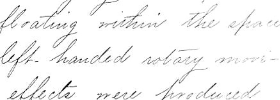
Fig. 4



An extremely rapid right-handed rotation of particles floating at A was observed. This spot A seemed to be the centre of a right-handed rotary movement of the liquid. Particles floating at b shot with extreme velocity towards c. They then returned slowly along d e until they again were repelled at b. Particles ~~f~~floating at a turned (revolved) around very rapidly without changing their place otherwise. Particles floating within the space f g h experienced a left-handed rotary movement. Similar effects were produced in the other water cell, but from the way in which the cells were arranged it was difficult to observe accurately the motion of the moving particles.

7. Experiments to determine the effect of other liquids placed in V instead of water.

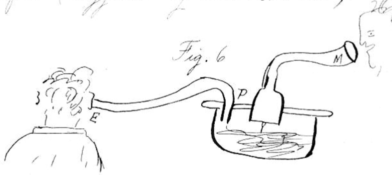
Fig. 5



(a)	When plain water was placed in V	No sound was audible at S
(b)	" " Cod liver oil ——	No sound audible at S
(c)	Cod liver oil & SO_4 ——	No sound
(d)	Salt water ——	Loud sound
(e)	Water & SO_4 ——	Loud sound
(f)	Mercury ——	Complete contact – no sound.
(g)	Bichromate solution —	" " weak sound.
(h)	" & Sulphuric acid —	Loud sound
(i)	Soapy water —	No sound
(j)	U liquor —	Loud sound

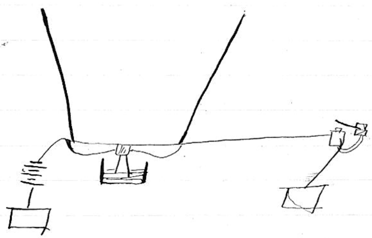
8. Experiment to determine whether the Transmitting Inst. is perfect (suggested by Mr. Hubbard).

Fig. 6



Pipe connected with P. Other end (E) of pipe placed in the ear. When Mr. Watson spoke into M. I heard at E the same curious mumbling half-indistinct pronounciation that had been transmitted electrically before. It is evident that the fault lies in the mouth piece M and perhaps in the membrane.

Thoughts.
(New Transmitter.)



Noted by A. G. B.
March 15th. 1876.

Wednesday, March 15th.

Instead of practical experiment I have come to the conclusion that I can best advance the subject by making a theoretical investigation of the effects produced upon a voltaic current by the vibration of the conducting wire in a liquid included in the circuit — and deducing thence the best way of increasing the amplitude of the electrical undulations so as to admit of the transmission of vocal utterances over long distances.

Noted March 15th. 1876
by A. G. B.

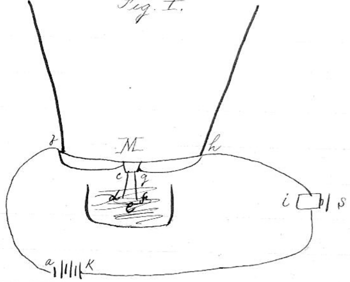
Monday, March 20th. 1876.

Theoretical investigation of the effects produced upon a voltaic current by the vibration of the conducting wire in a liquid included in the circuit

1. When a sound is made in the neighborhood of the membrane M (Fig. I.) the air acting upon the membrane throws it into vibration. The wires c d, g f, are caused to dip more or less deeply into the water, e, accordingly as the membrane M is depressed or elevated. The more deeply the wires c d, g f, are immersed

the less resistance does the liquid (e) offer to the passage of the current. Hence the vibrations of M occasion variations

Fig. I.



in the resistance of the circuit (a b c d e f g h i K); and thus affect the intensity of the current traversing it.
But the magnetization of (i) – an electro-magnet placed in the circuit – is dependent upon the intensity of the current traversing its coils. Hence the vibrations of M cause the electro-magnet (i) to attract its armature, S with a varying force.

If the armature, S, be so arranged as to be capable of free motion; then the vibrations of M will be copied by S; and the sound resulting from the vibration of S will be similar to that which occasioned the vibration of M.

2. In order to obtain the best audible effect

from S – the amplitude of the vibration of S should be as great as possible. Hence the amplitude of the electrical undulations traversing the circuit, a b c d e f g h i k, should be large; or, in other words, the difference between the maximum and minimum of intensity in the current should be as great as possible.

3. By Ohm's law we find that (I) the intensity of a current is equal to (E) the electro-motive force divided by (R) the resistance of the circuit.

$$I = \frac{E}{R}$$

4. The total resistance (R) of the circuit, a b c d e f g h i k, (Fig. I) consists of (B) the internal resistance of the battery, (L) the resistance of the line and the instruments upon it, and (W) the resistance of the water or other liquid included in the circuit. $(R = B + L + W)$

Hence

$$(b)\quad I = \frac{E}{B+L+W}$$

5. The vertical vibration of the wires c d, g f, (Fig. I) occasions an alternate increase and decrease in the resistance of the water (ε). The maximum intensity (I) of the current is reached when the minimum resistance (W) of the water is attained; and the minimum intensity (i) when the maximum resistance (W) is reached: Hence

(c) $I = \dfrac{E}{B+L+W}$

(d) $i = \dfrac{E}{B+L+W}$

6. (w) Let the minimum resistance of one cell of water (w) = 50

(E) Let the electro-motive force of one cell of battery (E) = 100

(W) Let the maximum resistance of one cell of water (W) = 100

(B) Let the internal resistance of one cell of battery (B) = 10

(L) Let the resistance of the line (L) = 10

7. (Fig. 2)

A

(c) I = 1. 428

(d) i = 0. 833

B

C

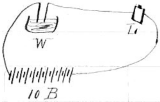
4.
3.
2.
1.
Zero lines.

8. (Fig. 3)

A

(c) $I = 6.25$

(d) $i = 4.76$



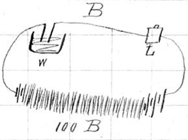
9. (Fig. 4)

A

(c) $I = 9.43$

(d) $i = 9.00$

C



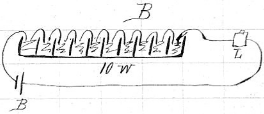
10. (Fig. 5)

A

(c) $I = 0.19$

(d) $i = 0.10$

C



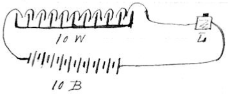
11. (Fig. 6)

A

(c) I = 1.64

(d) i = 0.90

B



C

(Fig. 7)

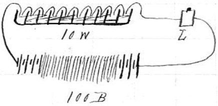
12.

A

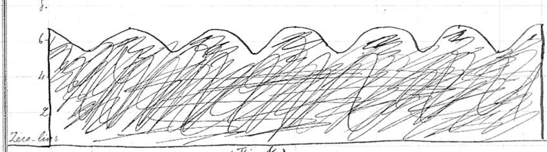
(c) I = 6.62

(d) i = 4.97

B



C



(Fig. 8.)

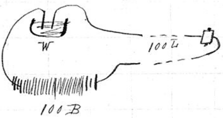
13.

A

(c) I = 4.88

(d) i = 4.76

B



C

14. (Fig. 9)

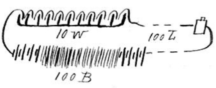
A

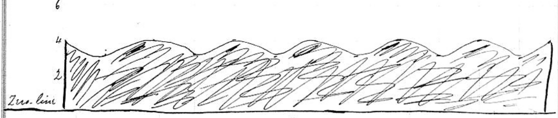
(c) $I = 4.00$

(d) $i = 3.00$

C

B





15 (Fig. 10)

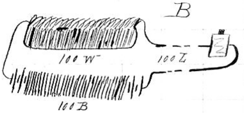
A

(c) $I = 1.42$

(d) $i = 0.83$

C

B



16. Increase of battery-power occasions an increase in the intensity of the current; and a diminution in the amplitude of the electrical undulations.

17. Increase of water resistance occasions a diminution in the intensity of the current; and an increase in the amplitude of the electrical undulation

18. Increase of the resistance of the line occasions

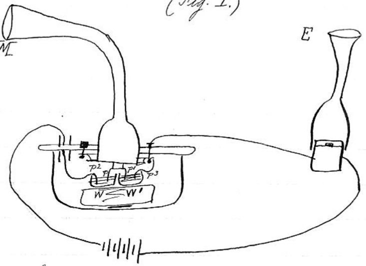
a diminution in the intensity of the current and a diminution in the amplitude of the electrical undulations.

Noted by A. G. B.
March 20th. 1876.

March 20th 1876.

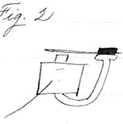
1. Mr. Hull and I tried one or two experiments with the apparatus shown in Fig. I.

(Fig. I.)



Two dishes of water (w w') were used - First salt water was used and secondly dilute sulphuric acid. Sounds were heard from E but much more faintly than I had expected. The instrument shown in Fig. 2 was also used as a Receiver but I could not obtain nearly such a good sound, as with the single wire (see Fig. 1 page 40) [p. 32 of this MS.]. Points $PP^1P^2P^3$ were of platinum.

Fig. 2



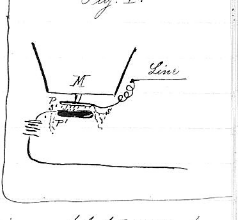
in all the experiments noted above has been immensely greater than the line, and battery put together — in fact that the water-resistance has been much too great for the battery: so that the current would be more economically increased by diminishing the water resistance than by strengthening the battery.

The water resistance can be diminished —

1. by acidulating the water as much as possible —
2. by increasing the metallic surface exposed to the water — and
3. by bringing the metallic surfaces nearer together

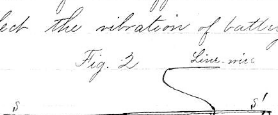
2. A form of instrument worth experimenting with is that shown in Fig. I — where a membrane (M) sets in vibration the platinum plate (P) which is separated from another platinum plate (P') by a narrow piece of sponge (SS') moistened with acidulated water.

Fig. I.



3. If P and P' were made of two different metals we should have in effect the vibration of battery plates.

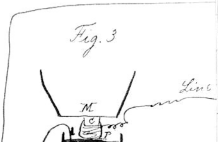
Fig. 2



4. Let a number of copper (C) and zinc (Z)

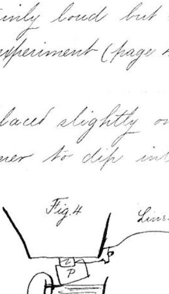
plates be arranged upon a sounding-board (S S') as in Fig. 2 – with moistened sponge or cloth between them. Such a battery would surely be exquisitely sensitive to sounds. The vibration of the sounding-boards would certainly materially affect the current – occasioning very strong undulations of electricity upon the line.

5. Willie Hubbard and I made some experiments this evening to test the effect of enlarging the metallic surface in contact with the water.



A piece of platinum foil (P) Fig. 3 – 5/8 of an inch in breadth was attached to the cork C and vibrated in the water. The sound was certainly loud but not so loud as in our original experiment (page 40).

6. The platinum foil was placed slightly on one end so as to cause one corner to dip into the water as in Fig. 4. Sound just about as loud as before. No sensible difference.



4. In the course of these experiments it was observed that the attraction of the platinum for the liquid caused the liquid to rise considerably above the level of the water as at P Fig. 5 – so that the platinum was really too

deeply immersed and its vibration therefore did not make so much difference in the resistance of the liquid as if it only touched the surface of the liquid.

Fig. 5

6. The sides SS' of the platinum foil (Fig. 5) were then slightly oiled but the edge P was left untouched. There was then a repulsion between the sides SS' and the liquid but an attraction between the water and P. The result was that the sound audible from the Receiver was much strengthened — indeed it was as loud or even louder than that heard in Experiment I. page 40 [p. of this MS.]

7. The oiling was repeated. The sides SS' and the edge P (Fig. 5) being well-oiled. Result — no sound audible from Receiver.

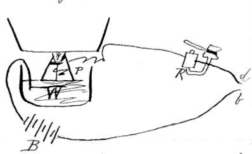
8. The oil was then rubbed off the edge P. Sound audible from Receiver but not nearly as loud as in Experiment 6.

9. The platinum wire P' (Fig. 3) was replaced by a large surface of platinum foil without sensibly increasing the sound at the Receiver.

10. In all these experiments a saturated solution

of salt in water was adopted in place of dilute sulphuric. A sort of scum collected in bubbles around and upon the platinum foil P (Fig. 4) which evidently affected the sound at the Receiver by causing the level of the liquid surface in contact with P to rise. A strong smell of Chlorine gas proceeded from the water.

(Fig. 6)

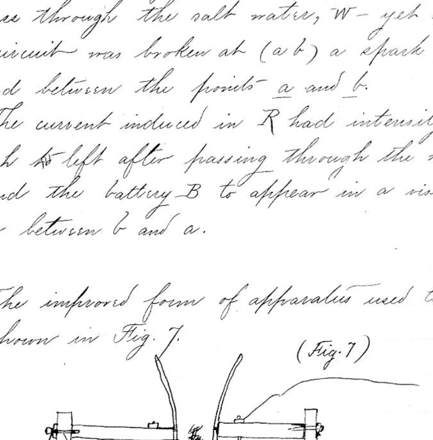


11. Although the plate P (Fig. 6) was in contact with W, so that the voltaic current was obliged to pass through the salt water, W – yet when the circuit was broken at (a b) a spark appeared between the points a and b.

The current induced in R had intensity enough ~~to~~ left after passing through the water W and the battery B to appear in a visible form between b and a.

12. The improved form of apparatus used today is shown in Fig. 7.

(Fig. 7)

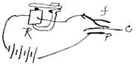


Noted by A. G. B.
March 23d. 1876.

March 24th 1876.
(Friday)

1. Tuning fork, f, vibrated against a moistened cloth, C, placed on platinum foil P.

Fig. I.



The sound of f was mechanically conducted to R so that I could not be sure of the result. I do not think that there was any audible effect at R due to electrical action.

2. Observed that two pieces of platinum foil PP' appeared to attract one another when placed upon circuit as in Fig. 2 - Especially when the corner of one was presented to the other

Fig. 2.

When they were brought into contact they adhered and when one was pulled the other followed for some distance before it was separated. I could not make the two pieces of platinum foil PP' adhere when the battery was disconnected.

3. The points PP' were brought into contact so as to make them adhere. The circuit was then broken but PP' continued to attract one another till they were forced apart.

Fig. 3.

4. The experiment was made to see whether a third piece of

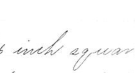
platinum foil, P^2, would be supported by the attraction of PP'. A very light piece of platinum foil (P^2) (3/16 inch long by 1/16 inch broad) was supported when the battery was in circuit, and remained supported after the circuit was broken. But if the circuit was incomplete when P^2 was presented to PP' no attractive force was manifest.

5. A piece of copper wire (No. 23) about half an inch long was evidently attracted by PP' but was too heavy to be supported.

6. A piece of platinum foil 3/16 inch square was not supported though evidently attracted. It would remain adherent by its edges for a moment and then fall.

7. The piece of platinum foil mentioned in Exp. 4 was also supported by two copper wires as in Fig. 4. Platinum foil P - copper-wires C C'.

Fig. 4



8. The platinum foil mentioned in Exp. 6 proved too heavy.
I happened to moisten it slightly with salt and water before presenting it to the wires CC' — and at ~~was~~ once a very peculiar noise proceeded loudly from the Receiver R. It was like the grinding of knives somewhat. This same

noise has been ~~alluded~~ alluded to before at page 33 (Exp. 6.).

9. Platinum foil used in Exp. 7 was supported by two copper wires as in Fig. 4 – only that the instrument R was not placed in the circuit. In this case there was no spark when contact was broken.

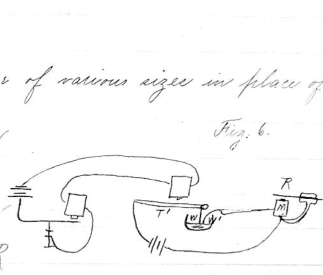
10. Experiments made with Automatic Transmitter arranged as on page 52 [p. <u>43</u> of <u>this</u> MS.] The platinum foil used in experiment 5 page 69 [p. <u>57</u> of <u>this</u> MS.] was employed with the Automatic Transmitter. P platinum foil P' platinum wire. Results not so satisfactory as with wires.

Fig. 5

11. Tried the same experiment with about No. 25 platinum wire: Slightly louder sound. In both these cases the vibration of the Receiver was barely visible.

12. Tried copper wire of various sizes in place of platinum.
Very much improved result.
Wire No. 20 resulted in a vibration of R

Fig. 6.

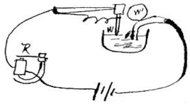


so great as to strike the face of the magnet (M). I could not test them comparatively as in both cases R struck the face of the magn

13. R (Fig. 6) was brought into the same room with T and T' so as to observe closely the effect of any variation in the vibration. Tried the effect of placing the wires W W' nearer & further apart & immersing them deeper

14. As W' (Fig. 7) was placed deeper and deeper in the liquid the amplitude of vibration at R increased until its maximum was reached and then no further increase in the amplitude of R's vibration took place when W was still further immersed. R did not strike the face of the magnet.

Fig. 7.

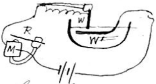


15. As the wire W was immersed the amplitude of vibration at R diminished. R's vibration was greatest when W just touched the surface of the water.

16. Approximating the wires when both were vertical did not seem to increase the amplitude of R's vibration very sensibly.

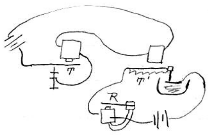
17. When W' was placed under W as in Fig. 8 – the approach of W' to W caused such a sudden increase of vibration in R as to cause R to strike the face of the magnet with great force.

Fig. 8



18. By means of a measure I tried to estimate the amplitude of vibration of T, T', and R.

Fig. 9.

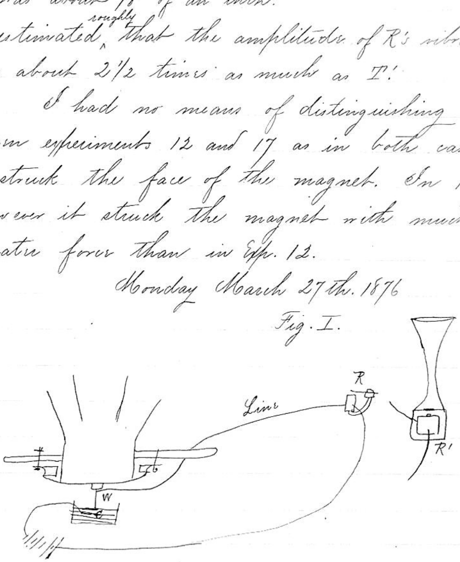


T was about 1/16 of an inch
T' was about 1/8 of an inch.
I estimated roughly that the amplitude of R's vibration was about 2 1/2 times as much as T'.

I had no means of distinguishing between experiments 12 and 17 as in both cases R struck the face of the magnet. In 17 however it struck the magnet with much greater force than in Exp. 12.

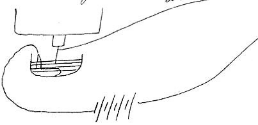
Monday March 27th. 1876

Fig. I.



1. A membrane was arranged as in Fig. I. with a thick copper wire, c a piece of copper directly underneath with a mere film of liquid between. Little or no sound from the Receiver R or R'.

Fig. 2.



2. Receiving Instrument as arranged before. Sound much louder - especially from R' (Fig. I)

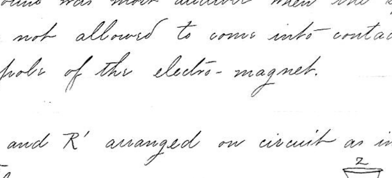
3. With Receiver R. Fig. 3 my father noticed that

Fig. 3.

the sound was most audible when the spring S was not allowed to come into contact with the pole of the electro-magnet.

4. R and R' arranged on circuit as in Fig. 4 - p. 80.

Fig. 4.

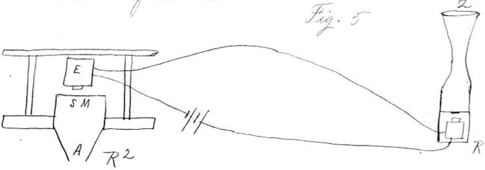


When S was plucked with the finger the sound was clearly audible from R'.

5. When sounds were sung into Z of R' the notes

were audible from R.

Fig. 5



6. A spring S was fastened to a stretched membrane M — and an electro-magnet E fastened over it. Circuit as in Fig. 5.
Upon singing into A the sounds were heard from Z of R' — and upon singing into Z of R' the sounds were audible from A. The word "papa" uttered into Z was intelligible at R^2.

When words were uttered into Z articulate sounds proceeded from A but were unintelligible.

When words were uttered into A articulate sounds were audible from Z but were unintelligible.

Noted March 27th. by A. G. B.
Copied March 30th. by
M. G. H.

Thoughts.

Fig 6.

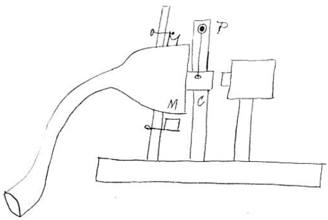
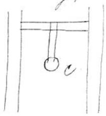


Fig. 7



1. Suspend cylinder of iron, C. Fig. 6 (and Fig. 7) from pivot p. so as to prevent weight of cylinder from affecting membrane M.

2. Make cylinder C Fig. 6 itself an electro-magnet.

Noted Monday, March 27th A. G. B.
Copied Thursday, March 30th M. G. H.

Fragmentary Thoughts.

1. If vibration of Battery plates by lessening & increasing internal resistance of cells will create undulations in the current, would vibration of the liquid contained in the battery produce undulatory current.

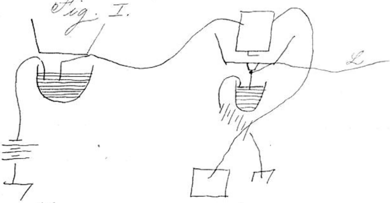
2. Continuous current produces rotation of permanent magnet - why not vice versa.

Noted Feb. 1st. 1876
by A. G. B.

3. Measure intensity of current by change of pitch produced in vibratory armature.

Repeater for transmission of the human voice Fig. I.

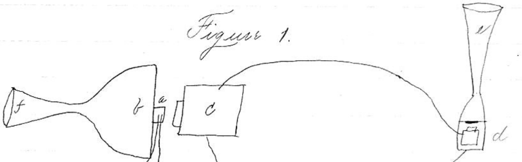
Fig. I.



Noted March 19th 1876 by A. G. B.
All these thoughts copied April 1st by M. G. H.

Saturday April 1st 1876.

Figure 1.



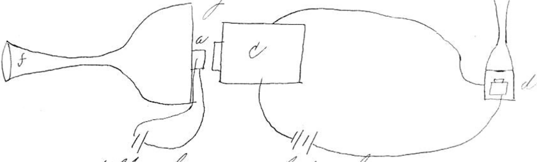
1. A little electro-magnet a was fastened to the stretched membrane b as in Fig. 1, & placed in front of electro-magnet C. Sounds were uttered into f and they were faintly audible from e.

2. My father uttered a variety of sounds

of different pitch into f - and very loud sounds proceeded from e whenever certain very high sounds were made.

3. A current was passed through the electro-magnet a, Fig. 2. When a & c were of the same polarity little or no sound Fig. 2.

Fig. 2

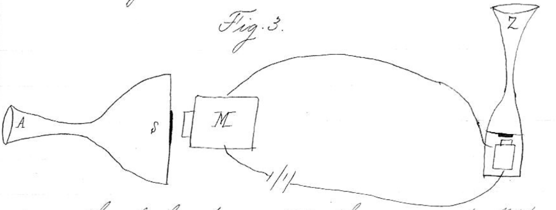


was audible from e but when a & c were of opposite polarity the audible effect was much louder, though at its best it was very faint.

5. Upon uttering sounds into e, faint sounds were heard at f.

6. The electro-magnet a was removed and a piece of clock spring S substituted about 1/2 inch long & 1/2 inch broad. See Figure 3.

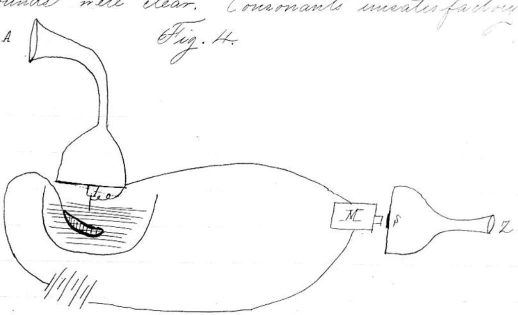
Fig. 3.



S is the clock spring, M the magnet. Upon singing into A sounds were heard at Z and upon singing into Z sounds were heard at A much more distinctly than in any of the preceding cases.

7. Arrangement as in Fig. 4. M magnet; S spring attached to stretched membrane. On speaking into A sounds were perfectly audible from Z. Much louder than any yet obtained with the voice. Unmistakeably articulate sounds proceeded from Z. Vocal sounds were clear. Consonants unsatisfactory.

Fig. 4.

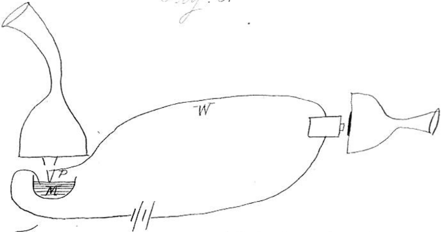


Thoughts.

April 1st Saturday 1876.

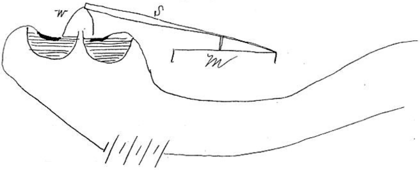
8. Try vibration of an imperfect conductor in a good liquid conductor. Say carbon or animal tissue in mercury. Attach lead pencil p (Fig. 5) to membrane having first attached the plumbago to the wire W. Then let the point p vibrate in mercury M. See Fig. 5 next page.

Fig. 5.



9. Try increasing amplitude of vibration by using Morey's style as in Fig. 6.

Fig. 6.

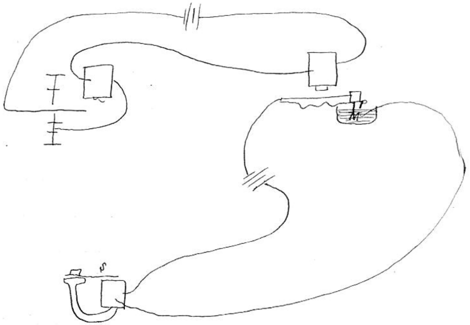


m. membrane, S style, w arch of wire to be vibrated.

Noted by A. G. B. April 1st 1876.
Copied by M. G. H. April 3d 1876.

Sunday April 2d 1876.

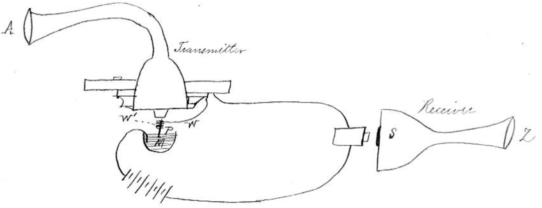
Fig. 1.



1. P plumbago taken from lead pencil — M mercury. The spring S vibrated with such amplitude as to strike the face of the magnet.
2. The sound from S was louder when the plumbago was caused to dip most deeply into the mercury.

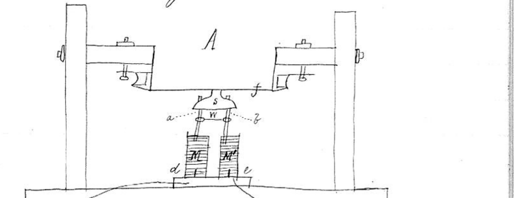
Noted April 2nd A. G. B.
Copied April 5th M. G. H.

Figure 4 (See page 76.)



Wednesday, April 5th.

Fig. I.



1. Apparatus arranged as in Fig. I. c a cork attached to a membrane f. The cork c carries

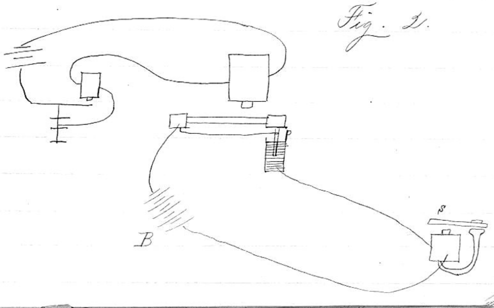
two pieces of pencil in a. b. which are metallically connected by a copper wire w.

The plumbago styles a. b. dip into mercury M M' contained in two glass cells. The mercury is connected with the battery + line wire by means of two wires d, e. In the Receiving Instrument S is a steel-spring attached to a stretched membrane.

When my father sang into A the sounds were loudly audible at Z. Articulate sounds were audible at Z when ~~sounds~~ words were uttered into A. Vowel qualities could be discriminated, but not consonant sounds.

2. Automatic Transmitter arranged as in Fig. 2 page 93. Plumbago P vibrated in mercury. With one cell of battery B there was a slight visible vibration of S. As the battery power was increased the amplitude of the vibration of S increased until with three cells S struck the face of the magnet.

Fig. 2.



3. The spring S was then bent upwards as shown in Fig. 3 so as to place it further from the face of the magnet, and experiment 2 was repeated. The amplitude of the vibration of S Fig. 3 increased continuously as the battery was made more powerful. I was unable to employ more than five cells, and with this power, the amplitude of vibration of S Fig. 3 was sensibly three if not four times as great as the vibration of P fig. 2.

Fig. 3.

4. Apparatus arranged as in Fig. 4 page 89 [p 73 of this MS.]. Same receiving instrument employed as is shown in Fig. 1.

P. plumbago vibrating in mercury M.

For lack of a proper stand my father held the transmitter so as to allow the plumbago P to dip into the mercury while Mr. Richardson sang into A.

The sounds were loudly audible at Z.

5. The transmitter was necessarily held unsteadily & great differences in the intensity & quality of the sounds proceeding from Z were observed.

When P was only slightly immersed the sound at Z was feeble but every now and then it would suddenly burst forth so loudly as to startle the ear placed at Z. At such times my father noticed a bright spark between

P and M showing that the point P had vibrated in & out of M occasioning an intermittent current. I can now recognize by ear a vast difference in the quality of the sounds produced by the intermittent and undulatory currents.

In the case alluded to above so long as the plumbago never left the mercury I could hear not only the pitch of the sound, but could recognize the quality or timbre of Mr. Richardson's voice. When the spark appeared at P I could ~~hear~~ hear, it is true, the pitch of Mr. Richardson's voice, & that very loudly, but the quality had gone.

The sound was not different in quality from that produced by my Reed arrangement.

6. When the pencil P (Fig. 4 page 89) [p. 73 of this MS.] was deeply immersed the pitch & timbre of Mr. Richardson's voice were loudly audible at Z but every now & then a deafening sound would proceed from Z having the characteristic of the intermittent current — that is that the pitch was manifest, but not the quality of the voice.

This sound would stop suddenly and then burst out again. When the stoppage occurred the steel spring S (Fig. 4 page 89] [p.] would go with a click against the face of the magnet & stick — showing that there wa

a continuous current.
In such cases I found that the pencil P had been so deeply immersed as to allow the copper wire W to touch the mercury.
7. Mr. Richardson & my father sang simultaneously into the tube A notes of different pitch. At Z both the sounds were audible without confusion, but only for a moment.
The undulatory current every now & then would be changed into an intermittent current, & the sounds would then be heard at Z very loudly but beating in such a way as to render it impossible to discriminate one pitch from the other. The sound partook more of the nature of a rapid trill than of a musical note. The shortness of the pencil P rendered it impossible to prevent the intermittent current from making its appearance. The experiment must be repeated with a more perfectly arranged apparatus.
I am satisfied however from the above experiment that my theory is correct — that musical notes which conflict with one another when transmitted simultaneously by means of an intermittent will not interfere with one another when the undulatory current is employed.

Noted April 7th 1876
by A. G. B.
Copied April 8th by M. G. H.

Friday, April 7th 1876.

Thoughts.

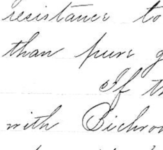
1. While at Osgood's today – the idea came forcibly to me that the gelatine film used in the Heliotype process may be made of use in Autographic Telegraphy.

Gelatine being an animal product is probably a conductor of electricity offering considerable resistance to the passage of the current.

Bichromate of potassium as used in the Heliotype process forms with the gelatine an insoluble compound under the action of light – which will probably offer less resistance to the passage of the current than pure gelatine does.

If then we write upon gelatine with Bichromate of potassium and then expose it to the light – the writing might conduct electricity from the style S Fig. 1 to the metal plate P below and the problem of utilizing my Autograph Telegraph be solved.

Fig. 1.



S – style
g – gelatine
P – metal plate

It may be however that the Bichromate solution only affects the surface of the film, although from the action of the film in absorbing ink in some parts and repelling it in others it would seem as if the Bichromate penetrates the whole substance.

2. Should it prove that the substance formed by the union of gelatine + Bichromate of potassium is a non-conductor of electricity the film might be used in this way.

Place the gelatine on a metal plate and subject it to the action of Bichromate. Then write upon the gelatine with ordinary black ink, and expose to the light.

The ink will prevent the light from acting upon the gelatine under the writing but everywhere else an insoluble compound will be formed.

Place the whole in warm water + the gelatine under the writing will be dissolved out leaving the metal surface below bare.

3. A similar idea. Albuminize and sensitize a metal plate with Bichromate and proceed as in Experiment 2.

Noted April 7th 1876 by A. G. B.

Copied April 8th. 1876

by M. G. H.

Monday, April 10th 1876.

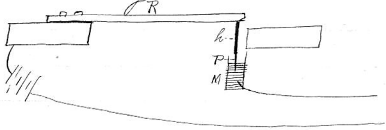
1. Tried whether bronze-ink would form a conducting surface. Bought what is known as "Chinese Metallic Ink," Morse sounder gave no signal through it nor was galvanometer needle affected.

2. Metallic powder used in painting called "Finest Silver" acted as a non-conductor.

Thoughts.

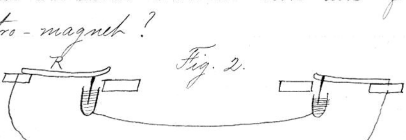
3. Attach brass-holder h for plumbago point P to a free reed R as in Fig. 1 and vibrate in mercury M.

Fig. 1.



4. Why should not R Fig. 2 set its unison R in vibration without the aid of an electro-magnet?

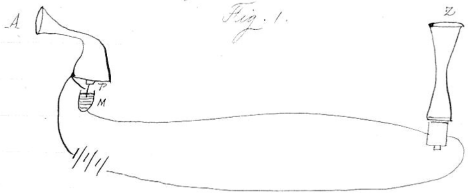
Fig. 2.



Noted April 10th 1876 by A. G. B.
Copied Apr. 12th by M. G. H.

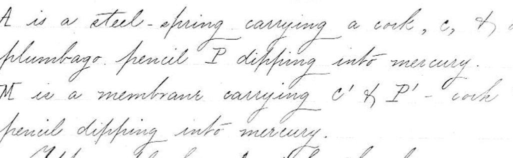
Tuesday, April 11th 1876

Fig. 1.



1. Instrument arranged as in Fig. 1.
P plumbago - M mercury. When Willie Hubbard sang into A the notes were clearly and loudly audible from Z.
Vowel sounds could be discriminated at Z, but not consonants.
2. Instrument arranged as in Fig. 2.

Fig. 2.



A is a steel-spring carrying a cork, c, & a plumbago pencil P dipping into mercury.
M is a membrane carrying C' & P' - cork & pencil dipping into mercury.

Upon plucking A with the finger a sound was audible at Z, but very faintly.
3. The battery was increased to eight cells. Then each pluck of the spring A was clearly audible at Z.

Cannot be sure whether the current was undulatory or intermittent. I am inclined to suspect that it was the latter.

Fig. 3.

4. When the circuit was made & broken at A a distinct click was audible at Z.

Noted April 11th by A. G. B.
Copied April 13th by M. G. H.

Thursday, April 13th 1876.

1. Stanley's autograph style will certainly succeed if we can only obtain a good enough conducting-ink. Surely some solution can be found which will leave deposit of pure metal upon evaporation. "Bronze inks" containing metallic powder mechanically suspended do not seem to do, unless indeed the metal could be suspended in a fluid that is itself a good conductor.

2. Will not a solid conductor of high resistance vibrated in a fluid of high resistance produce undulations of greater amplitude than

if one of the two were a good conductor.
Vibrate plumbago P in saturated solution of salt, S.

Fig. 1.

3. If in addition a piece of metal (M Fig. 2) is placed in the salt & water, just under the pencil-point P will there not be an additional effect due to the alternate approximation and separation of the plumbago & metal.

4. Mercury might be substituted for the metal - as in Fig. 3.

Figure 2.

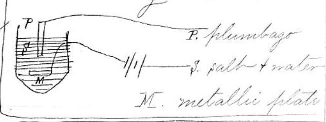
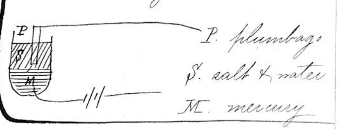
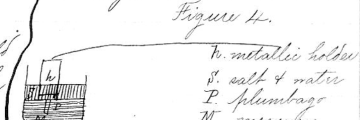


Figure 3.



5. Metallic holder h. Fig. 4 carrying plumbago pencil P may be vibrated in mercury & salt-and-water as in Fig. 4.
Undulations would be caused by the vibration of the metal h in the salt & water S; by the motion of the plumbago P in the mercury M; and by the alternate approximation & separation of the two good conductors h and M. Surely the amplitude of the electrical undulations would be greatly

Figure 4.

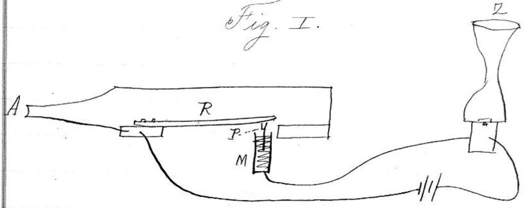


increased by such an arrangement.

Noted April 13th 1876 by A. G. B.
Copied April 14th by M. G. H.

Saturday, April 15th 1876.

Fig. I.



1. Free Reed R arranged as in Fig. I. P - plumbago, M - mercury.

Upon blowing into A the reed R vibrated and the sound was audible from Z.

2. Visited various stereotyping and electrotyping establishments in Boston in search of ideas. In one place a process was at work that suggested a means of depositing copper upon a plumbago surface.

I wrote upon the card shown in Fig. 2. with a soft lead-pencil. Then immersed the card in a saturated solution of sulphate of copper - and sprinkled some iron-filings upon it. Copper was deposited upon the plumbago surface as shown

Fig. 2.

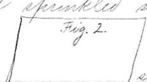


Fig. 2. I tested the conducting surface to see whether a Morse Sounder could be worked through it upon Stanley's plan. I find it can.

Experiments were made with Prof. Horsford this evening - but we failed to have copper deposited so successfully as in the above.

Noted by A. G. B.
April 16th 1876

M. G. H. April 16th.

Experiments

made by

A. Graham Bell.

Vol. II.

Tuesday April 18th 1876.

1. Experiments with lead pencils of different kinds.

1. to find out which was the best for the purposes of Autograph Telegraphy.

1. Steamboat No 2.
2. W Cundy No 2.
3. Eagle No 2.
4. Faber No 2.
5. Faber No 4.
6. H. Ropes N.Y.
7. Graphite de Siberia de la Mine Aliber
8. Pure plumbago.

Some words were written with each pencil upon a card. Some sulphate of copper was poured on the card and iron filings sprinkled in.

The iron would turn brown and the plumbago would be unaffected until the iron and plumbago were brought into contact by rubbing.
The results seem to indicate that a soft lead pencil produces the best results, and that Faber's and Eagle's No 2. are the best pencils for the purpose
2. The iron filings became quite warm to the touch.

Thoughts.

The action does not seem to me to be a pure chemical action, for it seems neccessary to have the iron <u>touch the plumbago</u> in order that there should be a deposit on the later.

Prof. Horsford suggested that the iron and plumbago really formed a battery; but I could not see how any action could take place until there was a circuit. I now really think that this really <u>is</u> the action, and that a circuit is formed when a particle of iron <u>touches</u> a particle of plumbago.

If this is so it is probable that other metals may take the place of iron. Some metals should be selected very far away from plumbago in the electro. Series of elements.

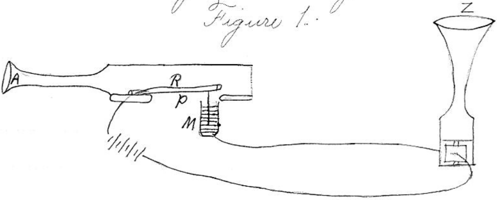
Try zinc instead of iron. This would give the same elements that have been adopted in batteries. zinc and carbon.

Noted April 19th 1876 by A. G. B.
Copied Saturday April 22nd by M. G. H.

Wednesday April 19th 1876.

1. Mr. Ware assisted me in trying my new reed-arrangement today.

Figure 1.



Upon blowing into A, the reed R. vibrated, causing the plumbago style P. to dip into mercury M. Sound loudly audible from Z.

2. Glycerine placed on top of mercury M. did not seem to interfere with the effect at Z.

3. Glycerine was substituted for the mercury M, and the style P. allowed just to dip into the glycerine. No sound audible from Z.

4 Style P. allowed to dip deeply into the glycerine in M.

Sound audible from Z fully as loud as when mercury had been used in M.

5 Experiments to produce metalic coating on

lead pencil marks.

All the marks were made heavily with a No 2. Faber pencil.

No 1. Card moistened with sulphate of copper and iron filings rubbed in slight deposition of copper.

No 2. Iron obtained by hydrogen substituted for the filings. No effect.

No 3. Brass filings employed. An immediate deposition of copper. The zinc became quite black. The copper deposited was soon covered with a black deposit, so that it lost the metalic lustre it had when first formed.

No 5. Zinc filings with same result.

No 6. Zinc filings pressed close to card for a moment, and then instantly washed off.

A distinct trace of metalic upon the plumbago.

No 7. Zinc filings were scattered upon the dry card they were then washed off with sulphate of copper.

An immediate deposite of copper took place.

No 8. Zinc filings sprinkled on the moistened card, and slightly brushed with a paste brush.

Immediate deposite of copper.

No 9. Card moistened with sulphate of copper. Zinc filings sprinkled on card, and pressed firmly with the finger for about half a minute.

Result - Copper and black deposit upon the plumbago.

No 10. Moistened card, zinc sprinkled on rubbed with finger, and instantly washed off. Result - Metalic copper deposited.

No 11. Same experiment as last.

Same result.

No 12. Moistened card held against a zinc plate for a moment.

Result uncertain.

No 13. Experiment 12 repeated.

Distinct traces of copper deposit.

No 14. Same as last.

No 15. Card moistened in sulphate of copper, held for about a moment, in close contact with zinc plate.

Traces of white deposit - Looks like zinc. Worked a Morse Sounder through the white deposit.

No 16. Card moistened in dilute sulphuric acid, and held for one moment against a zinc plate.

No deposit.

No 17. Same experiment as No 16.

No 18. Card moistened with sulphate of copper and held closely against zinc plate for one moment.

Very slight trace of copper deposit not enough to

No 19. University paper. Sulphate of copper and zinc. Slight deposit formed.

No 20. The paper was moistened with sulphate of copper.

Zinc filings were added, and immediately washed off.

A slight metalic deposit was left on the plumbago.

More sulphate of copper was poured on the paper, and iron filings rubbed on.

Best results obtained yet. Good metalic deposit. Sounder works well through it.

No 21. Same experiment as last

No 22. Same experiment with card instead of paper.

Not quite so good deposit.

No 23. Same as experiment 20.

Result very good indeed.

No 24. Same as No 20, excepting that the iron filings were allowed to lie on the paper, were not rubbed on.

Best result yet. Good metalic deposit

No 25. Same as last. Same result.

No 26. Paper immersed in sulphate of copper and zinc filings sprinkled on and allowed to float on surface. Copper deposit formed upon plumbago.

Best and thickest deposit yet obtained.

Noted April 19th 1876 by A. G. B.
Copied April 22nd 1876 by M. G. M.

Saturday April, 22nd 1876.

1. Upon repeating the experiment of vibrating plumbago in mercury (Page 3. Exp. 4.) it was found that the plumbago struck a copper wire immersed in the glycerine so that an intermittent current had been created.

When the plumbago was caused to vibrate freely in the glycerine, no sound was audible from Z (Fig 1. Page 3.) however deeply the plumbago was immersed.

2. When the plumbago was vibrated in sulphate copper a slight sound proceeded from Z. (Fig. 1. Page 3.)

3. Continuation of experiments to produce metalic coating upon lead pencil marks

No 1. In this and all the other experiments made today, the zinc filings were immersed in water before being sprinkled upon the paper so that they should at once sink when placed in sulphate of copper.

In No 1. the paper was first immersed in water, then the water was nicely covered with moistened zinc filings. Another

piece of paper was placed over the filings to keep them in place, and the whole was placed in sulphate of copper.

No 2. Same as last excepting that the second piece of paper to keep the filings in place was omitted.

No 3. Same as No 1. save that the filings were thinly scattered on the paper.

No 4. Same as last excepting in the omission of the paper covering over the filings.

No 5. Same as No 1. save that the vessel containing the sulphate of copper was violently shaken so that the zinc filings could not rest long on one spot.

No 6. Same as last without paper covering for the filings.

No 7. Same as No 2. excepting that filings were allowed to be in contact with the plumbago all night.

Noted by A. G. B. April 23rd 1876.

Sunday April 23rd 1876.

1. Experiments to produce metalic deposit upon lead pencil marks upon paper.

The paper was placed in sulphate of copper, and mercury poured over the writing.

No deposit.

2. Zinc filings were dissolved in mercury forming a pasty amalagam, which was placed upon the writing, and then sulphate of copper poured on.

A deposit like mercury made its appearance on the plumbago, or rather the amalagam adhered to the plumbago surface. No 1. and No 2. are specimens of the results obtained.

Noted April 23d 1876. by A. G. B.

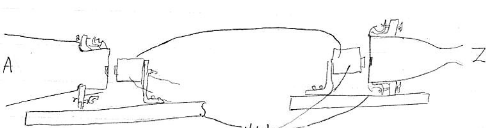
Tuesday April 26th 1876.
Tried experiments to see if the paper made any difference in the quality of the deposit. experimented with each kind of paper thrice, and find that that marked 4 is the best for the purpose.

A. G. B. April 26th 1876.
M. G. H. April 29th 1876.

May 3d and May 10th.
Exhibited instruments and their operation at prof. Trobridge's room Harvard University Tuesday May 3d, and at the Academy of Arts and Sciences May 10th 1876.

May 5th 1876.
Instruments at Mr. Hubbards House. Experiments with the Telephone arranged as in Fig I.

Fig I.

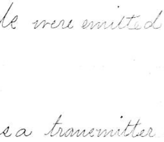


Mr. Hubbard and Miss Hubbard spoke simultaneously into A. I was able to hear both voices at Z. Articulation intelligible. Large aperature vowels such as [illegible] and dipthongs [illegible] are heard distinctly at Z. Other vowels are also audible and occasionally certain consonants. With a powerful battery I have heard a few sentences perfectly. For instance "What hath God wrought" was on two or three occasions perfectly distinct even to the th in "hath".

Noted by. A. G. B. May. 19th 1876.

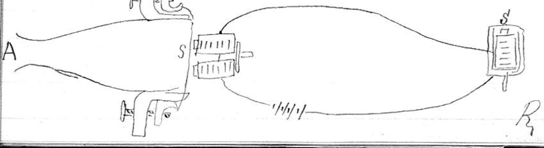
May 22nd 1876.

1. Tried the effect of a double-pole magnet with the telephone this afternoon. (as in Fig 1.)



Used as a receiver with the telephonic organ, good results were obtained. Very loud sounds were emitted from S.

2. Telephone in Fig 1. was used as a transmitter for the human voice. It was arranged upon circuit with the old receiver R_1 (Fig 2.)



Upon placing my ear against S I could hear very distinctly the sounds that were uttered into A. Consonants and vowels are equally intelligible. Although my ear was pressed tightly against S. I heard the sentence "Mr. Bell. "Are you going to the Centennial" with the utmost distinctness.

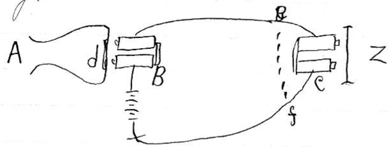
The effect was much better when Eddie Wilson spoke on the other side of the membrane, so that the impulses of the voice tended to push it from, not towards the magnet.

4. The telephonic organ was connected on circuit with the receiver R_1 (Fig 2.) The resulting sounds could have been heard all over a large hall.

Noted by A. G. B. May 22nd 1876.

June 30th 1876.

Returns from Philadelphia Exhibition monday.



Two magnets B and C have been made for experiments upon real lines. The resistance of B is 1650 and C. has a resistance of 1600

A is ordinary telephone. the membrane has a small piece of very thin sheet iron (Tagger's iron). attached to it is a flat disk of Tagger's iron.

I tried the instruments this morning with four carbon cells, I could not obtain any indications of attraction. Upon placing my ear at Z however I could hear a click when the circuit was broken.

When Wilson sang into A I could hear the sounds of the voice at Z. Upon breaking the circuit at C the sounds were inaudible at Z. No sounds were heard at Z when a wire connected e and f.

The sounds of Eddie Wilson's voice were reproduced by Z when there was only one cell on the circuit. This is most extraordinary especially when we consider that the resistance of the magnets alone, is equivalent to 3250 ohms or 320 miles of well-insulated (?) telegraph wire.

It is probable that the sounds proceed from Z when no battery is on the circuit. And that the inventive power of d acting upon the residual magnetism of B creates an undulatory current in C.

I fancied I could hear faint sounds from Z when no battery was on the circuit but other noises were loud, and besides I could hear Eddie's voice through the circuit although very faintly.

2. When Eddie Wilcox sang to Z faint sounds were audible from A. Four cells on circuit.

Thoughts.

Fig. 2.

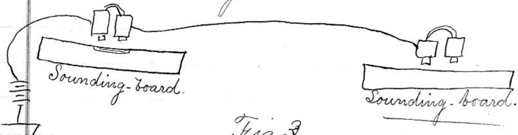
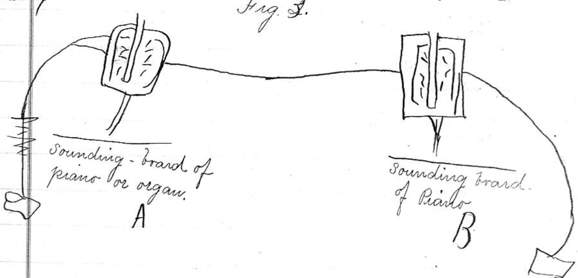


Fig. 3.



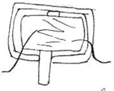
If piano A is played, why should not piano B copy every note, since the soundingboard is not(?) in vibration.

And if so what need of other apparatus for multiple Telegraphy. Play any note of one piano, and the signals will come on the string of the other piano.

The sounds will thus be sifted <u>after</u> they leave the wire.

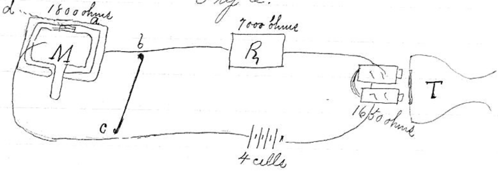
July 3rd, 1876

1. Williams made a magnet for me like that shown in Fig 1.
The resistance of the coil is 1800 ohms.



2. The instrument shown in Fig 1. was connected upon circuit with a telephone as in Fig 2. and resistance inserted as at R_1 Fig 2.

Fig 2.



Four cells of a carbon and bichromate battery were employed. As the total resistance of the circuit equivalent to 10.450 ohms, the battery had an inappreciable effect upon the magnetism of M. The steel spring armature (?) d, was not sensibly attracted by M. And yet sounds uttered into T were heard proceeding softly from a when a piece of copper-wire was laid from b to c.

Noted by A. G. B. July 3rd 1876.

Thursday. July 6th 1876.

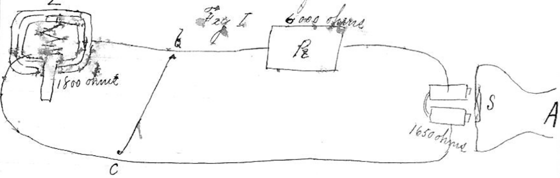
Instruments arranged as in (Fig 2. page 17) (page 16). Battery power gradually reduced to one cell. The sound emitted by a of M was little inferior in loudness to that heard when four cells were employed. It seems extraordinary that the vibration of a little piece of iron weighing a few grains should cause an audible sound upon a circuit of 10.450 ohms resistance with only one cell of battery. There can be no doubt that the sounds are electrically produced although Eddie Wilson's voice could be heard through the air also; for when Eddie Wilson prolonged his sounds, they were audible through the air to ______

But upon listening at a the sound was broken up so ________, when the a and d magnet M was cut off from the circuit by tapping with the wire b c upon the point b.

3. The battery was entirely removed from the circuit and the Rheostat (R_1 Fig 2 page 17) (page 16) disconnected.

When Eddie Wilson sung into T the sounds were audible from a of M.

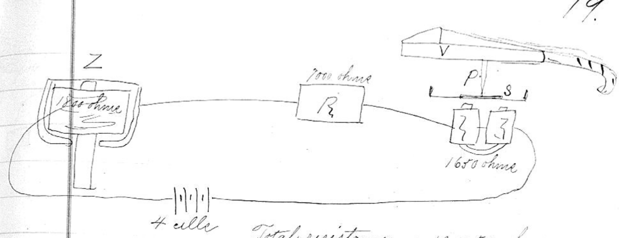
3 The Rheostat (R) was re-introduced into the circuit as in Fig 1 (page 19)(page 18) and the resistance of the circuit was



gradually increased. 4000 ohms resistance was introduced and still the sounds that were uttered into A were heard faintly proceeding from Z. The sounds were electrically produced as proved by the effect of the cut-off b c. When more than 6000 ohms resistance was introduced the sounds audible at Z through the air, were so much louder than those produced electrically at Z, that it was difficult to determine whether the sounds heard at Z were due to electrical undulations or to the air.

4. A lead-pencil p (Fig 2 page 20)(page 19.) was placed against the spring S, of the telephone T and a violin, V. was rested against p.

Arrangment upon circuit as in the diagram.



Total resistance = 10.450 ohms.

When the violin. V. was played the sounds were clearly audible from Z.

Noted by A. G. B. July 6th 1876.

Friday. July 7th 1876.

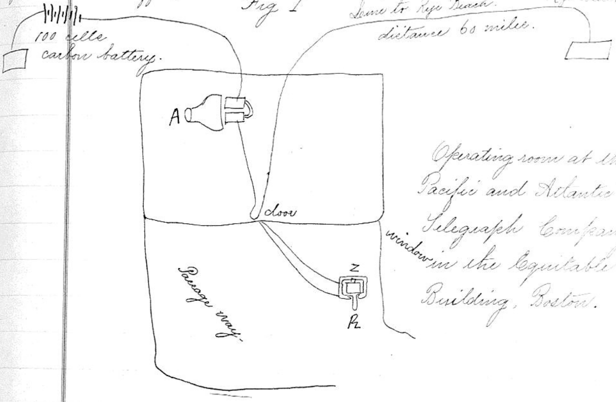
1. Had an opportunity of trying instruments upon a real line at the office of the Pacific and Atlantic Telegraph Company this morning at half-past six.

The instruments were arranged upon circuit as in (Fig 1 page 21) (page 20).

Mabel spoke at A and I heard her voice at Z. This is the first time the human voice has been transmitted along a real telegraph wire. Mabel articulated the word "Alec – Alec". I heard her voice proceeding from Z but could not distinguish the articulation.

Eddie Wilson then sang and spoke into A his voice was plainly audible at Z.

Battery in State St. office. Fig I Line to Rye Beach. Rye Beach.



Operating room at the Pacific and Atlantic Telegraph Company in the Equitable Building, Boston.

I distinguished clearly the sentences – "do you understand what I say?" and "do you hear me" and a few other sentences.

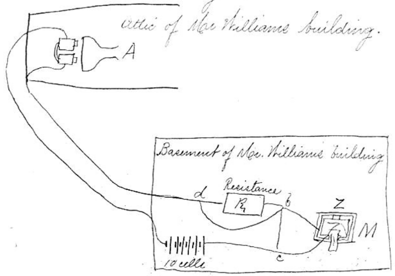
2. The telephonic organ was connected in circuit in place of the telephone T.

Every note and chord was loudly audible from the receiver R_1.

The only defect in the experiment is that R_1 is not placed entirely out of ear-shot of T I am to experiment again on Sunday morning.

3. I took the telephonic Transmitter and Receiver for the human voice to Williams this evening to try how much resistance I could transmit sounds through with the battery-power he could let me have viz (?) 10 cells.

Fig 2.



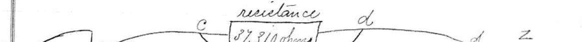
Eddie Wilson sang or talked into A in the attic of Mr. Williams building, and Mr. Watson and I listened at Z Fig 2. Z was entirely out of ear-shot of A. A Rheostat was placed at R_1 and the full resistance 8105 ohms introduced into the circuit. The sounds proceeding from Z came perfectly plain and the articulation as distinct as upon a short circuit; but slightly fainter.

4. A second Rheostat similar to the first was introduced into R_1 so that the total resistance at R_1 was 16210 ohms. The sounds at Z were not sensibly diminished in intensity. No sound was audible from M when the armature (?) Z was removed.

5. A third Rheostat (the largest in the store containing a total resistance of 21,100 ohms) was introduced into the circuit, so that the total resistance interposed at R_1 was 37,310 ohms.

The sounds proceeding from Z were perfectly plain and were very slightly diminished in intensity. The difference in intensity however was very marked when the cut-off (a b) was used. No sound was audible when the cut-off (b c) was employed. (See Fig 2.)

(Fig 3.)



Total resistance of circuit equals 40.760 ohms.

6. No further resistance being obtainable it was decided to reduce the battery power.

The battery was reduced from 10 cells to 1 cell and still sounds were audible from Z (Fig 2.), very slightly fainter than when 10 cells were employed.

7. Upon removing the battery altogether as in Fig 3, sounds were still perfectly audible from Z — No sounds were audible from M. when

(a.) The armature Z was removed;

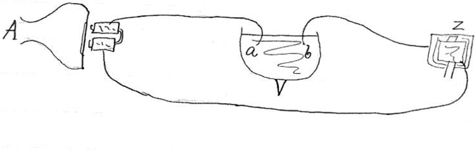
(b.) When the circuit was broken;

(c) or when the cut-off (a b) was employed.

The sounds were much louder when the cut-off (c d) was used so as to cut out the resistance.

All these facts convinced me and Mr. Watson that the sounds audible at Z were electrically produced, and were not merely mechanically conducted along the wire. And yet it seems almost too marvellous for belief that the vibration of a little piece of thin iron S. weighing only a few grains, should induce electrical undulations upon a circuit of 40,760 ohms resistance (a greater resistance than from here to England,) so as to have the vibration reproduced at Z. After such an experiment as the above I feel confident that we shall be able to transmit vocal sounds through the cable and this too without a battery!

(Fig 4.)



8. In order to be perfectly sure that a considerable resistance had been introduced into the circuit, it was determined to introduce water into the circuit in place of the rheostat.

The arrangement is shown in Fig 4.

The sounds uttered into A were clearly audible from Z, when the wires a and b just touched the water in the vessel V.

No sound was audible from Z when either of the wires a. b was removed from the water

The sounds audible at Z became sudenly louder when the wires a. and b. were allowed to touch one another.

9. The vessel of water V (Fig 4.) was next removed and the circuit completed by the means of the human body. Mr. Watson took the wire d, in one hand, while I listened at Z (Fig 5.) Nothing was audible at Z so long as the circuit was incomplete, but the moment Mr. Watson completed the circuit, by touching the wire b, I heard (at Z) the sounds that were uttered into A, by Eddie Wilson.

Fig 5.

No sensation whatever was experienced by Mr. Watson; while the induced currents were thus passing through Mr. Watson's body, I distinctly heard the following sentence proceed from Z "Can you hear anything or nothing?"

Noted by A. G. B. July 9th 1876.

Sunday July 9th 1876.

1. I met Mr. Downs at the Pacific and Atlantic Telegraph Company's office in the Equitable Building about six o'clock this morning. The telephonic organ was connected with the main line to New York, and the New York operator was signaled to place his ear to his relay, and let us know if he heard anything.

I then played "Yankee Doodle" and "Auld Lang Syne", and a few chords upon the organ. Presently came a message from the New York operator that he had heard the music "elegantly". He was then asked if he had recognized any of the airs. He replied laconically "Yankee Doodle.

2. The experiment with the telephones (as described in (par. 1. page 20.) (page 19.) was repeated with success.

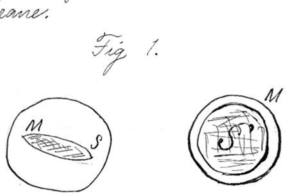
The battery was then removed from the circuit, It was unfortunate that the instruments T and R_1 as shown in (Fig 1 page 21) (page 20) were not out of ear-shot of one another, so that I can not say decidedly that the sounds uttered into A (Fig 1 page 21) (page 20) were audible at Z; but I think and believe they were. The experiment is to be repeated on Wednesday night at half-past ten when the instruments will be placed entirely out of ear-shot of one-another.

Noted by A. G. B. July 9th 1876.

Tuesday July 11th 1876.

Tried improved apparatus at Williams' to-day with great success. Tried varying the shape of the armature attached to the membrane.

Fig 1.



S. is the armature with which I have hitherto experimented. It was attached to the membrane M. S' is the new armature consisting of a disk of thin tagger's iron almost as large as the membrane M' to which it was attached.

Two instruments were arranged one with the armature S the other with the armature S' and the audible effects compared.

They were alternately arranged upon circuit with the receiver M in the basement. Ten cells of a carbon battery were employed, and artificial resistance

R_1, to the amount of 16.210 ohms introduced into the circuit. When the instrument having the armature S' (Fig 1 page 27)(page 26) was used the sounds proceeding from Z (Fig 2 page 22.)(page 21) was used the sounds proceeding from Z were immensely louder than when the instrument with the armature S was employed.

2. When the armature S' was used conversation in an ordinary tone of voice was perfectly audible at the receiving instrument.

Indeed the softer the initial articulation, the more distinct was the utterance at the other end of the line.

When the initial utterance was loud the final articulation was also loud, but indistinct, and when the voice at the transmitting end was raised scarcely above a whisper, the sounds at the re-receiving end were very faint but perfectly distinct.

The total resistance of circuit was 19,660 ohms.

Noted by A. G. B. July 12th 1876.

Wednesday morning July 12th 1876.
(Thoughts.)

1. Try the effect (a) of varying the size of the armature attached to the membrane.

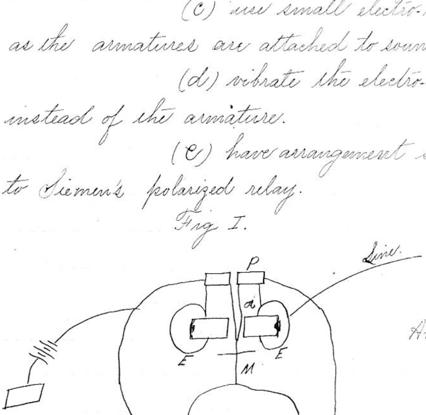
(b) vary the mass use thick pieces of iron attached to a sounding board.

(c) use small electro-magnets as the armatures are attached to sounding-board

(d) vibrate the electro-magnet instead of the armature.

(e) have arrangement similar to Siemen's polarized relay.

Fig I.



Hused.

P. permanent magnet. a. armature attached to membrane. M. E. E. electro-magnet.
d. d. double ear-trumpets.

Side view of armature and membran

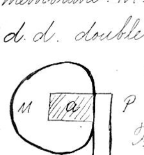
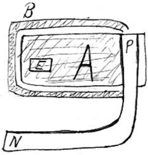


Fig 2.

P. N. Permanent magnet.
M. Membrane.
a. Armature.

Fig. 3.

Side view of proposed armature without membran[e]

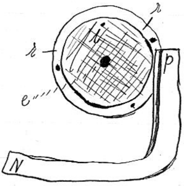


P. N. Permanent magnet.
A. Armature arranged in a bed (B) similar to a free reed.
E. One of the poles of the electro-magnet employed.

Fig. 4.

Another form of polarized armature without any membrane.

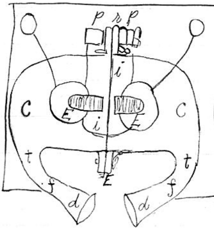
Side view.



i. Tagger's iron.
r. rim of soft iron.
P. N. Permanent magnet.
e. Pole of electro-magnet.

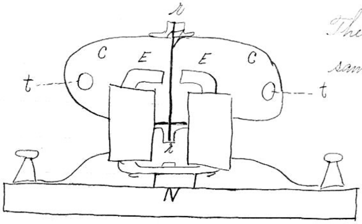
Fig. 5.

Plan of instrument shown in Fig 6.



PP. Pole of permanent magnet.
r. soft iron rim.
i. Tagger's iron.
E. Poles of electro-magnet.
C. Metalic casing enclosing the whole instrument.
t. Metalic tubes.
f. Flexible piping.
d. double ear-trumpet.

Fig 6.



The lettering is the same as Figs 4.5.6.

Noted by. A. G. B. July 12th 1876.

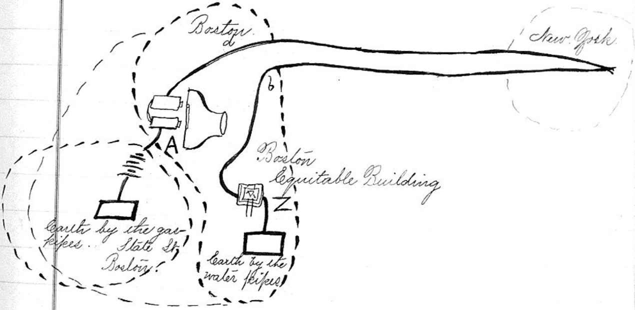
Wednesday evening July 12th 1876.

1. Sir. William Thomson was at Harvard University today and enquired for me. Prof. Peirce came with a carriage for me. Met Profs. Lovering, Peirce, Sylvester and Sir William. Sir William expressed a wish to see my experiment this evening.

Agreed to meet him at 10-30 p.m. at the Equitable Building. He expressed the feeling that the experiments noted in pages 21.22.23.24.25 (20.21.22.23.24.) were inconclusive. That there was no proof that the current had passed through the high resistance, for it might have taken the part of the earth in a real line and a current have been formed only on the short part of the circuit (see Fig 2. page 20.) (page 19.)

In Fig I page 21. (page 20.) since the receiving instrument was not at Rye Beach.

there was no proof that a current was formed on the line, as the line itself might have taken the part of the earth. He stated that the only way to be <u>certain</u> was to have the transmitter and receiver at the two ends of the circuit, although satisfactory results might be obtained by arranging the instruments as in Fig I (page 32) (page 31)



2. The lines of the Pacific and Atlantic Tel. Co. were injured by the storm last night, so that only four wires were in operation between New York and Boston.

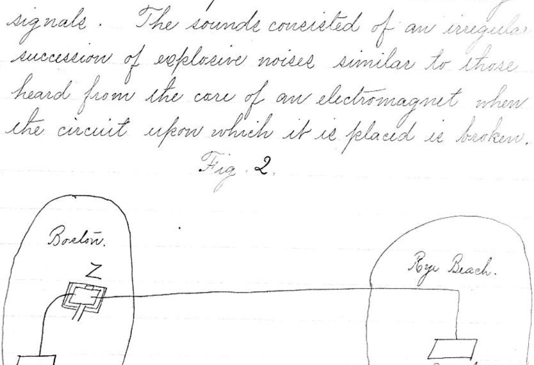
Two wires were crossed at N. Y. and the circuit completed as in the diagram.

The battery and gas-pipe earth were in State St. Boston; and the instruments and water-pipe earth in the Equitable Building.

Upon listening at Z a strange crackling noise was heard, but no trace of vocal sounds. Sir William thought this was due to operating on adjoining lines, or to lightening, or to leakage to the earth at intermediate points. The effect was quite new to him and to me.

2. The instrument Z was arranged upon the line to Rye Beach without any battery on the circuit as in Fig 2. (page 33)(page 32) and still these strange sounds were perceived. There was no other wire on the same posts with this wire. Another line came to Boston from Rye Beach, by a different route. The two wires made the same earth at Rye Beach, and the other wire was being used at the time, for some cable despatches. The sounds however were not suggestive of dots and dashes at all, and the operator who listened was quite unable to read any signals. The sounds consisted of an irregular succession of explosive noises similar to those heard from the core of an electromagnet when the circuit upon which it is placed is broken.

Fig. 2.



3. The telephonic organ was substituted for the telephone A (Fig I) The sounds were clearly audible from Z.

4. We telegraphed to N. Y. to have the operator pass the current through his relay. He did so but could not perceive any sound.

5. We told him to disconnect his wires and leave them free in air. He did so and still musical sounds proceeded from Z (Fig I)

This showed conclusively that there was some short circuiting of the current, leakage from one wire to the other by the posts probably.

6. While the wires were disconnected at N. Y. and the organ taken out of the broken circuit, the crackling sounds alluded to above were heard proceeding from Z

7. Connections as in Fig I (page 32) (page 31.) no vocal sounds heard from Z.

Current short-circuited by stretching a wire from <u>a</u>. to <u>b</u>. vocal sounds were clearly audible from Z.

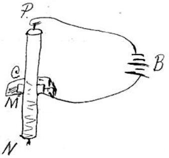
The Telephones (Transmitter and Receiver.) with which we have experimented have been presented to Sir William Thomson, as I have difficulties.

Noted by. A. G. B. July 17th 1876.

Thursday July 13th 1876

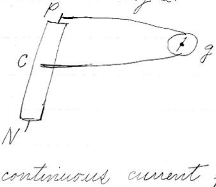
1. Tried an apparatus I had constructed a long time ago by Williams, but which had produced no effect. It has been long known that when a current of electricity is passed

Fig I.



through a permanent magnet from one pole P. to the centre c. or vice-versa - that the permanent-magnet (P.C.N.) revolves upon its own axis, and that the direction of the rotation depends upon the voltaic current. Why then (it occurred to me many months ago should not the converse be true.

Fig 2.



If a continuous current passes along the circuit P. and C (Fig 2.) causes rotation in P.C.N. why should not the rotation of P.C.N cause a continuous current upon the circuit P. and C. and deflect a galvanometer needle g. In former experiments the magnet had been moved by hand but today it was rotated by steam power. No deflection of the galvanometer was observed. The galvanometer was an upright one. The needle was weighted at one end and a permanent magnet was placed below in order to keep the needle in position.

The steel of which the magnet P.C.N. was made was very poor, and it was not well magnetized. Have ordered another instrument to be made.

Noted by. A. G. B. July 17th 1876.

Friday July 14th 1876.

1. Repeated experiments with telephones and high resistance, making connections as in Fig 1 (page 37.) (page 36.) Sounds audible from Z that were uttered into A.

2. Resistance was placed in the circuit by passing the current through plain water at W. and W' (Fig 2.) sounds uttered into A. audible from Z.

3. Sounds uttered into A (Fig 2.) faintly audible from Z, when the battery was removed from the circuit.

Noted by A. G. B. July 17th 1876.

Fig 1.

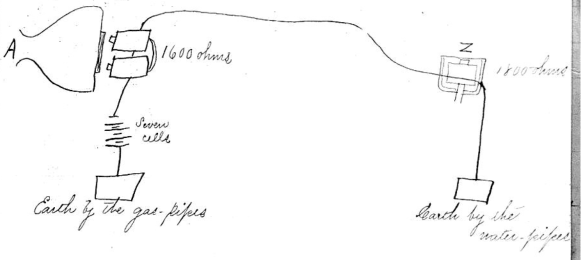
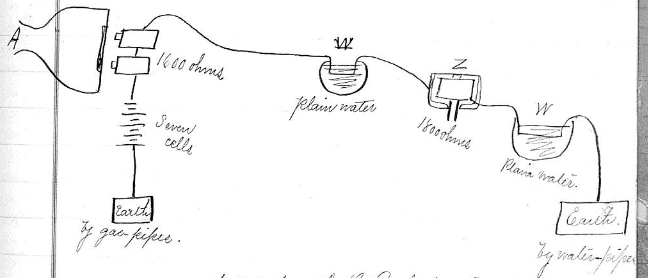


Fig 2.



Noted by A. G. B. July 17th 1876.

Saturday July 15th 1876.

1. Williams completed permanent magnet as shown in Fig 2. (page 35) (page 34.)

Upon testing it with the same galvanometer as that mentioned (page 35) (page 34.) no deflection of the needle was obtained.

Upon examining the magnet I found it was cracked down on one side which of course would prevent the circulation of currents.

Ordered another to be made.

Noted by A. G. B. July 17th 1876.

Monday July 17th 1876.

1. Permanent magnet (See Fig. 2. page 35.) (page 34.) completed. Upon rotating it no deflection of needle resulted when the galvanometer mentioned in page 35. (page 34.) was used.

2. Upon using a delicate astatic needle as in Fig. I. page 39. (page 37.) a deflection of 75° was at once obtained when P.C.N. was rotated. The needle swung between 30° and 75° gradually coming almost to rest at 55°.

3. Connections made as in Fig. 2. page 39. (page 37.) galvanometer needle (g.) flew up to its stop at 90°.

Fig. I.

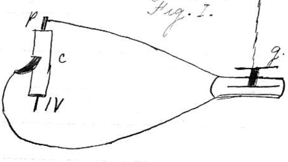


Fig. 2.

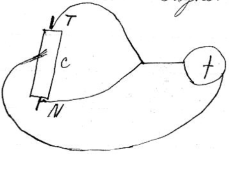


Fig. 3.

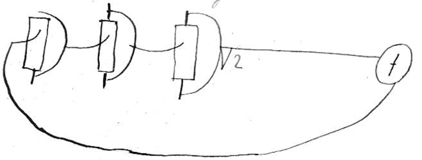
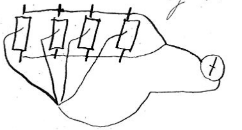


Fig. 4.



4. Figs. 3 and 4. show batteries of permanent magnets. Fig. 3. shows the arrangement for intensity and Fig. 4. for quantity.

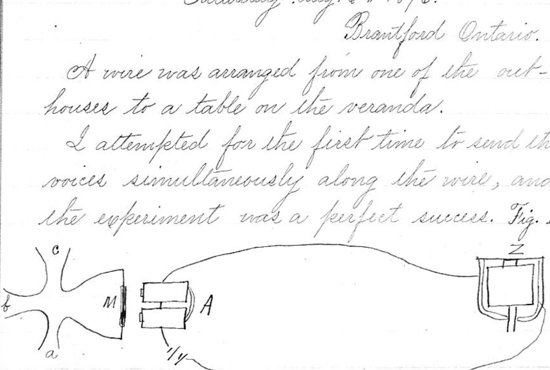
Noted by. A. G. B. July. 17th 1876.

Saturday. Aug. 6th 1876.

Brantford Ontario.

A wire was arranged from one of the out-houses to a table on the veranda.

I attempted for the first time to send three voices simultaneously along the wire, and the experiment was a perfect success. Fig. I



Extracts from Mr. Bells Note-book.

Mr. Watson favored the protrusion of the wire w.
3. beyond the extremity of the armature A, as the resistance of the air to the motion of w, would cause it to make better contact with B; and I suggested expanding the point w into a fan like shape, by means of paper or wood so as to better catch the air. This seems to me a very valuable idea.

4. A piece of paper P (Fig 3), was attached to the extremity of the wire w. w.' connections being arranged as in Fig 2.

Fig. 3.

The vibrations of A (Fig. 3.) at once became intense. This was by far the most satisfactory experiment yet made. Upon clipping down the paper P. ~~became greater~~ the amplitude of the vibrations of A and of P became greater until a maximum was reached. Farther clipping diminished the amplitude.

Three mouth pieces a. b. and c. were arranged so as to direct the voices of three persons upon the single membrane. M. Mary, Francis and I then sang the three parts of some Bishop's glees into the mouth pieces a. b. and c. and the sounds were perfectly audible at Z. The experiment is a very important one for it shows that with the undulatary current a single transmitting instrument A, will suffice for any number of simultaneous messages, while with the intermittent current there be a distinct instruments for each message sent, and in addition there must be special instruments for inducing the current upon the line in order that communication may be established in both directions.

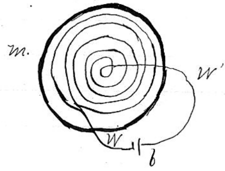
The more I think of it, the more I see that the undulatory current is the thing.

But one thing more is wanted and that is to find a way of strengthening the sound at Z.

I am gradually making out the details in my mind. I am convinced now that the undulatary current will travel to any distance and that there will be no difficulty in working it with instruments that will be ludicrously simple in construction.

I have received a letter from Prof. Gage. on the subject of Telephony, in which he suggests a method of increasing the amplitude of electrical undulations in a manner that had already occurred to me in a somewhat different form. He suggests placing a light spiral of insulated copper wire upon the membrane in Fig. I. in place of the steel spring. see Fig. II.

Fig. II.



m. is the membrane and w. w' the wire coiled upon it, and b. a small battery for passing a current through w. w'. The wire w. w' can be vibrated in front of A. Fig. I instead of the steel-spring and the stronger the battery power b. Fig. 2. the greater the audible effect at Z Fig. 1.

I think the idea a very valuable one

Noted by. A. G. B. Aug. 5th.
Copied by. M. G. H. Aug. 10th. 1876.

Brantford Ontario.

August. 10th 1876:

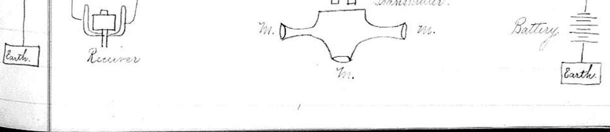
The experiments last night were very satisfactory, as demonstrating the power of the undulatory current to travel any distance. At the same time the experiments show certain difficulties we shall have to contend with in disturbances upon the line itself.

The atmosphere seems to be in a curious electrical condition, affecting the making of the lines.

The moment I put my receiving instrument to my ear, I hear perfectly deafening noises proceeding from the instrument even when there was no battery on the circuit. Explosive sounds like the discharge of distant artillery, were mixed up with a continuous crackling noise of an indescribable character. In spite of these disturbing inferences I could hear vocal sounds in a far away sort of a manner, and when there was singing the air was distinctly manifest.

Fig. 1.

Paris (distance 8 miles) Brantford (distance 60 miles) Toronto.



The battery in use was in Toronto sixty-eight miles from Paris. Transmitting Instruments was in Brantford, and the Receiver in Paris eight-miles distante.

Our first experiment was with "low resistance coils." on our instruments, and, as I said, the vocal sounds were very faintly audible in Paris the crackling noise being very loud indeed.

I telegraphed to Brantford (by another line) telling the operator to change the electro magnet upon his instruments so as to place on a "high-resistance" coil. At the same time I made a similar change in Paris. The vocal sounds then came out clearly and strongly, and the crackling noises were not nearly so annoying though they still persisted.

Various songs were sung in Brantford all of them being recognized at once in Paris, and I even recognized the singers by their voices.

The operators were Mr. Griffin, Mr David C. Bell and my cousin Miss Lily Bell. My father had made some engagement, so he told me he could not be present, and yet one of the voices I heard was so like my fathers that I telegraphed to inquire the name of the singer, and it was my father after all.

Words and sentences uttered in Brantford in an ordinary conversational key with the voice scarcely raised above a whisper were audible in Paris, but the articulation was in most cases unintelligible. I recognized at once "To be or not to be: that is the question" &c and "Do you understand that" but sentences with which I was not familiar were not understood.

The words of the songs were all intelligible to me, as I happened to be acquainted with them, with the exception of one "Maggie May" was sung by Mr Griffin and other voices joined in the chorus, I could hear the combination of voices as distinctly as the single voice.

Noted at Brantford Ontario by
A. Graham Bell. Aug 11th 1876
Copied by M. G. H. at Boston. Aug 15th 1876

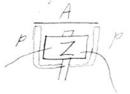
Tuesday Sept. 12th 1876.

1. Recommenced experiments with Mr. Watson yesterday. we are to devote a portion of every day to the perfection of instruments to work with intermittent currents. Object being to transmit two messages simultaneously on the same wire from different stations. Experimented today with intermittent current. Nothing new to be noted.

2. Experiments with undulatory current. I discovered to-day that the vocal sounds audible

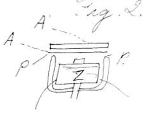
from the Receiver Z. are intensified to a great degree when the armature A. is not allowed to touch the poles. P.P. but is held about a millimeter from them.

Fig. 1.



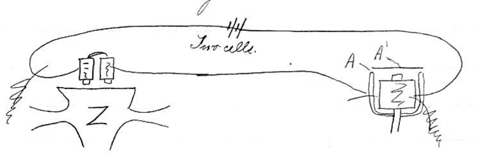
3. Mr. Watson discovered that the sounds were similarly intensified when a second A was laid upon the first A. which latter was in contact with P.P. as before.

Fig. 2.



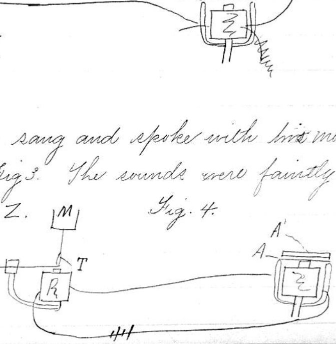
4. The sounds were clearly audible when a pile of armatures A'. A^2. A^3 &c were laid on the first armature A. The maximum loudness was obtained with only two armatures as in Fig. 2.

Fig. 3.



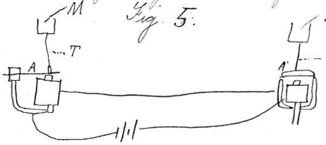
5. Mr. Watson sang and spoke with his mouth close to A' Fig 3. The sounds were faintly audible from Z.

Fig. 4.



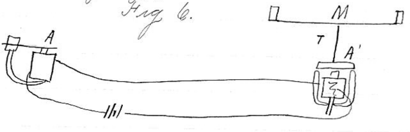
6. The membrane M. Fig 4. of an ordinary "Thread Telegraph" was connected by a thread T. with the spring of one of my Receivers R. Upon singing and speaking into M. the sounds were faintly audible from A'

Fig. 5.



7. Membrane M. and M'. (Fig 5.) were fastened by threads T T' to the armatures A A'. Upon singing into M the sounds were faintly audible from M'; and upon singing into M' the sounds were faintly audible from M.

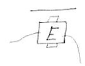
Fig 6.



8. The armature A' (Fig 6.) was fastened by a thread T to the centre of the membrane M. of a tambroine. The diameter of the membrane M. was about 10 or 12 inches. Upon plucking the armature A a sound was audible from M when it was held away at arms length. This is the loudest sound yet heard with the undulatory current.

9. Experiments were continued using the same instrument A (Fig 6.) as transmitter but varying the receiver. The armature A (Fig 7.) was held in front of single pole, electro-magnet E. Plucking plainly audible, when A was made of steel or iron.

Fig. 7.

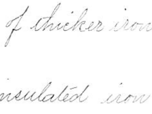


Sound very faintly audible when of thicker iron than could be called "sheet iron."

10. Empty helix H (Fig 8.) of insulated iron wire was laid on Receiver R_1.

Sound plainly audible from H.

Fig 8.



11. The sound was increased by placing a wrought iron nail inside the helix.

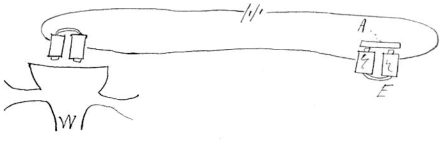
12. No difference observable when a single cell of battery was connected with the wires (a and b.)

The helix H was made of No 38 (B) wire and neccessarily had a high resistance. The experiment should be repeated using a stronger battery on the circuit a. H. b.

13. A flat spiral S (Fig 9.) of insulated copper wire was used as an armature for the receiver R_1. Upon placing the ear closely against S a faint sound was audible which was not intensified by crossing a.b. or by connecting them with the poles of a battery.

Fig 9.

Fig 10.

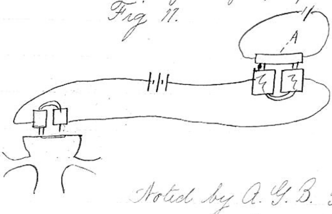


14. An ordinary electro-magnet E (Fig 10) had closely applied to its poles an armature A. When Mr. Watson sang into (W) his voice was audible (faintly) from A even when the armature A consisted of a piece of iron a quarter of an inch thick. This looks as if the vibration which is audible is a molecular movement, and not a vibration of the armature as a whole.

Thoughts.

15. If the sound audible from A (Fig 10) is the result of molecular disturbance the amplitude of the molecular vibrations may probably be increased by passing a current through the armature, as in de la Rive's experiment. See Fig 11. for proposed experiment.

Fig 11.



Noted by A. G. B. Tuesday night
Sept 12th 1876.

be made of much stiffer springs. It seems to us also that the larger and stiffer the vibratory armatures of both Transmitter and Receiver can be made, the less likely will it be that their pitch should be changed. The rigid contact points of the old Transmitter will evidently not do for heavy armature. We propose to make a transmitter like that shown in Fig 2.

The fixed point P. makes and breaks contact with a spring S. attached to the armature A. This make and break is for the local circuit. The contact point P. makes and breaks contact with a spring S. which is insulated from the armature A. this make and break operates for the main circuit and is entirely independent of the local circuit.

Fig.

Fig 2.

Noted by A. G. B. Sept 14th 1876.

T. A. W.

Thursday Sept. 14th 1876.

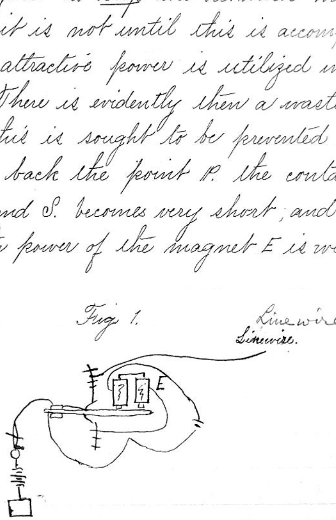
1. Instead of having the instrument shown in (Fig 2.) constructed to-day. Mr. Watson and I have been discussing various improvements suggested in the instrument. We have also visited

the Institute of Technology for the purpose of studying closely the apparatus invented by Helmholtz. In all the forms of instruments we have used or seen employed by others, there is one defect which seems to us to weaken the vibrations of the armature of the transmitting instrument, and that is that the power of the electro-magnet is always opposed to the normal vibration of the armature.

For instance the spring S. comes in contact with the point P. (See Fig 2 page above 51)(page 48.) where the armature A is normally moving away from the electro-magnet E; but it is just at this moment that the magnet is used at first to stop the outward motion of A, and it is not until this is accomplished, that the attractive power is utilized in moving A. There is evidently then a waste of power. If this is sought to be prevented by screwing back the point P. the contact between P and S. becomes very short; and thus again the power of the magnet E is weakened.

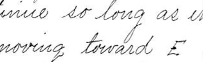
Fig 1.

Line wire
Linewire.



2. If it could be so arranged that the contact between S. and P. should not take place until the armature A. has made its full excursion from the magnet E, and is just about to swing back; and that the contact should continue so long as the armature A is normally moving toward E: we should then have the attraction of the magnet co-operating with the normal motion of the armature which would then be kept in uniform vibration

3. Why should not the principle of the vibratory circuit-breaker come in to play? Let the armature strike a body of <u>slower vibration</u> than itself. Fig 2.



Let a notch be cut in the extremity of the armature A large enough to allow the end of a light spring S to fit loosely into it. One side m, makes metalic contact with S. but the other side i, is insulated. Let S have normally a much slower rate of vibration than A. Then upon plucking A so as to set it in vibration, we should find that its vibration continues, and the following should be the mode of its action.

As A advances towards E the point m. strikes S. and carries it with it.

As the normal rate of vibration of S is slower than that of A, S tends to lag behind and therefore presses firmly against m. all the time the armature A moves rapidly towards E. The magnet E is thus excited during the approach of A assisting the motion. But as A nears the limit of its excursion it begins to move slowly and the spring S. having acquired impetus from m. as it flies over to i breaking the circuit. The armature A. then swings back, during its rapid motion from E the spring S (having a slower rate of vibration than the armature A) tends to lag behind, and then remains against the insulated point i until the armature A is nearly ready to swing back, when it again flies over to m. reclosing the circuit.

Fig. 3.

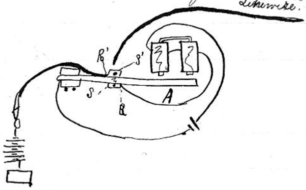
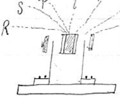


Fig. 4.

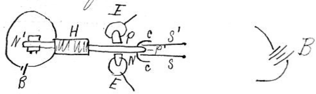


4. Figs 3 and 4. show an arrangement for local and main circuit R_1 and R_1' are rings or rather bridges of metal for the springs S and S' to make contact with. The iron i, of the armature A is insulated on both sides by means of

pieces of paper P. P'. Experiment will show the best part of the armature to which to attach the circuit breakers.

Print 5. Another idea. Use polarized armatures and utilize the repulsive power of the magnet.

Fig 5.



Place the armature A inside a helix H which is excited by a local battery B. The armature A then becomes magnetic and its poles are P'and N'. Now if it can be so arranged let the electro-magnet EE, after the current from a local battery B' has passed through it, so as to the poles P.and N, when the spring S' touches the contact wire c', and the opposite when S touches c.

The action of the apparatus would then be as follows. Pluck the spring N'P. so as to set it vibrating. Let S' touch C' then the pole P' would be attracted by N and repelled by P. When P. has nearly reached the limit of its oscillation towards N, the springs S and S' fly over against c and P respectively, and the poles P and N are suddenly reversed, N. therefore repels P' and P attracts it.

Query would the vibration of A occasion an undulatory current in the coils of the helix H.

The current passing through the electro-magnet EE would be an intermittent and reversed current with the breaks of the circuit so short as almost to constitute it a pulsatory and reversed current.

Fig 6.

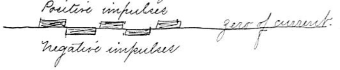


Fig 6. shows a graphical representation of the current.

6. It seems to me that for practical purposes it is unnecessary to use such a complicated arrangement as that shown in Fig. 5. (page 53) Such an arrangement is interesting as affording a theoretically perfect vibration, still for practical purposes I doubt whether it offers any greater advantages than that shown in Figs 2. 3. 4. 5.

If Mr Watson approves of the idea I shall have an instrument constructed to-morrow like that shown in Fig 6.

Fig 6.

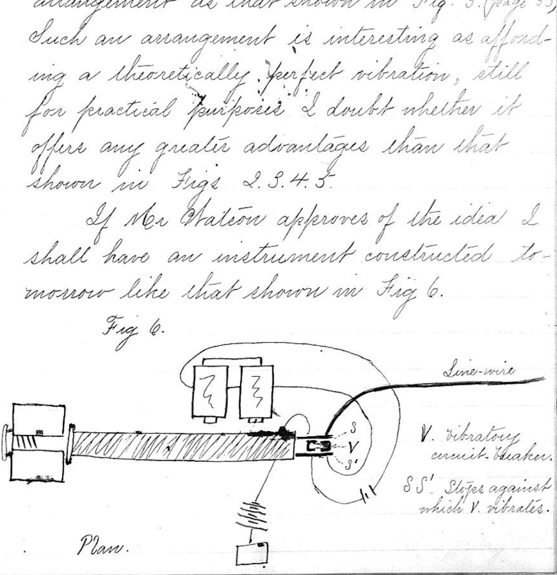
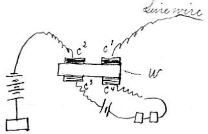
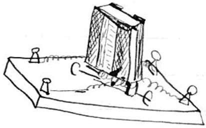


Fig 7.



Vibratory current-breaker.
W. thin piece of wood
$c^1. c^2. c^3. c^4.$ - pieces of copper or
platinum foil.
Plan of V. C. B.

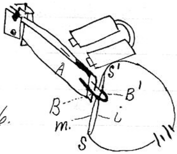
Fig. 8.
Elevation of V. C. B.



Noted by. A. G. B. Sept 14th 1876

T. A. W.

Fig 1.



Friday Sept. 15th 1876.

1. Experiment tried this evening with promising success. To the armature A was soldered a bridge B. B' of copper wire. A german silver spring S. S' was introduced into the space between the wires B and B'. One side of the spring S. S' was covered with paper so as to be insulated, and the other side m. presented a metalic surface to the wire B. Upon plucking the armature A it was thrown into continuous vibration, and the spring S. S'

partook of the motion.

Mr Watson had occupied the greater part of the afternoon, in the construction of the instrument, and I visited the South Boston Blind Asylum, with Mr. Kinsey dining with him afterwards so that it was quite late before we could try the instrument. The result seemed promising although our first attempt was a failure.

Mr Watson had constructed a rocker like that shown in Fig 8 (page 55) (page 55), but it was so large and heavy, that it could not be moved by the armature. A light german-silver spring however as in Fig 1 (page 56) (page 55) gave evidence of vibration, but it was difficult to adjust the spring. It seemed to alter the pitch of the armature, when it was adjusted a mere hair's breadth. The best effect was obtained with the end S' projecting about a half an inch above B B.

Noted by A. G. B. Sept. 18th 1876.

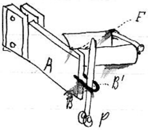
Saturday Sept. 16th 1876.

1. Experiments with apparatus described on preceding page, continued this afternoon.

Springs of german silver of various sizes were employed, and the distance between the wires B and B' varied. It was found that the best vibrations were obtained when the space B. B' was reduced to a slit just wide enough to admit the spring S. S'. without touching both wires B. B'.

When the slit was reduced to a minimum it was found that strong vibrations were caused in A when springs of all shapes and sizes were introduced, even a simple piece of copper wire used in place of S. S' proving sufficient to restrain the vibrations. In these cases the wire B' was insulated by means of a piece of paper so that the spring S. S' should not come into metalic contact with it. By sliding the spring or wire S. S'. upwards or downwards it was found that there was a point in each spring where the maximum effect was produced.

Fig 2.



2. A german silver spring F. P. was suspended so as to form a pendulum, and an iron nut was fastened to the extremity of F. P. so as to give the pendulum a slow rate of vibration, or oscillation, It was found that in this case the pendulum F. P. controlled the motions of A instead of vice-versa as before. It is evident that there is a struggle between the

vibrator A and the vibrator F. P. and which one of the two possesses greater inertia will control the movements. In the case shown in Fig 2. it was found that the motion of F. P. was very rapid (to the eye) when the wires B. B.' struck it at a point near P. The oscillations of F. P. became slower as the wires B. B.' struck the pendulum further and further away from the weighted extremity P.

Thoughts.

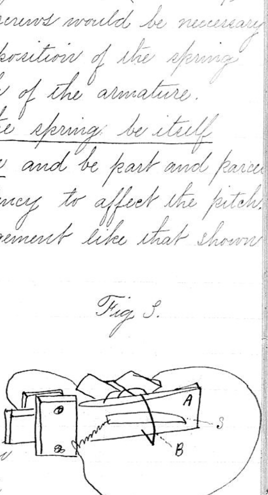
3. One objection to the use of spring &c. like those shown on pages 56-57. (55 and 57) is, that adjustment screws would be necessary so as to regulate the position of the spring as it affects the pitch of the armature.

Why should not the spring be itself carried by the armature and be part and parcel thus avoiding any tendency to affect the pitch.

We shall try arrangement like that shown in Fig 3.

A (the armature) has the whole of one side covered with an insulating material so that there is no metallic communication between S and A until the spring S. comes into contact with the copper-bridge B.

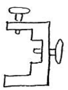
Fig 3.



spring S. S' was also thrown into strong vibrations. This shows that the idea will work.

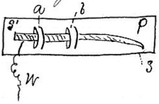
We propose having an instrument constructed like that shown in Fig 7 (page 61) (page) after having experimented with Helmholtz' tuning forks in the manner shown in Fig 6 (page 61) (page 61) so as to discover the best arrangement of springs.

2 We have obtained the loan of one of the large tuning-forks used in Helmholtz experiments and propose fixing an adjustable clamp upon the prongs like that shown in Fig 2.



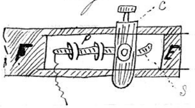
A piece of pasteboard like that shown in Fig. 3. is to be clamped on to the prong as shown in Figs 4 and 5.

Fig. 3.



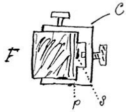
P. pasteboard.
S. S'. german silver spring adjustable through the loops a. b.
W. conducting wire.

Fig 4.



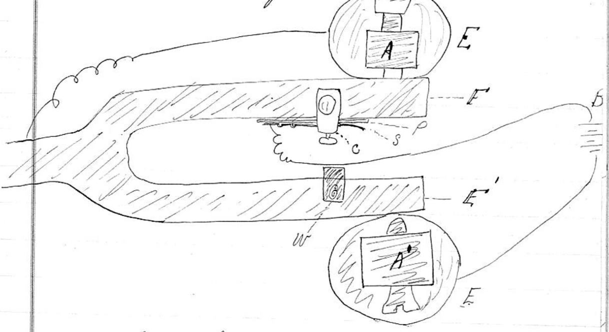
F. prong of Tuning fork
P. paste board. } shown in Fig. 3.
S. spring - }
C. clamp shown in Fig 2.

Fig 5.



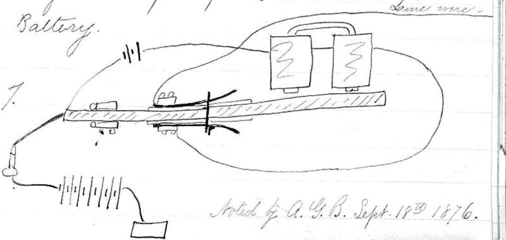
F. prong or fork.
C. clamp shown in Figs 2 & 4.
P. paper. }
S. spring } shown in Figs 3 & 4.

Fig 6.



C. clamp shown in Figs 2. 3. 4. & 5.
P. paper. }
S. Spring. } Shown in Figs 3. 4. & 5.
F. F'. prongs of fork.
W. weight as a counter poise to clamp C.
E E' coils of Electro-magnet.
A A' Adjustable pole-pieces.
B. Battery.

Fig 7.

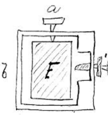


Noted by A. G. B. Sept. 18th 1876.

Tuesday. Sept. 19th 1876.

1. Mr. Watson made a clamp like that shown in Fig 1. this morning; but we have been unable to experiment with it as yet.

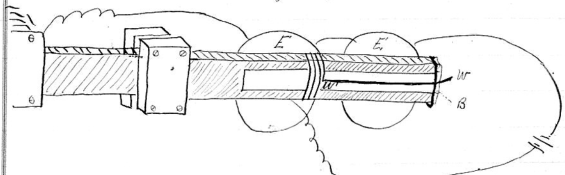
Fig 1.



It is too broad however for the fork F as the side b. does not nearly touch the side of the fork F. we are convinced also that the screw a. should have been inserted in the side b. Mr. Watson is to alter this.

2. Experiments renewed with spring armature A. Fig 2. A bridge of copper wire B was soldered to the extremity of the armature A. and a slip of paper P. was pasted over the armature so as to insulate the surface. A copper wire w.w'. was adjusted so that the naked extremity of the wire passed beneath the bridge. B.

Fig 2.



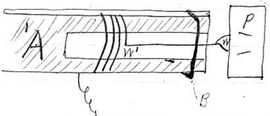
The other wire was secured in place by coiling the insulated part of the wire, three or four times round the armature at w'. Upon plucking A. it was kept in continuous vibration by the intermittent contacts of w and B.

2. Upon sliding the coils of wire w' forwards on the armature so as to cause it to make the end w to protrude, a much better vibration was occasioned.

3. Mr. Watson favored the protrusion of the wire w. beyond the extremity of the armature A as the resistance of the air to the motion of w would cause it to make better contact with B; and I suggested expanding the point w into a fan like shape, by means of paper or wood so as to better catch the air. This seems to me a very valuable idea.

4. A piece of paper P. (Fig 3.) was attached to the extremity of the wire w. w'. connections being arranged

Fig. 3.



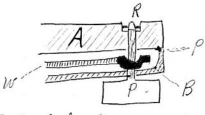
as in Fig. 2. The vibrations of A (Fig. 3.) at once became intense. This was by far the most satisfactory experiment yet made. Upon clipping down the paper P the amplitude of the vibrations of A and of P became greater until a maximum was reached. Farther clipping diminished the amplitude.

Thoughts.

5. This plan of Mr. Watson's seems to me to be an excellent way of making the vibrations of w. w' slow without increasing either the weight of the wire w. w' or making it longer. If the inertia alone of the wire w. w' is to be utilized, we must either make it very heavy, in which case of course its position must and will require determination as it will affect the pitch of the armature; or we must make it very long and slender, in which case it would be delicate and liable to get out of order. By utilizing the resistance of the air, we can make the wire or spring w w' thick enough to stand wear and tear; and as stout as we please, so long as we have a good surface exposed to the air, the instrument should work. Of course however the proper extent of surface to be exposed must be determined by the resistance offered by the air to the motion of P. will also affect the motion of A and hence affect the pitch.

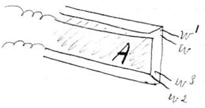
5. Forms of apparatus shown in Figs have suggested themselves to me.

Fig 4.



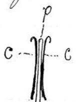
R.P. Rocker of copper pivoted at R into the armature A. Bridge B. insulated from A by P.' W. wire connecting B with battery.

Fig 5.



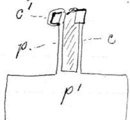
The copper wires w' w2 w3 w are insulated from the armature A, and from one another

Fig. 6.



P.P'. paper.
C.C. copper slips.

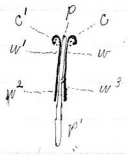
Fig. 7.



c.c'. copper slips.
P.p' paper.

Fig 8.

Combination of parts shown in Figs 5. 6. 7.
Noted by. A. G. B.



Tuesday Sept. 19th 1876.

Go on to page 69

Omit

1. I neglected to record some suggestions concerning the transmitting of vocal sounds.

I have not obtained as satisfactory results (so far as distinctness is concerned) as those obtained by Sir William Thomson and Prof. Watson at the Philadelphia Exhibition. Upon thinking over the differences between the instruments used by him and those employed by ourselves here Mr. Watson and I have come to the conclusion that the material of the armature used may be of importance. We have been employing thin sheet iron (Tagger's Iron), which has become oxidized.

The armature of the Philadelphia Instrument is made of blue clock-spring. We tried the effect of using clock-spring last week with much better results than those obtained with the iron; but the distinctness was very slightly improved. Still we are of the opinion that it was improved, though of course there is nothing to show that this was not the result of a mere change of armatures, instead of being the result of the substitution of steel for iron.

2. It is a greater question in my mind whether the imperfect effect of the articulation may not be due to the large size of the

armature. It covers a large portion of the membrane, as it must be long enough to extend opposite both poles of the magnet.

Now one of the instruments in Philadelphia has a very small piece of clock spring (no larger than my thumb-nail) glued to the center of the membrane, so as to vibrate in front of the pole of a straight electro-magnet.

So far as I can recollect, I think that I used to obtain the most distinct sounds by using that instrument, and the loudest sounds by employing the other, consisting of the double pole magnet. I do not know which instrument was employed by Sir William Thomson. Certainly a small piece of spring fastened to the centre of the membrane would interfere far less with its vibration than a large piece extending right across.

3. Mr. Watson suggests also that the small size of the space contained in the mouth piece, has something to do with a proper vibration of the membrane. He suggests a boxlike arrangement like that in Ries' Telephone.

4. He also suggests making an attachment to a Ries' Telephone, for making and breaking the circuit upon our new principle.

He thinks that not only the pitch but the quatily of the voice would be heard at the Receiving end with an intermittent current, if the duration of the make could be made proportional to the density of the air, during the continuance of the sound. That is when there is a great condensation - long contact - a slight condensation - slight contact.

He thinks that a long contact is required to thoroughly magnetize the magnet at the Receiving end: so that changes in the duration of the successive contacts would occasion analagous changes in the strength of the successive attractions of the distant electro-magnet; so that the armature would be constrained to copy the _form_ of the original vibration, and emit a similar sound.

The idea looks feasible, though I have very strong doubts of the success of the plan, on account of the inactivity of the Receiving electro-magnet during the _breaks_ of the circuit.

It is not at all improbable however that the plan may succeed.

Noted by A. G. B.

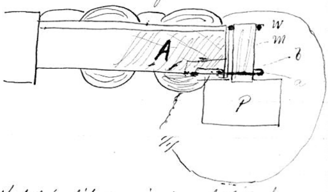
Wednesday morning Sept 20th

Wednesday Sept. 20th 1876.

1. Experiment tried this morning as illustrated in Fig 1.

A. armature.
M. metalic slip movable about the wire W.
a. b. two wires limiting the oscillation of M. a & b. are insalated from A by means of pieces of paper P' glued to the armature A.
P. piece of paper attached to M. to serve as a fan to offer resistance to the air.

Fig 1.



Metalic slip M. is insulated from wire b, by having paper pasted on the back.

The instrument worked satisfactorily. The paper however was so large that it divided into nodes while vibrating.

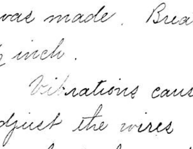
2. The paper P. was cut away until it was entirely removed, with ever increasing, and good effects. It was evident that the metalic surface M. offered sufficient resistance to the air and that all the surfface exposed below a only interfered with the contact of M. and a.

The resisting surface should be above a so that the extremity of M. may have the maximum amplitude, consistent with the vibration. ✝ (See Addendum)

3. A metalic slip M. (Fig 2) of german silver was made. Breath (a. b) 3/8 inch, length (b. c) 1/2 inch.

Vibrations caused but it was difficult to adjust the wires w w', on account of the length of the surface c. d. liable to come in contact with w.

Fig 2.



A. armature
P. paper.
w. w'. wires limiting motion of
M. metalic slip of german silver insulated from w' by paper pasted on back.

4. The metalic slip M. in Fig 2 was cut to a point P. as in Fig 3. Very forcible vibration of the armature A ensued especially when the wires w w' were brought very closely together.

No rattling sound was audible; but a pure, musical note of a very agreeable quality.

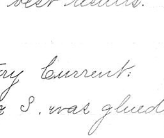
5 The best effect was produced when the wires w and w' seemed to be in actual contact with P all the time. Either the natural elasticity of the paper pasted upon the back of P. suffices to make P. make and break contact with w, or the spring of the wires w. w' attained the same end.

6. A piece of indian rubber was glued to the back of the point P. and the wires w. w' brought into actual contact with P. Very forcible vibrations were occasioned in the armature A although I think that experiments 4 and 5 gave the best results.

Omit A go on 66.72

7. Experiment with Undulatory Current. A circular piece of clock-spring S. was glued between to membranes m. m' of goldbeater's skin so as to be in the centre opposite the pole of a straight electro-magnet E – as suggested on pages 64. 65. pages Notes 1 & 2.

Fig 4.



Upon singing and talking into A the sounds audible from the Receiving Inst were fully as loud as when a large armature and double pole magnet was employed. The armature in this case was just the area of the pole of the electro-magnet in front of which it was placed (diameter 3/4 of an inch.) The articulation however was just as indistinct as before. Shall try single membrane and experiment as before suggested on page 28 (page) (Wednesday July 12th.

Noted by A. G. B.

Thursday Sept. 21st 1876.

Addendum.

Thursday Sept. 21st 1876.

1. Upon showing the record of yesterday's experiments to Mr. Watson he found exception to the deductions made from experiment 2 (page 67) (page 70.)

Viz - that all the surface P. exposed to the action of the air <u>below</u> <u>a</u> interfered with the contact of m. and a.; and that the resisting surface should be placed <u>above</u> a. to produce the best effects.

The point at issue will be seen by a glance at figs 1 and 2 page 70. (page 73)

A is the armature, to the extremity of which is attached a rod or wire of metal b movable upon an axis a. and carrying a card or other light material exposing a large surface S. to the action of the air.

The object of the arrangement is to secure a firm contact between b. and w. during the motion of A <u>from</u> the spectator, and entire absence of contact during its motion towards him.

It seems to me that the arrangement shown in Fig 2. will achieve this end much better than that shown in Fig 1. but Mr. Watson seems to think otherwise.

Noted Sept 21st 1876 by. A. G. B.

Original notes made Sept. 21st 1876. removed and copied Sept. 23d 1876

By A. G. B. and M. G. H.

Fig. 1.

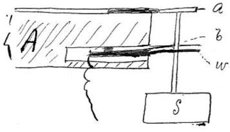


Fig. 2.

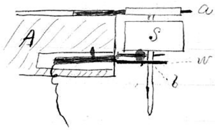


Fig. 3.

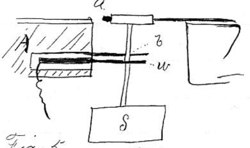


Fig. 4.

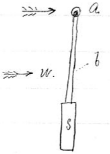


Fig. 5

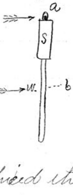
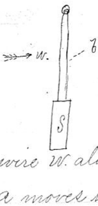


Fig. 6.



Figs. 4. 5: 6. are end views respectively of the arrangements shown in Figs. 1. 2. 3. In Figs 3 & 6. the axis a. is fixed the wire W. alone moving. In Figs 1 & 4. 2. & 5. the axis a moves in the same direction and rate as w

He thinks that when W. strikes b. Fig 1. the resistance of the air opposes the motion of S. which is placed at the end of the lever a. S. so that w. acts upon b at a mechanical disadvantage. while in Fig 2. W. acts upon b. at a mechanical advantage, hence the contact between b and w. must be firmer than in Fig. 2.

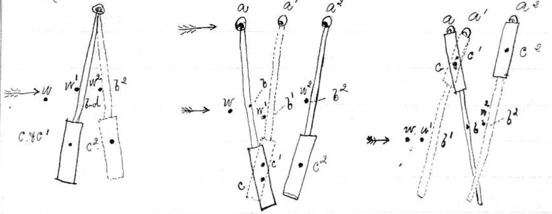
Now I would readily admit that such is the case if the point a were fixed and the point W. alone moving as in Fig 3. But it seems to me that the motion of the point of suspension a very materially alters the case. In Figs 4. and 5. end views are obtained of the instruments shown in Figs. 1 and 2. It must be remembered that not only does the wire W. advance in the direction of the arrow-head, but that the point a advances in the same direction, and at the same rate of speed. Now the motion of a tends to turn the point a around the centre of pressure c as shown in Figs. 8 and 9. and it will be observed that the motion of a to a' causes the point b. with which w. will come into contact, or collision, to move in the one case (Fig. 8.) in the same direction with w. and in the other (Fig 9.) in the opposite direction. It is evident then that when w comes into collision with b the firmness of the contact will in (Fig. 8.) be equivalent to the velocity of w. minus the velocity of b. while in (Fig. 9.) it will be. w. plus. b.

Then again there is another advantage that the arrangement in (Fig. 9) has over that in (Fig. 8.) namely in the time of contact.

We want the contact to begin at the moment the armature begins to move towards the magnet (that is, the more the point a (Figs 8 and 9.) moves in the direction a') and stop the moment it returns.

Now in (Figs 8 and 9.) we can compare the rates of motion in the two cases. The point a moves successively to a' and a^2. and in both cases the point w. moves in the same direction, and same rate of speed

Fig 7. (a.&a'.&a².) Fig. 8. Fig. 9.



Now it will be seen that in the arrangement Fig 9. the wire w will come into contact with b when a has moved a very small distance a.a'. while in that shown in Fig 8. it will not strike b until a has travelled a much greater distance. The rate of motion of the points a & a' is supposed to be the same in Figs 8 and 9. so that the contact between w and b will take place much more suddenly in Fig 9. than in Fig. 8. Indeed the more the centre of pressure c is depressed below w. the longer is the contact between w and b delayed, and if the lever a c (Fig 8.) were made very long contact between w and b. would be avoided altogether unless the amplitude of a's vibration could be made very great. Upon the other hand the longer the lever a b (Fig 9.) is made the more quickly will contact be made between w and b.

After the contact between w. and b. has been affected it becomes a question as to whether the contact between w and b. continues greater in the arrangement shown in Fig 8 or Fig 9. It seems to me as if it should continue to be greater in Fig 9. although I am by no means certain. At all events it is evident that in Fig. 8. the pressure is <u>less</u> than if the point <u>a</u> was fixed, and in Fig. 9. <u>greater</u> because the point <u>b</u> has a motion of its own due to the motion of <u>a</u>, and this motion in Fig 8. is in the same direction with that of <u>w</u>, while in Fig. 9. it is in the opposite direction. It may be however that an advantage is gained in firmness of pressure in using arrangement in Fig 9., for certainly the pressure would be <u>less</u> than that in Fig 8. if the point a were fixed. However one great advantage the <u>quickness</u> of <u>contact</u>

Noted Sept. 23d 1876.
by. A. G. B.

Thursday Sept. 21st 1876.

1. Experiments. A metal rocker <u>m</u>. <u>i</u> (Fig 1.) was attached to an axis <u>a</u> upon the armature A. <u>m</u>. made metalic contact with A. and i was insulated.

Fig. 1.

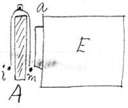
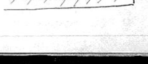


Fig 2. shows side view of said arrangement.

The armature A vibrated but with little amplitude.

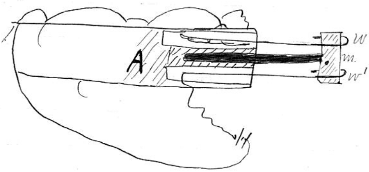
The result though unsatisfactory in some respects - shows that such an arrangement would work.

Fig. 2.



2. Mr Watson tried arrangement like that shown in Fig 3. with much better success than last, but not nearly so good as has been obtained. The metal slip M. made

Fig. 3.

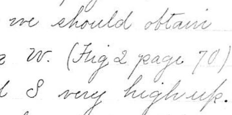


metalic connection between the two wires W & W'. Quite satisfactory vibrations were obtained.

3. If theory broached on pages 70-3 (pages 76-8) is correct we should obtain best results by placing W. (Fig 2 page 70) (page 73.) very low and S very high up.

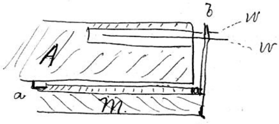
Third arrangement shown in Fig. 4. could not get satisfactory vibrations The upright u. however had a decided motion of its own.
Experiment inconclusive.

Fig 4.



4 Shall try experiment like that shown in Fig 5.
M. metal flange extending along the underside of A upon axis a. a.
T. long style vibrating between W & W'.

w is for the local circuit, and w' for the main.



Noted by A. G. B. Sept. 21st 1876.

Friday Sept 22nd 1876.

1. Spent last night in Haverhil so could not be here in time to begin early. Mr. Watson occupied time in placing room in order; and in making new connections; and in taking down and cleaning battery cells.

2. Tried experiment (No 4.) suggested yesterday.

Apparatus constructed like that in Fig 5. could not get vibrations from it at all. We both think that we have been wandering off upon a track that is unnecessary to explore and that the resistance of the air does not prove much of an auxiliary as we had anticipated. We do not think that any better or simpler arrangement can be well conceived, than that shown in Fig 7. page 61 (page

3. Repeated experiment No 7. page 68 (page 71) placing a reed-box in front of the mouth piece and talking into the reed-box. We are both inclined to believe that the sounds at receiving end were more distinct, and that perhaps the enlargement of the cavity in front of the membrane may make the sounds more distinct.
Propose borrowing one of Phonautographs from Institute of Technology.

Noted by A. G. B.
Sept 22nd 1876.

Saturday Sept. 23d 1876.

1. Experimented with Mr. Gage's apparatus. Nothing new.

2. Willie Hubbard made his appearance today, and gave me particulars of experiments made at Centennial Establishment by Sir William Thomson.

The single pole and double pole magnets were used alternately and with equal effect, so it is evident that we were wrong in ascribing the success to the use of the single pole magnet. Membrane moderately tight battery power 12 cells of carbon, freshly put up for the occasion. The transmitting telephones were used alternately, as soon as one became hot it was removed and the other one used. Here then probably is the cause of success, the powerful battery. We shall try this. Perhaps too it might be well to try magnet with thick wire and low resistance.

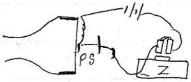
Prof. Watson spoke loudly into the Transmitting Instrument.

Shall try thicker membrane, larger cone and stronger battery.

Noted by. A. G. B.
Sept. 24th 1876.

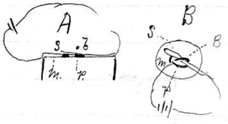
Monday Sept. 25th 1876.
Experiments with intermittent current to use membrane.

Fig 1.



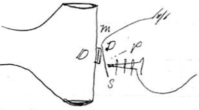
P. Platinum disk.
S. Screw.
Poor effect at Z
Crackling sound due to imperfect contacts between P. and S.

Fig: 2.

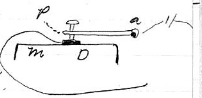


M. membrane.
P. Platinum disk.
B. Metal bridge.
S. Spring insulated on its lower surface.

1. Arrangement as in Fig 1. poor effect, crackling sound but no musical note.
2. Arrangement in Fig 2. (A or B). spring S. insulated on lower surface; poor effect better than 1. occasionally loud musical note from Receiver, but generally a "frizzling" sort of sound.
3. (Fig 2.) spring S insulated on upper surface same effect as last.
4. (Fig 3.) D disk of platinum.
S. Spring soldered to disk. Fig 3.
P. Platinum point.
M. membrane.



Effect "frizzling" sound, occasionally loud musical note, especially when pitch of membrane was used.
5. (Fig 4.) P. Platinum point resting by its own weight upon disk D.
Best effect produced either musical note or continuous current. Occasionaly "frizzling". lever P. a. too heavy.



Think that the arrangement in Reis's Telephone will give best results. Intend to make M. of india rubber and other arrangements a la Reis.

Rheotome.

6. Tried the relative effect of having the point P. carried by the armature A or fixed exteriorly to it.

In both cases obtained good vibrations, but obtained best results when point P. is fixed. Beginning to be afraid that the arrangement from which we have wandered (Fig 2 page 50.) (page) is after all the best. Amplitude of vibration obtained from A 3/8 inch with cells.

Undulatory.

7. Upon showing Telephone to Mr Kinsey was surprised to find utterance very distinct especially when high notes were employed. Mr. Kinsey understood readily the majority of sentences that were spoken in a high pitch of voice. Same sentences unintelligible in low tone, although the sounds were louder.

Battery power 4 cells, newly set up in splendid working order.

Noted by. A. G. B. Sept. 27. '76

Tuesday Sept. 26th '76.

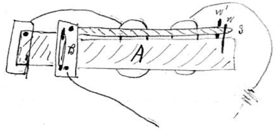
1. Intermittent Fig 1.

A. Armature insulated from B.

S. Spring in metalic contact with B. and

insulated from w!
Effect - slight vibration of A.
S. vibrates so as to have nodal point where w. and w' struck it.

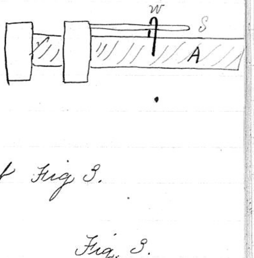
Fig. 1.



2. Fig 2. similar arrangement as last but wire W. about centre of armature.

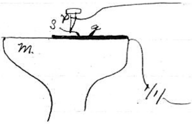
Fig. 2.

Could not get more than a trace of vibration excepting when S. projected about an inch beyond w.



3. Membrane attachment Fig 3.
M. membrane.
g. German silver extending from side to the centre of the membrane and glued to it.
S. Spring soldered to g.
P. Platinum point.

Fig. 3.



Unsatisfactory.

Undulatory.

4. Tried instrument with six cells of battery, freshly made up. Articulation very distinct with high notes and occasionly distinct with low notes.

5; Tried effect of varying force of voice. The audible effects did not differ so much in loudness as the original sounds. The softest articulation, seemed at the receiving instrument, to be little inferior in loudness to the effect of the loud articulation, and I think more distinct. A buzzing or "hollow" sound accompanied the loud articulation.

6. Tried whispering. An audible effect was produced at the receiving end, a curious 'soft rustling sound very difficult to detect, but both Mr. Watson and I agree in believing that an effect was audible. The sounds were so faint however that it was impossible to analyze them. X. See (Page 86)

7. Whistling was very clearly audible. This seems strange, for the vibration of the transmitting membrane was hardly tangible and yet the sounds came out well.

9. Tried sounding box B. as a Receiver. Upon speaking and singing into T. the sounds were audible from B. at a distance of one foot.

Noted by A. G. B. Sept. 27th 1876.

Fig. 4.

* Mr. Watson disagrees with me, he thinks that the whispering was just as audible or nearly so as the vocal sounds. Of course he listened to my whispering which was much louder than his own.

A. G. B. Sept. 28th 1876.

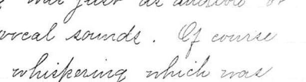
Wednesday Sept. 27th 1876.

1. Used sounding board as transmitter spoke and sang into it.

Sounding box. B.

Sounds faintly audible from A.

Fig. 7.

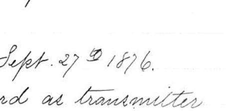


2. Tamborine used as Transmitter Fig 2.

T. Tamborine.

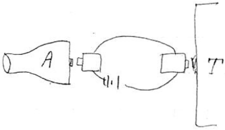
S. Small steel spring

A. Armature of Receiver.



Effect, upon speaking and singing before T. exceedingly faint sounds audible from A. Upon speaking into A. faint sounds audible from S.

3. Used Tamborine as Receiver Fig 3.
sounds uttered into
A. loudly audible
from T. but articu-
lation very indistinct.



4. Experiments with Intermittent - all so unsatisfactory, that there is no need to note them here.

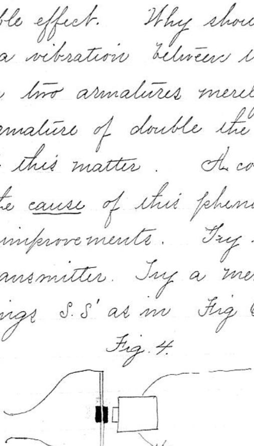
Noted by A. G. B. Sept 27th 1876.

Wednesday Sept. 27th 1876.
Thoughts.

5. Continuous experiments show that a double armature on the Receiver increases very greatly the audible effect. Why should this be? Is there a vibration between the two armature or are the two armatures merely equivalent to one armature of double the thickness.?

Test this matter. A correct understanding of the cause of this phenomena may lead to improvements. Try same thing with Transmitter. Try a membrane M with two springs S. S' as in Fig 6.

Fig. 4.



6. The loudness of sounds at Receiving end is sensibly the same whatever the size of the spring attached to the membrane, - or at least the loudness does not vary entirely in proportion to the size of spring. Test therefore the minimum size of spring that will produce audible effect. The smaller the spring can be made the less will it interfere with the vibration of the membrane.

7. Why should not iron filings scattered over the membrane do. Use double membrane containing iron filings between.

8. I forgot to state among Experiments made to-day that wetting the membrane did not seem to affect its vibration at all but rather improved it. Moisten with glycerine and water as in Ear Experiments.
If small metalic surface or iron filings prove successful try to use the membrane of the human ear as a Transmitter. Attach light piece of iron or steel to malleus having removed stapes and incus.

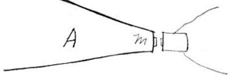
Noted by. A. G. B.
Sept. 27th 1876.

Thursday Sept. 28th 1876.

1. Undulatory Current.

Phonautograph cone A. Fig. 1. used to condense sound vibrations upon the membrane M. Effect, sound barely audible at the Receiving end of the line.

Fig. 1.



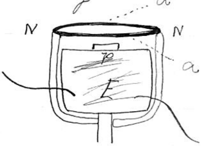
2. Apparatus (Fig 1.) A used as a Receiver with intermittent current obtained loudest sounds yet heard. With undulatory current the sounds were audible, at the open extremity A. of the cone, sometimes quite loudly – but no improvement in distinctness. The sounds were the loudest yet obtained with the undulatory current.

3. Tested difference between single and double armatures on the Receiver, and both Mr. Watson and I are certain that the double armature increases very materially the loudness of the sounds. Upon this point I also obtained the independent judgment of Mr. Kinsey, and there can be no doubt about it.

We have been unable to try armature of double the thickness, but I feel sure that the effect is due to the double armature, and not to the thickness, and the following explanation occurs to me.

The armatures a.a' are in contact Fig 2 with the pole N N and partake of its polarity. The armatures a a' having therefore the same polarity tend to repel one another now when the current traversing E becomes stronger the pole P. attracts a downwards, and at the same time a and a' tend to repel each other more powerfully. when the current through E is weakened the armatures return to their normal position.

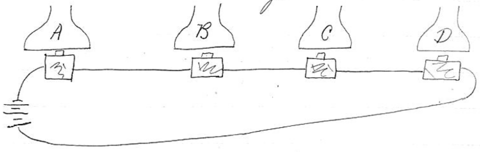
Fig. 2.



Thoughts.

4. Try the following experiment for transmitting messages.

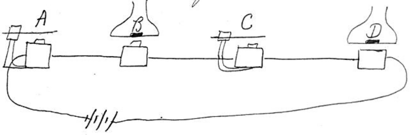
Fig 3.



Arrange for stations A. B. C. D. as in Fig 3 Let listeners be stationed at B and D. Let Transmitters be stationed at A and C. Let Transmitter A. transmit a message to D by sounding his signals on a horn or other instrument into A. While Transmitter

C. Transmits his message to B in simila[r] way. Perhaps the simplest way of trying [the] experiment would be to pluck springs as in Fig. 4.

Fig. 4.



6: For the mere purpose of transmitting musical notes it may be well to increase as much as possible the amplitude of the inducing vibration; but for transmitting vocal utterence and timbre it seems to me that we should increase the amplitude of the electrical undulations certainly; but <u>not</u> by increasing the amplitude of vibration of the inducing body. Indeed the less the amplitude of the vibration of the inducing body the more distinct should be the effect. For if we were to increase the amplitude of the vibration, it almost necessarily follows that we <u>distort the form of the vibration</u> and thus obtain loudness at <u>the expense of distinctness</u>.

Our most distinct effects have been obtained when the pitch of the voice was <u>high</u> (with loud speach) and the lower tones were distinct only when the articulation was <u>soft</u>. In both cases the amplitude was small.

Why not try the effect of the simultaneous vibration of a <u>number of armatures</u> in front of a number of electromagnets included in the same circuit somewhat as in Fig 5.

Fig. 5.

I shall attempt to calculate the effect of arranging the magnets as in Figs 6 & 7.

Fig. 6.

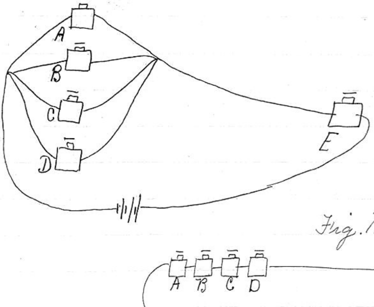
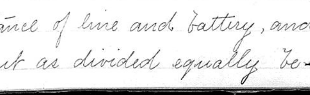


Fig. 7.



Ignore the resistance of line and battery, and consider the current as divided equally between all the magnets. The problem is to obtain by the simultaneous vibrations of the armatures of A. B. C. D. electrical undulations in E of as great amplitude as possible.

Electro-motive force - $100 = E$
Resistance of circuit - $= R$.
Resistance of each magnet. $= r$.
Strength of current - $= S = \frac{E}{R}$

In Fig. 7. $S = \frac{E}{5r}$; in Fig. 6. $S' = \frac{E}{r + \frac{2}{4}}$

Hence $\frac{S}{S'} = \frac{1}{4}$

Hence the strength of current in arrangement Fig 6. is four times that shown in Fig 7. But the current in Fig 6 divides into four A. B. C. D hence the intensity of the current in each magnet is one fourth of that passing through E

Call the intensity of current in Fig. 7 - 100 then in Fig. 6. it is 400.

In Fig 7.

Intensity of current traversing.	In Fig. 6.
A = 100	A = 400
B = 100	B = 100
C = 100	C = 100
D = 100.	D = 100
E = 100	E = 400

In Fig 6. the four magnets A. B. C. D. offer together one quarter resistance of E, and each magnet A. B. C. D. may be considered as constituting one fourth of that resistance (as only one fourth of the current passes through each). Hence each magnet A. B. C. D. constitutes $\frac{1}{16}$ th resistance of E or $\frac{1}{20}$ th resistance of the whole circuit.

In Fig 7. each magnet constitutes $\frac{1}{5}$ th of the whole resistance of circuit.

When the armatures of any of the magnets is made to vibrate in front of the pole, the current passing the electro-magnet is alternately strengthened and weakened. For simplicity let us suppose the resistance of the magnet to vary as as there is a constant source of electrical power in the battery. Suppose maximum resistance of magnet to be 12 and the minimum 8. and let only one of the magnets A. B. C. or D. have a vibration in its armature.

Then in Fig 6. normal resistance of magnets = 10.

Maximum resistance of A = 12. Hence maximum resistance of circuit = 202.
Minimum resistance of A = 8. Hence minimum resistance of circuit = 192.

Now if all four armatures A. B. C D. are caused to vibrate.
Maximum resistance of A. B. C. D. = 48 Hence maximum resistance of circuit = 208.
Minimum resistance of A. B. C. D. = 32 Hence minimum resistance of circuit = 192.

Normal resistance of circuit = 200.

In Fig. 7. when one armature A is vibrated.
Maximum resistance of A = 12. Hence maximum resistance of circuit = 52.
Minimum resistance of A = 8. Hence minimum resistance of circuit = 48.
Normal resistance of circuit = 50.
Now if all four armatures A. B. C. D. are caused to vibrate.
Maximum resistance of A. B. C. D = 48. Hence maximum resistance of circuit = 58.
Minimum resistance of A. B. C. D. = 32. Hence minimum resistance of circuit = 42.

In order to compare these results together we must compare them comparatively.
Now the normal resistance of circuit in Fig. 7. is four times as great as circuit in Fig. 6.
Let us call normal resistance of Fig. 6 = 100 and normal resistance of Fig. 7. 400.

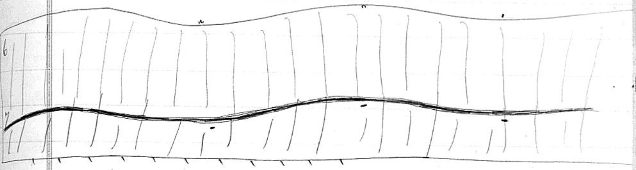
Then in Fig. 6. { maximum resistance of circuit = 104
minimum resistance of circuit = 96

Fig. 7. { maximum resistance of circuit = 404
minimum resistance of circuit = 336

Fig. 6. min. strength of ~~current~~ $= \frac{1}{104} = 0.9615$ (0.009615)
max. strength of ~~current~~ $= \frac{1}{96} = 1.0416$ (0.010416)

Fig. 7. min. strength of current $= \frac{1}{404} = 0.2155$ (0.002155)
max. strength of current $= \frac{1}{336} = 0.2697$ (0.002976)

Graphical representation of Electrical Undulations.

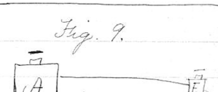


Compare with these the arrangement in Fig 8 where one electro-magnet A, is used having a <u>resistance</u> equivalent to A.B.C.D. in Fig 6; and that in Fig. 9. where the electro-magnet A has a resistance equivalent to A.B.C.D Fig. 7.

In. Fig. 8.

Max. resistance of A = 12.
Max. res. of circuit = 52.
Min. res. of A = 8.
Min. res. of circuit = 48.

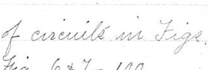
Fig. 8.



In. Fig. 9.

Max. res. of A = 48.
Max. res. of circuit = 58.
Min. res. of A = 32.
Min. res. of circuit. = 42.

Fig. 9.



Take normal resistance of circuits in Figs. 8 and 9, as the same as in Fig. 6 & 7 = 100
Max. res. of circuit. Fig. 8 = 104.
Min. res. of circuit Fig. 8 = 96.

In Fig. 9

Max. res. of circuit = 116
Min. res. of circuit = 84

Intensity of current.

Fig. 8.

Min. int. $= \frac{1}{104} = 0.9615.$

Max. int. $= \frac{1}{96} = 1.0416.$

Fig. 9.

Min. int. $= \frac{1}{116} = 86206.$

Max. int. $= \frac{1}{84} = 119047.$

Fig. 6.
Strength of current.

Fig. 6	Min. =	96
	Max. =	104
Fig. 7	Min. =	22
	Max. =	30
Fig. 8	Min. =	96
	Max. =	104
Fig. 9	Min. =	86
	Max. =	119

Noted by. A. G. B.
Sept. 28th 1876.

Friday Sept. 29th 1876.

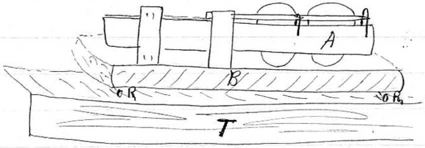
1. Repeated experiments described in note 1 page 56. (page) note 1. page 59 (page) notes 2. 8. 5. page 62. (page) notes 1 & 2 page 79 (page) for the purpose of deciding which form of instrument works best. We have so far found the results very variable, sometimes obtaining good vibrations, and at other times failing.

Having noticed that the pressure of the finger upon the wooden base seems to affect the vibration of the armature, we today determined to screw the base firmly to the table. We were unable to obtain more than a trace of vibration upon any of the above plans.

While Mr. Watson was plucking the armature in the vain attempt to set it vibrating, (on the plan shown in Fig 1. page 79 (page 1) happened to be unscrewing one of the screws which fastened the base to the table, and to our surprise the armature at once began to vibrate but with little amplitude. Upon screwing the base firmly again the vibration stopped, nor could we cause its renewal until the base was loosened. It seems to be essential to the vibration that the base should be loose.

2. We placed rubber pipes $R.R_1$ between the base B, and the table T Fig 1. The vibrations of A at once became intense.

Fig. 1.



As long as the rubber tubes R R were retained in place all experiments alluded to above were successful, but the amplitude of A's vibration at once diminished when the base B came in contact with any solid object, and the vibration of A stopped when the base B was pressed firmly against the table.

The end A. Fig 2. was observed to be in vibration - when A' was held in the fingers or weighted, the amplitude of A's vibration was very greatly increased.

Fig. 2.

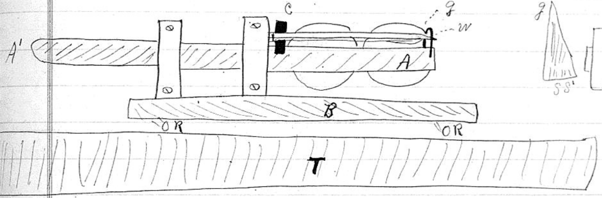
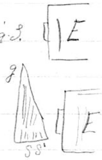


Fig. 3.



A A' Armature. g. german silver spring and w. wire contact point.
B. Base. R. Rubber tubing. T. Table.

4. Upon looking downwards upon g (Fig. 2.) its vibration caused it to assume the appearance shown in Fig. 3. and a spark S showed where the contact was broken. Upon placing a card C, between g and A (Fig. 2.) so as to increase the pressure between g and w, the amplitude of A's vibration was very much increased and the spark S shifted into its place to S' showing that in the latter case the contact between g and w (Fig. 2.) was not broken until the armature had completed its swing towards the electro-magnet E. when the

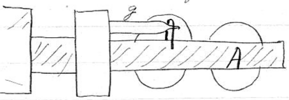
the spark was at S, the circuit was broken when the armature was half way towards E and it was very probably <u>made</u> again before it had completed its swing from E.

<u>The position of the spark will evidently determine the duration of the make of the</u> circuit by showing the precise spot where the circuit is broken.

5. Water spark arrester introduced, annihilated the spark and diminished the amplitude of A's vibration when arranged as in Fig 2. The introduction of the spark, arrester however very perceptibly <u>increased</u> the vibration of A when taken as arranged in Fig. 4.

6. Condenser reduced the spark and did not seem to affect vibration of A materially.

Fig. 4.



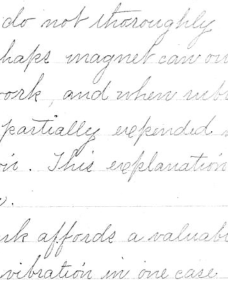
Noted by A. G. B.
Oct. 1st 1876.

Saturday Sept. 30th 1876.

1. Intermittent Current. Nothing new to-day. Have contented ourselves with verifying yesterday's experiments. Results obtained very important. Rubber tubes under base produce wonderful effects, do not thoroughly understand cause. Perhaps magnet can only do a certain amount of work, and when rubber is omitted its force is partially expended in setting table in vibration. This explanation suggested by Mr. Watson.

Position of the spark affords a valuable index of the condition of vibration in one case and diminishing it in the other.

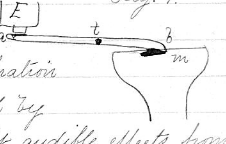
Fig. 1.



2. Undulatory.

Lever a and b set in vibration by membrane M. (suggested by Mr. Watson) Very slight audible effects from Receiver. Mr. Watson suggests magnet on each side of a to prevent the attraction of E from causing the end b of the lever to press upon M, and thus interfere with its vibration.

Fig. 2.



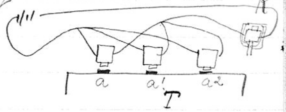
3. T Tambarine. $a.a'.a^2$ armatures of electro-magnets. $E.E.'E.^2$

Sang to Tambarines.

Loudness at R noted in arrangement shown at Fig 4. sounds audible but rather softly.

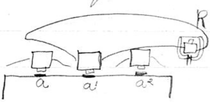
4. (Fig. 3.) sounds barely audible, much softer than in (Fig. 4.)

Fig. 3.



5. (Fig. 2.) sounds audible much more plainly than either Figs 3 or 4; but at best very faint.

Fig. 4



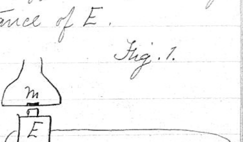
Noted by. A. G. B.
Oct. 1st 1876.

Oct. 1st 1876.

Calculation to determine effect of resistance of magnet is affecting the amplitude of the electrical undulations and audibility of sound at Receiving end.

The vibration of m affects the current passing through E and the effect is probably proportioned to the resistance of E.

Fig. 1.



Let us consider then the vibration of m. as increasing ~~or diminishing~~ the resistance of E. The intensity of the current traversing the circuit B.C.E.T. is caused to vary on account of the varying re-

resistance of E.

Call normal resistance of E $= r$

Resistance of rest of circuit $= R$.

Electro-motive ~~force~~. $= E$.

Effect of motion of m. towards E (Fig 1.) supposed to be proportioned to resistance of E call $= \frac{r}{x}$

Effect of motion of m. from E (Fig. 1.) call $= -\frac{r}{x}$

Maximum of intensity of current $= I$

Minimum of intensity of current $= i$

$$\left.\begin{array}{l} i = \dfrac{E}{R + r + \frac{r}{x}} \\[2ex] I = \dfrac{E}{R + r - \frac{r}{x}} \end{array}\right\} \text{Hence } \frac{i}{I} = \frac{x(R+r)-r}{x(R+r)+r}$$

There are evidently three cases to be considered, viz. (1) When $R = r$, and R is (2) greater or (3) less than r. Let $R = yr$

$$\rightarrow \therefore \frac{i}{I} = \frac{x(yr+r)-r}{x(yr+r)+r} = \frac{x(y+1)-1}{x(y+1)+1}$$

Where x and y are both functions of r, x expressing the change in the resistance of r occasioned by the vibrating; and y showing the relation subsisting between the resistance of r and the rest of the circuit R.

Electrical

Experiments

by

A. Graham Bell

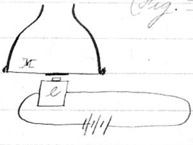
Vol. III.

Sunday, October 1st, 1876.

The problem before us in utilizing the undulatory current is evidently how to obtain the maximum of inductive action with the minimum of vibrating motion.

In order to do this satisfactorily it seems to me to be necessary to understand the nature of the effect produced upon the current. Does the vibration of M (Fig. I)

(Fig. I.)



occasion an inductive action of its own which is merely superposed upon the current traversing e - or is the effect proportional to the magnetical power of e? Experiments so far seem to indicate that the latter supposition is correct. The power of the electro-magnet (e) however depends upon the electro-motive force of the battery and upon the resistance of the electro-magnet (e) relatively to the rest of the circuit.

When the electro-motive power of the battery is kept constant - variations in the intensity of the current may be considered - without error - as due to corresponding changes in the resistance of the circuit.

The effect then of the vibration of M is supposed to depend upon the magnetical power of the electro-magnet ($\underline{e}$); and the power of the electro-magnet depends upon the resistance of its coils relatively to the rest of the circuit, and upon the electro-motive force of the battery.

The electro-motive force (E) of the battery is constant – and the vibration of $\underline{M}$ is considered as causing a variation in (R) the resistance of the electro-magnet ($\underline{e}$) Express the resistance of the circuit in terms of R.

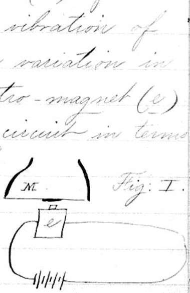


Fig: I.

E = Electro-motive force of battery.

R = Minimum resistance of e.

AR = Maximum resistance of e.

BR = Total resistance of the circuit exclusive of

I = Maximum intensity of current.

i = Minimum intensity of current.

$$\left.\begin{aligned} I &= \frac{E}{R(B+1)} \\ i &= \frac{E}{R(A+B)} \end{aligned}\right\} \therefore \frac{I}{i} = \frac{A+B}{B+1}$$

The difference between I and i will be at its maximum when B is at its minimum and <u>vice versa</u>. Hence the greater the resistance of e (Fig. I) relatively to the rest of the circuit the greater will the amplitude of the electrical undulations be. But as the absolute intensity of the current is equal to the electro-motive force divided by the resistance of the circuit – the greater the resistance of e the less the absolute intensity of the current and the less the magnetic power of e. It is evident then that for a given circuit a certain resistance of e can be found which will yield the maximum effect.

Noted Oct. 1st. by A. G. B.
Copied Oct. 14th. 1876
by A. G. B.

Monday, Oct. 2nd. 1876.

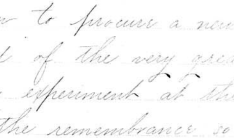
Upon reading over a few of the records in the 2d volume of my electrical experiments I was struck by an experiment made July 11th (page 27) which I had quite forgotten. Why we have relinquished the improved form of armature shown in Fig. I. page 27 (2d vol.) I cannot think. Shall repeat the experiment.

It will be a good plan to repeat all the earlier experiments – with the improved receivers we now have.

Noted Oct. 14th. 1876
by A. G. B.

Oct. 2d to Oct. 7th. 1876.

The experiments have been irregularly conducted during this week — and have not been noted in consequence of omission to procure a new book. We are convinced of the very great importance of noting every experiment at the time it is made — as the remembrance so soon fades away. A number of experiments made during the last few days have been forgotten. Experiment referred to above (Monday Oct. 2d.) was tried during the week. The large armature was found to be infinitely superior to the small one employed (Fig. I.)



A large disk (D) of thin steel was glued to the membrane M. and Mr. Watson spoke with his mouth almost in contact with D condensing his breath by means of his hands. I listened at D'. The articulation was much more distinct than any heard yet. I then spoke with my mouth against D' and Mr. Watson listened at D and the artic. was intelligible. We then held the following conversation.

The following conversation took place. I think this was on Saturday the 7th of October.

Bell to Watson. "If you understand what I say, say something to me."

Watson to Bell. "It is (decidedly) the best I
(as heard by me.) ever heard".

Bell to Watson. "It is the best I ever heard."

Watson to Bell. "Success at last has (attended) our efforts."

Bell to Watson. "Let us then be up & doing
With a heart for any fate—
Still achieving still pursuing
Learn to labor and to wait."

Noted by A. G. B.
Oct. 14th. 1876.

Monday Oct. 9th. 1876.

Fig. I.

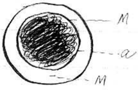
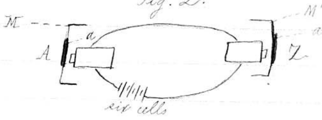


Fig. 2.



Two telephones shown at A and Z Fig. 2 were ready for trial today. Armatures a a' (Fig. 2) like that shown at a (Fig. I) were glued to membranes M M' (Fig. 2) as illustrated in Fig. I

I spoke with my mouth close to A condensing the air upon the membrane with my hand while Mr. Watson listened at Z. Then Mr. Watson spoke against Z and I listened at A. The articulation was so distinct and clear that we were enabled to hold the following conversation through the wire which was recorded by each of us at the time. The two records were as follows.

Conversation as recorded by A. G. Bell stationed at one instrument.	Conversation as recorded by T. H. Watson stationed at the other.
Bell. If we can manage to understand each other on this short circuit I think we may try a real	Bell. If we can manage to understand one another on this short circuit I think we can try a real

telegraph wire.	telegraph line.
Watson. It seems to me that the articulation is almost distinct enough for practical use.	Watson. It seems to me that the articulation is almost distinct enough for practical use.
B. I understand every word you say, but I think the armature of your telephone must be loose as a curious hollow sound accompanies the articulation.	B. I understand every word you said, but I think that the armature of your telephone must be loose as a curious hollow sound accompanies the articulation.
W. The armature is loose at the edges but I do not think that that is the cause of the hollow sound.	W. My armature is loose at the edges, but I do not think that that is the cause of the hollow sound.
B. It seems to me that the articulation is most distinct when I do not press my ear closely against the membrane.	B. It seems to me that the articulation is most distinct when I do not place my ear closely against the membrane.
W. I understand you better when you speak conversationally rather than so deliberately.	W. I understand you better when you speak conversationally rather than so deliberately.

At this point the experiment was interrupted by the arrival of a friend. After some delay the conversation was resumed.

Recorded by Mr. Bell.

B. A gentleman has just come in to see me. Do you know his name?

W. Please repeat that.

B. A gentleman has just come in to see me, do you know his name?

W. I do not know his name. Is he interested in telephony?

B. He is interested, but neither pecuniarily nor professionally. Can you receive a message from him? See if you can understand his voice.

W. Repeat last word.

B. Voice, voice, v-o-i-c-e voice. See if you can understand his voice.

W. Request him to talk to me.

Mr. Mack. I fear it

Recorded by Mr. Wats

B. A gentleman has jus come in to see me — —

— — — — — —

W. Please repeat that.

B. A gentleman has just come in to see me. Do you know his name?

W. I do not know his name. Is he interested in telephony.

B. He says he is interested but neither pecuniarily nor (accessorily.

— — — — — — — — —

— — — — — — —

— — — — — — — —

— — — — — — — —

W. Repeat last word.

B. V-o-i-c-e voice. Do you think you can understand his voice?

W. Request him to talk to me.

Different voice. I fear you

will be difficult to understand me. My voice is not so distinct as Mr. Bell's.

W. (as understood by Mr. Mack) Most intensely distinct but not — — — — — —

W. (as understood by Mr. Bell) Yes it was quite distinct but somewhat fainter.

Mr. Mack. Please repeat what you said to me.

W. (as understood by Mr. Mack) It was quite distinct but somewhat fainter.

W. (as understood by Mr. Bell) Yes, it was quite distinct but somewhat fainter.

B. I want to tell you this gentleman's name.

W. Please introduce him to me through the wire.

B. Wait a minute.

will not be able to understand me. My voice is not so distinct as Mr. Bell's.

W. That was quite distinct but somewhat fainter.

Same voice as before. Please repeat what you said to me.

W. That was quite distinct but somewhat fainter.

Bell's voice. I want to tell you this gentleman's name.

W. Please introduce him to me through the wire.

B. Wait a minute.

W. I am waiting.

B. Allow me to introduce my friend, Mr. Mack of Belmont, Massachusetts.

W. (as understood by Mr. Bell) Mr. Mack, I am glad to make your acquaintance.

W. (as understood by Mr. Mack) Mr. Mack I am glad to make your acquaintance.

W. I am waiting.

B. Allow me to introduce my friend Mr. Mack of Belmont, Massachusetts

W. Mr. Mack I am glad to make your acquaintance.

(The final sheet from which this is copied is missing. there were one or two sentences more.)

In the evening of the same day the Walworth Manufacturing Company lent Mr. Bell the use of their telegraph line, extending from their office in Boston to their factory in Cambridgeport - a distance of about 2 (two) miles. The company's battery consisting of 9 Daniels cells was disconnected from the circuit and another of ten carbon elements substituted. Articulate conversation was then carried on through the wire. The sounds at first faint and indistinct became suddenly quite loud and intelligible. Mr. Bell in Boston and Mr. Watson in Cambridgeport took notes at the time of what was said and heard, and of which the following are copies.

Conversation as recorded by Mr. Bell.	Conversation as recorded by Mr Watson.
B. What do you think was the matter with the instruments?	B. What do you think is the matter with the instruments?
W. There was nothing the matter with them.	W. There is nothing the matter with them.
B. I think we were both speaking at the same time.	B. I think - - - - at the same time.
W. Can you understand anything I say?	W. Can you understand anything I say?
B. Yes I understand everything you say.	B. Yes I understand everything you say.
W. The reason why you did not hear at first was because there was a relay in the circuit.	W. The reason why it did not work at first was because there was a relay in the circuit.
B. You may be right but I found the magnet of my telephone touching the membrane.	B. You may be right but I find - - - that my - - touches the membrane.
W. I cut the relay out and then the sounds came perfectly.	W. I cut the relay out and then the sounds came out perfectly.
B. I hear every syllable, try something in an ordinary conversational voice	B. I hear every syllable, try something in a conversational voice.

W. Shall I connect their battery in the circuit?

B. No, there is no necessity to connect their battery in the circuit, the sounds come out quite loudly.

W. I am now talking in quite a low tone of voice.

B. The sounds are quite as loud as before and twice as distinct.

W. Cut out the battery and then talk.

B. All right, I will cut out the battery now if you will keep listening.

B. I thought you were going to try somethins.

W. Is the battery cut out?

B. No, but I will do it now.

B. Do you hear anything now?

B. Did you hear anything?

W. Shall I connect their battery in the circuit?

B. No, there is no necessity for putting their battery in the circuit as the sounds come out quite distinctly.

W. I am now talking in quite a low tone of voice.

B. The sounds are quite as loud and quite as distinct.

W. Cut out the battery and then talk.

B. All right, I will cut out the battery now if you will keep listening.

B. I thought you were going to say something.

W. Is the battery cut out?

B. No, but I will do it now.

B. Did you hear anything?

<table>
<tr><td>W. No, not a sound.
B. Say something to me when I cut out the battery again.</td><td>W. No, not a sound.
B. Say something to me when I cut out the battery again.
W. I could not hear a sound.</td></tr>
<tr><td>B. I fancy I heard a trace of your voice.
W. Shall I put on their battery to see if it increases the effect?
B. I'll tell you what we'll do. We'll take off our battery & put on theirs as before.</td><td>B. I fancied I heard a trace of your voice.
W. Shall I put on their battery to see if it increases the effect?
B. I'll tell you what we'll do. We'll take off our battery altogether & put on theirs as before.</td></tr>
<tr><td>W. Is our battery off?
B. Yes, our battery is off. What have you been doing. The sounds were quite soft at first but now they are quite loud.
B. Shall I put on our battery again?</td><td>W. Is our battery off?
B. (Very indistinct)</td></tr>
<tr><td>W. (Very indistinctly) That was very indistinct put on our battery.
B. We may congratulate ourselves upon a great success.</td><td>W. That was very indistinct put on our battery.
B. We may congratulate ourselves on our great success.</td></tr>
</table>

W. Both batteries are on now (Another sentence heard indistinctly)	W. We deserve success. Both batteries are on now.
B. Repeat the last sentence.	B. Repeat last sentence.
W. Both batteries are on now.	W. Both batteries are on now.
B. I understood that before, but I thought you said something else.	B. I understood that before, but I thought you said something else.
W. Remove their battery, please	W. Reverse your battery, ple
B. All right our battery is the only one on now.	B. All right our battery is the only one on now.
W. I have put battery cells on here.	W. I have six Daniels' cells on here.
B. How many cells have you there?	B. How many cells have you there.
W. S-i-x.	W. S-i-x six.
B. Please whisper something to me.	B. Please whisper something to me.
	W. I am now whispering.
B. I could hear you whispering but could not understand what you said.	B. I could hear you whispering but could not understand what you said.
W. Perhaps we have got the batteries opposed to one another. Had you not better reverse your	W. Perhaps we have got the batteries opposed to one another. Had you not better reverse yours

battery and see what
the matter is - or rath-
er what the effect is?
B. I will try the effect
of reversing my battery.
B. Is this any better?
W. That sentence was
accompanied by that
curious crackling sound.
B. Yes I hear it too.
B. What time is it by
your watch?
W. What are you doing?
I have not heard any-
thing except - - - for
quite a while.
B. I asked you what
time it was by your
watch perhaps you
hear me better now
because I have reversed
the battery again.
W. My battery is now
cut out.
B. Dont you think we
better go home now?
W. Yes- but why does
your talk come out so

and see what the ef-
fect is?
B. I will try the effect
of reversing my battery.
B. Is this any better?
W. Much fainter accom-
panied by that curious
bubbling sound.
W. What are you doing?
I have not heard any-
thing except that bub-
bling sound for quite
a while.
B. I asked you — —
— — — —
— — — —
because I — —
— —
W. My battery is now
cut out.
B. Do you think we had
better go home now?
W. Yes - but why does
your talk come out so

much fainter now?
B. Because I had re-
moved the magnet
further away from
the membrane.
W. That was very much
more distinct.
B. Will you try to
understand a long
sentence if I speak
right on?
W. I will.
B. A few minutes ago
I heard a fire engine
pass by the door. I
dont know where the
fire is but the number
of the box is 196.
W. The time by my
watch is five minutes
past ten had I better
not go into Boston.
B. Yes I think it time
to stop now.
W. Shall I go to
Exeter place
B. Yes, but look in here
in case I have not gone.

much fainter now?
B. Because I removed
the magnet further
away from the membrane
W. That was very much
more distinct.
B. Will you try to
understand a longer
question if I speak
right on?
W. I will.
B. A few minutes ago
I heard a fire engine
go past the door. I
dont know where the
fire is, but the number
of the box is 196.
W. The time by my watch
is five minutes past
ten had I better not
go into Boston.
B. Yes, I think it is
time to stop now.
W. Shall I go to Exeter
place.
B. Yes but look in here on
your way in case I have not gone

W. Let us talk conversationally without noting. | W. Let us talk conversationally without noting.

Copied from notes
by M. G. H. Oct. 16, 1876.

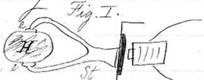
Wednesday, Oct. 11th. 1876.

Communicated the results of Monday's experiments to the Academy of Arts & Sciences. At the conclusion of the meeting the members tested apparatus with good results. All were convinced. Upon the motion of the Hon. Geo. B. Emerson the congratulations of the Academy were tendered to me upon my success.

Noted Oct. 19th.
by A. G. B.

Thursday, Oct. 12th. 1876.

Dr. Bowditch called upon me to try the effect of using a double stethoscope as a means of increasing the audibility of the sounds. The sounds were undoubtedly louder when received as in Fig. I.



H. head of listener
St. Stethoscope.
e, e. Ear pieces.

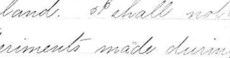
Noted Nov. 12th. 1876.

Thursday Oct. 12th. - Sunday Nov. 12th

Systematic notation of experiments during this month has been almost impossible on account of many circumstances - specially because I have been out of town in the evenings at Cambridge and at Bradford - and have been professionally engaged during the day. Mr. Watson's absence in Philadelphia for one week and subsequent illness from Typhoid Fever interrupted experiments - and what little time I could spare from professional duties latterly has been devoted to writing a specification of a patent to send to England. I shall note here now the principal experiments made during the month.

1. The success of enlarging the steel armature of the Telephone (see page 5) led me to think of dispensing with the membrane altogether.
A disk of thin steel A (Fig. 2) about six inches in diameter was fastened in front of the electro-magnet e. On speaking to A the articulation was heard from Z much more distinctly than we had heard before.

Fig. 2.



2. The following facts have been conclusively proved by our experiments with the form of apparatus shown in Fig. 2 page 5.

1. That the sounds audible from the Receiving Instrument are loudest when the speaker condenses the air against membrane by means of his hand.

2. That the sounds from the Receiving Instrument are most distinct when the speaker speaks against the same side of the membrane on which the electro-magnet is placed.

3. That the articulation is most distinct when the membrane is omitted and a simple plate of steel used as in Fig. 2. p. 15 [p. 18].

4. That the audibility of the sounds depends upon the resistance of the electro-magnets of the Transmitting & Receiving Telephones - The greater the resistance of the coils the better the effect - the current being supposed of the same mean intensity throughout.

3. Arrangements have been made with Prof. Rogers for experiments between Exeter Place & Cambridge Observatory - and a line has been

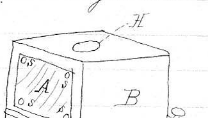
erected connecting me with the Boston and Cambridge circuit at the office of Messrs. George & Stearns Electricians No. 39 Pearl St.

Conversation was carried on by word of mouth over the circuit between Exeter Place & Pearl St. on Friday morning the 10th of November.

Mr. Greenough and Mr. — of the Boston gas works as well as Mr. George were present at the Pearl St. end of the line. The instruments used were those shown in Fig. 4. Instruments shown in Fig. 3 were constructed somewhat about the 19th or 20th of October — before Mr. Watson left for Philadelphia — and they are still the instrument preferred.

The electro-magnet is placed in a box B of wood. The front of the box was then cut away and a sheet of thin steel A screwed on to it by screws SSSS. A hole H was left in the top of the box, for the purpose of speaking into.

Fig. 3.



Two instruments were made and arranged upon circuit as in Fig. 4.

Fig. 4.

Upon speaking into the hole H Fig. 3 the voice was heard very loudly from the other telephone but indistinctly. Upon placing the mouth against the plate A and speaking the sounds became perfectly distinct from the other telephone.

Upon condensing the air against the armature A by means of the hand - the utterance was perfectly distinct and quite as loud as when we spoke into the hole H. When we blew against A Fig. 4 the sound was audible at Z.

Noted by A. G. B.
Sunday Nov. 12th. 1876.

Saturday Nov. 11th. 1876.

1. Experiment between Exeter Place & Observatory made this evening. Mr. Watson in Boston - A. G. B. and Prof. Rogers in Cambridge. Magnets of 25 ohms resistance produced scarcely any effect. With magnets of 100 ohms resistance sounds came out splendidly. Conversation was carried on with the greatest ease. Articulation the most distinct yet obtained.

2. Mr. Watson thinks that the sounds were re-enforced by the armatures of the Morse

sounders on the circuit — as they must have vibrated synchronously with the armatures of the telephones.

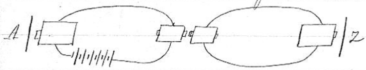
3. Sounds were faintly audible in Cambridge when the battery was cut out altogether.

Noted by A. G. B.
Sunday Nov. 12th. 1876.

Sunday Nov. 12th. 1876.

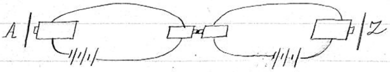
1. Tried following experiment: Sounds uttered in the neighborhood of A Fig. 5 were faintly audible from Z.

Fig. 5.



2. The experiment was varied as in Fig. 6.

Fig. 6

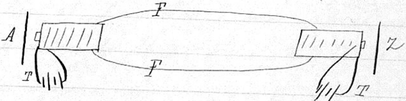


Conversation was carried on between A & Z just as if they had been on the same circuit. The magnets had each a resistance of one ohm.

Thoughts.

Fig. 7.

1.



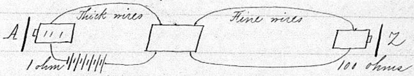
Use induction coils. Trial batteries in circuit with thick wires T — Main circuit without battery connected with fine wires.

Noted by A. G. B.
Nov. 12th. 1876.

Monday Nov. 13th. 1876.

Tried Induction coil as in Fig. 8.

Fig. 8.



1. Sounds spoken at A plainly though faintly audible from Z. Mr. Watson thinks that the word "faintly" does not express the intensity audible. He says the sounds were loud although faint as compared with ordinary arrangement.

2. One cell of battery placed on the secondary circuit - five on primary — sounds from Z nearly as loud as we have ever had.

3. Three cells on each circuit. Sounds uttered at A audible from Z. Sound uttered at Z audible at A. The sounds heard at A much more distinct than those heard at Z.

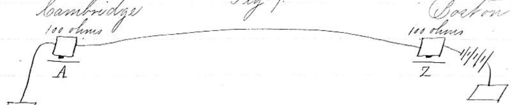
4. Twenty-five ohms coil placed in primary circuit in place of one ohms coil. Sounds much fainter from Z.

Noted by A. G. B.
Monday Nov. 13th. 176.

Monday Nov. 13th. 1876.

Experiment between Boston & Cambridge this evening. Mr. Watson in Cambridge. Battery 15 cells. Upon placing my ear to the Telephone a loud rushing sound was heard something like the rushing of a tempest through the leaves of a forest. Voice from Cambridge inaudible. Circuit as in Fig. 9.

Fig. 9.



Upon breaking circuit in Boston taps were heard ~~faintly~~ very loudly upon Z. When the circuit was broken at A taps heard softly from Z.

Upon reversing battery rushing sound disappeared. It only came when the zinc element was connected with the ground.

Upon reversing battery Mr. Watson's voice at A reproduced itself audibly at B. Conversation was then carried on. Visitors were present at both ends so there was [illegible] very little experimenting done.

At Boston end Mr. & Mrs. [illegible] Hubbard. Cambridge end Prof. & Mrs. Rogers, Mr. & Mrs. Waldo, Prof. Hill, & Prof. Trowbridge.

Noted Nov. 14th. 1876.
by A. G. B.

Tuesday, Nov. 14th. 1876.

We were connected this morning with the observatory circuit and tested Telephones with Prof. Rogers at the Observatory end and Prof. Bell at the Boston end. The experiment was conducted for the purpose of finding the cause of the rushing sound and the clock beating in the circuit. The rushing sound was not heard at all, when Mr. R. broke the circuit the clock was heard by B. and not by R. when B. broke it was heard by

R. and not by B.
The clock is undoubtedly Bond's clock as we counted the beats and found that they corresponded to Bond's and not to the observatory clock. Conversation was carried on between the two ends with perfect ease.

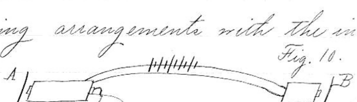
In the evening Mr. Bell experimented to see if he could produce artificially the rushing sound and found he could exactly by passing the circuit through a piece of cloth saturated with acidulated water; an imperfect contact in the circuit seemed also to give the same sound.
The analogy to the wet cloth in the Camb. circuit is in the cable that crosses Charles River, which Mr. George says is leaky. The experiment leaves little doubt that the rushing sound is caused by the decomposition of water (see page 26).

Wednesday Nov. 15th. 1876.

Tried following arrangements with the induction coil.

Fig. 10.

#1



Words spoken at A distinctly audible at B. While making this experiment we used the double stethoscope to listen with, and by resting one edge of it against one side of the membrane so as not to deaden the vibration of the centre we found that the sounds were very much more intense and the articulation very much more audible we propose to go to Codman & Shurtleff's and see if we can procure a rubber cone of the shape in Fig. 11 large enough to fit over the whole membrane and used both as a speaking tube and a hearing trumpet.

Putting magnet over which spring was being plucked into the primary circuit at A the sounds were plainly audible at B. and putting it into the secondary circuit at A they were still audible, with neither increase nor decrease, if anything a slight decrease.‡

‡ Three cells on primary circuit and three upon secondary circuit.

A. G. B.

Tried Gage's sounding Box as a receiver and transmitter for the voice and got unsatisfactory results.

Tried our old receiving instrument the iron Box Magnet in circuit with one of our latest forms of Telephone, used it both as a receiver and transmitter and got the best results we have yet obtained. We will try to get an arrangement of speaking tube and hearing tube like this.

Fig. 11.

A = Mouth and ear piece
B = Flexible tube
C = Magnet end

We found this evening that the rushing sound can be produced perfectly by placing the circuit closer of our key lightly against the side of the anvil but could not produce it with the Platinum points of the key no matter how lightly they were rested together which would seem to indicate that the tarnished brass of the circuit closer had something to do with the production of the sound. Is this an electrical effect analogous to the vibration of Trev. Bars by heat. It seems to me that it is a vibration so rapid that it sounds like a hiss.

Noted Nov. 15th. 1876. T. A. W.

Nov. 15th. 1876 Continued.

Attempted to try our Telephone this evening between Exeter place and the Observatory.

Articulation barely audible and signals sent by means of our Tap Alphabet were so faint that it was with great difficulty we could communicate by that means. Finding we could not improve the effects we decided that there was something wrong with the wire, and closed the experiment at 9.30 P.M.

Noted Nov. 16th. 1876.

T. A. Watson.

Thursday Nov. 16th. 1876.

It was discovered this morning that there was a cross between the Cambridge wire and another wire between the Boston City Hall and the museum which defect will be rectified today.

The experiment last evening was a convincing proof that articulation can be transmitted in a circuit which is too imperfect to work a Morse Instrument, as the articulation was surely though faintly audible.

Went out to the Observatory this morning and brought in the telephone which had been left there for three or four days and when I got back it was too late to experiment.

Noted Nov. 17th. 1876.

T. A. Watson.

Friday Nov. 17th. 1876.

On Wednesday night upon returning from Cambridge I connected my telephone in circuit with Cambridge wire for the purpose of observing noises on circuit. Could hear the ticking of a clock - twenty-eight ticks and then a pause. Also heard faint tapping as if due to operating on another circuit. Occasionally the rushing sound referred to on pages 21 and 22 made its appearance - but only when the Z pole of the battery was put to earth. I do not understand why the c pole placed to the earth should make any difference if the cause is the decomposition of water as rendered probable by experiment noted in page 24. I am inclined to think now that the cause of the rushing sound was not a defect in the cable, from Boston to Cambridgeport as supposed before - but must be located at City Hall. Mr. George gave me particulars of the fault discovered there which was evidently of long standing.

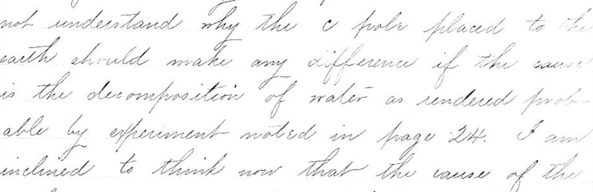
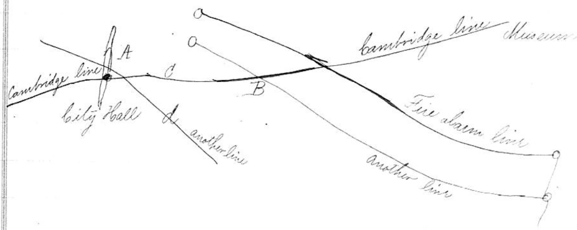


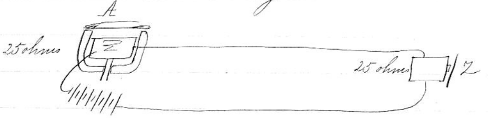
Fig. 12.



The Cambridge line passed between the fire-alarm wire and another wire in passing from City Hall to Museum - and it had bent downwards so as to touch the lower line at B. In order to remedy this - the Cambridge wire had been tightened so as to clear the lower line and had been fastened to the same insulator A which was used as the support for another line. The two wires had been fastened together with insulated copper wire! Now Monday evening was quite wet and stormy - and the insulating material had become wet so that probably there was a leak from line C to line d and the decomposition of the rain-water at this point was probably the cause of the rushing sound heard on that evening. This probably would explain the reason for the sound only coming when the Z pole was put to earth - for there must have been a battery on both lines C d and when these were opposed to one another - they would neutralize each other's action at A and thus no decomposition of the water take place and no sound be heard. On Wednesday evening the line C came into contact with line B and stopped communication. The major portion of the current from our battery went to the earth through the line B – and only a small portion of it reached Cambridge by line C. Thus taps made in Boston were loud while taps received in Boston from Cambridge were very feeble. And yet Mr. Watson's voice was audible in Cambridge and a sentence or two was understood. For instance I heard and understood the sentence – "If you understand what I say send me five taps."

Yesterday we tried old receiver as a Transmitter, as in Fig. 13 with great success. The sounds audible at Z were louder & more

Fig. 13.



distinct than any yet obtained. When Mr. Watson spoke at Z sounds audible from A were loud and distinct.

We propose to make instruments like those shown in Fig. 14 and 15.

Fig. 14.

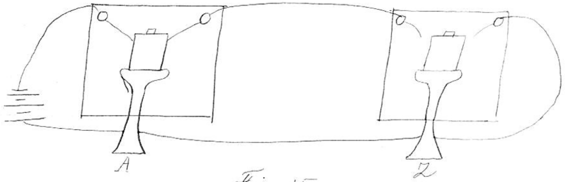
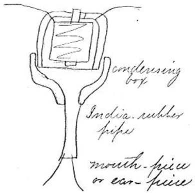
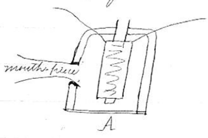


Fig. 15.



Mr. Watson has constructed apparatus shown in Fig. 16 - which we have been unable to try yet. We anticipate good results from this instrument as the air can be condensed upon the <u>inside</u> of the armature A.

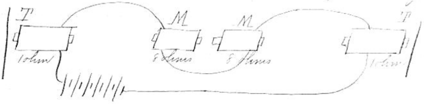
Fig. 16.



Noted by A. G. B.
Nov. 17th. 1876.

Saturday Nov. 18th. 1876.

Tried the experiment shown in the following diagram



T T Telephones M M Single Pole Electro Mags. and moved the magnets to and fro while a sustained musical note was being sung, could not perceive any difference in the intensity of the sound.
While carrying on a conversation in the ordinary manner through the wire I suggested placing a steel disc over the hole in the Box which covers the Mag. in the Teleph. on doing this the articulation became louder and much more distinct than when we talked into the hole of the box; we also found that a piece of paper over the hole produced the same effect but in a somewhat more intense degree a paper collar box inverted over the hole and the voice condensed into that improved the sound still more. The collar box inverted over the steel membrane gave nearly as loud and more distinct articulation than ~~any~~ when we talked directly on to the membrane.
Ever since we first tested our latest form of

telephone we have been puzzled by the fact that talking into the hole that was made for that purpose in the box was transmitted very indistinctly though loudly very different results from what we expected after trying our old form of Tel. by talking at the back of the membrane that is the side on which the magnet is. Our experiments today, noted above, of placing a membrane over the hole and talking against that instead of directly into the box have led me to form this theory, which I think will explain the indistinctness that we have heretofore been unable to account for.

The theory is this: The air contained in the box has a rate of vibration of its own, and re-enforces certain tones more than others, thus distorting the form of the composite vibration, now it seems to me that placing a membrane over the hole would force the air contained in the box to copy more perfectly the form of the vibration.

This theory if correct will explain why all forms of speaking tubes that we have used to converge sound vibrations upon the membrane, have given such poor results.

We propose to try the Phonautograph cone arranged with a membrane over the large end, and a steel membrane at the small end,

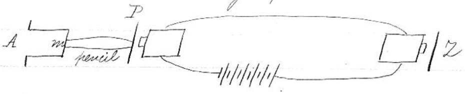
then a slight motion of the large membrane will create a large motion of the small membrane on the principle of the Hydrostatic Paradox, and a small piston working in a pipe might be used instead of the small membrane.
Prof. Bell suggests that the above idea if correct may be applicable to all forms of hearing tubes for deaf persons.

Noted Nov. 18th. 1876
T. A. Watson.

Saturday Nov. 18th. 1876.

I am inclined to think that Mr. Watson's idea noted above is very valuable as affording a means of setting the steel disk in vibration without placing the mouth in close contact to it. An experiment made at the same time as those mentioned above has not been noted.

Fig. 17.



A lead pencil was placed between the plate P and the membrane M of an ordinary "thread telegraph" A. Upon speaking into A sounds were audible from Z with nearly as good effect as when the voice was condensed directly against P. Upon speaking to Z sounds were closely audible from A.

Prof. Cross of the Institute of Technology has pointed out a defect in the undulatory currents produced by the vibration of bodies capable of induction action. The intensity of the current is not only directly proportioned to to the velocity of the motion of the inducing body, but inversely proportional to the square of the distance of the vibrating body from the pole of the electro-magnet — or $I = \frac{v}{d^2}$.

Hence the form of the sound-vibration is not produced in fac-simile in the electrical current — but is distorted — and it becomes a question whether this distorted vibration is copied by the armature of the Receiving Telephone or whether the armature of the Receiving Telephone copies the exact motion of the first. I am inclined to think that this is so — but certain peculiarities in the effects produced seem to me to be explicable upon the idea suggested by Prof. Cross. For instance the fact that we have observed again and again that very low soft sounds are audible more distinctly at the receiving end than louder sounds. Indeed it has often occurred to us that what we gain in loudness we lose in distinctness and *vice versa*. Again we have observed that articulation in a high pitched voice is much more distinct than when uttered in a low pitch.

The amplitude of the vibration of the inducing plate is of course smaller for soft sounds than for loud and smaller for high pitched than for low - Hence the distance from the pole of the magnet is not varied so much in soft or high tones as in loud or low tones - and the distorting influence of the distance is not so great.

This has led me to think of the effect of vibrating the conducting wire in a liquid of high resistance - but I now see that here also a distorting effect is produced - for as the wire descends into the liquid the current becomes absolutely stronger & stronger - but as the membrane which carries the wire descends lower & lower its motion becomes slower & slower until it stops. Now if the current were purely undulatory its intensity would diminish as the motion of the wire diminished and when it reached its lowest point it would be zero - but the fact is that at the lowest point the current reaches its *maximum* and hence the vibration must be very greatly distorted -

probably still more distorted than in the case of the induced undulatory current. I think then that in seeking to increase the audible effects - we must not do so by increasing the amplitude of vibration of the inducing body but by increasing the resistance of our magnets and the strength of our battery. Indeed I think that with our present arrangement our effort should be to produce the maximum of inductive action with the minimum of vibratory motion in the plate.

This evening we tried apparatus between Boston and Cambridge. The circuit has been put in good order this morning. Mr. Watson was in Boston - I in Cambridge

I reached Cambridge about 7.40 and at that time Mr. Watson should have been ready to begin experiments. Upon connecting my telephone - I could hear nothing - nor could I obtain any trace of a current. Upon making & breaking the circuit no sound was audible. I waited till 8 o'clock occasionally tapping - but with no effect. I then examined all the connections at the Cambridge end and found them perfect. About ten minutes past 8 I found that a feeble current had suddenly made its appearance and that Mr. Watson was tapping. We had the

100 ohm coils on our telephones. Upon listening I could hear Mr. Watson's voice very faintly — only a sentence or two intelligible. I then signalled him by the tap alphabet to change the coil & put on the 250 ohm coil.

This was done & the articulation as ever became louder & more intelligible, but it was not nearly so good as with the 100 ohm coils on Sat. Nov. 11th see page 18.

Mr. Watson informed me that the battery was turned on about a quarter before eight — but that he could not obtain any results. At ten minutes past 8 he reversed the battery and then there was a slight manifestation of a current. As we talked the sounds seemed gradually to become louder and more distinct — until they were fully as loud as on Sat. Nov. 11th. Mr. Watson informed me that Mr. Curtis Hubbard was present with a friend "Mr. Bush - B-u-s-h - Bush." I held conversation with them through the wire — and then Mr. Winlock at the Cambridge end spoke with Mr. Hubbard at the Boston end. After some conversation experiments were resumed. The five hundred ohm coils were put on. The sounds obtained were very faint — as faint as with the 100 ohms.

The 100 coil was then replaced at my

end; but by a misunderstanding Mr. Watson had in his instrument the 250 ohm coil. Nevertheless the articulation was audible at either end as loudly as we have heard it yet. Mr. Watson then changed his coil for the 100 ohm coil originally employed and the sounds at either end were as loud as we heard them. The arrangement was precisely similar as at first when we were unable to hold communication. It seems to me that the iron cores of the magnets must have acquired a certain amount of permanent magnetism and that the battery at first had tended to reverse the magnetism and hence we had obtained no effect. When the battery was again reversed the magnetism of the cores had been almost destroyed or reversed - so that at first we obtained feeble results - but little by little they recovered their power. Mr Watson agreed with me as to the principle but thought that the effect was more likely due to the magnetism of the steel plate. The cores were of the best soft iron and the reversal of the current would instantly reverse their polarity - but the plates were of steel and they would require some time to become fully magnetized - or to be de-magnetized. In this I agree with him. To test the matter I reversed the direction of the current through my magnet and at once the sounds emitted by it were much feebler. Upon re-reversing the direction of the current the sounds recovered their power. In order more conclusively to settle this point I directed Mr. Watson to reverse his battery for five minutes - and after experimenting to replace it as it was.

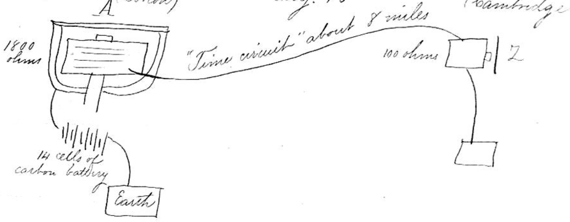
When the battery was reversed we found it impossible to communicate by word of mouth - even the sounds made by making and breaking the circuit were very feeble. When the battery was again reversed so as to leave it as before - the sounds audible were exceedingly faint - but each succeeding sentence came out louder & louder until in about five minutes they had become as loud as we have heard them.

Mr. Watson held an ordinary tuning-fork in front of the steel plate of the telephone - and I heard the note due to its vibration distinctly. He then removed the telephone and vibrated the tuning-fork in acidulated water included in the circuit - I heard the sound distinctly.

I also heard it but much more feebly when plain water was used.

The following experiment was then tried as illustrated in Fig. 18.

Fig. 18



I heard at Z distinctly but faintly what Mr. Watson said at A – but still more extraordinary is it that Mr Watson at A heard distinctly but softly what I said at Z.

That is – the undulations induced in a magnet of 100 ohms had traversed 8 miles of wire and a coil of 1800 ohms resistance and produced an audible effect at the distant end of the circuit. This seems to me to be very encouraging.

We have decidedly made a great step in advance today by understanding the causes of many of our difficulties. The experiments with coils of different resistances must all be repeated as the results obtained to-day are unreliable from the fact that we were not careful to pass the current always through the coils in the same direction.

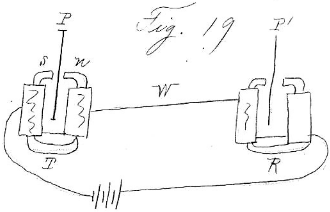
Noted by A. G. B.
Sunday Nov. 19th. 1876.

Sunday November 19th. 1876.

It has struck me today that the instrument invented on the 11th of July gets over every difficulty yet observed in utilizing the undulatory current - and will doubtless prove sufficiently powerful to be used without a battery. So many ideas noted in my note-book have not been tested that I think it may be valuable to collect them together. I must certainly have the Instrument shown on page 30 (Vol. 2) Figs. 4, 5 + 6. - constructed.

Mr. Watson suggests writing all experiments "to be tried" in a separate book or in another part of this book that they may not be forgotten. I think it might be well to make a separate note of such experiments - referring to pages and illustration - but it seems to me that the experiments to be tried should be described in the same part of the book as experiments already tried and under the dates of their conception - so that the continuity of the researches may not be interrupted - for one experiment suggests another & if the two things are noted in <u>different</u> <u>places</u> the continuity is lost. I shall read through all the books of Experiments, and keep a record in another book (which need not be preserved) of the pages where proposed experiments were described. As fast as we try these experiments we can tick (?) them off in our book as tried. The apparatus shown in Figs. 4, 5 & 6 (page 30 Vol. II.) certainly seems to me from theoretical considerations more perfect than any other yet described.

Fig. 19



The plates P and P' are rendered permanently magnetic in the way shown in detail in Figs. 4, 5 & 6. page 30 Vol. II. Now the vibration of P creates in the coils of electro-magnet N S an undulatory current which is distorted in each coil by the superadded effect due to the varying distance of the plate.
But the effect due to the varying distance of the plate from the poles is just neutralized by the opposite effects produced in the two coils; while the effect due to the mere motion of the plate is doubled.
For instance let the plate move towards N. The approximation of P and N and the separation of P and S produce currents of the same

polarity in the coils of of N and S because the poles S and N are of opposite polarity hence the effect due to the mere motion of P is the same in both coils & is therefore doubled — but the distorting influence of the distance of the plate is done away with if the coils of S and N have equal resistance. For the current in N will be that caused by the motion of P increased by the approximation of P and N — while in coil S the current will be that caused by the motion of P diminished by the separation of P and S.

Hence if P rests normally midway between S and N and if the coils of S and N have equal resistance the increase of the current in the one coil just balances the diminution of the current in the other — thus leaving the undulatory current undistorted, but of twice the intensity it would have had if the electro-magnet had been on only one side of the plate P.

I think that the reason this form of apparatus has not been made was the difficulty in communicating a correct vibration to a plate like P without placing the mouth closely against it. Mr. Watson's plan (see page 30) or some plan founded on experiment illustrated in Fig. 17 page 31 may however be

47

made of use. If my theory is right it should be found that upon speaking loudly to plate P Fig. 19 the distinctness of the articulation heard at P should be undiminished.

I propose to have instrument made so as to enclose in boxes of different kinds so as to test the best way of setting the plate in vibration. Fig. 20 illustrates one proposed form of box in which M, M' are membranes. Another form is shown in Fig. 21 – in which M represents the steel membrane P a pencil or other solid conductor of sound, and M' M^2 stiff membranes attached to P.

Fig. 20

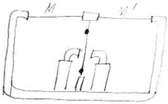
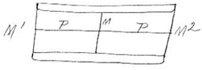


Fig. 21.



Mr. Watson agrees with me in thinking this plan feasible.

Noted by A. G. B.
Nov. 19th. 1876.

P.S. The instruments shown in Fig. 19 should work with or without a battery – and the direction of the voltaic current should be immaterial.

Monday Nov. 20th. 1876.

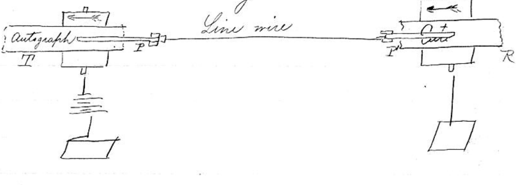
Mr. Watson has been at work today construc-ting apparatus shown in Fig. 19. He expects to have it completed tomorrow about noon.

Noted Nov. 21st. 1876
by A. G. B.

Tuesday Nov. 21st. 1876.

A new form of Autograph Telegraph has just occurred to me. Vibrating plates tuned to the same pitch at either end of the line are to be used and styles attached to them as in Phonautograph experiments.

Fig. 22



Write message on metallic surface with non-metallic ink at T — receive it on chemically prepared paper at R. The plates P P' may be kept vibrating by means of local batteries or by wind or by other means. All that is necessary is that they should be timed to unison with one another. Such a message could not be intercepted unless by an instrument of whose armature is of similar pitch.

It may be possible that autographic despatches might be transmitted simultaneously by using plates of different pitch for each message as in. Fig. 23.

The messages of T & T' would both be received upon each of the Receivers R & R' - but the message of T' would come out as an irregular line upon R and hence would not be legible there - producing effect somewhat like that shown in Fig. 24 - and the message of T would produce a similar illegible effect upon R' as in Fig. 25.

Fig. 23

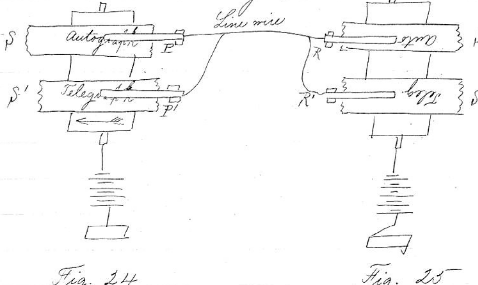
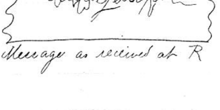
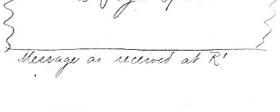


Fig. 24



Message as received at R

Fig. 25



Message as received at R'

Many months ago I had the idea of using vibrating bodies - as a means of regulating the speech of mechanism so as to produce synchronous motion in the machines at distant places.
It seems to me that the above plan is feasible could we most certainly try it after we have perfected the transmission of utterance.
The vibration of the plates P & P', R and R' should be sufficiently rapid and the motion of the slips S S' S^2 S^3 sufficiently slow to preserve the motion of R & R' being drawn as a curve upon S^2 S^3.

Noted by A. G. B.
Nov. 21st. 1876.

Wednesday Nov. 22d. 1876.
Completed instrument as shown on P. 38 Vol. III and tested in all the ways we could suggest with very poor results; but Mr. Bell thinks that we are not treating it fairly for we cannot hear the articulation when we use only one pole of the El. Mag. nearly as well as with our box Telephones.

We find that the L shaped Permanent Mag. will not magnetize the membrane attached to it, & propose substituting an El. Mag. for it.

Noted Nov. 23d. 1876. T. A. Watson.

Thursday, Nov. 23d. 1876.

Constructed today Membranes, to fit our Box Tel's, of iron rather thicker than the steel we have been using; have turned an annular recess in one pair, making it much thinner than the centre.

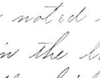
I have also enlarged the hole in the top of the box, making it nearly 4 inches in diam. instead of 1½ inches.

Several ideas in regard to the Insts. have occurred to me today which I have noted under the head of "Experiments to try" in the last part of this book, but Mr. Bell thinks I had better repeat them here.

The ideas referred to are these.

1st. The membrane of the receiving instrument must be more delicate than that of the Trans. Inst. as the force acting upon it is far more delicate than that acting upon the trans. Membrane.

2d. An Inst. made thus,



AA = Membrane of iron or steel
B = Mag.
C = Box enclosing the whole.

would I think neutralize the distorting effect suggested by Prof. Cross, if such effect really exists and give us sounds of greater intensity

than with our present form.
3d. In our present form of Inst. we get the inductive effect only of the centre of the membrane; now if we were to make the face of the core of our Elec. Mag. nearly as large as the membrane I think we would utilize the inductive effect of the whole of the vibrating membrane.

Noted Nov. 23d 1876

Thursday Nov. 23d. 1876.

I disagree with some of Mr Watson's conclusions - for instance the first.

Thoughts resumed Nov. 25th. 1878 at the Massachusetts General Hospital.

Letters appear every day in the newspapers about the application of electro-magnetism as a motive power and I think it would be well to complete an electro-motor on my old principle — and patent it before any one else thinks of the applicability of the Telephone as a means of obtaining a motive power from electricity. The extreme delicacy of the Telephone as a means of detecting the presence of a very feeble current — (equalling if not exceeding in delicacy a reflecting galvanometer) — is a proof to my mind that by means of the Telephone we obtain from an electric current a very much larger proportion of mechanical power than by any other contrivance we possess at the present time. The sound audible from the Telephone is the audible index of the mechanical motion of the plate — unless indeed it should be proved that the sound is chiefly produced by a molecular derangement in the plate. In a Receiving Telephone it is undoubtedly the case that there is a mechanical movement of the plate as we can feel it tremble when producing a

loud sound – but on the other hand sounds are emitted by large masses of iron when used as Telephone armatures.
It is almost inconceivable that the articulation produced for instance from a hammer-head in place of a plate of iron can be due to a mechanical motion of the whole hammer-head and I am forced to the conclusion that in every case (in the Receiving Telephone) we have a double action produced – a mechanical and a molecular vibration.
These two motions are produced simultaneously but in different proportions according to the mass and shape of the armature. It is probable that as we increase the mass without changing the surface exposed to the magnet – we obtain molecular motion at the expense of mechanical motion and vice versa – and when our armature is very thick and massive as in the case of the hammer-head – the sound audible may be considered as due entirely to molecular movement.
In a thin plate however it seems to me likely that the sound is produced chiefly if not entirely by the mechanical action of the plate – and I would utilize a thin plate as a means of obtaining power from electricity.

Magnets exert great power upon their armatures when these latter are placed very near to the poles – but the power decreases so rapidly when the distance between the armature & the poles is increased – that the problem in utilizing the attractive power of a magnet is to produce a long stroke by a very slight movement of the armature. This can be accomplished and has been accom- by making the armature the short arm of a lever and using the long arm to actuate mechanism – but here it is evident that increase of stroke is obtained at the expense of power so that some combination of magnets is wanted to give the needed power – and not only do the magnets always act at a mechanical disadvantage – but the complication of mechanism and the friction of the different parts – must very much reduce the power before it can be utilized in producing work.

Now the plan I explained to my father in the summer of 1874 and to Mr. Watson and to Mr. Hubbard in the winter of 1874–5, of combining the power of a number of magnets through the medium of an incompressible fluid such as water seems to me eminently feasible – especially if the armatures of the magnets are thin plates

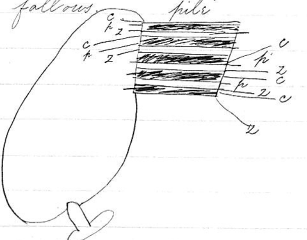
as in the Telephone. The power of any number of magnets may be combined in this way without loss due to mechanical complication or to friction and can be utilized so as to produce great motion and little power — or great power and little motion — as desired — by causing the water to actuate a piston of greater or less diameter.
(See new note-book)

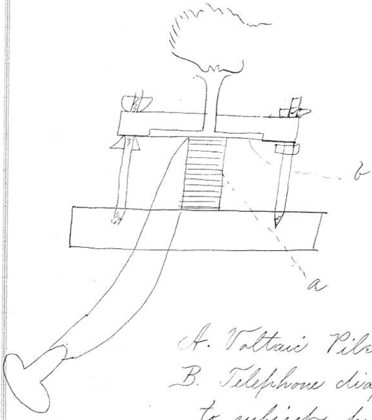
Noted Nov. 25th. 1878
by A. G. B.

Mass. Gen. Hosp. Dec. 2d. 1878.

My new note-book is in Cambridge — so I jot down here a few ideas for trial.

Make the original voltaic pile. Take disks of copper & zinc separated by moistened cloth — calico — cotton — paper or some suitable substance, and subject pile to vibration by means of Telephone diaphragm as follows.





A. Voltaic Pile.
B. Telephone diaphragm used to subject pile to a varying pressure.

Instead of copper carbon might be employed and then we would have a double action. Internal resistance of battery would be diminished by the approximation of carbon & zinc poles separated by the moistened cotton, and also by the pressure of the carbon + zinc surfaces in contact (à la microscope) – vibratory action imparted to the battery would probably cause a very much greater variation in current than simply varying the external resistance.
The experiment can be very easily tried and if successful we can then seek to construct

Carbon pile exaggerated to make clear its construction.

a vibrating battery that will be constant in its action and not be liable to polarization.

If successful I see no reason why the loudness of the articulation might not be increased almost indefinitely by increasing the number of elements in the pile - and by using induction coil. Pass current from battery through primary wires of coil and have telephone in circuit with secondary coil. If the variation of current could be made so great as to produce spark upon secondary coil - he would have the varying pitch of the voice produced by the spark - and it is just possible that even articulation might be produced by it. It would indeed be a novel thing to ~~[illegible]~~ have artic. prod. by the spark of an induction coil without any receiving telephone.

A. G. B.

Noted Dec. 2d. 1878.

Experiments to try.

Do the Magnets with armatures in circuit with the telephones strengthen the undulating effect.

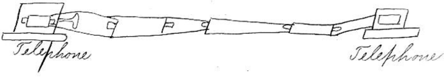
Try two persons talking at once.

Verify the results obtained by using ordinary Morse Sounders for Telephones.

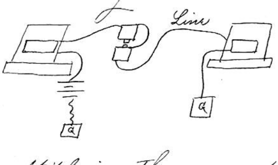
Settle whether the box on the back of our latest telephones has anything to do with the improvement that these instruments show on the former instruments.

Try large box on the back of our large Membrane.

Try the effect of a series of induction coils arranged thus



Try this arrangement.



Try multiplying the magnets in the above arrangement

Prof. Hill suggests holding the base in the teeth to see if we can hear the articulation any better.

Nov. 18th. 1876.

All of our old experiments having for an object the transmission of the voice have had one element of failure in them, viz. the armature or wire to be vibrated was attached to the central point of a flexible membrane which point being weighted became a nodal point. Repeat all experiments with a stiff disc instead of a flexible one.

Nov. 18th. 1876.

Try iron instead of steel for our membrane and see if reversing the battery effects the sounds; also try several plates of taggers iron together.

Nov. 18th. 1876.

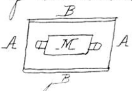
Try listening with the stethoscope and ear trumpet with a membrane over the large end.

Thursday Nov. 23d. 1876.

The receiving Membrane must be more delicate than the transmitting because the force acting on it is far more delicate than that acting on the transmitting membrane.

Nov. 23d. 1876.

Try this form of instrument.



M = magnet

AA = steel or iron membranes

B = box surrounding the whole

the talking to be done at one end; then form would I think neutralize the distorting effect suggested by Prof. Cross if such effect is the trouble with our single membrane Insts. at any rate I think it will increase the loudness of the articulation.

Nov. 23d. 1876.

Try extending the surface of the pole of the electro-mag. thus

A = Membrane

B = Mag. with large pole.

I think that with a magnet like that shown above more of the surface of the membrane, would be utilized, than when the magnet was simply opposite the centre.

Entered by T. A. Watson
Nov. 23d. 1876.